NTT Technical Review

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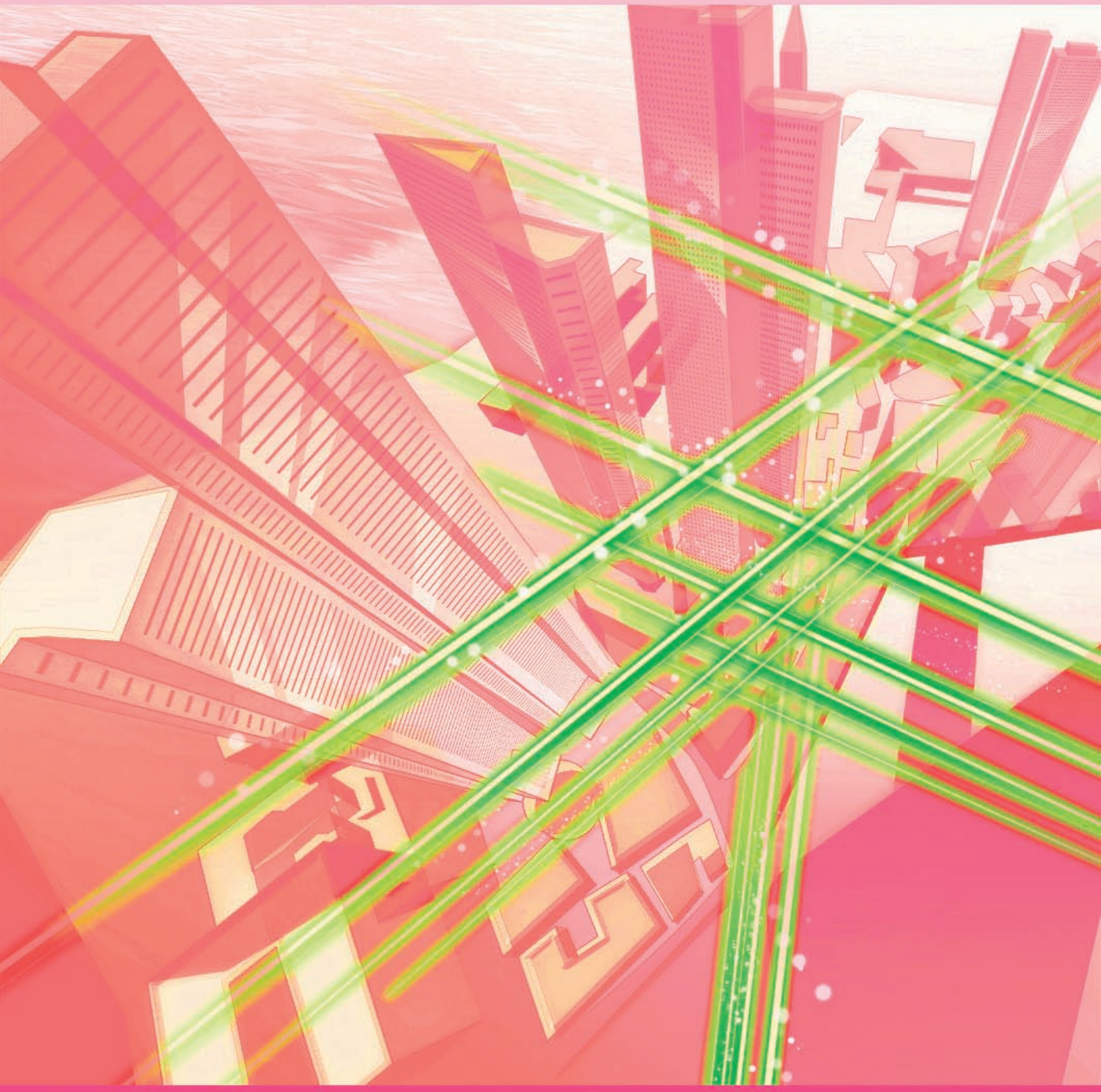
2014



March 2014 Vol. 12 No. 3

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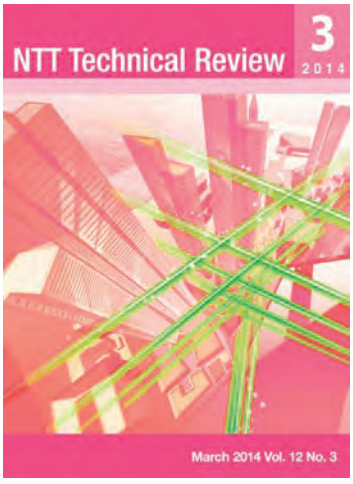

External Awards/Papers Published in Technical Journals and Conference Proceedings

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Pursuing the Ultimate —Becoming a Globally Advanced Enterprise through Management and R&D Working Together with Vision

Sadayuki Sakakibara,
External Board Member of NTT
Chairman of the Board of
Toray Industries, Inc.

Overview

Toray Industries, Inc. has been a long-term leader in the development of Japan's world-class fiber technology. In our first View from the Top interview with an External Board Member of NTT, we sat down with Sadayuki Sakakibara (Chairman of the Board of Toray Industries, Inc.) to learn the secret to creating a succession of advanced, world-first technologies and to hear about management philosophy of looking ahead to next-generation strategies.

Keywords: management, R&D, vision

Fiber technologies for diverse fields, from underwear to airplanes

—Mr. Sakakibara, we are honored to have you as our first External Board Member of NTT to be interviewed for our View from the Top column. Could you please tell us about the fiber industry in which Toray Industries has such a major role? It is said that the Paris Fashion Week could not be held without Japanese fiber, which suggests that Japanese fiber technology has high standards even from a global perspective.

Yes, I think that most people think about the world of fashion when the subject of fiber comes up. It is certainly said that Japan's fiber industry is globally advanced in terms of its technological strength, sensitivity to human needs, and product lineup. Top designers ask us to develop advanced materials and we provide them with new materials. The support that we give to the top-class fashion business as represented by the Paris Fashion Week is made possible by a partnership between a yarn manufacturer like us and small- and medium-size cloth and dye manufacturers in Japan's Hokuriku region and elsewhere.

Technology development takes time. For example, Toray Industries was awarded the Popularity Award at last year's Mainichi Fashion Grand Prix for the "Sillook" silky polyester material that was developed 50 years ago. The invention of nylon fiber marked the beginning of a great challenge to create artificial materials that could surpass natural fibers such as silk, cotton, and wool.

At the time, the main problem in developing new

synthetic fibers such as nylon, polyester, and acrylic was how to manufacture them with a high level of quality. The last 50 years have also seen the successive creation of textiles with new textures such as suede-like artificial leather.

Most people are probably unaware that technology developed by Toray Industries is being used in their everyday clothes. A recent example is UNIQLO's HEATTECH material. More than 300 million HEATTECH products have been sold. Many technologies originally developed for use in sports-related and other materials went into the development of HEATTECH products. Specifically, HEATTECH technology applies four types of fibers to achieve a material that absorbs sweat and dries quickly while generating heat and retaining warmth without uneven dyeing. We also provide new technologies for use in other UNIQLO products. These technologies are supported by Toray Industries' research and technology development group that has more than 1200 members.

In actuality, textiles and clothes represent just the tip of the iceberg in the application of fiber materials.

More than half of our synthetic fibers are used in fields other than clothing, for example, curtains, umbrellas, carpets, automobile seats, tire cords, and air bags, which are close to our daily life.

We are also developing materials in areas such as films, resins, carbon fibers, water-treatment membranes, medical materials such as for artificial dialysis, pharmaceutical products, and electronic and information materials using core technologies such as high polymer chemistry, synthetic organic chemistry, biotechnology, and nanotechnology. With these technologies in hand, our aim is to maintain our position at the top of the fiber industry and expand our business globally.

A business model centered on stable supplies and research activities that pursue the ultimate

—How does Toray Industries maintain its leading role in fibers?

The production and sales processes in the fiber business have been established over many stages, yet, in some ways, inefficiencies still remain, as in the use of complicated distribution channels. At Toray Industries, however, we have created a unified development-and-supply business model from raw fiber to finished garment by coordinating the activities of our

global production bases. This model enables us to respond promptly to market changes.

Our approach is to seek sustainable growth cycles on a global scale.

To this end, we start in Japan with pioneering and innovative research and technology development with the aim of developing advanced materials and commercializing value-added products. We also endeavor to drastically reduce costs by establishing new production technologies in addition to pursuing innovative process development. Furthermore, in terms of commodities, we provide our customers with a stable supply by having production performed at the most optimal overseas base taking demand and costs into account.

Our global expansion began in Thailand 50 years ago, and we have since expanded our operations to 23 countries and regions including Japan. In managing a business overseas, it is important to adopt a long-term approach over short-term profits with the idea of contributing to the development of industry, the expansion of exports, and the raising of technology standards in that country.

—Your business model centered on stable supplies appears to be the reason for Toray Industries' success.

Well, not completely—it's not this model by itself that keeps Toray Industries at the top. Another key factor here is a spirit of "pursuing the ultimate" in research and development (R&D), what I would call the "DNA" of Toray Industries. Without this DNA, I could not talk about Toray Industries. In our corporate culture, management and R&D activities move together in unison.

To give you an example, let me tell you about the

"fineness" of fiber, which we have been pursuing since the founding of the company. More than 40 years ago, we developed yarn with a fineness under a diameter of 1 μm, which was made possible by using a special spinneret-nozzle technology that enables a single strand of yarn to be made up of about 1000 extra-fine threads.

However, we continued our pursuit of ultimate fineness and recently developed nanofibers with diameters ranging from 10 to 20 nm. You can imagine a fineness of 20 nm as the result of stretching a nylon chip the size of a grain of rice from the earth to the moon (he smiles)!

These technologies were born from a culture that prizes the pursuit of the ultimate. As far as we are concerned, management and R&D are simply inseparable. I take pride in saying that the growth that Toray Industries has so far enjoyed would not have taken place if these two entities had not been working closely together.

People are behind novel technology made possible by vision and conviction

—Of course, R&D is not always successful. Continuing a certain line of research appears, in a sense, to have an element of gambling.

Whenever we found ourselves in a difficult situation, we stuck to a management philosophy of protecting jobs instead of laying off people while continuing our R&D efforts.

To give you an example, the R&D department began its research on carbon fibers in the 1960s. This research was supported by a vision and a strong conviction that "an era in which carbon fibers will be needed is definitely coming."

From that time on, we pursued the ultimate in strength and elasticity in carbon fibers. We entered into a joint development project with the Boeing Company in the United States, and in 1982, they adopted carbon fiber for the first time in the Boeing 737 airplane. At that time, the use of carbon fiber was limited to components such as movable members of the wings and tail assembly, but this has changed over time. In the current Boeing 787, about 30 tons of carbon fiber are used per airplane in all structural members including the fuselage and wings. The era of "all carbon fiber" aircraft has truly arrived. Today, carbon fiber from Toray Industries has a worldwide share of about 40%.

However, in 2002, when I became president of Toray Industries, the information technology bubble had collapsed, and the economy throughout all sectors of society had fallen flat. In this market, our business performance was by no means favorable, and if that situation had continued, we would probably have gone bankrupt in two years. In this sense of crisis, I made an appeal to our employees, saying "I am committed to protecting everyone's job, but I will also push through drastic reforms with no exceptions. The next two years will be a severe trial for all of you, but I need you to believe in what I plan to do." It has been said that the era of lifetime employment is over, that such a practice is out of date, but it is exactly people in safe and secure employment that manifest their full potential. I believe that placing importance on people is linked to the development of an enterprise and is the basis for fostering an attitude of contributing to society.

As a result, we have never cut down on expenditures for R&D—the source of our company's existence—no matter how severe the environment has been.

To continue developing technology in our pursuit of the ultimate, we spend more than 50 billion yen a year on R&D and maintain an R&D workforce of about 3,500 people.

As I touched upon earlier, this R&D effort is carried out with an eye to the society of the future and to global environmental problems too. We are placing

particular importance on three major issues: carbon dioxide emissions and global warming, water shortages caused by the growing population, and the depletion of oil and other natural resources.

As you probably know, securing an inadequate supply of water is becoming an increasingly serious problem in various regions of the world. Of the 7 billion people in the world today, it is said that 800 million do not have ready access to drinking water and that 2.5 billion people do not have access to appropriate sanitation.

This water problem can be solved by deploying water-treatment technology using high polymer membranes, for example, and the problem of global warming can be addressed by reducing the weight of aircraft by about 20% using carbon fiber to improve fuel efficiency. All in all, we want to make a significant contribution to solving these environmental problems through the application of our technologies.

—By the way, Tokyo is hosting a "big event" in 2020. Are you working on the development of any new materials with an eye to the event?

Among our fiber materials, we take great pride in our high-function materials commonly used in sportswear. To date, many of these materials have been adopted in many products. Unfortunately, we won't be able to announce the material that we are developing for the event until after the event is over, so we ask everyone to be patient until then. In the development of this material, we are looking for ways to reduce water resistance and to make the material lighter to provide a better fit over the entire body and reduce the load on the user. Our plan is to move forward with the development of this material in preparation for the next big event.

An opportunity for business expansion in the NTT Group

—Mr. Sakakibara, how do you see the business environment for the NTT Group and what are your expectations for NTT R&D from the viewpoint of an External Board Member?

I believe that the present business environment is providing the NTT Group—the largest telecommunications operator in the world—a great opportunity for expanding business that leverages the awesome R&D capabilities of NTT.

After assuming the position of an External Board Member of NTT, I paid a visit to a number of research laboratories to observe a variety of research activities. Based on my experiences as a member of the Council for Science and Technology Policy, Cabinet Office, and as the chairperson of the Keidanren (Japan Business Federation) Committee of Industrial Technology, I can say without hesitation that the R&D capabilities of NTT are the best in the world.

As the economy becomes increasingly global in nature, I believe that forming tie-ups with top global companies in various fields regardless of a company's past history is the way to long-term success. To roll out services that are closely related to everyday life, as in health-promotion, learning-support, and elderly/child monitoring services, it will be essential to link up with experts in those fields.

Open innovation, while involving the way that an organization is set up, is, in the end, all about people. How do we go about changing the corporate culture of an organization of working people? That is the important question. I believe that the key to solving those problems that our customers and our business departments present to us is to send out researchers and engineers to our customers' sites with the aim of obtaining a good understanding of "on-site conditions," "actual goods," and the "real situation." In an extremely large corporation like NTT, the business departments, research laboratories, and engineering departments tend to be widely dispersed, so there is a real need for the management team to actively encourage and support the people engaged in open innovation in those departments and laboratories.

One of my personal mottos is "survival of the fittest." As Charles Darwin said in *On the Origin of Species*, it is not necessarily strong and big individuals

that survive, but individuals that can adapt to changes in their environment. This holds true in a corporate environment as well. I have great expectations that NTT researchers and engineers will make a big contribution to the expansion of NTT business by adapting to changes in the telecommunications business environment—which can undergo drastic upheavals—and by actively pursuing open innovation through tie-ups with companies having world-class standards.

Interviewee profile

■ Career highlights

Sadayuki Sakakibara joined Toyo Rayon Co., Ltd (now Toray Industries, Inc.) in 1967. He became President and Representative Member of the Board in 2002 and Chairman of the Board in 2010. He assumed his current position as External Board Member of NTT in June 2012.

Activities of Energy and Environment Technologies Committee to Improve Energy Efficiency

Yuji Uenishi, Jiro Nakamura, and Keiichi Saito

Abstract

The NTT Group is facing many challenges in the areas of energy and the environment, from the rapidly increasing cost of electrical power to various global environmental concerns. This article introduces some initiatives of the NTT Information Network Laboratory Group's Energy and Environment Technologies Committee to realize a sustainable infrastructure that is able to continue providing safe and secure connectivity while adapting to future increases in traffic and power consumption.

Keywords: energy environment, energy saving, sustainable infrastructure

1. Introduction

For the NTT Group, global environmental issues such as global warming, depletion of natural resources, and threats to biodiversity are unavoidable issues to be managed as part of the Group's corporate social responsibility. At the same time, the rising cost of electricity year-on-year is becoming an even more urgent issue for NTT as a heavy user of electrical power for information and communications technology (ICT) equipment such as routers and servers, as well as the machinery necessary to cool the ICT equipment.

In fiscal year (FY) 2012, the total amount of electricity used by the NTT Group was approximately 8600 gigawatt-hours (GWh), representing approximately 1% of the total commercial power consumed in Japan. From another perspective, this electrical power consumption is the source of 93% of the total carbon dioxide (CO_2) emissions by the NTT Group (**Fig. 1**). Currently, the NTT Group is almost 100% reliant on commercial power for this electrical energy, and because the cost of power in Japan is currently based on imported fossil fuels, the unit price for power is rising yearly (**Fig. 2**). This is a situation that the NTT Group cannot ignore, even regarding its short-term revenues. Furthermore, with the rapid expansion of high-volume content services such as video and new smartphone services, traffic is continuing to increase, ICT equipment must then be

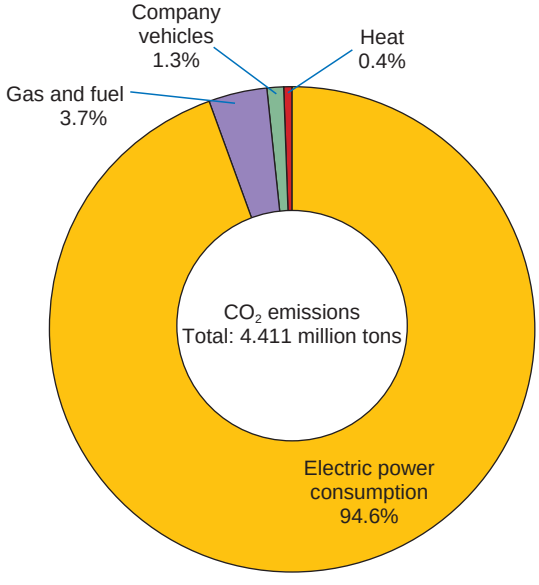

Fig. 1. Sources of CO_2 emissions of the NTT Group in FY2012.

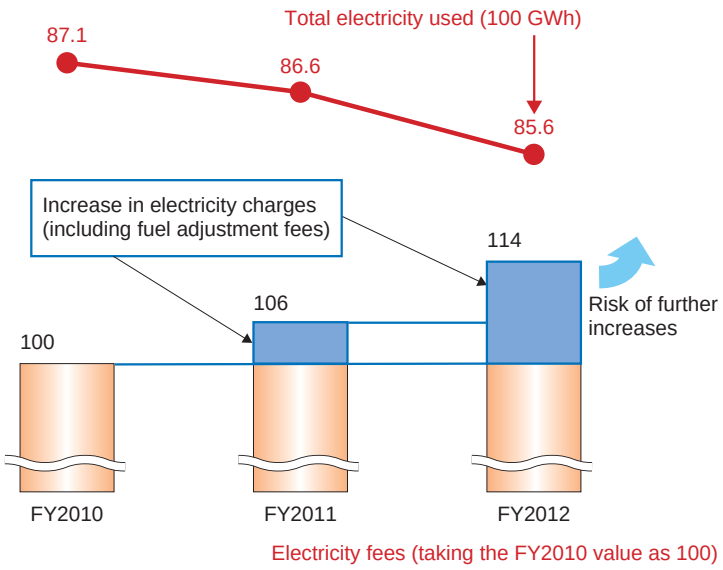

Fig. 2. NTT Group trends in total electricity consumed and electricity fees.

upgraded to increase capacity, and the power required to provide these services also increases.

As part of planning for future networks, the NTT Information Network Laboratory Group has established the Energy and Environment Technologies Committee as a strategic coordinating organization spanning all of the laboratories within the Laboratory Group. The committee is working to resolve both global environmental issues in the future as well as the urgent issue of energy costs. Its objectives are to draft a research and development (R&D) strategy and promote development of technologies that contribute to a sustainable society by providing stable ICT services and by reducing the power consumption of ICT services, reducing the accompanying CO_2 emissions, and reducing the use of resources.

2. Energy and Environment Technologies Committee's network infrastructure vision

The committee takes the position that a sustainable infrastructure providing continuous connectivity 24 hours a day, 365 days a year must be implemented using resource-conserving technologies that reduce the total power consumption of network systems, advance energy management, increase energy self-sufficiency by integrating renewable energy and other energy-generation and energy-storage technologies, and adapt to resource risks, as well as using environmental energy technologies such as technology to mitigate environmental interference in communications equipment.

The set of technologies that must be addressed in order to implement a sustainable infrastructure is shown in **Fig. 3**. These technologies are divided into six technology groups, which are: (1) Power source related technologies that will provide power and increase the energy self-sufficiency of future networks; (2) Air conditioning related technologies that will increase the energy efficiency of communications buildings; (3) Technology that links network equipment with power and air conditioning equipment; (4) Energy-saving technology in network architecture and equipment contributing to energy-saving ICT; (5) Resource conservation technologies for green ICT; and (6) Technologies for dealing with interference from the external environment such as electromagnetic radiation or lightning. The committee is promoting R&D on technologies in each of these areas.

When promoting specific R&D, the committee establishes practical working groups to carry out feasibility testing of the technologies developed in each laboratory. These groups promote the development of the technologies by performing evaluations in real environments, either at the Musashino R&D center or an external office building. Each technology is connected as required—which may involve installing it in an office or using it to supply power to communications equipment—or is tested from an environmental

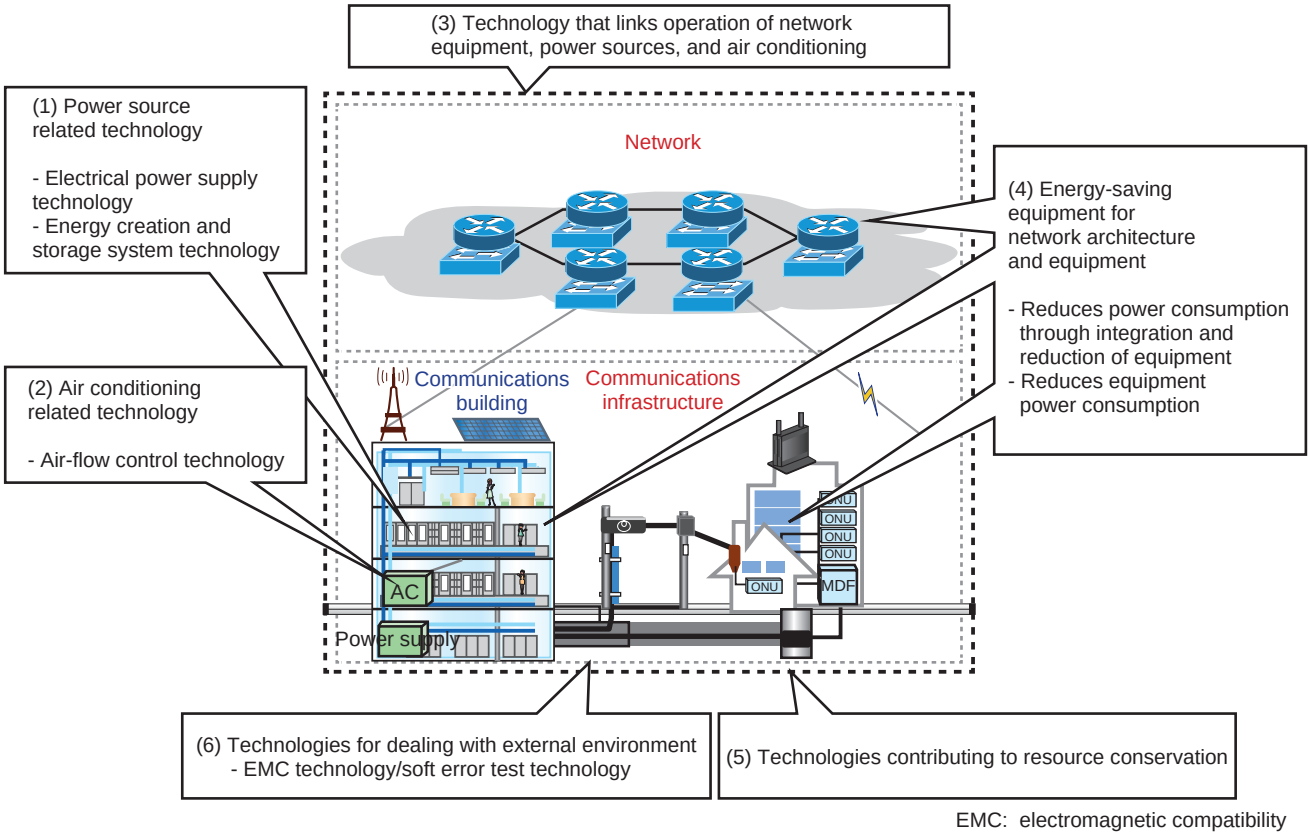

Fig. 3. Six technology groups related to environmental energy.

energy perspective, and the groups cooperate with the developing laboratory by selecting issues to be addressed in areas such as usability or deployment in a business [1].

3. Overview of the six technologies

(1) Power source related technology

The speed and capacity of ICT equipment continues to increase along with the ever increasing amounts of network traffic, and the power consumption is expected to increase accordingly. The NTT Group has developed direct-current (DC) power supply technology to supply DC power efficiently to ICT equipment within communications buildings and datacenters. NTT must also reduce its power costs, improve resistance to power outages, and provide more stable power for its businesses. To do so, it will be necessary, in the medium and long terms, to consider energy creation systems using renewable energy or fuel cells, energy storage systems that are used all of the time and not just for backup, and other new energy systems that increase energy self-sufficiency or provide distributed power. Accordingly, the committee is promoting R&D on initiatives to achieve a stable power supply from power generation to provision [2].

(2) Air conditioning related technology

Hotspots often occur in machine rooms where network equipment is installed. Hotspots are areas where the local temperature is higher than the surrounding area. The use of air conditioning to cool these areas can increase power consumption. We have developed technology that increases the cooling efficiency of air conditioning by placing a flow control panel called a diffuser at the equipment exhaust port or the cool air intake port. We are also developing other ways to improve energy efficiency within communications buildings. One example for improving air conditioning efficiency involves rearranging network equipment in a machine room according to the air conditioning conditions [2], [3].

(3) Technology linking control of network, power supply, and air conditioning equipment

As the use of server and network virtualization technology expands, the electrical load of ICT devices and the accompanying quantity of exhaust heat are expected to fluctuate with the amount of traffic. Consequently, it is essential to improve the efficiency of power supply and air conditioning technology so that the power supply and air conditioning can be controlled according to fluctuations in traffic flow and processing load. The committee is advancing R&D on technology to link control of power and air conditioning equipment with ICT equipment in order to resolve these issues [2].

(4) Energy-saving technology for network architecture and equipment

To create a future convergence network, with the goal of establishing a shared network infrastructure applicable for different services and domains, the committee is promoting a simplified network architecture composed of fewer network nodes and servers. This will reduce overall power consumption and the power consumption of individual network devices. It is also conducting R&D on other energy-saving technologies such as network terminals that have a sleep function, and the optical network unit, an optical communication device used in end-user households [4].

(5) Technologies contributing to resource conservation

As the service life of ICT equipment, telephone poles, cables, and other equipment used to provide information and communications services expires, some equipment must be disposed of. This is also necessary when equipment must be updated to provide new services. Such disposal amounts to approximately 800,000 tons of waste per year. The NTT Group has achieved zero emissions with such material by promoting reuse and recycling. To achieve further conservation of resources, the committee is focusing on technical initiatives to lengthen and extend the life of current equipment, to conserve resources when updating equipment, and to carry out recycling with high added value.

(6) Technologies for dealing with the external environment

As new technologies are introduced to implement a sustainable infrastructure, it is essential to increase reliability by controlling—as much as possible—how certain external environmental factors such as lightning, electromagnetic radiation, and cosmic rays affect the infrastructure. It is also important to avoid generating new electromagnetic noise. In particular, the introduction of smart meters in homes, the expansion of wireless sensor networks for visualizing power use and other data, and the use of distributed power sources with new energy creation and storage systems mean that sources of electromagnetic radiation are increasing, and the electromagnetic environment for ICT equipment is therefore expected to get worse. Manufacturing processes for circuit boards are expected to become finer still, and the risk of software errors occurring will continue to rise. To deal with these circumstances, the committee is promoting the development of EMC (electromagnetic compatibility) testing and mediation technology for new equipment and services as well as design and operations technologies to reduce software errors [5].

4. Future prospects

With the Energy and Environment Technologies Committee as its core, NTT Energy and Environment Systems Laboratories is advancing plans for a future vision and technical validation in collaboration with other NTT laboratories, with the goal of reducing management risk related to energy and resources. We will continue to promote technical development to further increase energy and resource efficiency in the overall business activities of the NTT Group by rapidly reflecting external trends and the needs of the workplace.

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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 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 researching 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.

Jiro Nakamura
Group Leader, Environmental Information Systems Project, NTT Energy and Environment Systems Laboratories.
He received the B.E., M.E., and Ph.D. degrees in applied chemistry from Osaka University in 1987, 1989, and 1995, respectively. He joined NTT LSI Laboratories in 1989, where he worked on the development of microfabrication technology. He moved to NTT Information Sharing Laboratory Group in 2001. Since moving to his present research department in 2004, he has been engaged in developing environmental sensing systems and analyzing the influence of ICT on the global environment.

Keiichi Saito
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He received the B.E. and M.S. degrees in science and engineering from Waseda University, Tokyo, in 1989 and 1991, respectively. He joined NTT in 1991 and conducted research on Li-ion battery materials until 1995. He was then engaged in new business development until 2010. He is currently working on the promotion and development of services and systems related to energy and the environment.

Power Supply and Air Conditioning Technologies for Sustainable Telecommunication Infrastructure

Toshio Watanabe, Hiroya Yajima, Morihiko Matsumoto, Toshihiro Hayashi, Hideaki Hashimoto, Joji Urata, and Hiroto Kitabayashi

Abstract

Improving the energy efficiency of telecommunication equipment rooms and datacenters, which account for much of the power consumed in the NTT Group, is important for both the global environment and reducing electric power costs. This article describes recent discussions held by the Energy and Environment R&D (research and development) Committee and recent R&D on power supply and air conditioning technologies intended to achieve a sustainable telecommunication infrastructure.

Keywords: HVDC power feeding, air-conditioning control, energy material

1. Introduction

The NTT Group is conducting research on energy conservation of network facilities. We present some recent research and development (R&D) activities relating to technologies on power saving for power supply and air conditioning systems. NTT Energy and Environment Systems Laboratories has previously developed a low-energy-loss high-voltage direct current (HVDC) power feeding system and is moving forward with achieving further energy savings in telecommunications equipment rooms and datacenters through more advanced energy management of power feeding systems, air conditioning systems, and information and communications technology (ICT) equipment. Telecommunications services are part of the basic social infrastructure and must be sustainable even during disasters. Together with the development of technology for controlling multi-source power supplies and systems for creating and storing energy (fuel cells, batteries, etc.) to achieve a stable power supply, we are promoting medium- and long-term R&D on next-generation materials for energy creation and storage systems (**Fig. 1**).

We introduce three R&D activities in the following sections. First, we describe practical trials on an HVDC power feeding system that is ready for commercial use. The trials were conducted in an actual operating environment. We then present the most recent work on datacenter energy management systems, including the use of virtualization software for optimizing ICT load arrangements and air conditioning system operations. Finally, we introduce studies on next-generation materials for energy creation and storage designed to reduce power costs and power outages into the future.

2. Actual-operation trials for HVDC power feeding system

The development of the HVDC power feeding system has been completed, and the system is now ready for commercial use. Sales of ICT equipment operating on 380 VDC (voltage direct current) have begun, but it will remain necessary to supply power to

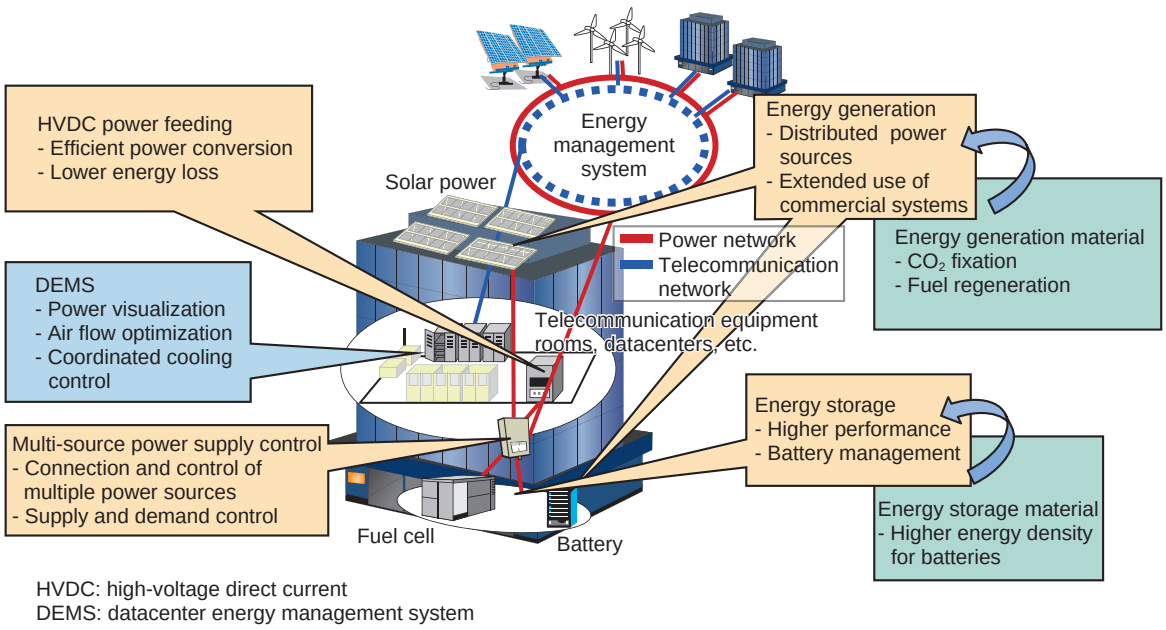


Fig.1. R&D to achieve power saving in telecommunication equipment rooms and datacenters.

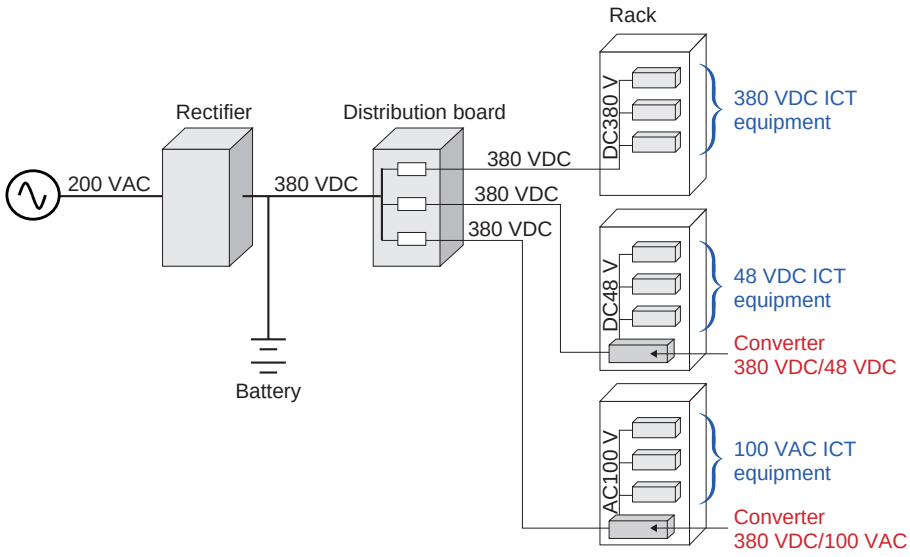


Fig. 2. Configuration of HVDC power feeding system with converters.

existing 48-VDC or 100-VAC (voltage alternating current) ICT equipment until the high-voltage equipment comes into widespread use (**Fig. 2**). In response to this requirement, we have been conducting machine room trials in a telecommunications building with a view to introducing in the NTT Group an HVDC power feeding system that incorporates a converter for converting 380 VDC to 48 VDC or 100 VAC. These trials involve evaluating the overall performance and reliability of power feeding systems that include converters, and designing and investigating various methods of construction, operation, and maintenance.

NTT Energy and Environment Systems Laboratories

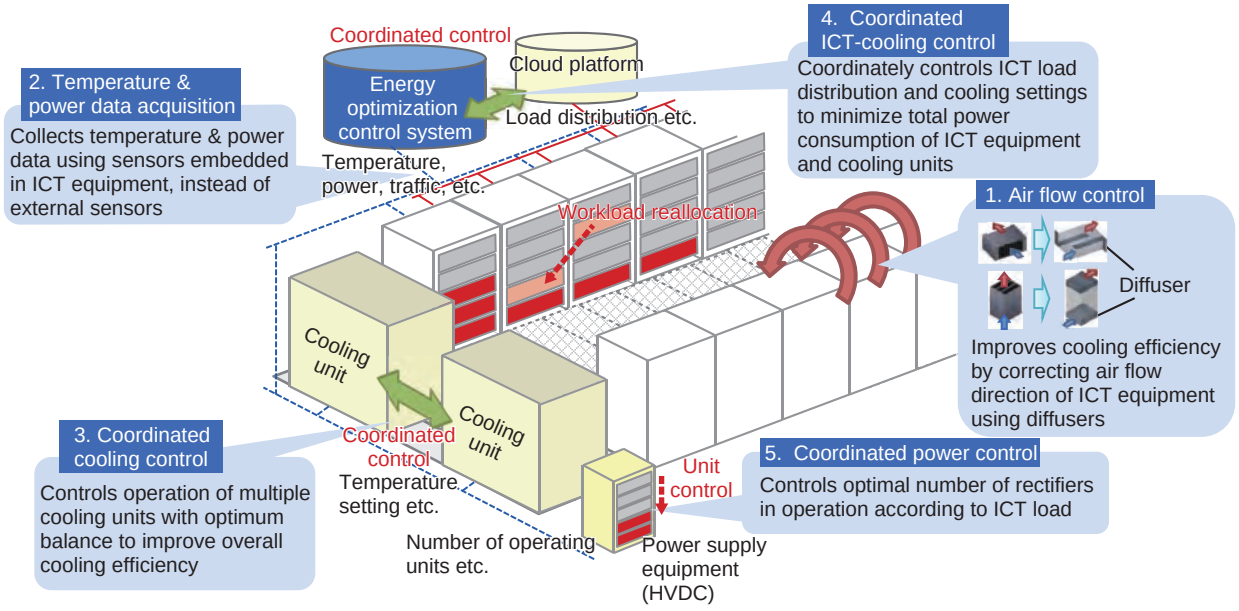


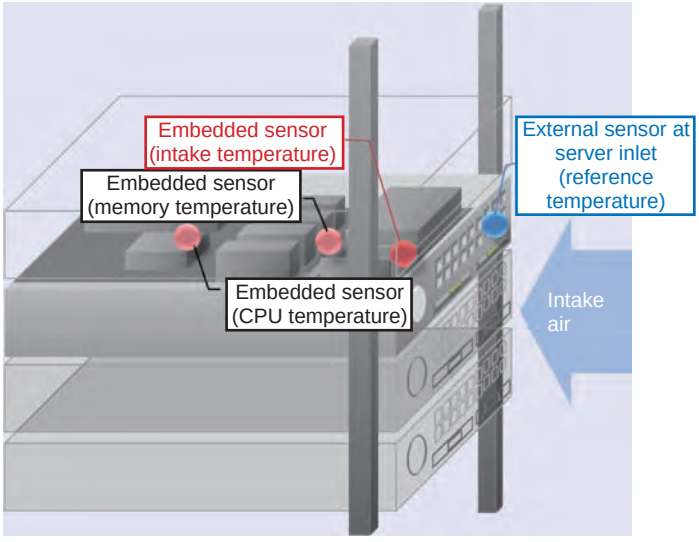
Fig. 3. R&D to achieve energy saving in datacenters and telecommunication machine rooms.

is mainly responsible for evaluating the overall power feeding system performance and reliability. The performance evaluation involves testing for efficiency, voltage accuracy, and noise level, and verifying robustness in actual operation. Because sudden changes in power can be expected in actual operation, the evaluation includes examining the continuity in ICT equipment operation in a dynamic environment when 1) commercial power outages and restorations occur, 2) inrush current occurs when equipment is turned on, 3) fluctuations take place in ICT equipment power consumption, and 4) short circuits occur in ICT equipment input. The reliability evaluation includes calculating the overall power feeding system reliability from the failure rates of individual equipment components and evaluating how the inclusion of converters affects overall system reliability. We performed these various evaluations, clarified what items need attention when a system is constructed, and made proposals to improve the power feeding system for actual operation.

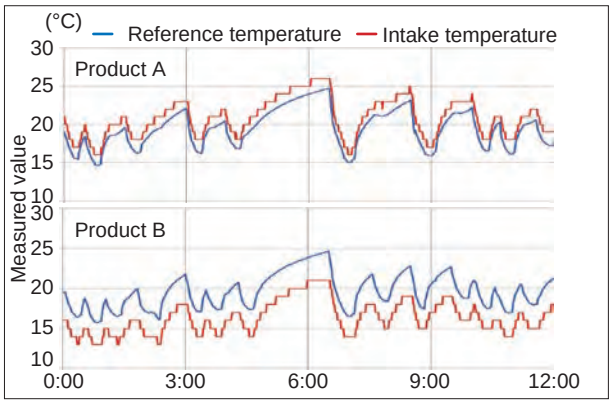
In future, NTT Energy and Environment Systems Laboratories will conduct further R&D to improve the efficiency of power conversion equipment. We will also provide companies with technical support for system introduction and cooperate with vendors to expand the lineup of 380-VDC ICT equipment to promote widespread use of the HVDC power feeding system.

3. Towards energy-efficient telecommunication machine rooms and datacenters

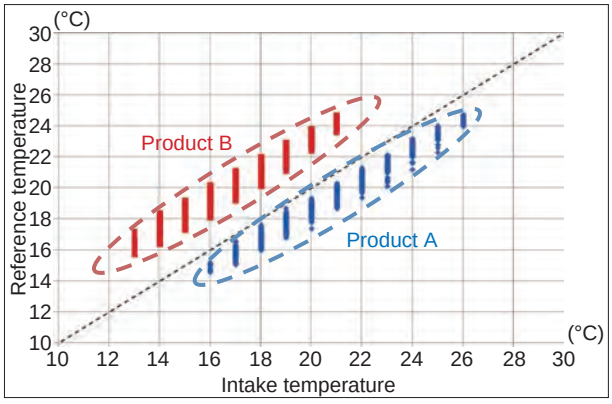
ICT equipment, cooling units, and power supply equipment account for the majority of energy consumed in telecommunication machine rooms and datacenters. Thus, overall optimization of all three components is essential for saving energy. NTT Energy and Environment Systems Laboratories has been researching and developing optimal energy control technology that is aimed at reducing the energy consumed in telecommunication machine rooms and datacenters (**Fig. 3**). Specifically, R&D is underway on the following technologies: air flow control technology to prevent local temperature increases and achieve efficient cooling; data acquisition technology using embedded sensors of ICT equipment to collect temperature and power consumption data without using external sensors; coordinated cooling control technology that optimizes the settings of multiple cooling units for balanced and efficient operation; coordinated ICT-cooling control technology that optimizes the setting of cooling units and load distributions of ICT equipment to minimize the total power consumption of the ICT equipment and cooling units; and power supply unit control technology that optimizes the number of operating units of power supply equipment according to the operating level of ICT equipment.



Intake temperature and reference temperature



Time series of intake temperature and reference temperature



Scatter plot of intake temperature and reference temperature

Fig. 4. Temperature and power data acquisition using embedded sensors in ICT equipment.

3.1 Temperature and power data acquisition technology using embedded sensors in ICT equipment

Monitoring of room temperature distribution and equipment power consumption is necessary to make telecommunication machine rooms and datacenters more energy efficient. Such monitoring data are generally collected by installing external sensors, but the cost of these sensors and their installation can be a problem when measurements are taken in many places.

ICT equipment has built-in sensors for monitoring equipment states such as CPU (central processor unit) temperature, voltage, and fan speed. Using these embedded sensors instead of external ones would greatly reduce costs. An investigation was conducted on the use of embedded sensors to acquire intake temperature and power consumption of commercial servers produced by multiple manufacturers. The results revealed problems concerning the data acquisition interface and the accuracy of the acquired sensor data.

Regarding the interface, nearly all of the servers enabled acquisition of intake temperature and power consumption sensor data via the IPMI (intelligent platform management interface), but the IDs (identifications), quantity, and location of sensors differed from product to product. We are using the results of the investigation to promote standardization of the data interface and dissemination of compatible equipment.

In evaluating the accuracy of the sensor data for the intake temperature, a difference was found between the embedded sensor data and the reference temperature measured at the air intake side, and this difference varied among products (**Fig. 4**). Future tasks will be to promote the standardization of sensor accuracy requirements and investigate technology for eliminating variations among products by correcting the sensor data.

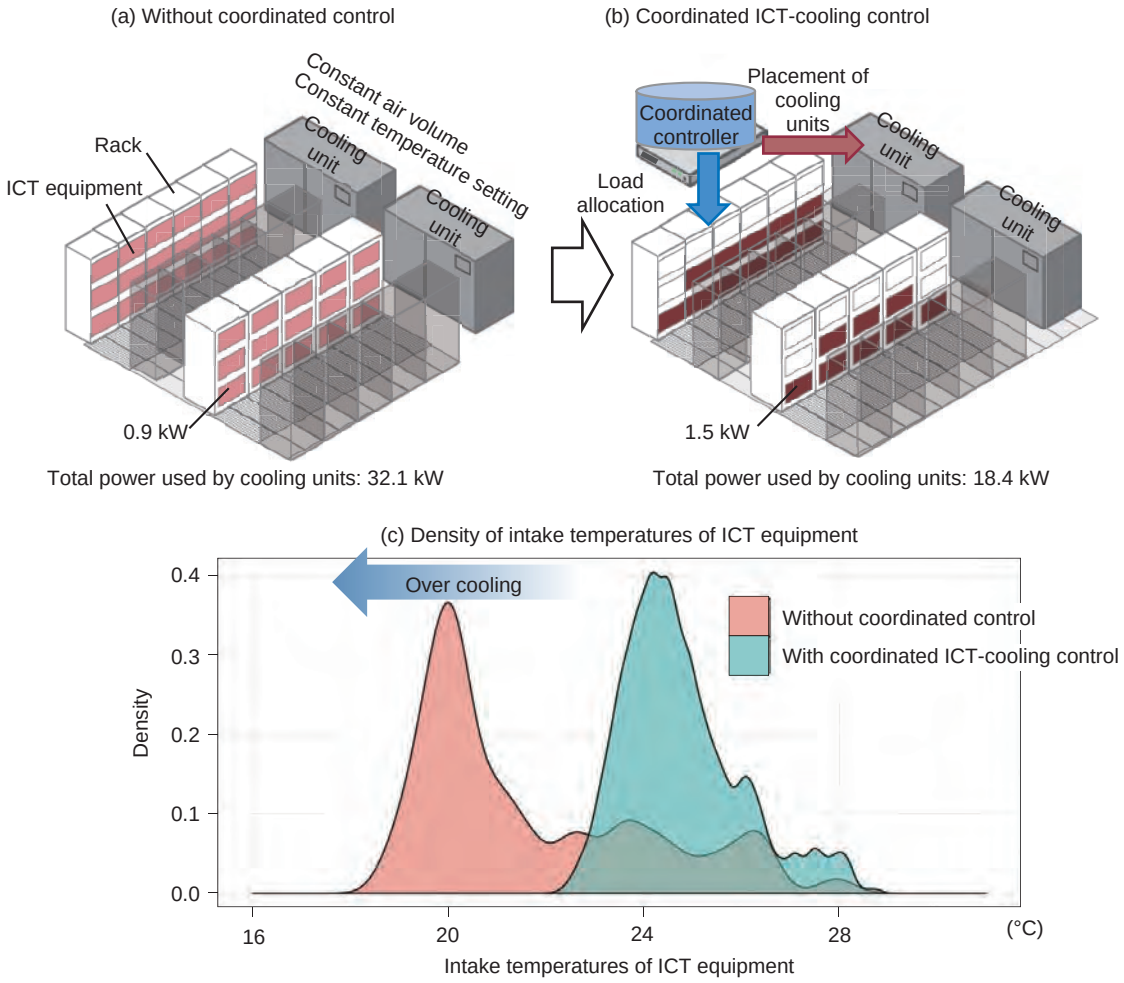


Fig. 5. Configuration and result of coordinated ICT-cooling control.

3.2 Coordinated ICT-cooling control

Cooling units in telecommunication machine rooms and datacenters are operated with a margin so that the intake temperature of ICT equipment does not exceed the upper limit for reliability concerns. ICT equipment is often operated with a focus on processing efficiency, with less consideration given to ease of cooling by cooling units. Cooling would be more efficient if it were possible to allocate load to ICT equipment located in areas where the cool air supplied by cooling units can easily reach. In recent years, such dynamic and flexible load allocation has become possible through live migration of virtual machines.

Therefore, we have been working on coordinated ICT-cooling control technology with the objective of reducing the power consumed by ICT equipment and cooling units. We have developed a method of coordinately controlling the setting of cooling units and the load distribution of ICT equipment and a method of efficiently solving the optimization problem for the control in order to minimize the total power consumption while maintaining the intake temperatures of ICT equipment below upper limits.

We present here experimental results to demonstrate the reduction in power use by cooling units using the coordinated ICT-cooling control. The case in which the load distribution on ICT equipment is uniform and the setting of cooling units is controlled so that the intake temperatures of ICT equipment do not exceed the upper limit (i.e., without coordinated control) is presented in **Fig. 5(a)**, and that in which the load distribution is optimized by the coordinated ICT-cooling control is presented in **Fig. 5(b)**.

The results verify that coordinated ICT-cooling control technology can reduce the power consumed

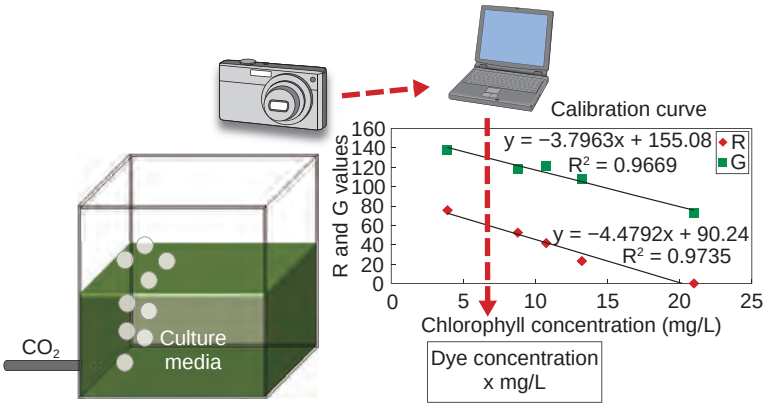


Fig. 6. Experimental system and process used to measure dye concentration. Microalgae density is estimated by analyzing RGB information of a digital camera image.

by cooling units by 42%, while satisfying intake temperature constraints.

In future, we plan to proceed with the development and verification testing of optimal control algorithms implemented in an actual cloud environment.

4. Next-generation material technology for key component of energy generation and energy storage systems

Our medium- and long-term R&D efforts in energy production and energy storage include conducting research on next-generation materials for creating key materials and components of energy generation and energy storage systems.

4.1 Highly efficient CO_2 fixation by algae

We are focusing on green energy technology involving green fuels, green power generation, and carbon dioxide (CO_2) fixation-and-fuel-reproduction in order to reduce dependence on fossil fuels and to lower energy costs. Part of this research involves looking at the price fluctuations and cost risk of CO_2 emissions. We introduce here technology for achieving highly efficient CO_2 fixation (which refers to, for example, photosynthesis) by using algae for CO_2 fixation-and-fuel-reproduction.

There is enormous biodiversity in algae, especially microalgae, and they have very beneficial features, including 1) a much higher multiplication rate than that of terrestrial plants (population doubling time of a few hours), 2) ten times higher CO_2 fixation volume per unit area than that of a forest, and 3) a high lipid content. These features have drawn attention to the use of microalgae as a fuel resource that does not compete with food resources.

However, in the search for optimized cultivation conditions, advanced analysis is necessary. This analysis requires preprocessing using methods such as optical density or high performance liquid chromatography to quantify the amount of dyes (chlorophyll etc.), which correlates with photosynthesis activity and with the cell concentration and total amount of organic carbon, which are required for evaluating the amount of CO_2 fixation. We therefore focused on an easily implemented (and real-time, non-destructive) technique for quantifying microalgae dye from the RGB (red, green, blue) values of a digital camera image.

We have established a technique that can approximate the correlation between the RGB values of a digital camera image and the dye (chlorophyll) concentration in culture media with a linear function (**Fig. 6**). This simple and real-time image analysis enables us to estimate cell densities or growth rates of microalgae nondestructively by using a low-cost commercial digital camera. We plan to apply this technique in the future in the search for cultivation conditions that lead to highly efficient CO_2 fixation.

4.2 Li-air battery technology

Our research on energy storage has focused on high-energy-density battery technology with the medium- and long-term objectives of improving robustness against power outages and increasing the use of solar and wind electrical power generation for natural (renewable) energy. We explain lithium-air (Li-air) battery technology for achieving a ten-fold

increase in the energy density of Li-ion batteries, which have the highest energy densities of widely used secondary batteries.

The Li-air battery consists mainly of an air electrode (cathode), electrolyte, and anode (**Fig. 7**). Our objective is to improve the performance of the air electrode, which plays an important role in battery reaction and largely governs battery performance. The air electrode contains the reaction sites between Li ions and oxygen in air, so a function for passing oxygen while preventing electrolyte leakage is needed. The reaction site is highly activated by using a RuO_2 (ruthenium oxide) catalyst for the air electrode in combination with a dimethyl sulfoxide electrolyte. As a result, both the charging and discharging capacity increases to about 1000 mAh/g, and the charge-discharge voltage difference decreases to about 0.7 V.

Secondary battery performance is generally evaluated in terms of capacity discharging, charge-discharge efficiency, and number of charge-discharge cycles. Previous research has focused on improving performance in these areas. In the future, we will work on improving techniques for preventing electrolyte leakage and improving oxygen permeability, which is thought to be linked to increasing the number of charge-discharge cycles, and we will also search for materials to optimize the air electrode structure.

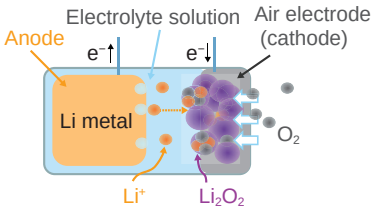


Fig. 7. Li-air battery (discharge reaction).

5. Future work

In line with discussions held by the Energy and Environment R&D Committee, we will strongly promote R&D in power supply and air conditioning technologies for reducing the cost of electric power and enhancing the tolerance of the telecommunication infrastructure against power shortages.

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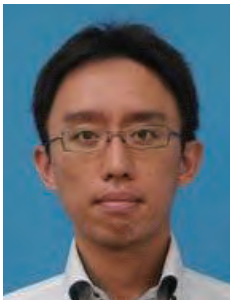

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Energy-saving Technology of Air-conditioning Systems for Datacenters

Yosuke Udagawa

Abstract

This article describes the features of two air-conditioning systems for datacenters developed by NTT Facilities. One is the FMACS-V (facilities multiunit air conditioning system-5th generation) hybrid, which received the 2012 Technology Award by the Japan Society of Mechanical Engineers. The other is the FTASCL-RS/C (facilities task cooler rack-shaped/compressor type), which received the 2012 Technology Prize from the Japan Society of Refrigerating and Air Conditioning Engineers. An evaluation of the FMACS-V hybrid operated by NTT EAST is also briefly described.

Keywords: datacenter, free cooling, packaged air conditioner

1. Introduction

In recent years, the use of servers and other information and communications technology (ICT) equipment has spread widely in our society, and their importance as a social infrastructure has been increasing. However, the operation of ICT equipment generates a large amount of heat and requires year-round air conditioning, so there is a strong demand for reduced power consumption of air conditioning systems. When the air conditioning is interrupted, the temperature around the ICT equipment rises, and in the worst case, operation of the ICT equipment must be stopped. Such stoppages may affect services, so the air conditioning system must be highly reliable.

NTT Facilities has been developing ICT air conditioning technology to both reduce power consumption and increase reliability for over 30 years, contributing to the reduction of power consumption by the NTT Group and other industry enterprises. Commercial air conditioning solutions that are based on the developed technology are divided into air conditioning systems and air flow control technology for efficiently distributing the cool air supplied by the air conditioning systems to cool ICT equipment.

The air conditioning systems that we have already developed are the floor-mounted FMACS (facilities multiunit air conditioning system), the rack-mounted FTASCL-RS/C (facilities task cooler rack-shaped/compressor type) (**Fig. 1(a)**), and the ceiling-mounted FTASCL-CM/C. Currently, the fifth-generation FMACS-V has been introduced, and there is a slim space-saving model and an indirect outdoor air cooling type hybrid model (**Fig. 1(b)**) in addition to the standard model.

An example of air flow control technology is aisle capping (**Fig. 1(c)**), in which the path of the cool air supplied to the ICT equipment from a raised floor (cold aisle) is compartmented to physically separate the low-temperature air supplied to the ICT equipment from the high-temperature exhaust air, thus achieving efficient cooling.

The developed air conditioning technology has been well-received at conferences for its high energy-saving capabilities. In 2012, the FMACS-V hybrid[*1] floor-mounted air conditioner for ICT equipment, which also uses indirect outdoor air cooling, received the Technology Award from the Japan Society of Mechanical Engineers[*2], and the FTASCL-RS/C

*1 The FMACS-V hybrid and FTASCL-RS/C are being developed in cooperation with Hitachi Appliances.

(a) Indoor unit of FTASCL-RS/C (b) Indoor unit of FMACS-V hybrid (c) Aisle capping

Fig. 1. Air conditioning solutions.

rack-mounted air conditioner for ICT equipment received the Technology Prize from the Japan Society of Refrigerating and Air Conditioning Engineers[*3].

2. FMACS-V hybrid

The FMACS-V hybrid has a simple system configuration in which only a refrigerant pump is added to a conventional compressor-equipped air conditioner (**Fig. 2(a)**) for cooling with outdoor air. The system automatically switches operating cycles according to the outdoor air temperature. In seasons when the outdoor air temperature is low, the system operates in the pump cycle using the refrigerant pump (**Fig. 2(b)**); in seasons when the outdoor air temperature is high, the system operates in the compression cycle using the compressor (**Fig. 2(c)**). The refrigerant pump consumes only about one-eighth the power consumed by the compressor, and therefore, operation in the pump cycle greatly reduces the annual energy consumption.

The air conditioning system in datacenters is operated throughout the year, so the effective use of low-temperature outdoor air for cooling in the cold seasons is important in reducing the annual power consumption. Low-temperature outdoor air can be used in two ways. One is direct outdoor air cooling, in which outdoor air is brought into the building directly; the other is indirect outdoor air cooling, in which a heat exchanger or other means is used. Operation using direct outdoor air cooling alone throughout the year is difficult in Japan, so it is generally used together with other air conditioning systems that have heaters. That, however, increases construction costs because of the redundancy in air conditioning facilities. Another problem is the reduction in indoor air quality that results from introducing a large amount of outdoor air directly, and there is concern for the effect this may have on the ICT equipment.

To avert the problems that accompany direct outdoor air cooling, we adopted the indirect outdoor air cooling method and developed an air conditioning system that can operate in a pump cycle using a pump to circulate the refrigerant. That system enables switching to outdoor air cooling operation by simply switching the pipe flow path. Moreover, it does not require an opening in the exterior wall of the building for drawing in outdoor air, so it is relatively easy to introduce in existing structures. The effect on indoor air is the same as for conventional air conditioners.

Problems with breakdowns in refrigerant pumping had previously prevented its application to commercial products. We solved that problem by developing a new pump mechanism and control system that enable safe operation and successful commercialization.

*2 Technology Award of the Japan Society of Mechanical Engineers: A prize awarded for excellence in new technology to stimulate mechanical engineering and industry in Japan.

*3 Technology Prize of the Japan Society of Refrigerating and Air Conditioning Engineers: A prize awarded for the development and popularization of science and technology relevant to refrigeration and air conditioning, and particularly for excellence in new technology.

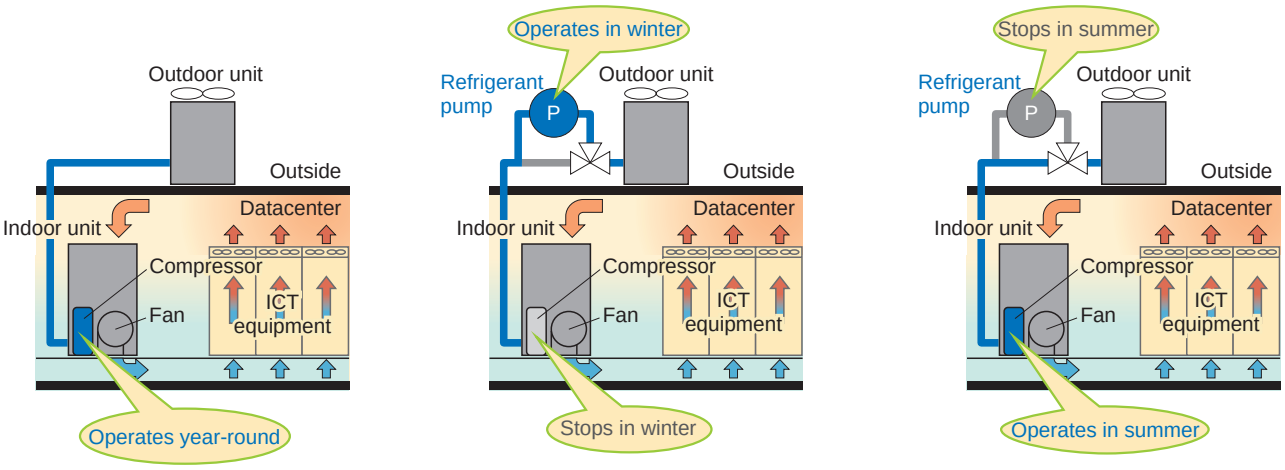


Fig. 2. Operating conditions of air conditioners.

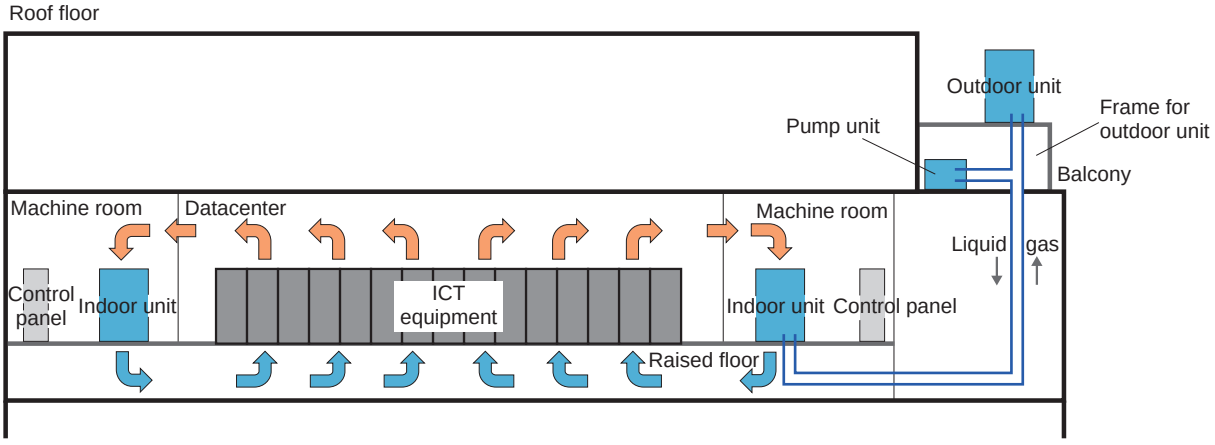


Fig. 3. Configuration of air conditioning system.

2.1 Field evaluation of the FMACS-V hybrid

Development of the air conditioner included verification in a test room, but we also installed the system in an actual NTT EAST datacenter located in Hokkaido for further testing. That datacenter is actively adopting technology for reducing power consumption in order to reduce the burden on the environment. As described later in this article, the energy-saving effect of this air conditioning system is higher in regions where the outdoor air temperature is low throughout the year. We therefore took advantage of the cool climate of Hokkaido to evaluate the effect of this system on reducing power consumption.

The arrangement of the air conditioning system units is illustrated in **Fig. 3**. The indoor units are placed in machine rooms adjacent to the server room, and the outdoor unit and pump unit are placed in an outdoor space on the roof of the building immediately above one of the machine rooms.

The indoor and outdoor air temperatures for the period for which the calculations were performed are shown in **Fig. 4**. The average indoor temperature was 23°C, and the range over the entire year was from 20°C to 25°C, which is suitable for the operation of ICT equipment. The result was a 46% reduction in power consumption compared to an ordinary air

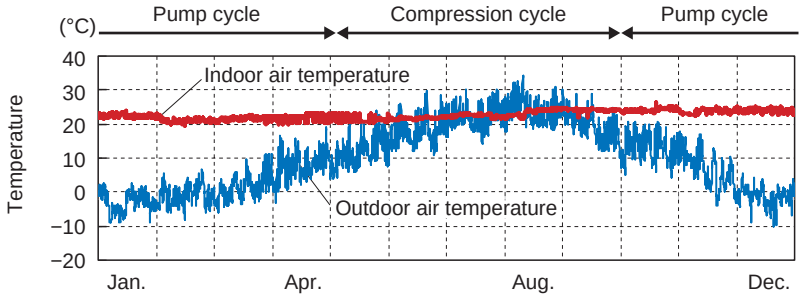


Fig. 4. Indoor and outdoor air temperatures measured at Hokkaido datacenter (in 2011).

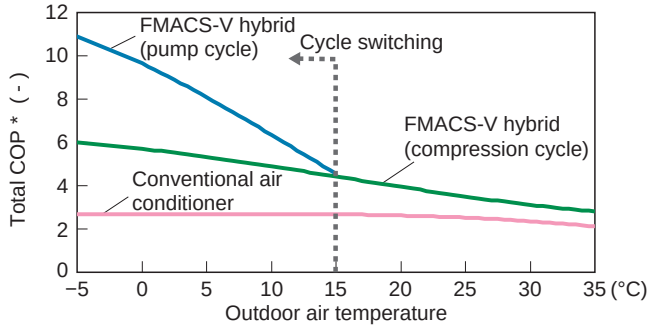


Fig. 5. Relation between total COP and outdoor temperature.

conditioning system. However, the air conditioning load was a low 40% in the period for which the calculations were done, so we expect that the energy-saving effect would be higher if the amount of generated heat and the air conditioning load were higher.

NTT EAST has continued to use this system at their Hokkaido datacenter even though the evaluation period has ended. They intend to continue their efforts to reduce power consumption at this datacenter by using this system when they expand the air conditioning system in the future.

2.2 Effects of reducing energy consumption

The relationship between the air conditioning efficiency of the FMACS-V hybrid system and the outdoor air temperature is shown in **Fig. 5**. We can see a striking increase in efficiency from operation in the pump cycle compared to that in the compression cycle. That is to say, a longer pump cycle operation results in a greater reduction of power consumption, so the energy-saving effect will be greater in regions where the outdoor air temperature is low throughout the year. The annual power consumption ratios for an ordinary computer air conditioning system and for the FMACS-V hybrid system are compared in **Fig. 6**. We can see from the figure that the maximum reduction in power consumption is 54% for Sapporo but only 42% for Tokyo. These results show that we can expect our system to contribute greatly to reducing the amount of power used by air conditioning systems.

2.3 Expansion of the FMACS-V hybrid lineup

Currently, the FMACS-V indirect outdoor air cooling hybrid system is being developed as the L model for medium-to-large office buildings and datacenters (rated cooling power of 45 kW). To further expand the range of system applications, we will later move forward with development of an M model (rated cooling power of 20 kW) that has a smaller cooling capacity for introduction in small office buildings and server rooms. Adding the FMACS-V hybrid (M) to the lineup will make it possible to meet a broader range of customer needs and to further contribute to

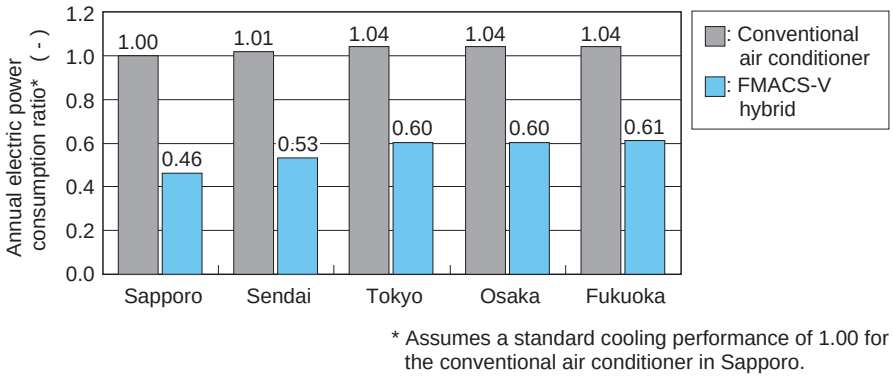
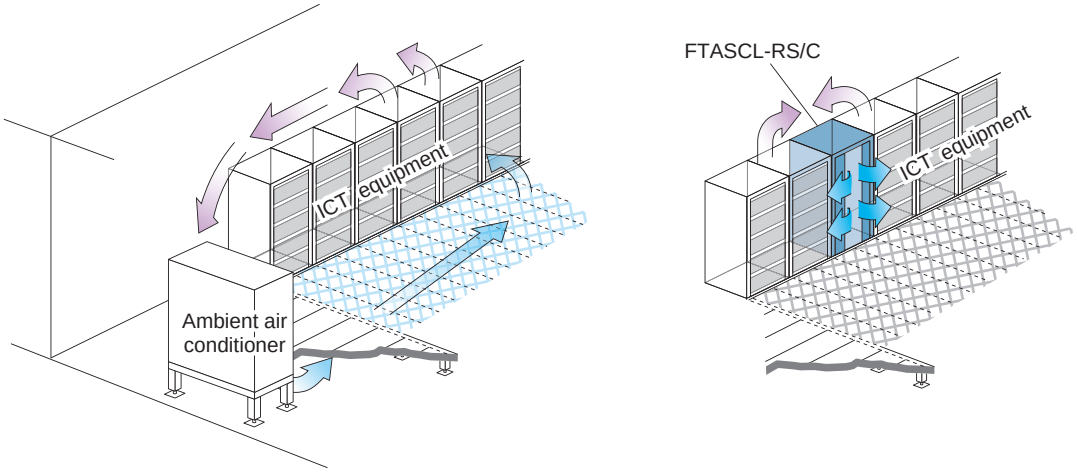


Fig. 6. Comparison of reduced annual power consumption between conventional system and FMACS-V hybrid system.



(a) Air flow of ambient air conditioner

(b) Air flow of FTSACL-RS/C

Fig. 7. Air flow of different air conditioners.

energy efficiency.

3. FTASCL-RS/C

The FTASCL-RS/C is an indoor air conditioner than can be mounted on racks in the same way as ICT equipment. With the conventional air flow method, a large volume of air has to be moved from a wall-mounted air conditioner (also called ambient air conditioners) to distant ICT equipment via a raised floor (**Fig. 7(a)**). With, rack-mounted air conditioners, however, the air conditioners can be placed near ICT equipment that produces large amounts of heat to take air in from the back and push air out from the front (**Fig. 7(b)**). This reduces the distance the air travels and the power consumed by the fan operation. Also, highly efficient operation is possible because the rack-mounted air conditioner can collect hot air (30–40°C) directly from the hot aisle (the aisle into which the hot exhaust from the ICT equipment flows).

With an air conditioning system that uses only ambient air conditioners, the cool air supplied from vent panels in the cold aisle may be insufficient, particularly in regions of high heat generation density, and hot air pockets can form from recirculation of hot exhaust air from the hot aisle to the cold aisle. That makes it difficult to maintain the prescribed temperature for air taken into the ICT equipment. With ambient air conditioners, it is therefore necessary to lower the indoor temperature setting for the entire room in order to maintain the proper ICT equipment air intake

temperature. Consequently, it is often necessary to deal with excessive air flow, and operation becomes inefficient. Such problems can be solved by placing rack-mounted air conditioners near the ICT equipment. Supplementing the cool air supply with rack-mounted air conditioners makes it possible to set the ambient air conditioner temperature and air flow rate to reasonable levels and achieve efficient operation.

Moreover, because the rack-mounted air conditioner vents cool air directly into the cold aisle, it is highly compatible with aisle capping. An air conditioning system that combines rack-mounted air conditioners with aisle capping can reduce the annual power consumption by 58% compared to a conventional air conditioning system that comprises an ordinary air conditioner used together with a raised floor configuration.

4. Conclusion

This article presented the award-winning FMACS-V Hybrid system, an indirect outdoor air cooling hybrid air conditioning system for ICT equipment, and the FTASCL-RS/C rack-mounted air conditioner for ICT equipment; both are highly reliable and highly energy-efficient air conditioning systems for datacenters. We will continue to expand the product lineup to further contribute to reducing power consumption in the ICT field.

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He received the B.E. and M.E. degrees in mechanical engineering from Waseda University, Tokyo, in 2003 and 2005, respectively. He joined NTT Facilities, Inc. in 2005. He is currently researching air-conditioning systems for datacenters. He recently developed an outdoor air cooling-type air-cooled package air conditioner FMACS-V hybrid, which reduces annual power consumption. He is a member of the Japan Society of Mechanical Engineers, the Japan Society of Refrigerating and Air Conditioning Engineers, the Society of Heating Air-conditioning and Sanitary Engineers of Japan, and the Architectural Institute of Japan.

Smart Buildings: Conserving, Creating, and Storing Energy—the Smart Office Building Trial Project

Keiichi Saito and Jun Takase

Abstract

A project is underway to implement NTT Group research and development and various energy-conserving policies and systems in an office building to investigate their effectiveness in conserving energy, and to evaluate their usability in actual operation. In this article, we introduce the systems used in this trial and the practical results obtained thus far.

Keywords: energy-saving, energy creation, energy storage

1. Introduction

To advance the NTT Group goal of implementing new systems that will realize a smart, energy-conserving society and a safe and secure living environment, we have implemented various energy-saving systems and devices, both existing and under research and development (R&D) within the NTT group, in some of our offices in the Granpark Tower in Minato Ward in Tokyo. The purpose of this trial is to check their practical energy-saving results and effectiveness, and to evaluate their usability and determine the best operating methods. This trial is being conducted as a flagship smart building project in collaboration with NTT Facilities and NTT Communications, who are tenants in Granpark Tower, and NTT Urban Development, which is the owner of the building.

2. Overview of energy-saving policies

The energy-saving systems being used in the trial are shown in **Fig. 1**. The core is the Remoni power monitoring system, which automatically controls and creates visualizations of the amount of electrical power used in the offices. The trial includes lighting equipment such as the Smart Lighting Controller (SLC), which enables installation of light-emitting diodes (LEDs) and lighting control, and a power-supply-and-demand management system, which uses a combination of solar panels and lithium-ion (Li-ion) storage batteries to control power peaks in the office.

3. Remoni system for monitoring power and reducing peak power use

The office floor is divided into several blocks consisting of meeting rooms, shared space, and individual office spaces. Remoni was installed to visualize the power consumption of lighting fixtures and outlets used for office equipment in each of these blocks. Then, Remoni functions were used in coordination with the SLC lighting controller to study measures such as automatically turning off low-priority lighting when power consumption exceeded a pre-configured peak power level. The configuration data were also linked to the supply-and-demand management system that controls peak power in order to study how the output from solar panels and Li-ion storage batteries can be applied automatically, and even how to expand services in the future to integrate multiple buildings through the use of communications, so that if one building exceeds the peak power value, other buildings can adjust their levels to smooth out the peak.

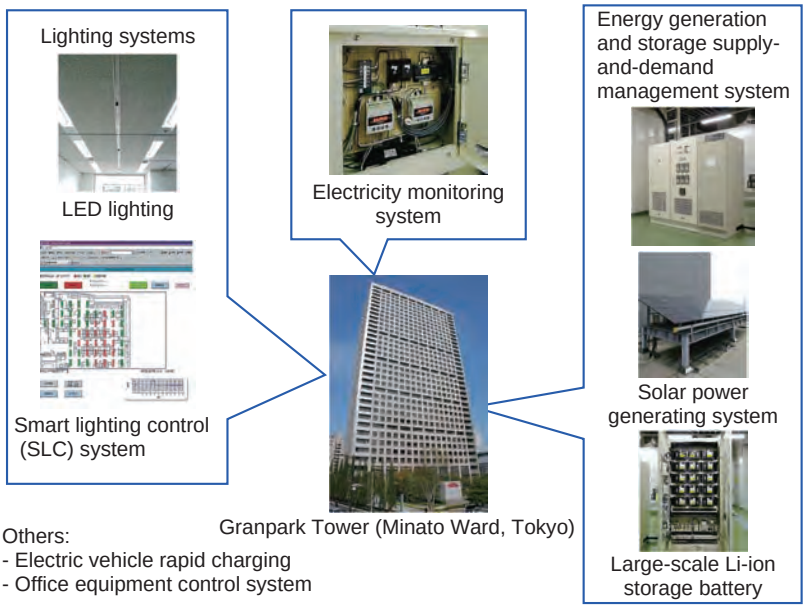

Fig. 1. Systems and equipment used in trial.

4. Lighting systems

Low-power LEDs were installed to replace conventional fluorescent lighting in offices, and the overall power consumption before and after the change was compared. The frequency of using the lights differs for each block in an office floor, so the effect of the switch is somewhat scattered. Nevertheless, it was confirmed that a power saving of over 50% can be achieved in blocks where lights are usually on during working hours. However, other measures to reduce power consumption by reducing the number of fluorescent lights in offices have already progressed, and switching to LEDs in areas where this has been done yields reductions of only a few percent. We have begun implementing measures such as thinning the LEDs while maintaining the lighting level. We have also installed lighting controllers on some floor blocks. These controllers enable lights to be turned on and off through the web from personal computers (PCs) at each desk. This allows conventional measures such as turning off all lights during lunch time or at a set time at the end of the day, but also promises further effects by enabling employees to turn out lights at individual desks from their PCs while they are out of the office or away from their desks for meetings or other reasons. The changes in power consumption for lighting before and after installing the lighting control system are shown in **Fig. 2**. The figure compares one month of data before and after installation (above and below). The horizontal axis shows power consumption through a single day, with the minimum to maximum power consumption represented as a color gradient from blue to red. A comparison of the upper and lower graphs shows that many regions that were red before introducing the system become purple or blue afterwards. We assume this is a result of encouraging individuals to turn out the lights. In the future, it will be necessary to study how to increase awareness about the importance of saving energy and to promote further operational measures that increase the effects of using this system.

5. Supply-and-demand management system

This system supplies power to some of the offices in the building using a combination of solar panels, which generate energy, and large Li-ion batteries, which store energy, together with the power supplied by the power company. In the trial, the amount supplied from the generated and stored energy is varied to reduce the peaks from the power system during normal times. However, the batteries can also be used as an emergency measure, providing backup power to the entire floor in the event of power outages due to a disaster (**Fig. 3**).

Solar panels with an output of 10 kW were installed on the roof of the Granpark building, approximately

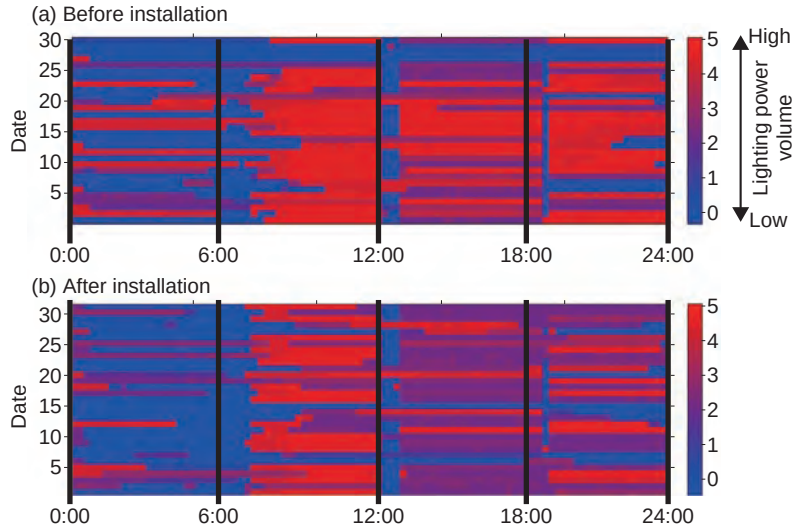

Fig. 2. Change in lighting power consumption before and after installing the lighting control system (five levels shown on color gradient).

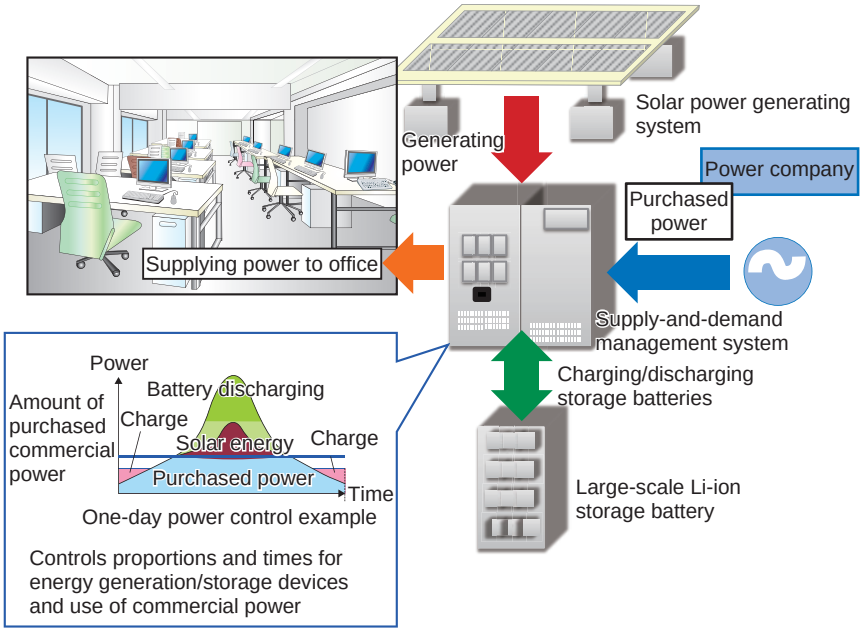

Fig. 3. Supply-and-demand management system overview.

140 m above the ground. The trial also involved investigating the use of specially designed mountings to deal with the strong winds that occur in such a high location, as well as implementing operational measures such as periodic inspections. The solar panels generate power at times that correspond closely to office work hours, so they basically supply power directly to the office floor through the supply-and-demand management system. Large-scale Li-ion storage batteries with a capacity of 25 kWh (12-cell module, where each cell has a capacity of 85 Ah (ampere-hours)) were also installed. In the trial, these

were charged overnight from commercial power and discharged during the assumed peak power times, providing approximately 80% of the power when combined with the solar panel generated power.

The capacity of the Li-ion storage batteries is limited because of the areas available to install them and because of other issues as well, and they can therefore become depleted during office peak times if solar panel output decreases due to rain or cloudiness. However, in this trial, we expect to obtain knowledge that will help identify optimal operating conditions, even if the battery capacity is limited. In the future, we will use this knowledge by linking it to automatic control of operations and adjusting battery discharge rates according to the predicted solar panel output, among other measures.

6. Other measures and future plans

Some other practical energy-saving measures include installing an office equipment control system that can reduce power consumption by externally adjusting clock frequencies and CPU (central processor unit) load in PCs installed on the office floor, and installing a rapid electric vehicle charging system that enables electric vehicles to be linked with storage batteries and to be charged even during peak commercial power times. We are currently analyzing the effects and usability of such measures.

We will continue our trials in the future. There are also plans to expand development into other areas such as linking buildings together and using communications to exchange data on their power use; adjusting the ratio of power sources used according to factors such as energy prices and the external state of supply and demand; and automating control of energy-saving measures to reduce power consumption.

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Power-saving Technologies for Network Equipment and Their Application—ONU/wireless-LAN Sleep Technologies

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Abstract

The amount of power consumed by equipment installed at various locations in the network is increasing with the spread of broadband services. In particular, a large amount of equipment is installed in user homes, and this home equipment accounts for most of the power consumed by the network. Reducing the power consumed by home network equipment is therefore becoming increasingly important considering the recent tightening of the electric power supply in Japan, as well as global warming concerns. This article introduces power-saving technology for in-home network equipment and power-saving technology for wireless local area networks.

Keywords: ONU sleep, wireless LAN, power-saving technology

1. Introduction

Network power consumption is increasing along with the spread of broadband services. The increasing amount of equipment that must be installed to provide services is given as the main reason for this rise in power consumption, and as it turns out, equipment installed on the end-user side in homes, or customer premise equipment (CPE), consumes most of the power in the network. For example, optical network units (ONUs) on the user side used for domestic fixed-line broadband services are responsible for 60% of all power consumed by the network (**Fig. 1**) [1]. The power consumed by one ONU is actually small (on the order of several watts), but because there are more than 10 million ONUs installed, their total power consumption is huge. If we now include the power consumed by wireless local area network (LAN) access points (APs) and home gateways (HGWs), this proportion of consumed power becomes even higher. In fact, we can surmise that the total amount of power consumed by this equipment is about the same as that produced by a single medium-scale thermal power plant. Such an enormous amount of power can place a large load on the environment. Power-saving technology for network equipment is therefore expected to become exceedingly important in the years to come. In this article, we introduce the most promising power-saving technologies and applications for access network equipment.

2. Power consumption in CPE and power-saving technology

2.1 PON system and ONU sleep technology

At present, the main network scheme for achieving fiber to the home (FTTH) is the passive optical network (PON). A key feature of PON is that multiple ONUs share an optical fiber and a single optical line terminal (OLT) in the central station, which makes for economical provision of broadband services (Fig. 1). The main type of PON system currently used

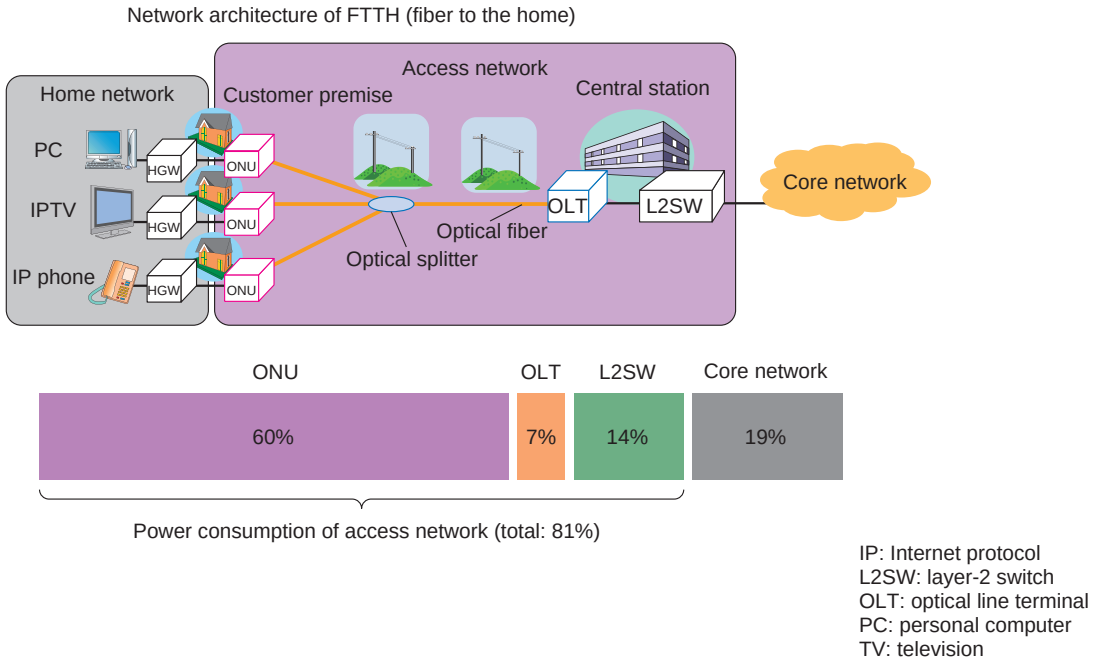


Fig. 1. Network architecture and power consumption of access network equipment relative to the entire network.

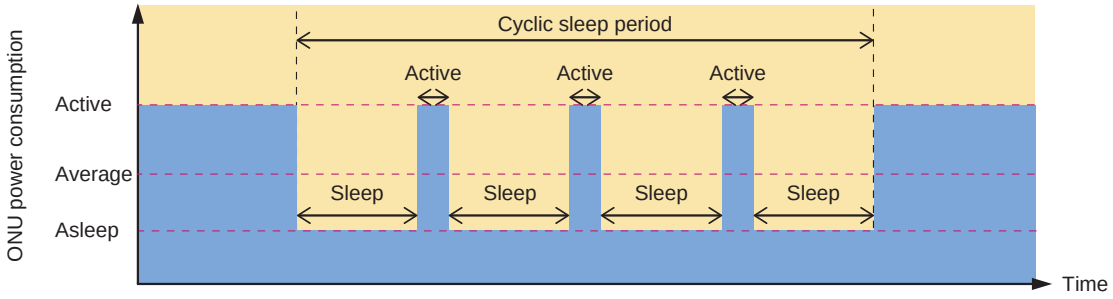


Fig. 2. ONU sleep technology (cyclic sleep).

in Japan is Gigabit Ethernet-PON (GE-PON), which has a transmission capacity of 1 Gbit/s; a next-generation 10-Gbit/s-class PON is now under development.

A typical power-saving technology in PON systems is *ONU sleep*. This technology reduces power consumption by turning some ONU functions and devices off during times when there is no traffic. A number of sleep methods have been standardized by international bodies such as the International Telecommunication Union, Telecommunication Standardization Sector (ITU-T) and the Institute of Electrical and Electronics Engineers (IEEE). ITU-T Recommendation G.987.3, for example, prescribes (1) a dozing mode that turns off ONU transmit functions in the absence of upstream signals and (2) a cyclic sleep mode that turns off the transceiver intermittently in the absence of upstream/downstream signals. In cyclic sleep mode, an ONU wakes up for only a very short period of time (**Fig. 2**), and while this mode requires advanced control techniques between the OLT and ONU to determine whether sleep should be continued, it can be expected to provide stable communications quality and to conserve power. In summary, basic ONU sleep technology as described above has come to be prescribed as a standard, but

technology for achieving an even greater power-saving effect and sleep technology that can reduce power consumption in coordination with peripheral devices are now being pursued as a field of research that is expected to expand in the future.

2.2 Sleep technology in wireless LAN

A wireless LAN terminal or station (STA) is normally used in an awake state, which means that power will usually be supplied by a battery. A variety of power-saving techniques have consequently been devised at the control and device levels. For example, there is a sleep control function prescribed in the IEEE 802.11 standard that enables an STA to make a transition from its usual awake state to a sleep state. In the sleep state, power to some circuits is suspended, which significantly reduces power consumption. In this state, however, no signals can be transmitted or received.

A wireless LAN AP, on the other hand, is usually connected to a commercial power supply, and as a result, no power-saving functions have yet to be prescribed. However, APs are beginning to be deployed in increasing numbers to cope with the many and diverse devices equipped with wireless LAN functions and to offload mobile traffic originating in the large number of smartphones now in use. Greater environmental consciousness is also driving expectations for power saving in APs.

3. Advanced sleep technologies and their application

We introduce here three advanced ONU/wireless-LAN sleep technologies coming out of NTT laboratories.

(1) Deep sleep technology that maintains a telephone standby state during long power outages at the time of a disaster by keeping ONU power consumption to a bare minimum.
(2) Coordinated sleep technology that improves the power-saving effect through coordination between the ONU and other CPE components.
(3) Wireless LAN AP sleep technology that aims to save power in wireless LAN APs.

3.1 Deep sleep technology

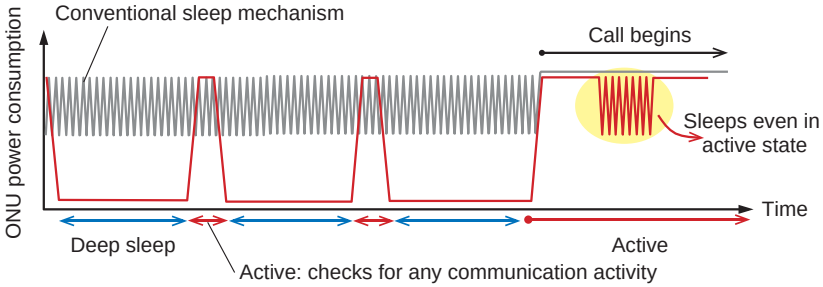
FTTH connects the user's house with the NTT exchange via optical fiber to provide the user with a broadband Internet connection and telephone and video services. The FTTH configuration is such that if a power outage occurs because of a natural disaster or other unforeseen event, operations may be suspended, and services may be unavailable. Unlike conventional telephone lines, optical fiber cannot easily supply power from the exchange, and consequently, finding a way to ensure communications during emergencies has become an issue of concern.

One method that can be considered for providing services during a power outage is to equip ONU equipment with a battery so that the ONU can be operated by battery power at such times. Here, however, operating an ONU by battery for a relatively long time while maintaining an active state would require an extremely large battery capacity, so greatly reducing the amount of power consumed by the ONU itself is crucial. At the same time, there will invariably be a need to make emergency calls at the time of a power outage, so a mechanism that would allow calls to be made and received during a crisis must be investigated.

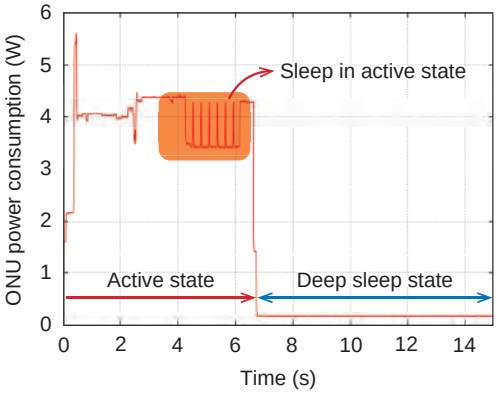
In light of the above, we have undertaken research on saving power through a *deep sleep* scheme that provides for long-term telephone-call standby during power outages. As shown in **Fig. 3(a)**, deep sleep suspends nearly all ONU functions and sleeps in long one-second intervals, resulting in significant power savings compared to conventional ONU sleep. In addition, deep sleep applies conventional ONU sleep while a call is in progress to reduce power consumption during this time. We evaluated the deep-sleep effect using test equipment and found that power consumption could be reduced to about 200 mW in the deep-sleep state compared to 4 W in the active state, as shown in **Fig. 3(b)**.

While deep sleep technology can greatly reduce the power consumed by an ONU, almost all ONU functions are suspended in this mode, which means that arriving packets are simply discarded. In the case of an incoming call on an ordinary IP (Internet protocol) phone, a call control server sends the packets requesting call reception and will resend those packets if they do not arrive at their destination. However, if the packets continuously fail to be received and a timeout occurs, no call can be received, as shown in **Fig. 4(a)**.

However, to receive re-sent packets and ensure reception of an incoming call, the ONU must maintain an active state in which power consumption is high for a certain length of time, as shown in **Fig. 4(b)**. We therefore investigated a method for shortening this time through cooperative operation with equipment on the exchange side. In this method, the OLT buffers incoming-call packets and sends them out synchronized with the ONU active state, as shown in



(a) Deep sleep operation and power-saving operation in active state



(b) Evaluation of power-saving effect by deep sleep control (using actual equipment)

Fig. 3. Deep sleep technology.

Fig. 4(c). In this way, the ONU can shorten its active time for receiving incoming-call packets, thereby obtaining a large power-saving effect. In an evaluation using test equipment, we found that the amount of power consumed by an ONU in a standby state allowing incoming calls can be reduced to less than 1 W on average. This result demonstrates the potential of deep sleep as a viable technology.

3.2 Coordinated sleep technology

The number of CPE units installed in homes is increasing as the home network market expands. At the same time, an increase in environmental consciousness is driving the spread of CPE equipped with power-saving functions such as those described in IEEE 802.3az Energy Efficient Ethernet (EEE) and IEEE 802.11 Power Saving Mode (PSM). However, while most CPE equipment is connected to the ONU via the HGW (**Fig. 5**), these power-saving functions operate independently of each other, and as a result, they do not necessarily operate optimally from the viewpoint of the entire network. For example, if a power save timing mismatch occurs between communicating with another CPE and entering a power-saving state, a transition will unavoidably be made to a normal state before a power-saving effect can be obtained. In fact, a reduced power-saving effect caused by such a mismatch in communication timing can be particularly noticeable in CPE such as ONUs where traffic tends to concentrate. In response to this situation, we are researching and developing coordinated sleep technology that greatly increases the power-saving effect by synchronizing communication timing between the ONU and HGW.

The ONU and HGW connect and communicate via a UNI (user network interface) that interconnects the telecommunications carrier's equipment and user equipment. During ONU sleep, however, any input of upstream traffic from the HGW cancels ONU sleep, forcing the ONU to revert to its normal state. In particular, an ongoing inflow of traffic from the HGW frequently disturbs ONU sleep, thereby degrading the power-saving effect. To obtain a power-saving effect through ONU sleep, a sleep state ranging from several

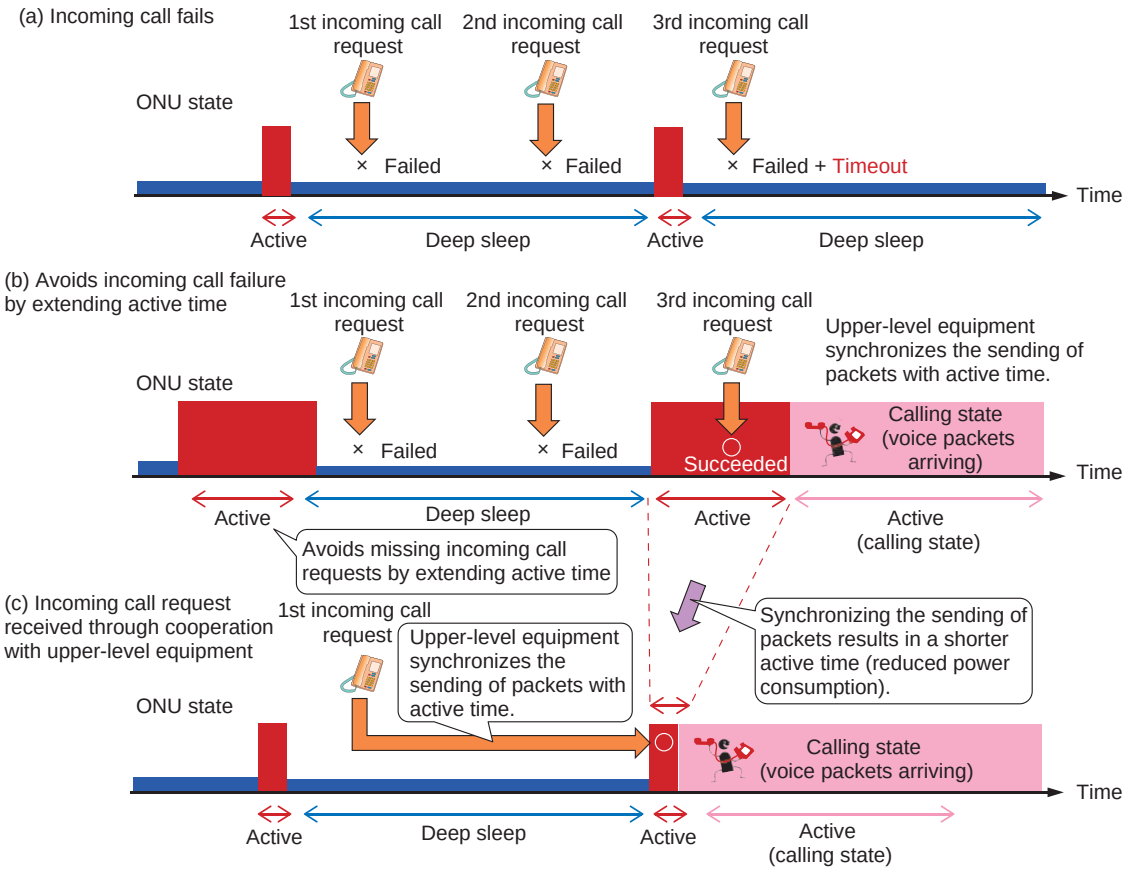


Fig. 4. Receiving an incoming call request in deep-sleep control.

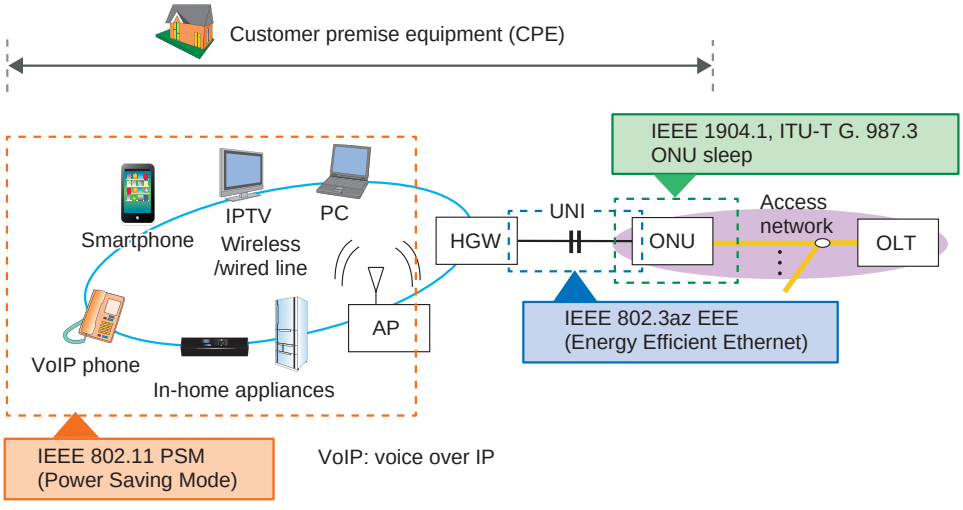
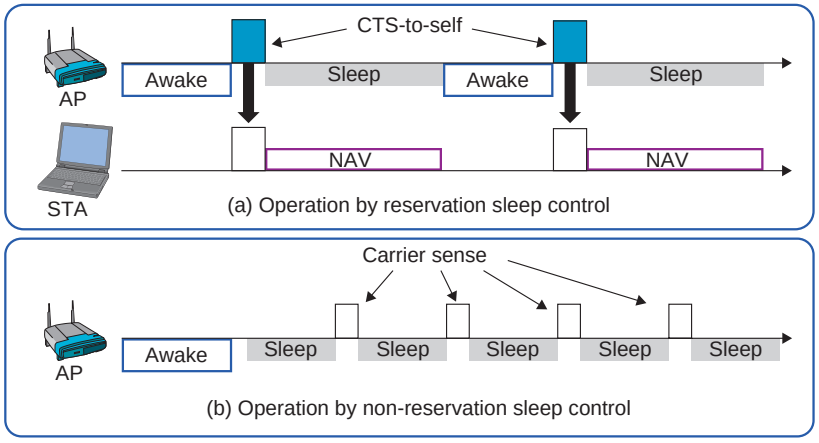


Fig. 5. Power-saving technology in CPE.



CTS: clear-to-send

Fig. 6. Operation by reservation/non-reservation sleep control technologies (wireless).

tens to several hundreds of milliseconds must be secured (depending on the type of transceiver). An effective method in this regard is to temporarily suspend the inflow of traffic. We therefore developed a technology for maintaining the ONU sleep state by notifying the HGW side of ONU sleep and buffering upstream frames at the HGW during ONU sleep. We evaluated this technology in a 10G-EPON system that complies with the ONU sleep mechanism specified in IEEE Std. 1904.1 SIEPON and IEEE 802.3az EEE, and we succeeded in reducing power consumption in target components by about 40% compared to past values.

We consider that coordinated sleep technology between the ONU and HGW can also be effective for CPE with wireless LAN functions. Looking forward, we seek a large, overall power-saving effect by establishing coordinated operation among many units of equipment.

3.3 Wireless LAN AP sleep technology

As described earlier, power-saving functions for STAs have come to be standardized, but no such functions have been specified for APs. We have proposed two types of power-saving technologies to rectify this situation: reservation sleep control and reservation-less sleep control [3], [4]. Either control method maintains connectivity with the AP without having to change or add functions in STAs. Here, we outline each of these methods and their respective effects on power saving.

Operation by reservation sleep control is outlined in **Fig. 6(a)**. In this control method, the AP first notifies the STA of a transmission-prohibited period, that is, a network allocation vector (NAV), and then enters a sleep state. An STA in which a NAV is set transmits no signals during this AP sleep period and therefore generates no upstream packet loss.

Operation by reservation-less sleep control is outlined in **Fig. 6(b)**. In this case, the AP alternates between a sleep state and carrier-sense interval in short cycles. In contrast to reservation sleep control, this control method does not notify the STA of the NAV, which means that there can be times in which the AP fails to receive signals transmitted from the STA. However, the AP can sense signals transmitted from the STA during the carrier-sense interval, and if it does, it will make a transition from a sleep state to an awake state and receive frames that have been re-sent from the STA.

The results of simulating sleep efficiency using these control methods are shown in **Fig. 7**. Both of these control methods exhibit a traffic dependency, and while reservation-less sleep control is superior in the relatively low traffic region, the reservation sleep control is superior in the relatively high traffic region. This is because in the low traffic region, the difference in sleep per unit time between reservation and reservation-less sleep control has an effect on sleep efficiency, while in the high traffic region, re-sent frames frequently appear in reservation-less sleep control, thereby decreasing the opportunities for entering the sleep state.

In future research, we plan to clarify the performance

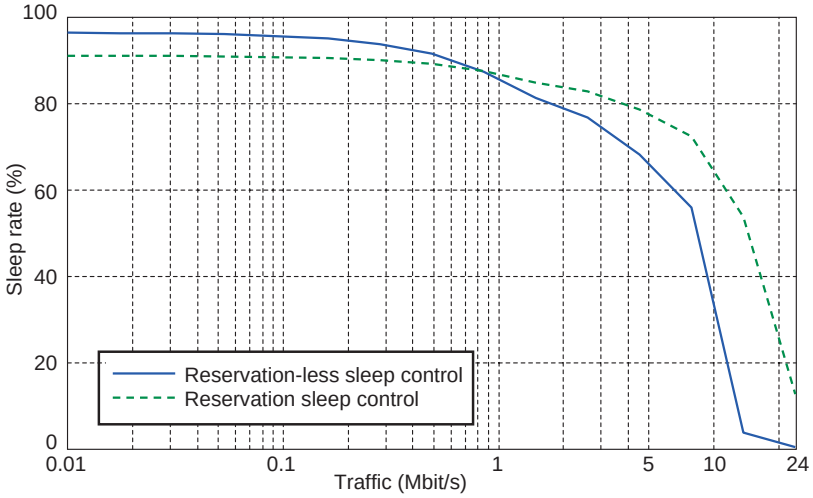


Fig. 7. Performance of reservation/reservation-less sleep control technologies.

and applicable regions of sleep control methods using test equipment and more precise evaluation techniques.

4. Future developments

The amount of communication equipment installed on the user side is expected to continue increasing with the spread of broadband, and it is safe to say that the overall amount of power consumed by this equipment will also increase. It can also be assumed, however, that the demand for power-saving communications devices will become increasingly stronger in order to reduce the load on the environment. Because the sleep technologies introduced in this article are power-saving technologies based on communication protocols, they can help achieve a power-saving effect in all types of equipment supporting those protocols. These technologies should therefore be able to contribute greatly to the deployment of a power-saving telecommunications network.

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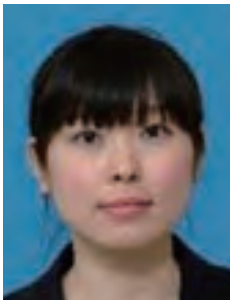

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EMC Technology that Protects Network Equipment from Electromagnetic Problems

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Abstract

NTT has prohibited the use of wireless devices in telecommunications equipment rooms to prevent interference from such devices causing serious equipment failures. However, there is a growing call to improve the efficiency of maintenance work in these rooms by establishing conditions for the safe use of wireless devices. Demand is also growing to make networks more resistant to natural disasters such as lightning, damage from which has been increasing in recent years. This article introduces our activities that address these issues.

Keywords: EMC, in-house standards, TR

1. Introduction

The NTT Group aims to build a telecommunications infrastructure that provides continuous connections 24 hours a day and has therefore been working to establish an efficient maintenance framework and to reduce the number of faults that occur. In addition, it has been implementing measures to reduce the energy consumption and CO_2 emissions of telecommunications equipment, power supply systems, air-conditioning systems, etc., and measures to reduce operating expenses (OPEX) in order to provide high-quality telecommunications services at low prices. The use of electromagnetic compatibility (EMC) technology is being applied to support these efforts [1], [2].

The purpose of EMC technology is to provide reliable telecommunications services by preventing the equipment that makes up a telecommunications infrastructure from radiating electromagnetic waves that might interfere with other equipment and also from being affected by electromagnetic waves from other equipment, or even from lightning.

This article introduces some recent development activities in the area of EMC. Specifically, it introduces activities to improve maintenance efficiency by enabling wireless devices to be used safely in telecommunications equipment rooms, and activities to reduce the number of faults caused by lightning.

2. Activities to enable the use of wireless devices in telecommunications equipment rooms

2.1 Background to this study

Today NTT prohibits, in principle, the use of wireless devices in telecommunications equipment rooms in order to avoid the risk of wireless devices interfering with telecommunications equipment and causing a serious failure. However, NTT is also studying a new operation and maintenance procedure that makes use of convenient tablet-type terminals equipped with wireless local area network (LAN) access capability, which have become widespread in recent years. An example of maintenance work carried out using a tablet is shown in **Fig. 1**. The worker in the telecommunications equipment room downloads procedure manuals to a tablet and conducts maintenance work with assistance from an operator at a remote site. The

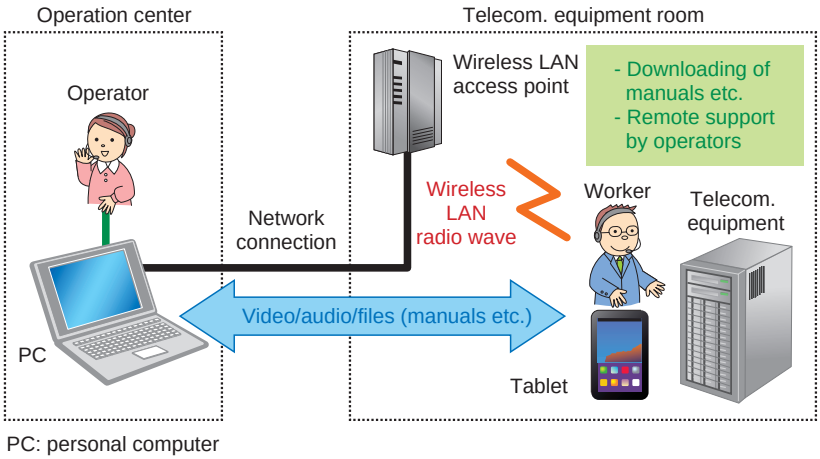

Fig.1. Example of maintenance work using a tablet.

worker and operator can communicate with each other using both audio and video, and it is easy to confirm the required tasks. Therefore, erroneous operations can be avoided, and work efficiency can be improved.

To allow this type of maintenance work, it is necessary to enable a wireless LAN to be used in telecommunications equipment rooms. However, as mentioned earlier, use of wireless devices is currently prohibited. Removal of this restriction will require the establishment of conditions under which radio waves from a wireless LAN do not affect telecommunications equipment, and the development of a guideline for the safe use of wireless devices.

2.2 Establishing conditions for safe use of wireless devices

With the aim of establishing conditions for the safe use of wireless devices in telecommunications equipment rooms and thereby enabling efficient maintenance work, in July 2011, NTT Energy and Environment Systems Laboratories and the Technical Assistance and Support Center, Maintenance and Service Operation Department, Network Business Headquarters, NTT EAST, took the initiative to create a Working Group on the Use of Wireless Devices in Telecommunications Equipment Rooms. This Working Group (WG) consisted of members from various companies in the NTT Group, and it initiated a study to measure the effect of wireless LAN on telecommunications equipment and to establish conditions for the safe use of wireless devices. The WG focused on the following areas:

(1) Measuring how a wireless LAN affects telecommunications equipment

The extent of the effect imposed by radio waves emitted from a wireless LAN depends greatly on a telecommunications system's immunity to interference. However, this immunity differs from system to system. Therefore, we measured the effect of radio waves from a type of wireless LAN that maintenance staff in the field have asked to use. The test system used for this measurement is shown in **Fig. 2**. The signal generator generates and amplifies wireless LAN signals, which are radiated towards telecommunications systems from an antenna. The test to evaluate the immunity of a system to external radio waves is called a radiation immunity test. The required basic test conditions are specified in ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) Recommendation K.48. However, evaluations based on the test conditions compliant with this recommendation face the following problems:

a) Since the recommendation uses a narrow-band AM (amplitude modulation) signal (1 kHz, 80%) as the test signal, the extent of interference measured based on this recommendation is likely to be different from that from the broadband signals of a wireless LAN.
b) The specified test electric field strength level does not necessarily match the electric field strength experienced when a wireless device is located close to a telecommunications system.

These problems were solved as follows. (a) The test

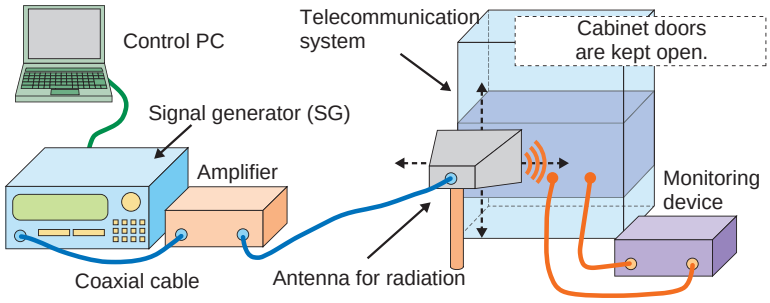

Fig. 2. Test system for applying wireless LAN signals.

signals used simulated signals from a wireless LAN (orthogonal frequency division multiplexing), and measurements were made in the 2.4-GHz and 5.2-GHz bands, which are standard for a wireless LAN. (b) The test level was set at the electric field strength that exists when a telecommunications system is 1 cm away from a wireless LAN (18 V/m).

We tested about 90% of all the telecommunications systems in use in telecommunications equipment rooms today and checked whether alarms were generated, or whether any degradation in performance (such as an increase in transmission loss) arose when test signals were applied. From the results of this test, we were able to specify the minimum distance between a wireless LAN and a telecommunications system at which the telecommunications system is not affected by radio waves from the wireless LAN and thus, where wireless devices can be used safely.

(2) Dealing with systems for which testing is difficult

Item (1) above described how we used a test system to radiate radio waves towards actual telecommunications systems, how we checked whether the radio waves affected telecommunications systems or not, and how we derived conditions for using wireless devices. However, in reality, most telecommunications equipment rooms accept collocation; that is, they also house telecommunications systems operated by non-NTT providers. Therefore, it is necessary to establish conditions for using wireless devices without fear of affecting the telecommunications systems of other providers, thereby also enabling these providers to use wireless devices. Setting up a test system that could be used to measure interference with other providers' systems was difficult, so it was necessary to devise an alternative means.

To solve this problem, we studied a method of estimating the lower bound of the immunity of these systems. At present, NTT's in-house standard requires that the electromagnetic interference level of telecommunications systems installed in telecommunications equipment rooms satisfy the requirements for Class A of the technical standard specified by VCCI (the Voluntary Control Council for Interference by Information Technology Equipment). Class A specifies that the electric field strength measured at a 3-m distance from telecommunications systems must be 76 dBμV/m or lower from 1 to 3 GHz, and 80 dBμV/m or lower from 3 to 6 GHz. The electric field strength is roughly inversely proportional to the distance from the radio wave radiating point. Therefore, the electric field strength at a point 1 cm away from a telecommunications system is about 300 times stronger than that at a point 3 m away from the system. Telecommunications systems in telecommunications equipment rooms work well even when they are installed close to each other. This implies that telecommunications systems in telecommunications equipment rooms have an immunity that is higher than the electric field strength of the disturbance wave radiated by adjacent telecommunications systems (about 300 times higher than the level specified in the VCCI standard). This fact makes it possible, as shown in **Fig. 3**, to estimate the lower bound of the immunity at a point 1 cm from a telecommunications system based on the electric field strength of electromagnetic disturbing waves (VCCI-specified level) at a point 3 m away from a telecommunications system. Determining the distance at which this estimated level becomes equal to the electric field strength of radio waves from a wireless LAN makes it possible to derive conditions under which radio waves from a wireless LAN do not affect telecommunications systems—in particular, systems of other providers that cannot be easily tested.

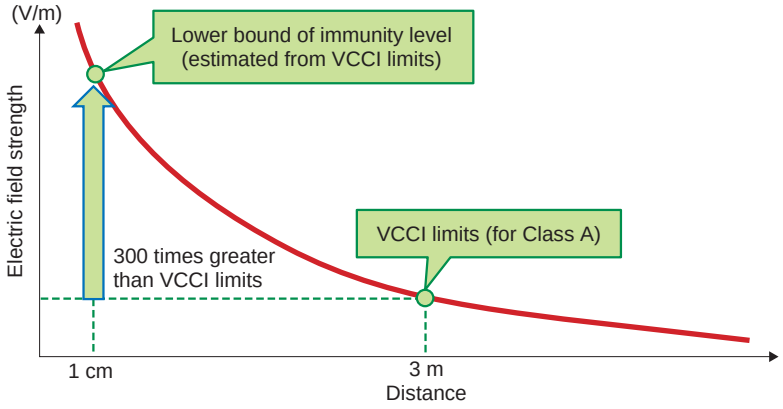

Fig. 3. Method of estimating a telecommunication system's immunity to radiation.

Using (1) the conditions for use of a wireless LAN derived from measuring the effect of radio waves from a wireless LAN on telecommunications systems, and (2) conditions for use of a wireless LAN derived from estimating the immunity level of telecommunications systems, NTT has developed a guideline that establishes the conditions under which wireless devices can be used safely in telecommunications equipment rooms, and thus has been improving the efficiency of maintenance work.

3. Activities to reduce the number of faults caused by lightning in an optical access service

3.1 Current state of faults by lightning

Most faults in an optical access service that are caused by lightning occur at optical access terminals such as optical network units (ONUs) and home gateways (HGWs), which are installed inside buildings owned and managed by customers. This is because it is difficult for NTT to implement protective measures against lightning inside buildings owned and managed by its customers. In contrast, telecommunications systems in NTT communication centers and datacenters have been protected from lightning by connecting these systems to ground and using lightning-resistant transformers in power supply systems.

For example, Japan's low-voltage power distribution network uses TT (Terre-Terre, or earth-earth) grounding, which does not use protective grounding conductors from the distribution network. Therefore, it is difficult to ground optical access terminals. In addition, since the configuration of local networks to which optical access terminals are connected has grown more diverse and complicated, lightning faults occur through different mechanisms, which were unknown until recently.

NTT has been working on a solution to this problem by carrying out activities to reduce the number of faults that occur, particularly those occurring in optical access terminals because of lightning, in order to provide reliable telecommunications services. The mechanism of how lightning damages optical access terminals is explained below, and measures to prevent such damage are also described.

3.2 Mechanism of fault occurrence in optical access terminals

To find out how lighting damages optical access terminals, it is necessary to determine the parts of the optical access terminal that are damaged and the path through which a lightning surge flows. For this purpose, in June 2011, NTT Energy and Environment Systems Laboratories and the Technical Assistance and Support Center, Maintenance and Service Operation Department, Network Business Headquarters, NTT EAST, took the initiative to create within the NTT Group a Working Group on Protection from Overvoltage, and began collecting ONUs/HGWs that had been damaged by lightning and analyzing the faulty parts.

This analysis has revealed that lightning-induced faults that involve damage to both the POTS (Plain Old Telephone Service) port and the Ethernet port have been increasing in number. The path through which a lightning surge flows and the mechanism of occurrence of lightning-induced faults are described below and shown in **Fig. 4**.

(i) A lightning strike raises the electric potential of

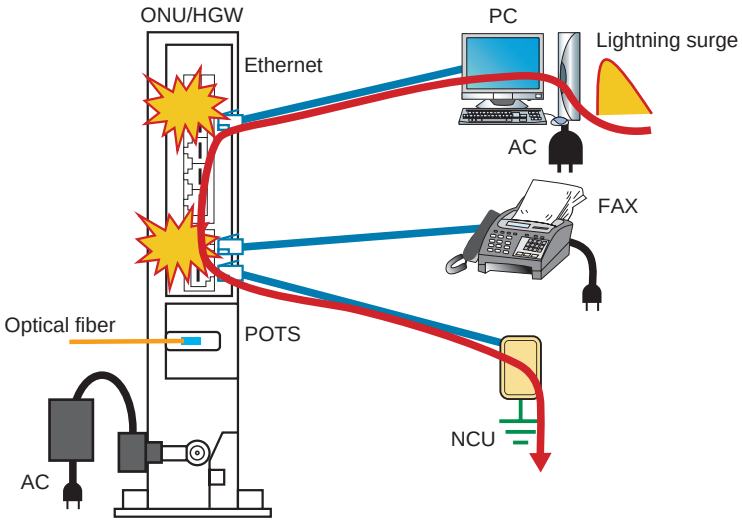

Fig. 4. Mechanism of fault caused by lightning.

the ports of all devices within the building.

(ii) Most facsimile machines and network control units (NCUs, i.e., units used to remotely control gas meter reading etc.) that are connected to the POTS port of the ONU/HGW have built-in surge protective devices (SPDs). When lightning strikes, the SPD operates and, as a result, the potential of some communication lines and power supply lines becomes equal to the ground potential.

(iii) A potential difference arises between the POTS port, whose potential is equal to the ground potential, and the other ports (the Ethernet port connected to a PC in Fig. 4), which remains at the raised potential.

(iv) This difference in potential causes an insulation breakdown between the Ethernet port and the POTS port, and both of these ports are damaged simultaneously.

This type of fault would not occur if the telecommunications device concerned had only a telephone port and an AC (alternating current) power port, as in the case of a conventional telephone. However, with the spreading use of optical access terminals such as ONUs/HGWs—which have multiple ports for connection to different devices and are thus susceptible to simultaneous damage to two ports—cases of lightning-induced damage are increasing in regions where lightning is frequent.

3.3 Overvoltage resistibility test for existing optical access terminals

To reduce the number of optical access terminals damaged by lightning, it is necessary to determine the technical requirements (resistance to lightning-induced overvoltage, testing method, etc.) for these terminals based on the above-mentioned mechanism of fault occurrence, and to develop terminals that satisfy these requirements.

(1) Revisions to technical requirements (TRs) concerning resistance to overvoltage

NTT has been complying with existing TRs concerning overvoltage resistibility (hereinafter referred to as *overvoltage TR*) of telecommunications systems. However, they do not embrace the technical requirements necessary to prevent the occurrence of faults by the above-mentioned mechanism. Therefore, we have established TRs for the Ethernet port of an optical access terminal, which is the port that provides a path for a lightning surge to reach the terminal, and have revised the overvoltage TR accordingly.

Specifically, we have added requirements for overvoltage resistibility between the Ethernet port and the POTS port as well as a method of measuring this. Since lightning-induced faults can occur between multiple Ethernet ports by the same mechanism, we have also added requirements for overvoltage resistibility between Ethernet ports and a method of measuring it.

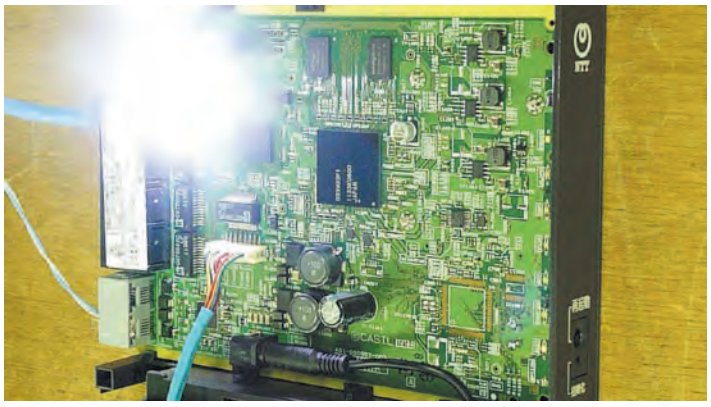

Fig. 5. Test terminal used for overvoltage test of Ethernet port.

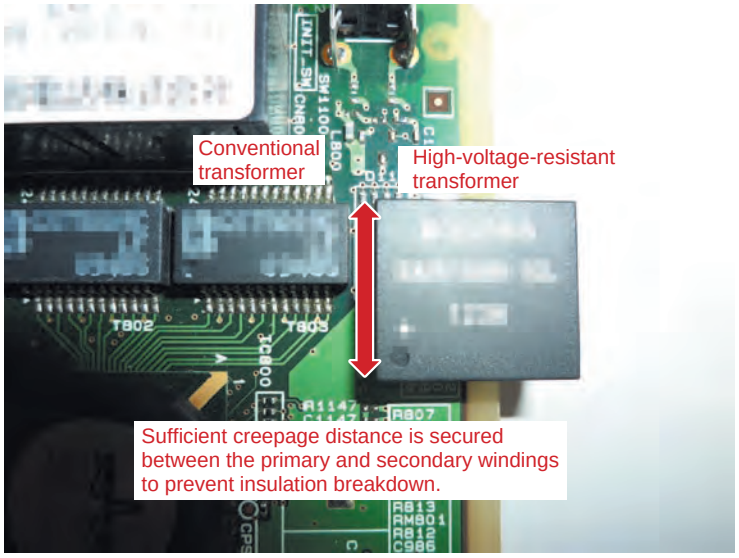

Fig. 6. Comparison of a high-voltage-resistant pulse transformer with a conventional one.

(2) Determining how to enable optical access terminals to satisfy the overvoltage TR

The output device of an ordinary Ethernet port is protected by an isolating transformer, called a pulse transformer, which provides isolation from the external wires connected to the network equipment that suffered from overvoltages. The Ethernet port of the standard ONU/HGW in use today also has a pulse transformer built into it. However, pressure is mounting to downsize the ONU/HGW; consequently, it is not easy to satisfy the requirements for both high packaging density and high dielectric strength simultaneously. We conducted a lightning surge test on existing ONUs/HGWs and found that a discharge occurs at a voltage lower than that specified for overvoltage resistibility in the overvoltage TR. When overvoltage was applied to a POTS port and an Ethernet port of the ONU/HGW, the bright spot shown in **Fig. 5** was observed. The bright spot indicates a breakdown occurred at the pulse transformer.

One way to strengthen the overvoltage resistibility is to increase the distance between the primary and secondary windings of the pulse transformer. A pulse transformer with an increased insulation distance is compared with an existing pulse transformer in **Fig. 6**.

To verify this solution, we conducted an overvoltage

resistibility test, in the manner used in Fig. 5, with a test terminal on which a pulse transformer with an increased insulation distance had been mounted. The test confirmed that no discharge occurred, indicating that the overvoltage resistibility was improved.

The NTT Group will continue to study a method of mounting the improved transformer on the ONU/HGW and also an alternative method of attaching an external lightning-resistant component to Ethernet ports. Improving the overvoltage resistibility of optical access terminals will help to reduce the number of lightning-induced faults. We will continue to pursue activities to reduce such faults in the future.

4. Conclusion

This article has introduced some of the recent developments in the area of EMC technology to protect network equipment from electromagnetic problems. Specifically, it has introduced activities to enable wireless devices to be used safely in telecommunications equipment rooms, and activities to reduce the number of faults caused by lightning.

We have developed a technique to determine conditions for using a wireless LAN while ensuring that the radio waves it radiates do not affect the surrounding telecommunications systems, and a technique to determine conditions for using a wireless LAN even in cases where it is difficult to conduct tests with actual telecommunications systems. These techniques have made it possible to use a wireless LAN safely in telecommunications equipment rooms, even those where telecommunications systems of non-NTT providers are collocated. Enabling the use of a wireless LAN in a telecommunications equipment room under these conditions will make it possible to improve the efficiency of a variety of maintenance tasks and thereby to reduce OPEX.

We also introduced the results of analyzing a new mechanism in which a lightning strike causes a fault between the POTS port and the Ethernet port of an optical access terminal, and activities to reduce the number of lightning-induced faults. Looking ahead, we will continue to pursue activities to reduce the number of lightning-induced faults, thereby leading to fewer dispatches of maintenance staff in the field and contributing to the reduction of OPEX.

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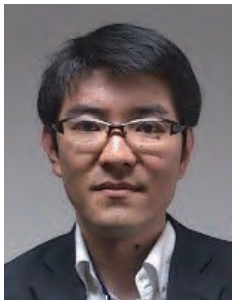

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Trends in Optical Access Network Technologies

Shigeki Sako

Abstract

The Second Promotional Project at NTT Access Network Service Systems Laboratories is focused on research and development of practical implementations of media network technologies. This article introduces the initiatives of the Second Promotional Project and the latest optical access network technologies. This Feature Article is based on a workshop presentation at the Tsukuba Forum 2013, held on October 18, 2013.

Keywords: optical access network, trend, implementation

1. Initiatives of the Second Promotional Project

The researchers at NTT Access Network Service Systems Laboratories are engaged in two main types of work. One team conducts core technical research on networks, and the other takes each of the technologies resulting from this network research and performs the research and development (R&D) required to implement them in the field, such as providing field support and establishing specific manufacturing technologies that are needed in the field. The Second Promotional Project deals with the latter. The main objective of the project is to implement technologies developed by the core research team in the field and to provide support for R&D and technical implementations carried out in the field.

R&D at NTT Access Network Service Systems Laboratories spans various technical fields and is divided into four categories according to field: optical access network technology, wireless access technology, infrastructure technology, and media network technology. The Second Promotional Project involves media network technology, with a particular focus on optical access networks, and also involves conducting R&D to improve the economy, quality, and stability of established technologies so they can be used in the field. Additionally, all installation configuration equipment is being developed in this project. This includes the equipment in NTT buildings, intra-office wiring cables, test equipment such as optical testing modules, underground and aerial cables and closures, drop cables, multi-dwelling wiring, connectors for optical network units, and indoor cables.

Examples of components that have been developed recently include an intra-office bending-loss insensitive (BI) cable. This BI cable uses hole-assisted fiber (HAF) technology in order to control the optical loss that occurs when the fiber is curved or bent compared with conventional cable.

Underground cable sections were conventionally operated by attaching an underground optical cable closure having both optical cable distribution and drop functions at each communication cable box or hand hole, but this led to problems including increased costs and operational difficulties. Therefore, we developed a new single-fiber count underground cable and separate closures for underground cable distribution points and drops in order to improve the operability of underground cable installations. The decision to hold the Olympic Games in Tokyo has accelerated plans to move facilities underground, so we expect these technologies to be widely used.

We have also built the highest-density aerial optical cables in the world, which are described in detail below. The aerial closures are also designed for better operability and economy than earlier closures. An

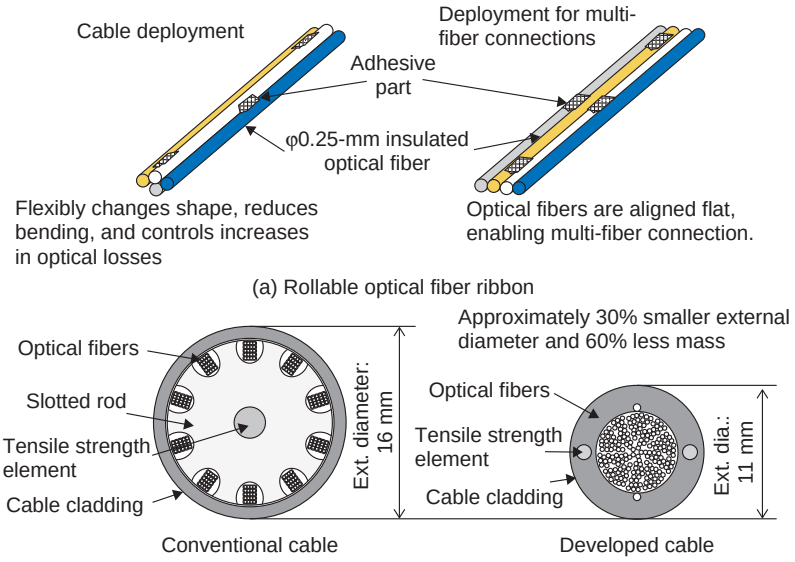

Fig. 1. Very-small-diameter high-density optical cables.

example is break-in technology. Conventionally, it was not possible to re-use the lower part of a cable if the fiber in an aerial section was partially cut. However, we developed a break-in pigtail to connect the upper and lower parts, and with it, we are now able to effectively use optical fiber that could not previously be used.

In collective housing such as multi-dwellings, the space for installing splitters, cabinets, and other equipment is usually limited, so we developed the E-cabinet series that can be installed in restricted spaces with varying shapes.

Intra-premises wiring generally involves using a conduit to service each room. However, copper cables occupy a lot of space in the conduit, which makes multi-cable installation difficult. Therefore, we used small-diameter, low-friction, indoor optical fiber, which enabled installation in existing conduits that only have a small amount of space available. Also, by giving the cable some rigidity, we were able to push it directly into the conduit without requiring the use of a wire-pulling tool. This greatly improved the deployment.

However, when there are no usable conduits, even in single dwellings, holes must be drilled in external walls, and this can be difficult in terms of obtaining agreement from the owner or because of the building structure. Thus, we developed a new wiring method that does not require holes to be drilled in external walls. Instead, it uses an indoor optical cable for restricted spaces that is able to pass through narrow gaps in doorways or window sashes. HAF technology was used to implement this cabling.

2. Recently developed access network technologies

2.1 Very-small-diameter high-density optical fiber cables

We have developed optical cables with the highest density in the world. The 200-fiber count cable is thin and lightweight, with an external diameter 30% smaller than conventional cables, and a weight 60% lighter. The core technology used to achieve these cables is the rollable optical fiber ribbon shown in **Fig. 1**. Earlier versions of optical fiber ribbon consisted of four parallel fibers insulated as a bundle, which enabled multi-fiber connections. However, when these were housed at high density, the optical fibers tended to bend significantly, which increased the optical losses. Consequently, cables were configured with a slotted rod to protect the fibers. The rollable optical fiber ribbon has four parallel optical fibers that are intermittently connected. Thus, the bending can be controlled, and they can still be connected as a bundle, as with conventional optical fiber ribbon.

Further, various economic benefits are gained by

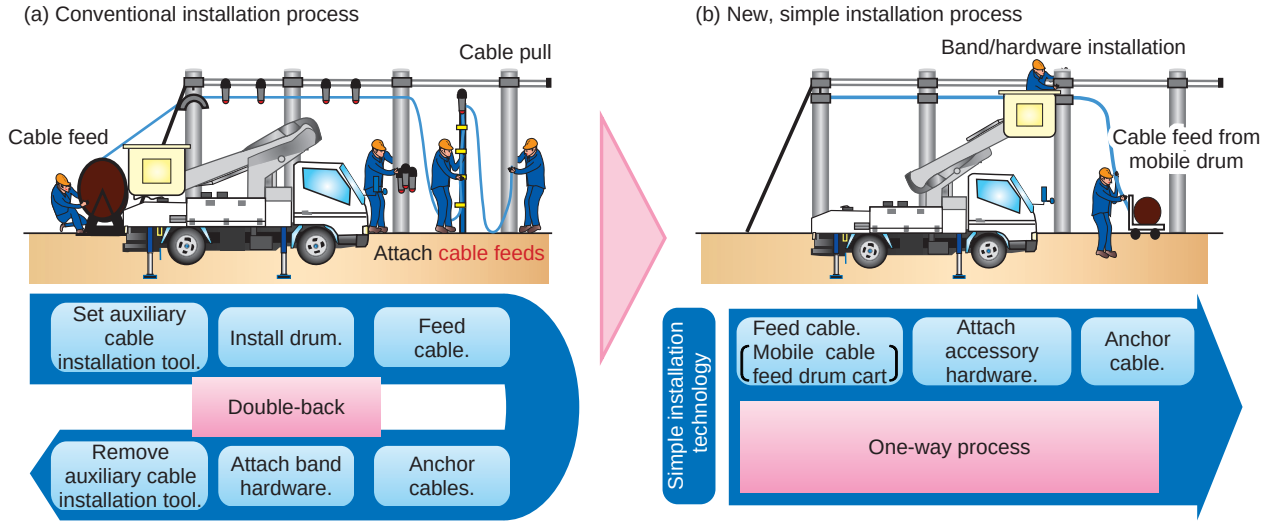

Fig. 2. Simple cable installation technology for rural areas.

reducing the diameter and weight; these include a reduction in the materials cost, which makes it possible to reduce the product price, reduced deployment cost, because pulling tools are not required, and less need for additional conduit in sections where the conduit is pushed up above ground.

2.2 Optical access facilities configuration technology for rural areas

In developing the optical services for NTT EAST and NTT WEST, optical equipment was deployed throughout the country. Facilities were already adequate in most urban areas, so development of rural areas was planned for the future. The environment in rural areas is different from that in urban areas in terms of the distances from NTT buildings to customer premises and the customer density (as well as river and valley crossings). Therefore, we developed easy installation technology suitable for rural environments and long-span aerial installation technologies.

In the past, installation was a round-trip process that consisted of first fixing a cable drum, then pulling out the cable through a cable pulley, and then, after terminating the end of the cable, backtracking along the route to complete the work of removing the lift and cable pulley and other necessary tasks. By contrast, the newly developed easy deployment method involves loading the cable on a portable drum and feeding out the cable as the cart moves along. The cable is raised onto the pole with each span, which makes a lot of the work and the need to double back unnecessary, so the job can be completed in one trip and with fewer workers (**Fig. 2**). To use this new and easier deployment method for trunk routes in rural areas, which require a 24-fiber count cable, the diameter and weight of the cables were reduced further still. This reduction was achieved by developing a 24-fiber count cable with the same dimensions as a conventional 8-fiber count flexible distribution cable. It is light enough to be moved on a mobile cart, and a single segment of the required length (500 m) can be fed out from the portable drum. Also, to handle distances over 500 m, we developed joints and spacers that enable multi-fiber connections to be made easily by having connector components attached to the cable at the factory. We also achieved easier installation for routes branching from the main line by using an 8-fiber count cable that is similar to an ordinary drop cable.

Long-span aerial installations on segments longer than the 60-m span between utility poles that is characteristic of rural areas has conventionally required special construction techniques for aerial work. However, we have developed new construction technology that does not require special techniques, tools, or devices. The new construction procedure involves building the aerial section with a suspension wire to which bundling wires are attached. Then, cables and a draw wire for future expansion are installed in the hangers. The bundling hangers are equipped with stoppers that prevent them from detaching and that

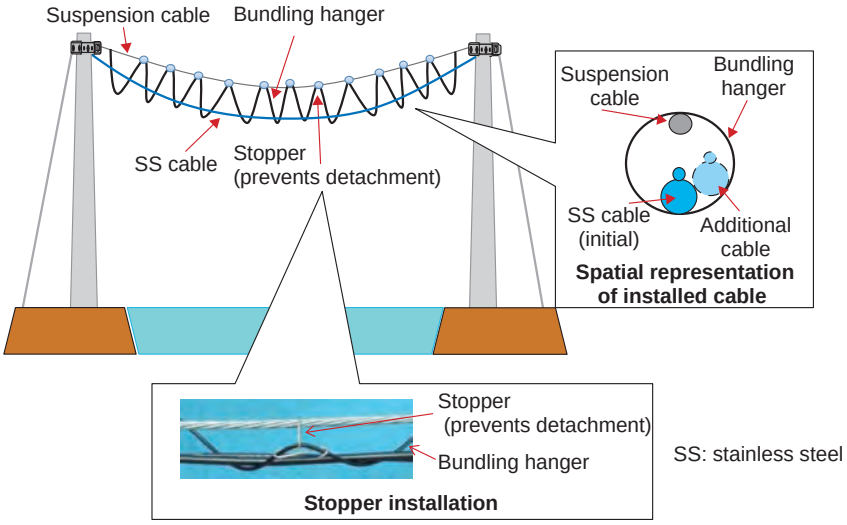

Fig. 3. Long-span overhead cable installation technology for rural areas.

prevent the cable from rotating or falling off (**Fig. 3**). This technology enables cables to be changed or added quickly. It should also help with rapid recovery when dealing with a disaster.

3. Future developments

The work to reinforce the optical access network providing the infrastructure for broadband services will continue, and future issues include how to maintain service quality for over 20 million customers while providing and operating new services, how to carry out the large amount of activation and withdrawal work efficiently, how to operate with both copper and optical services coexisting, and to do all of this without neglecting safety initiatives, which are the highest priority.

We will continue to deal with on-site demand and make full use of results from other labs and technology from our development partners, and to develop products that are useful in the field and that can be widely used in Japan and in other countries as well.

Profile

■ Career highlights

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Shigeki Sako received the B.E. and M.E. degrees in civil engineering from Tokushima University in 1988 and 1990, respectively. He joined NTT in 1990 and engaged in network plant planning and maintenance. He moved to NTT Access Network Service Systems Laboratories in 2011 and was responsible for the development of optical access network operation support systems. He has held his present position since 2013.

R&D Efforts on Wireless Access Systems Toward Realization of Future Networks

Masashi Nakatsugawa

Abstract

To actively support social and service environmental changes, NTT aims to comprehensively strengthen the competitiveness of network services. NTT has been investigating future networks that will provide users with the best user experience. This article introduces the research and development activities underway on wireless access systems. These efforts are being carried out with the goal of realizing future networks, and they include techniques to improve frequency utilization efficiency, reduce power consumption, and advance antennas/propagation, satellite communication systems, and wireless systems for disaster recovery.

Keywords: wireless access systems, frequency utilization efficiency, future networks

1. Introduction

The recent popularity of smartphones and tablet terminals indicates that mobile services—whose traffic nearly doubles year by year—are replacing fixed services as the major player in telecommunications. Although telecommunications carriers must expand the network capacity to support the increasing traffic, they are not able to earn revenue proportional to the traffic increase since most services are provided at fixed rates; in other words, the revenue does not increase with the traffic.

NTT is working to address this situation and has set the immediate goal of comprehensively strengthening its networks' competitiveness as one of its medium-term business strategies known as *Towards the Next Stage*. By replacing conventional networks with service-oriented future networks, NTT aims to provide various users with the best user experience as required by each user. This requires providing access methods to suit the user's environment, that is, the optimum combination of fixed and mobile services. It is important to provide multi-grade services to users in order to satisfy users' performance and cost demands.

NTT Access Network Service Systems Laboratories is pursuing the research and development (R&D) of fundamental and system technologies as part of efforts to realize future networks.

2. Direction of fundamental technologies for wireless access systems

Conventional R&D activities designed to enhance usability of wireless access systems—including mobile and nomadic services—are intended to achieve two goals: expanded service areas and increased communication speeds. To respond to the increase in mobile and nomadic service traffic, more sophisticated systems have been standardized, and associated technologies have been developed. For example, the data rate for wireless local area networks (WLANs) that conform to the IEEE 802.11 standard was initially 1 Mbit/s and now exceeds 1 Gbit/s in IEEE 802.11ac. With regard to mobile service, 3G (third-generation) cellular is migrating to Long Term

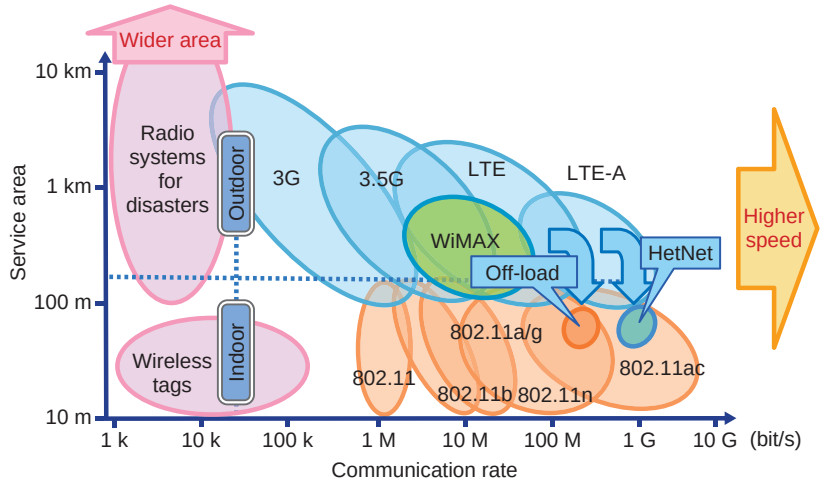

Fig. 1. Direction of fundamental technologies for wireless access systems.

Evolution (LTE) and eventually to LTE-Advanced (**Fig. 1**).

The optimum scenario is to distribute sufficient frequency resources to each user to improve the quality of experience (QoE); however, the frequency resources available are limited. Traffic offloading from the mobile service to WLAN may be a good approach to address the traffic congestion issue, but there is a concern that even the WLAN frequency resources will be insufficient. The key to resolving this issue is to increase the overall system communication capacity as a space by enhancing the frequency utilization efficiency (spectral efficiency).

3. Technologies to improve frequency utilization efficiency

NTT is researching fundamental technologies, starting with short-term solutions such as improving intra-system frequency utilization efficiency, to mid/long-term solutions such as improving inter-system frequency utilization efficiency. We are adopting three approaches in this research:

(1) Access point (AP) coordinated transmission techniques

Demands for WLAN frequency resources utilized to offload user traffic from mobile services have been increasing due to the increase in the number of WLAN APs and mobile terminals equipped with WLAN capability. In the 2.4-GHz band, which originally had insufficient frequency resources, user throughput is degraded because of frame collision and radio wave mutual interference, which reduces user satisfaction. Although the 5-GHz band still has sufficient frequency resources, these resources are expected to be depleted in the near future.

Two technologies to maximize areal throughput are being researched to improve user QoE against the backdrop of an explosion in the number of WLAN APs/stations.

i) High efficiency WLAN technology that can autonomously harmonize APs and terminals [1]–[6].

ii) Wireless resource control technology to cooperatively control APs through a server on the network [6], [7].

(2) Massive-MIMO technology

Massive-MIMO (multiple-input multiple-output) technology has been investigated to enable spatial sharing between systems and thus improve frequency utilization efficiency. The wireless entrance system may be the first example of applying Massive MIMO to wireless base stations. Terminals [8] can be simplified by using a sophisticated wireless entrance base station equipped with an antenna with approximately 100 elements; it can deliver radio waves with high directivity by beamforming and simple signal processing. It can also suppress interference power to other stations, which allows simultaneous transmission to large numbers of receivers. This significantly enhances frequency utilization efficiency (**Fig. 2**).

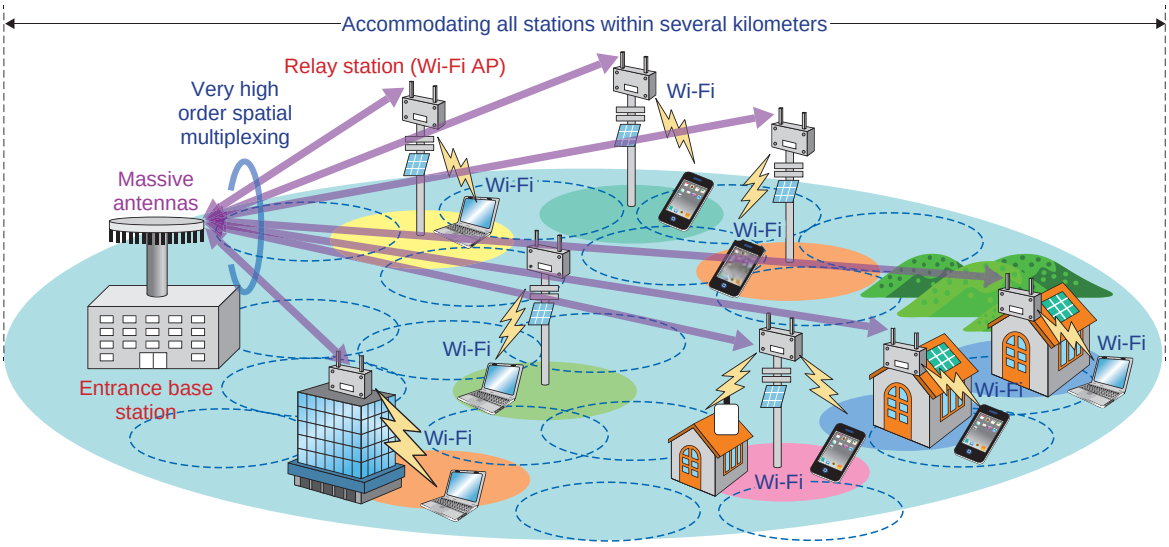

Fig. 2. Massive MIMO technology (example of entrance links for Wi-Fi).

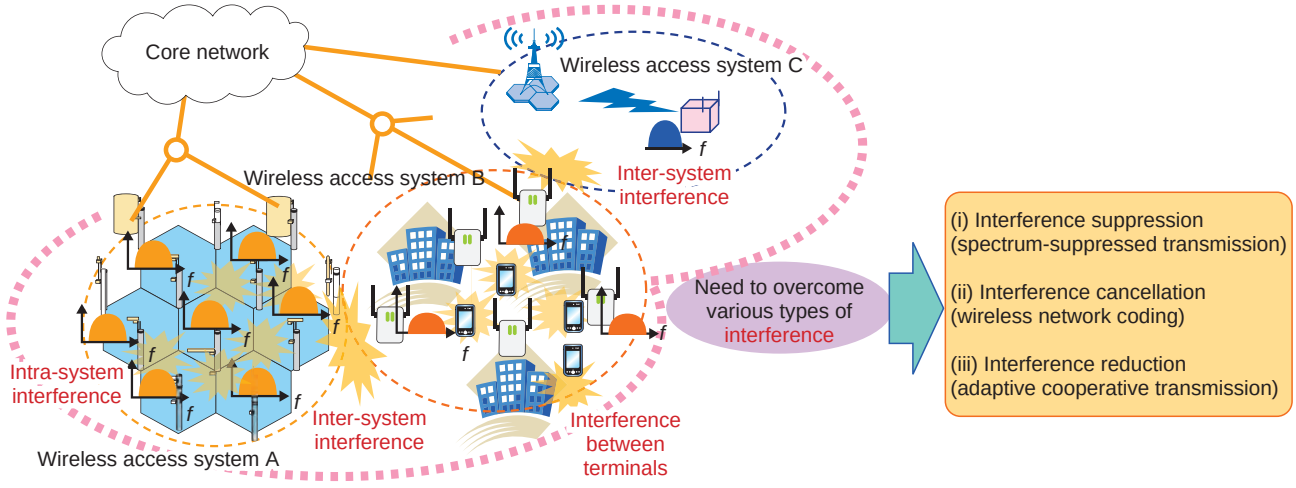

Fig. 3. Inter-system interference compensation.

(3) Inter-system interference compensation technology

Each system is generally assigned its own spectrum for its own use. To cope with the expected traffic increase, it is extremely important to improve frequency utilization efficiency by sharing frequency resources among different systems. With conventional methods, the system senses its environment before transmission and avoids collision with other systems through time or frequency adjustment. In all of these methods, however, a frequency resource is used by only one system, so frequency utilization efficiency is insufficient.

Three interference compensation techniques are being investigated that enable the frequency to be shared by accepting a certain level of interference power and then using signal processing to offset the effect of the interference. These techniques are as follows (**Fig. 3**).

(i) Interference suppression (spectrum suppressed transmission) [9]

(ii) Interference cancellation (wireless network

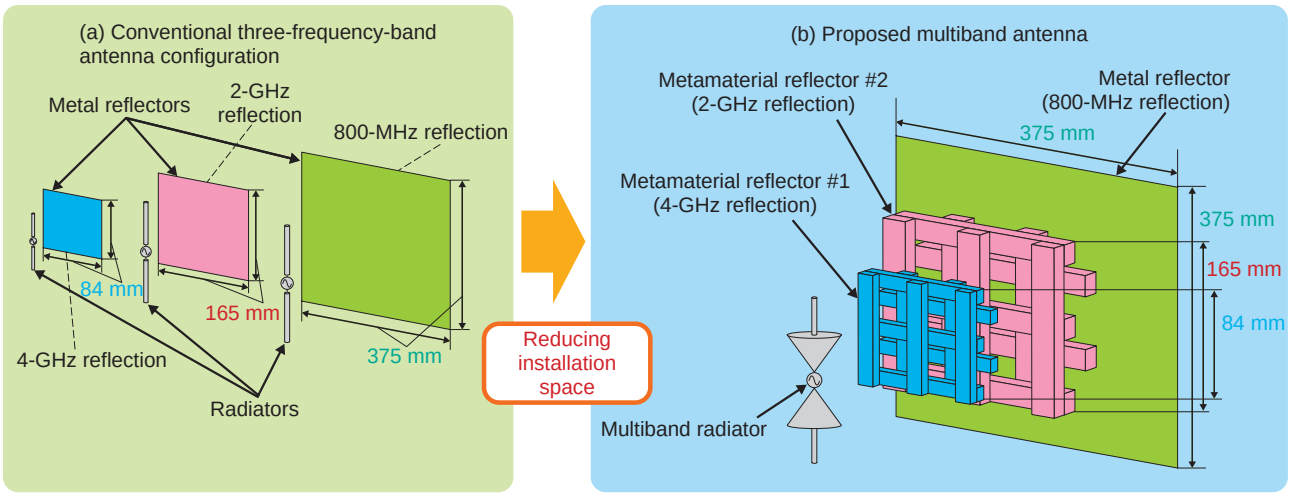

Fig. 4. Metamaterial antenna.

coding) [10]

(iii) Interference reduction (adaptive cooperative transmission) [11]

Our target is to raise frequency utilization efficiency by a factor of 10 from current levels by 2015.

4. Power consumption reduction technology

Some studies have examined ways to reduce power consumption and/or carbon dioxide emissions by using effective intermittent operation of wireless systems when no data are being transmitted.

Although a standard for power-saving operation exists for current WLAN terminals, no such standard exists for APs. We have been doing research on WLAN sleep techniques for APs. These techniques are expected to be significantly improved by taking the following considerations into account.

- Performance degradation is minimized by controlling the sleep time and/or frequency according to the traffic [12].
- No extra functions need to be added to terminals, and power-saving performance is improved through mutual-cooperation between multiple APs in addition to single-AP control [13].
- Systems operating without commercial electric power should be included within the scope of the investigation by combining environmental power generation and/or reduced-power devices.

5. Antenna and propagation technology

Antennas are portals for signals in wireless systems and so are extremely important devices. Improving their performance continues to be a major research topic.

We have been investigating multiband base-station antennas whose reflectors are composed of metamaterials [14]. Metamaterials have a periodic arrangement of dielectric materials. The occupied volume can be reduced by replacing several single-band antennas, each designed for a specific frequency, with a single multiband antenna. Three-frequency-band antennas have already been developed, and we are continuously working on increasing the number of frequencies that can be shared (**Fig. 4**).

Clarifying the propagation characteristics is at the core of our research activities and is essential for designing the link budget of wireless systems.

Transmission speeds of wireless systems have increased with the advances in technology, and because of this, views are changing on what propagation characteristics need to be clarified. Path loss characteristics were the main area of focus for the 1st or 2nd generation cellular systems in the ’90s. More recently, analysis of delay spread has become the focus of research for WLAN or 3G cellular systems. This spread is exemplified as the difference in signal arrival times due to reflections and diffraction of radio waves. Currently developed systems that use MIMO technology, for example, next-generation

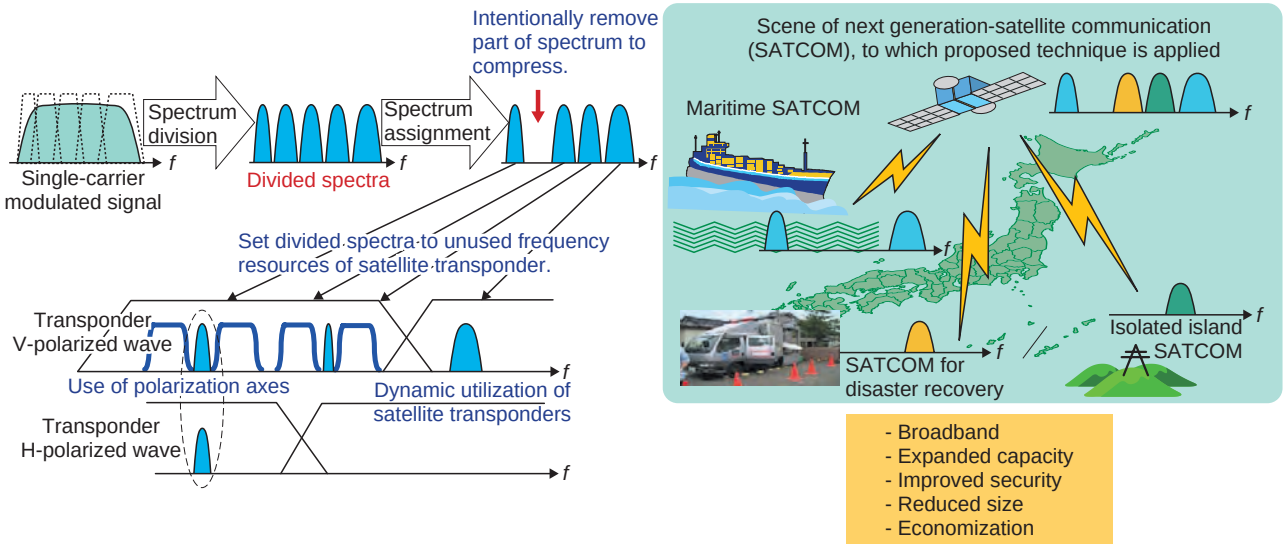

Fig. 5. Multi-domain signal processing technique.

WLAN, achieve high speed and reliability by transmitting/receiving signals via multiple antennas, which enables the use of multipath signals. This requires analysis and modeling of spatial propagation characteristics in addition to conventional receiving level and delay-spread characteristics [15]. The frequency bands of interest are expanding from the UHF (ultrahigh frequency) and SHF (super high frequency) bands often used by wireless communication systems, to both lower and higher frequency bands. We are currently working on constructing propagation models in these bands and will contribute to the standardization efforts underway by ITU-R (International Telecommunication Union, Radiocommunication Sector) and will also consult on propagation issues for the wireless businesses of NTT Group companies.

6. Satellite communication systems using multi-domain signal processing technology

The repeated assignment and release of different bandwidth signals within the frequency band of a satellite transponder fragments the frequency resource. Unused frequency resources that are not wide enough to be reallocated to new users cannot be used for communication; hence, the frequency utilization efficiency degrades. Multi-domain signal processing technology [16] is being applied to address this issue. In order to make effective use of the fragmented (and thus unused) frequency resources, a single-carrier modulated signal is split into subspectra that can be assigned to the unused frequency resources. In some cases, some parts of the subspectra may be intentionally deleted or concatenated to reduce the total frequency resource requirement. Moreover, the utilization of vertical and horizontal polarization axes enables the subspectra to be assigned over multiple domains such as frequency and space. Multi-domain signal processing technology makes it possible to effectively utilize unused frequency resources or to compress and transmit signals; with the limited transponder bandwidth, this yields wireless systems that can cope with more traffic than the conventional alternative. We have completed lab experiments and will conduct experiments using a real satellite transponder in 2014 (**Fig. 5**).

7. Wireless systems for emergency response

The experience gained in the aftermath of the Great East Japan Earthquake has strengthened the importance of wireless systems in dealing with emergencies. However, some of the systems currently in use were introduced a long time ago, and their specifications should therefore be reviewed. In light of this, it is necessary to digitize all of our relay, subscriber, and business wireless systems, and also to reduce their size and weight, increase their capacity and service area, and introduce simplified settings and operation procedures. We are currently working on realizing such systems.

8. Conclusion

Constructing the future access platform is crucial in order to provide users with the access method that best suits their environments and needs. Such methods will consist of finding the optimum combination of fixed and wireless access systems that will respond to various requests and fully satisfy user demands. We are continuing our research and development efforts to improve users' satisfaction with the communication services provided.

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Profile

■ Career highlights

Executive Manager, Wireless Access Systems Project, NTT Access Network Service Systems Laboratories.

Masashi Nakatsugawa received the B.E. degree in electronics and communication engineering and the M.E. degree in electrical engineering from Waseda University, Tokyo, in 1987 and 1989, respectively, and the M.S. degree in electrical engineering from California Institute of Technology, USA, in 1999. He joined NTT Radio Communication Systems Laboratories in 1989. His research experience includes the areas of MMIC circuit design, packaging technology, software defined radio, and wide-area wireless access systems. From 2010 to 2012, he was a Senior Manager in the Radio Division, Technical Planning Department, where he was involved in regulatory and standardization activities for wireless systems. He is currently responsible for the development of fundamental technologies for wireless access systems. He received the 1996 Young Engineer Award from the Institute of Electronics, Information and Communication Engineers (IEICE), and the Yokohama Research Park (YRP) Award from the YRP R&D Promotion Committee in 2002. He is a member of IEEE, IEICE, and the Japan Society of Applied Physics.

Structuring Future Access Network Systems

Hideaki Kimura

Abstract

The First Promotion Project initiated by NTT Access Network Service Systems Laboratories involves researching and developing optical access systems focusing on transmission devices. In this article, I introduce optical access transmission technologies that we have developed and also discuss a future optical access system that follows expected social and environmental changes.

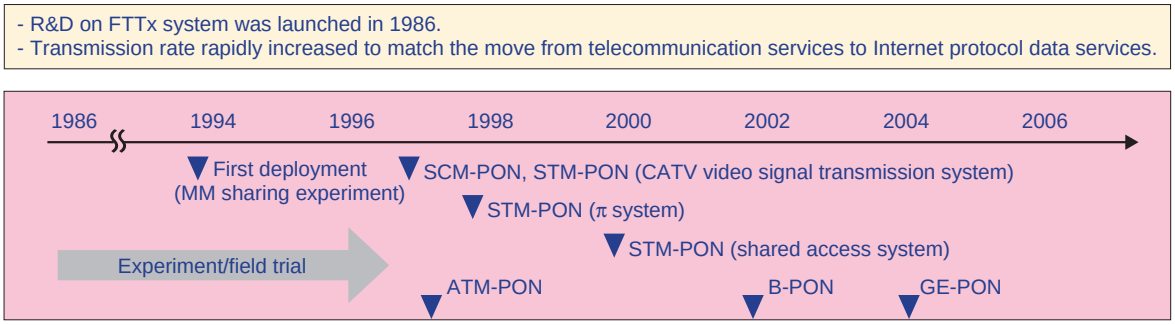
Keywords: access system, optical fiber transmission technology, R&D

1. Overview of R&D history at AS Labs

The research and development (R&D) history of transmission technologies at NTT Access Network Service Systems Laboratories (AS Labs) includes optical access, wireless access, and wide area Ethernet systems. We began R&D toward the commercial introduction of a passive optical network (PON), which is currently the basic representative technology of optical transmission systems, about 20 years ago. The PON available now was developed and commercially introduced as GE (Gigabit Ethernet) -PON about 10 years ago; it supports NTT EAST and WEST Group Companies' FLET'S HIKARI services for general consumers. At around the same time, video transmission technology was commercially introduced, and it supports FLET'S television services. In light of the lessons learned from the Great East Japan Earthquake, we are now researching and developing wireless access communications technologies that will prevent the disconnection of lifeline services. Regarding corporate customer services, AS Labs' wide area Ethernet ERP (Ethernet Ring Protection) and other technologies have been applied for Ethernet BEW (Business Ethernet Wide) services and are now in practical use.

The R&D history of FTTx (Fiber-to-the-X) is shown in **Fig. 1**. As the figure shows, R&D on optical access systems is centered on high-speed and wide area services such as STM-PON (synchronous transfer mode PON), B-PON (broadband PON) and GE-PON. The number of customers of GE-PON-based optical fiber access services has reached about 18 million. STM-PON offers multiple lines including telephone, ISDN (integrated services digital network), and dedicated lines. The transmission speed was initially 50 Mbit/s, which is fast enough for low-speed legacy services such as PSTN (public switched telephone network). However, as time went by, the age of the Internet came, and we undertook R&D on B-PON systems based on ATM (asynchronous transfer mode). ATM made it possible to stream multiple transmissions of data and video. The transmission speed of this system is 155 Mbit/s, which enabled bandwidth-guaranteed networks and priority control.

About 10 years ago, we began R&D on the Ethernet-based GE-PON system. This system is now the most popular optical access system in Japan. It can provide high-speed and wide-area services. Some system providers offer the maximum speed of 1 Gbit/s. In this way, the technologies and products researched and developed by AS Labs have made it possible to steadily offer high-quality and low-cost services to customers.



	STM-PON	B-PON	GE-PON
Supported standard	NTT's original	ITU-T G.983 series	IEEE 802.3ah
Transmission rate	16 Mbit/s	622 Mbit/s/156 Mbit/s	1.25 Gbit/s
Multiplexing method	TCM	WDM	
Frame transporting method	STM	ATM	Ethernet
Deployment year	1997	1997 (leased line) 2002 (FTTH)	2004

CATV: community access television
FTTH: fiber-to-the-home
IEEE: Institute of Electrical and Electronic Engineers
ITU-T: International Telecommunications Union, Telecommunications Sector
MM: Multimedia
SCM-PON: subcarrier multiplexing PON
TCM: time compression multiplexing
WDM: wavelength division multiplexing

Fig. 1. R&D history of AS Laboratories.

2. PON transmission technology

In this section, I review low-cost and low-energy-consumption PON transmission technology, and also discuss many other current and future services. The transmission scheme underlying multiple technologies, for example, STM-PON, B-PON, and GE-PON, is called time division multiplexing (TDM). In TDM, user data are interleaved and transmitted on a time axis. For down signals, data addressed to each ONU are placed on the time axis and transmitted from the optical line terminal (OLT) side; the optical network unit (ONU) picks up the data addressed to itself. With up signals, if the ONUs lie at different distances from the OLTs, the signals may collide at the splitter. Therefore, scheduling technology is applied in order to prevent such collisions. This technology measures the transmission delay time and adjusts the timing between OLTs and the ONUs. TDM has the advantage of being low cost compared to other multiplexing schemes, but it depends mainly on the performance of electrical devices and therefore limits the speeds that are possible. To increase the number of areas it can be applied to, we must consider increasing its speed and reach.

One transmission scheme that avoids the issues of TDM is wavelength division multiplexing (WDM). WDM proactively uses light wavelengths. It can multiplex each user data element and each service on the time axis without data overlap. Because the transmission paths are logically separated, the interference between signals becomes virtually insignificant. For example, even if we limit the data bit rate to 10 Gbit/s per wavelength (matching the limitation imposed by commercial low-cost electrical devices), a 40-Gbit/s data stream can be sent by dividing the stream into four wavelengths, multiplexing them, and transmitting them simultaneously.

The technology being investigated for the near term is frequency division multiplexing (FDM) transmission **(Fig. 2)**. FDM offers a narrower wavelength interval than WDM. Separate wavelengths can be assigned to many services and users, so it enables network services to be provided without interference between users and services. Some challenges remain, however, including cost, before FDM will be commercially available. Nevertheless, FDM is a highly attractive technology from the viewpoint of the

Optical FDM transmission achieves ultrahigh-capacity access networks and can provide video distribution with more than 100 wavelengths.
- High-sensitivity receiving technology with heterodyne detection enables long-distance transmission in access networks.
- Cost-effective long-distance transmission technology in access networks is achieved using WDM/FDM combination.
- Lower-cost system is achieved by sharing light source; light source is utilized for both upstream signal source and LO-LD.
- Wavelength tuning technology: arbitrary optical signal wavelength through the use of LO-LD

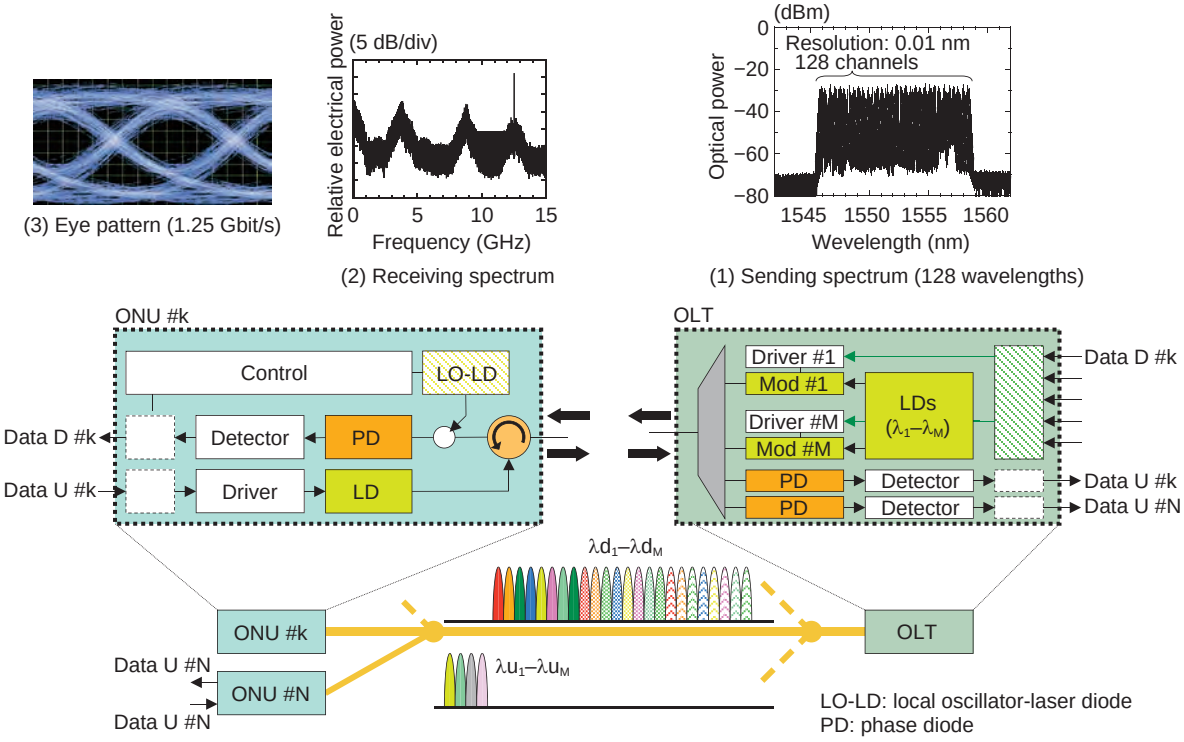


Fig. 2. FDM transmission technology.

importance of optical fiber transmission.

3. R&D trends

Here, I discuss current R&D trends for optical access systems. The first thing to consider is that our vision of society continues to change, so I feel that we need to carry out R&D by considering four basic trends.

The first trend is the rapid increase occurring in the speed and volume of communications including mobile systems. The traffic loads created by video systems will continue to explode as SD (standard definition) is replaced by HD (high definition) and SHD (super high definition) 4K/8K resolution. Future demands, however, include not only increased device speed and expanded reach, but also support of codec (codec/decoder) technology in order to satisfy various expected requirements such as those related to capacity and delay.

The second trend is the growing need for FMC (fixed and mobile convergence) devices. For example, one challenging issue is determining how to achieve low-latency to satisfy online game users.

The third trend is the emergence of service characteristics that are radically different from conventional services such as M2M (machine to machine) communication. For example, if we assume that one person has about 100 networked items, a new network technology that can support about 100 billion devices is needed just for Japan.

The fourth trend involves examining ways to secure high-reliability connections to ensure that lifelines remain connected. The biggest challenge is determining how to design environmentally friendly networks that consume less energy, while achieving cost savings at the same time. An image of two trends in access network R&D is shown in **Fig. 3**. Scenario 1 illustrates the current communication technology trend; it focuses on achieving high speeds and wider

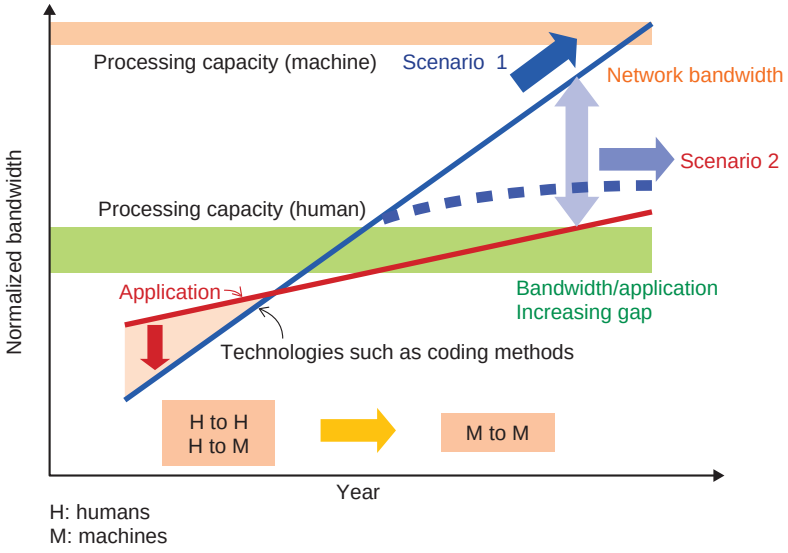


Fig. 3. Trends in access technology R&D.

usage areas. Scenario 2 reflects the more recent trend to deemphasize the need for higher speeds and wider areas. Currently, signs of scenario 2 are already appearing in some areas.

In the past, the communication line transmission speed was not high enough for attractive service applications. That is why R&D actively focused on improving the transmission speed. However, higher transmission speeds are not being targeted as much these days. Also, we have studied how much bandwidth communication lines must offer given the limitations imposed by the processing abilities of humans and machines. The processing ability of humans is quite limited, and network performance already exceeds it. From the viewpoint of transmission speed, the target should be to achieve a level of machine processing instead of human processing. Furthermore, we believe that higher speeds and wider areas are necessary only when targeting machines with high processing ability and low latency. It may be necessary to split the difference between scenarios 1 and 2. For example, for services offered directly to humans, the communication line quality should be focused on satisfying humans. This is already being carried out from the viewpoint of QoE (quality of experience) in some areas.

4. A new world realized by ultrahigh speed and ultralow latency

The direction of optical access system development in the coming years should be toward future services or the image of society that we want to create. My idea of a new environment that can be realized by ultrahigh-speed and ultralow-latency systems is described in **Fig. 4**. Here, I explain what type of society can be created with 100-Gbit/s high-speed optical access systems. In this environment, ultralow-latency networks can be installed that dispense with compression or codec processing. With this approach, business areas will be aggregated and sorted into real businesses and virtual businesses. Real businesses such as commodity distribution will be directed toward personal commodity distribution, in which pinpoint services will be provided to each individual. In contrast, virtual businesses will be an enhanced version of businesses now present in the Internet world. The key point of this world is that high speeds and wide areas create a real society. Simply put, we can create a world in which people can have what they need delivered to them immediately if they have any kind of communication device such as a telephone. Furthermore, depending on the development of personal commodity distribution, businesses may ultimately involve only communications and distribution. Creating such a world is a bit questionable from the viewpoints of industry and the economy, but it is, I think, the ultimate goal of network services.

5. Future access network systems

An image of what a future access network system

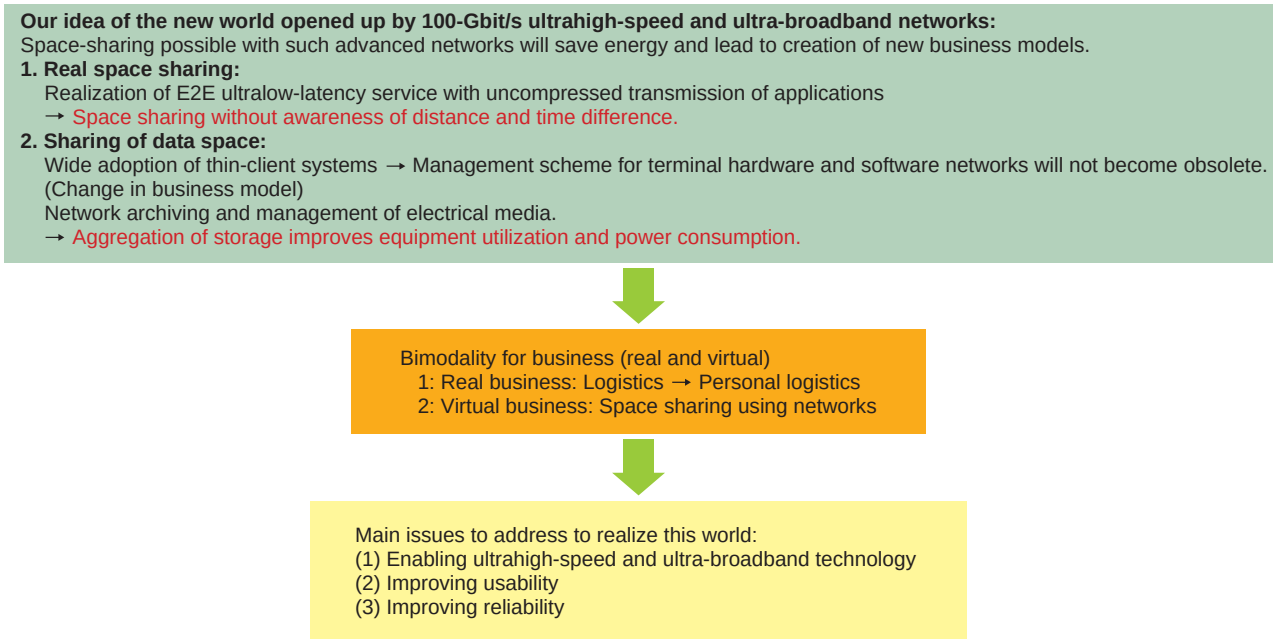
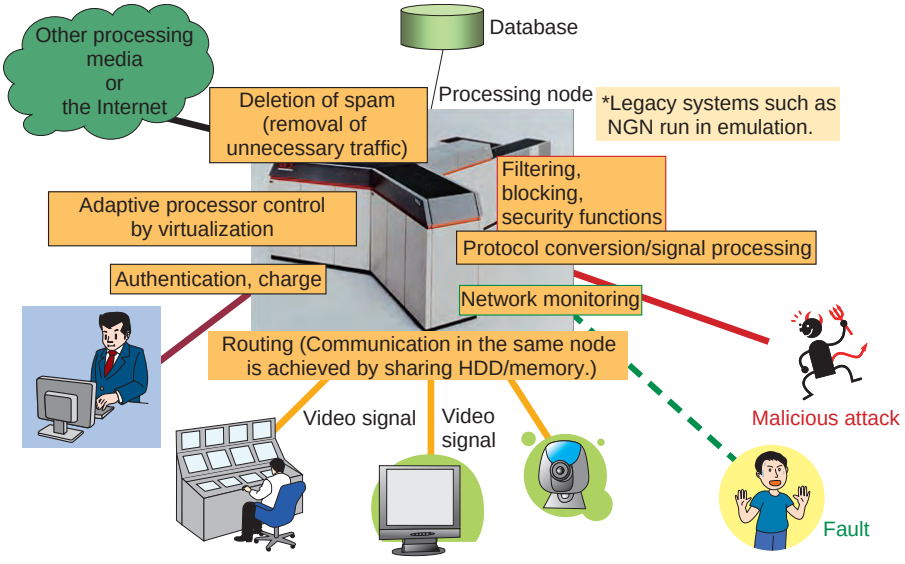


Fig. 4. New world achievable with ultrahigh-speed and ultralow-latency networks.



HDD: hard disk drive
NGN: Next Generation Network

Fig. 5. What should future access network systems be?

should consist of is shown in **Fig. 5**. Recently, the term *cloud* (*computing*) has taken many meanings. It is expected that all of the data that users hold will basically be stored in the cloud in the future. Regarding data distribution, I imagine that data will be exchanged not between each user or device in real space but between cloud servers or virtual users, and users will be able to temporarily view the stored data.

Ultimately, cloud servers will be integrated on single chips, and data distribution may be within a single chip. I think the current E2E (End to End) environment will shift to the environment that makes maximum use of the Internet: E2N2N2E (End to Network to Network to End).

The broadband market in Japan has already entered a saturated state. Because new and innovative technologies continue to be developed in the communication industry, the transmission technology market that supports broadband will most likely experience a downturn and will eventually shrink.

In the coming years, I think that while the broadband market will be vitalized through the emergence of mobile systems with supreme usability, services and applications will be the main players in the market. As for transmission systems, however, we will not stop our quest for technological innovations and thus will need to continue to invest in them to improve the technology.

Finally, I include three suggested contributions that we at NTT can make—either individually or collectively—as part of NTT's overall mission.

The first is to *contribute to the company*, which is rather obvious for one who belongs to a company. In addition to thinking of our research, we also need to think how we can secure profits for the whole NTT Group. The second is to *contribute to society*. This includes, for example, providing secure and stable connections in emergencies such as earthquakes or other disasters. Furthermore, we should contribute to the creation of a society wherein everyone can lead a comfortable life by being connected through networks and communications. The third is to *contribute to industry*. In the future, it will be important to develop new technologies that will vitalize other industries by not only conducting in-depth studies in particular areas but also by bringing the whole area of systems, services, and applications into view. At the same time, I think we need to design basic technologies based on new principles that are not simply extensions of existing technologies. As a result, I am aiming to make innovative changes to ensure that positive reinforcement defeats any negative spiral.

6. Future developments

I think that access systems in the future will shift from the conventional high-speed and wide-area vision that supports services and applications, or *the age of setting up the communication infrastructure base*, to *the age of ultrahigh volume and ultralow latency* that targets different service characteristics or information in the wider dynamic range including M2M. On the basis of this vision, we will continue our R&D with the goals of *easily staying connected whenever and wherever with whomever without disconnection* in order to increase customer satisfaction, and *business activatio*n to increase industry performance; I think that this defines our mission.

Profile

■ Career highlights

General Manager, 1st Promotion Project, NTT Access Network Service Systems Laboratories.

Hideaki Kimura received the B.E., M.E., and Ph.D. degrees in electrical engineering from Hokkaido University in 1987, 1989, and 1992, respectively. In 1992, he joined NTT LSI Laboratories, Kanagawa, where he engaged in research on package design for 100-Gbit/s level high-frequency wideband ICs and high-sensitivity receiver module design for optical subscriber systems. From 1994 to 1996, he was at NTT Transmission Systems Laboratories, Kanagawa, where he engaged in research on economical systems such as LD transceivers and PD transceiver techniques. From 1996, he was engaged in researching super-low-power transceiver modules for the optical subscriber system, system design, and basic technologies such as 1V-operation-super-small-size ONUs and a no-power-supply voice communication service for blackout situations caused by disasters. From 2003 to 2005, he worked in the personnel department of NTT EAST. In 2006, he began researching future optical access network systems based on WDM and DSP. From 2010 to 2012, he was an Executive Research Engineer in the Research & Development Planning Section. He is a member of the Institute of Electronics, Information and Communication Engineers and IEEE.

Rapidly Deployable Phone Service to Counter Catastrophic Loss of Telecommunication Facilities

Satoshi Kotabe, Toshikazu Sakano, Katsuhiro Sebayashi, and Tetsuro Komukai

Abstract

In this article, we describe a phone service system that enables us to rapidly restore service even when the regular facilities for information and communications technology (ICT) services have been catastrophically damaged in a large-scale disaster. Deploying a movable ICT resource unit with IP-PBX (Internet protocol-based private branch exchange) functionality to the affected areas makes it possible to immediately provide IP phone services using Wi-Fi. Users are able to access phone services using their own smartphones and telephone numbers, which makes the system convenient to use. We developed a prototype system and conducted subjective experiments with users. The results confirmed the effectiveness of the proposed system.

Keyword: resilient network, movable ICT-Unit, telephone service

1. Introduction

The Great East Japan Earthquake and tsunami that struck on March 11, 2011 served as a vivid reminder of the importance of information and communications technology (ICT) networks and services as a social infrastructure. People in disaster-affected areas were not able to use telephone and other ICT services for a long time—from weeks to months—after the event [1]. This situation severely restricted people's ability to confirm the safety of their family, friends, and relatives, and to check on their assets. There are two main reasons for why this happened. The first is the devastating damage the tsunami caused to the ICT network in the wide northeast coastal region of Japan. The second is the resulting explosive demand for ICT services that occurred in and around the damaged areas. These two factors caused serious traffic congestion and a large gap in the demand and supply of services. Dedicated efforts to restore services by ICT service providers helped to alleviate the situation [2]. However, the number of restored telephone lines was limited and was far short of fulfilling demand, particularly in the early stage of restoration. Reducing the gap between the demand and supply of services was therefore recognized as a critical problem that urgently needs to be solved.

We address this issue with our proposed network architecture that improves the resiliency of an ICT network through the use of a movable unit that accommodates resources for providing ICT services in a damaged area [3]. The unit, which we call the movable and deployable ICT resource unit (MDRU), is transported to the damaged area and used to quickly launch ICT services there. By restricting the area the MDRU is used in to local areas, we can provide service again in a very short time. This enables us to reduce the demand/supply gap, particularly in areas where ICT services are most in demand after a disaster.

We propose here an IP (Internet protocol) phone service system that is to be added to the MDRU. The proposed system is an extended IP-PBX (private branch exchange) system and is installed in the

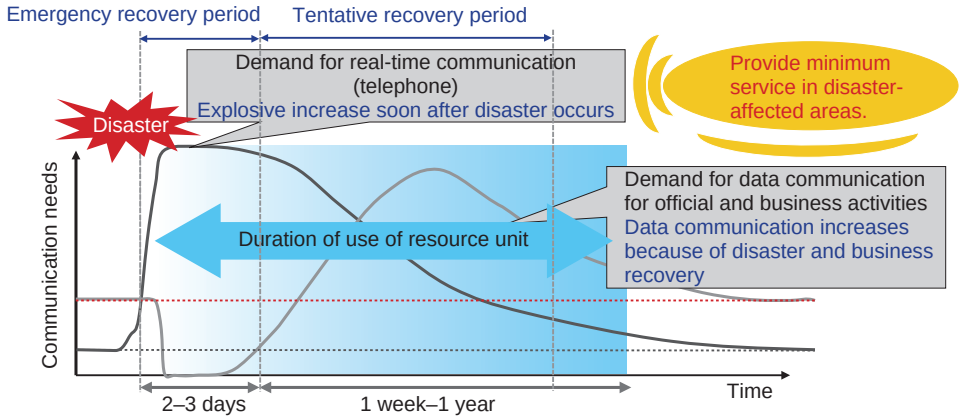


Fig. 1. ICT services in demand after a disaster.

MDRU. It dramatically simplifies the process of registering customer devices to the PBX. The MDRU provides a Wi-Fi access network. Any user within the service area (500-m radius) of the MDRU can connect their mobile device, for example, a smartphone, to the MDRU over the Wi-Fi access network and register the phone's number (known by the user and his/her communication partners). With these functions, the proposed system enables us to promptly launch a phone service, which is the service most in demand after a disaster occurs.

This article is organized as follows. We present the background that led to our proposed system in section 2. The details of the MDRU features are described in section 3, and the proposed IP phone service system is explained in sections 4 and 5. In section 6, we introduce a prototype of the phone service system along with other systems related to resilient network architecture. A subjective evaluation of the developed prototype and its results are described in section 7. We conclude the article in section 8.

2. Resilient network concept

The general trend of the demand for ICT services after a disaster is shown in **Fig. 1**. The horizontal and vertical axes respectively indicate the time and demand for ICT services. As shown in the figure, in the first few days after a disaster occurs, the demand for real-time communications such as telephone and email grows very quickly. This time span is the emergency recovery period, in which people's primary need for ICT services is to confirm the safety and security of their family, friends, relatives, and assets. Real-time communication in this time period is essential for efficient search and rescue operations and to save the lives of as many victims as possible. The period following this critical stage varies depending on the severity of the disaster. It could range from one week to a year, for example. In this tentative recovery period, people begin working on restoration, and the demand for data communications and processing starts to grow. Victims relocated to shelters need to adjust and make new lives, and the local government needs to support them and offer public services. Information systems are helpful for carrying out these activities smoothly.

In the 2011 disaster, ICT service providers were not able to meet these demands sufficiently. After the disaster, people not only in the damaged area but also in the surrounding areas, including Tokyo, immediately tried to contact friends and family on the phone. This caused severe traffic congestion in the telephone network. Telephone service operators restricted calls to prevent network resources from fatally breaking down. As a result, telephone and other ICT services were paralyzed. Furthermore, the network resources in the disaster area were severely damaged. It took weeks to months to restore them to a normal state. Consequently, one of the lessons learned from the 2011 disaster is that being able to effectively and consistently respond to the demand for services in disaster-stricken areas is a critical issue that urgently needs to be resolved.

We have been working to resolve this issue by focusing on the part of the ICT network where traffic congestion occurs. A typical network configuration is shown in **Fig. 2**. ICT networks usually have a layered

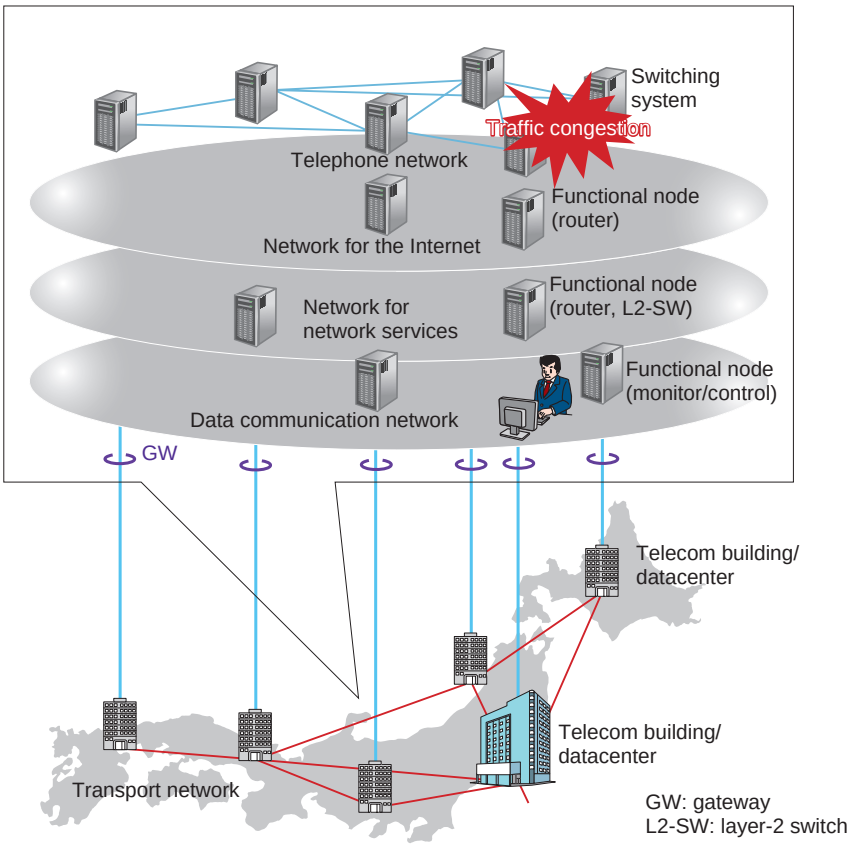


Fig. 2. Network configuration.

structure. The lowest layer is the transport network, which includes communication buildings, optical fibers, and optical networks. Networks for ICT services are constructed by installing service nodes in the buildings and interconnecting the nodes with links provided by the transport network. For instance, a telephone network (or PSTN: public switched telephone network) is formed by installing switching systems in the telecom building and interconnecting them with the links. The Internet is also established by installing and linking routers in the buildings. In this network configuration, the traffic congestion usually occurs at the switching system in the region where calls converge. With telephone traffic, it is very rare for the transport network layer to be the source of traffic congestion. This fact suggests that if calls in the converged area are diverted to a switching system in a vacant area in the transport network layer, the traffic congestion that occurred in the converged area can be reduced.

We took this into account and came up with a concept for improving network resiliency. It involves immediately deploying local services first, then restoring wide area services by linking the local service to an existing proper service node over the transport layer. In the first phase, the time needed to establish service can be reduced by focusing only on the local service restoration, thus meeting the emerging ICT demand just after a disaster. In the second phase, the local service is extended to wide area service without causing traffic congestion. Therefore, this concept is expected to be effective in resolving the aforementioned critical issue. In practical terms, the concept is realized by introducing an MDRU as a hub for deploying local services. The details of the unit are described in the following section.

3. Movable and deployable ICT resource unit

An MDRU is the platform upon which we can realize the concept described in the previous section. A resilient network with an MDRU is shown in **Fig. 3**.

If an ICT network is seriously damaged in a disaster, an MDRU is transported to the damaged area and set up there. The MDRU contains equipment for communication, information processing, and data storage. The MDRU can be driven itself and can also be transported by truck, train, or ship. Once the MDRU is set up in the damaged area, it promptly forms a wireless network to reach the user devices in the surrounding area and then starts delivering ICT services to the local users. After a while, it is connected to a wide area network (WAN) by any available means such as satellite communication links or optical communication links using undamaged optical fibers. An MDRU connected to a WAN acts as a frontline base of ICT services.

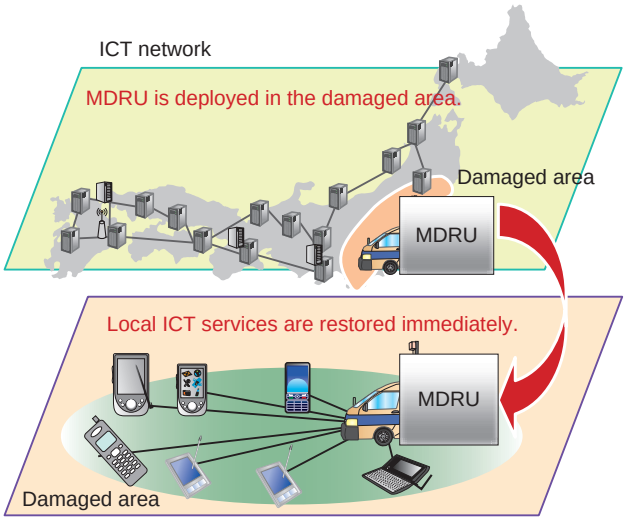
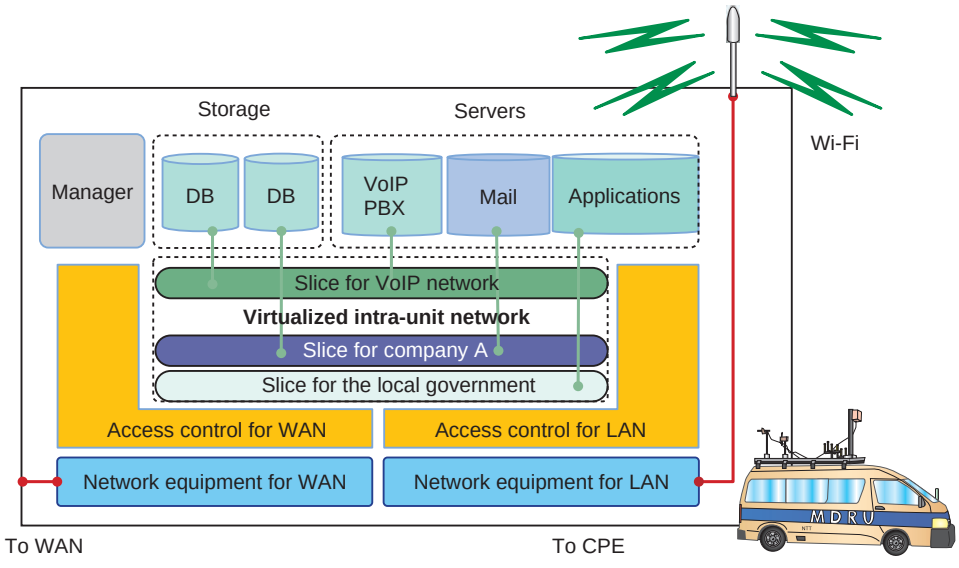


Fig. 3. Resilient network with MDRU as a platform.

The configuration of an MDRU is shown in **Fig. 4**. It comprises network equipment, an intra-unit network, servers, and storage devices. The network equipment is used for connecting to a WAN and for forming a local area network (LAN). The intra-unit network includes access control servers for WAN and for LAN to enable us to form multiple virtualized intra-unit networks. The servers have software for ICT services such as Voice over IP (VoIP) based PBX, an email server, and other applications. With the resources shown in Fig. 4, MDRU can offer communication functions and information processing and storage functions.

4. IP phone service for disaster relief

Phone service is the ICT service most strongly demanded just after a disaster. People need telephones to confirm the safety and security of their families, friends, relatives, and assets. Local governments also need the service to gather information on



CPE: customer premises equipment
DB: database

Fig. 4. Configuration of MDRU.

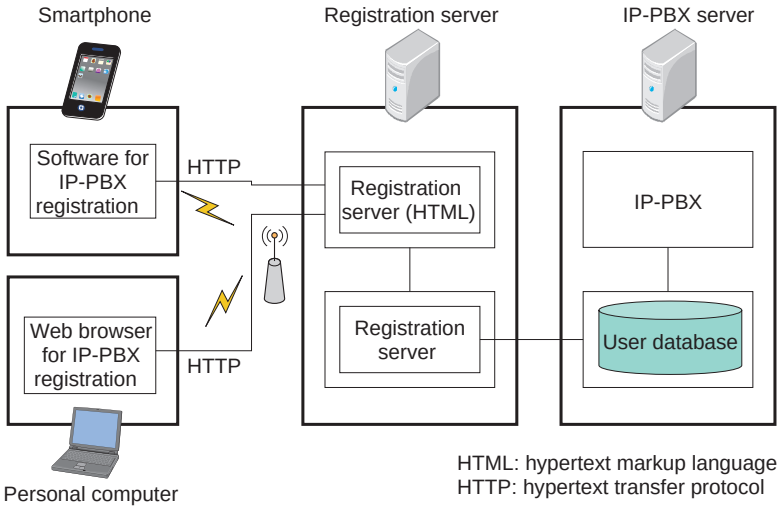


Fig. 5. Block-diagram of IP phone service system.

the scale of damage, the number of victims, and any other information necessary to plan rescue and restoration activities. Therefore, an IP phone service should be included in the resilient network architecture.

4.1 Features of the proposed IP phone service system

The proposed IP phone system employs an extended IP-PBX system that is installed in the MDRU. The system has the following features that allow quick and convenient startup of the phone service.

At service startup, the user database of the IP-PBX is empty. User data are incrementally added when users first register a device to the IP-PBX using their own phone number. In the PBX systems commonly used in companies, a PBX operation manager prepares the user data and installs it in the user database in the system before service startup. The proposed system enables us to omit this tedious and time-consuming user data preparation process.

The second feature is that the system assumes the usage of IP-connectable phone devices and the phone numbers originally provided by the phone service provider and owned by users. If a user wants to use the phone service provided by the proposed system, he/she connects his/her own phone device to the proposed IP-PBX system and registers the device and its regularly used phone number. Once registered, he/she can access the phone service with his/her device and regularly used phone number.

The user's phone device is assumed to be connected to the IP-PBX system in an MDRU via a wired or wireless IP-based network. This feature is related to the characteristics of the MDRU; it can form a Wi-Fi-based IP access network around the MDRU very rapidly. The candidate phone devices are smartphones and personal computers with VoIP software, both of which are rapidly penetrating the market. With this feature, users can quickly connect their phone device to the proposed IP-PBX system. In the descriptions hereafter, we assume a smartphone as the user device.

4.2 System configuration

A block diagram of the proposed IP phone system is shown in **Fig. 5**. The system consists of an IP-PBX server, a registration server, and user devices. The IP-PBX server includes the IP-PBX function and user database. The registration server acts as the interface between the IP-PBX and user devices. It offers information processing for user device registration and control functions for the user database. Each user device has software for IP-PBX registration in which the device's MAC (media access control) address and its phone number from the SIM (subscriber identity module) card are captured and sent to the registration server through simple user operation. The registration window of a smartphone and the information flow from the smartphone to the user database in the MDRU are shown in **Fig. 6**. When a user activates the IP-PBX registration software on his/her smartphone, the registration window shown in Fig. 6 is displayed. The window has information input areas for the

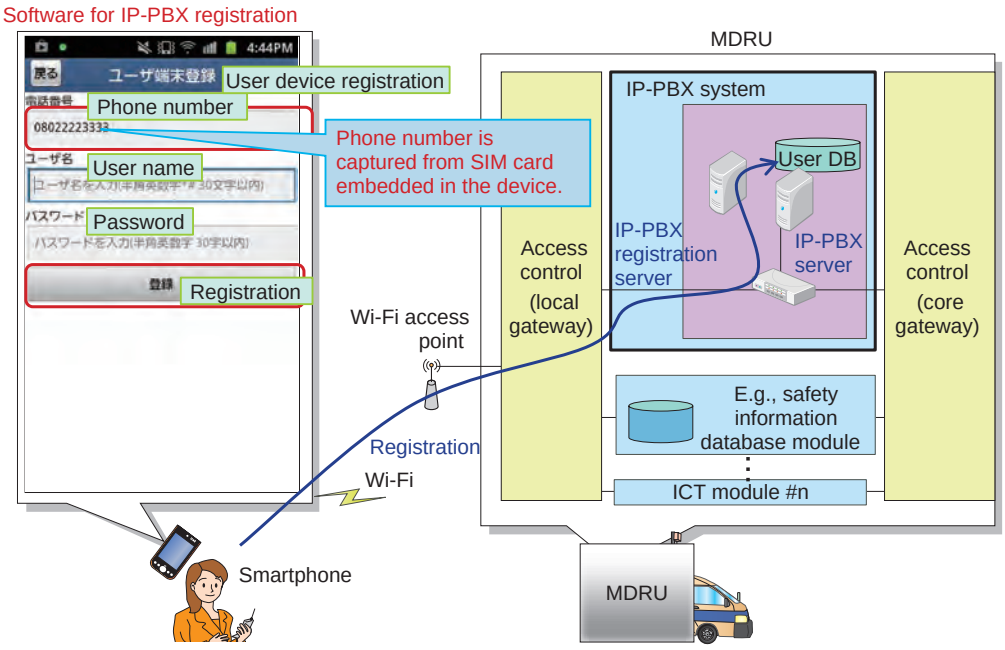


Fig. 6. Registration window of a smartphone.

phone number, user name, and password, which are required for user device registration, and a button for initiating the registration. The phone number is automatically captured from the SIM card embedded in the device and displayed on the window. The user confirms the automatically displayed phone number and inputs his/her username and password, and then taps the button to register. The inputs of the username and password can be omitted in critical situations. Once the user taps the registration button, the information is transmitted to the registration server in the MDRU and input to the user database in the IP-PBX server. Once the user database is updated, the user is ready to use the service with the registered smartphone.

5. Service usage

An illustration of the service in use is shown in **Fig. 7**. Each user first connects his/her smartphone to the MDRU over the Wi-Fi-based access network. Once a user has connected the smartphone to the MDRU, he/she can use the IP-PBX system to access the described services and to receive incoming calls with the smartphone.

The MDRU service usage has two phases. In the first phase, just after deployment, the MDRU is not connected to any WAN or service network and offers only a Wi-Fi-based access network in the vicinity of the MDRU. In the second phase, the MDRU is connected to the WAN and service networks such as the telephone service network provided by a telecom company.

In the first phase, users can use their smartphones to call people in the same affected area. In the second phase, users can call outside the affected area. When someone outside the disaster area wants to call a smartphone registered in the IP-PBX, the person first enters the main phone number of the IP-PBX, then the number of the smartphone as an extension number. Then, smartphones registered in the IP-PBX can receive calls from outside lines.

As mentioned above, the proposed service system enables people in disaster-stricken areas not only to make local phone calls promptly after a disaster, but also to make/receive long-distance phone calls in the second phase.

6. Development of a prototype MDRU and testbed

We developed a prototype MDRU to evaluate the feasibility of the proposed concept. The developed MDRU is shown in **Fig. 8**, and its specifications are

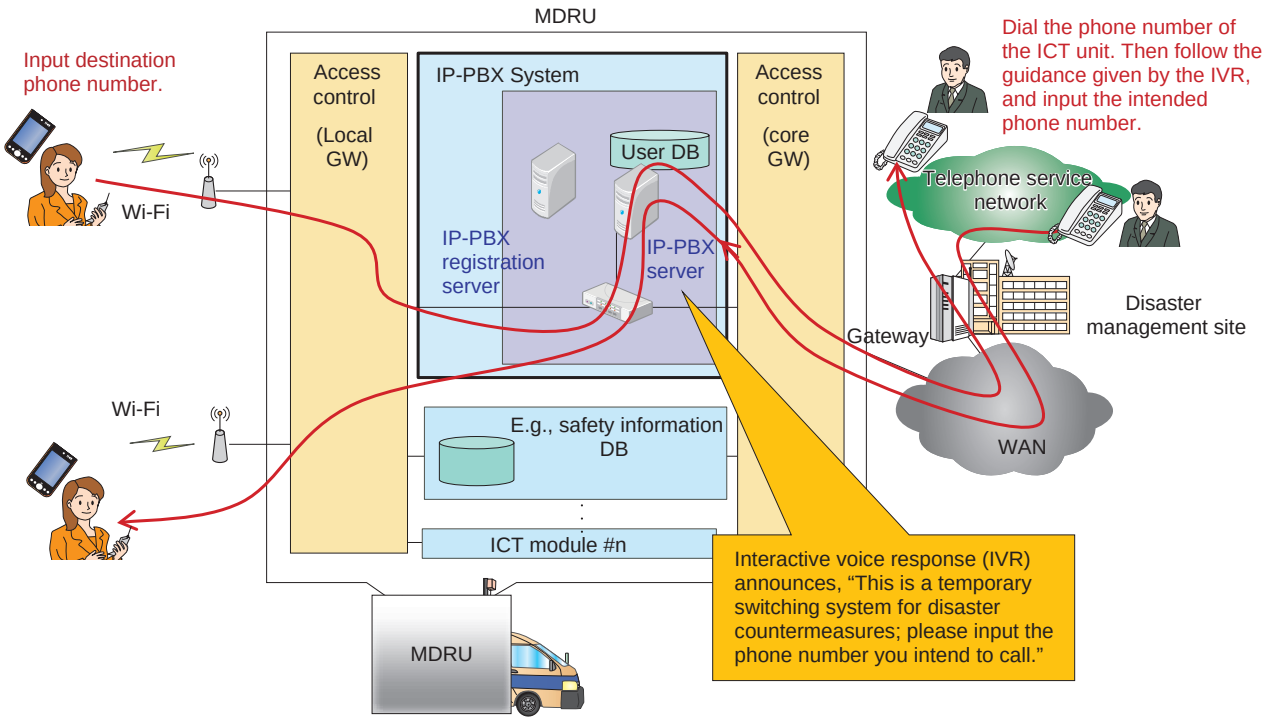


Fig. 7. Mechanism of establishing a phone line to an existing service network.

Fig. 8. Photograph of prototype MDRU.

listed in **Table 1**. The prototype is designed to be able to operate the internal equipment for five days without an outside power supply. The target features of the MDRU are listed in **Table 2**. The ICT services offered are voice, Internet access, and datacenter hosting by a single MDRU that constructs an area within a 500-m radius of the LAN. The phone service system proposed in this article and shown in Fig. 5 was also developed and installed in the MDRU. The phone service accommodates 5000 users. This capacity is extendable by connecting multiple MDRUs. Users access the MDRU using commercially available devices with Wi-Fi or Ethernet connectivity, for example, smartphones and personal computers. The ICT services provided by an MDRU in a disaster situation are restricted to local services in the first phase. Expansion to broad area services is achieved by connecting the MDRU to a WAN using undamaged optical fibers and/or satellite communication links. These capabilities of the MDRU will contribute to meeting the needs and expectations of people in the damaged area.

We also developed a prototype of a portable MDRU in which a function necessary for a specific service has been modularized to improve portability. The portable MDRU, in which we modularized the function for our proposed IP phone service system, is shown in **Fig. 9**. The portable MDRU comprises a small IP-PBX, mobile battery, Wi-Fi access point, and a VoIP adapter, and is carried in a carry case. We conducted an experiment and confirmed that the portable MDRU was able to operate for 5 hours, during

Table 1. Specifications of prototype MDRU.

Power supply	Gasoline-driven generator, lithium-ion battery power supply unit, external AC (alternating current) power
Number of racks	2 (8U 19-inch racks)
WAN I/F	1G media converter
Access NW I/F	Wi-Fi (2.4 G/5 G), 1G/100M Ethernet Fixed wireless access (5 GHz/25 GHz)
Access NW control I/F	Wide area ubiquitous network (920 MHz)

I/F: interface
NW: network

Table 2. Target features of the MDRU.

Service	- Voice, Internet connection, virtual NW for organizations such as local governments.
Capacity	- Single unit covers an area with 500-m radius containing 5000 people. - Voice service accommodates 5000 users; 100 concurrent user connections are possible. - Capacity is extendable by connecting multiple MDRUs.
User devices	- Commercially available devices with Wi-Fi or Ethernet connectivity such as smartphones and/or personal computers.
Expandability	- Expansion to broad area services is realized by connecting MDRU to WAN using optical fibers and/or satellite communication links.

Fig. 9. Prototype portable MDRU.

which 140 calls were placed, by using an 18,000-mAh mobile battery. The offered service and ICT resources are limited with this device, but the portability is improved by modularizing it.

We also constructed a testbed in order to simulate deployment of the MDRU after a disaster. An overview of the testbed is shown in **Fig. 10**. The prototype was deployed on a campus of the University of Aizu in Fukushima. It was connected to NTT's Yokosuka R&D (research and development) Center through the JGN-X (Japan Gigabit Network-eXtreme) experimental network. This R&D center has a gateway to feed the line into the existing service network. In the testbed, we connected the line to NTT's FLET's

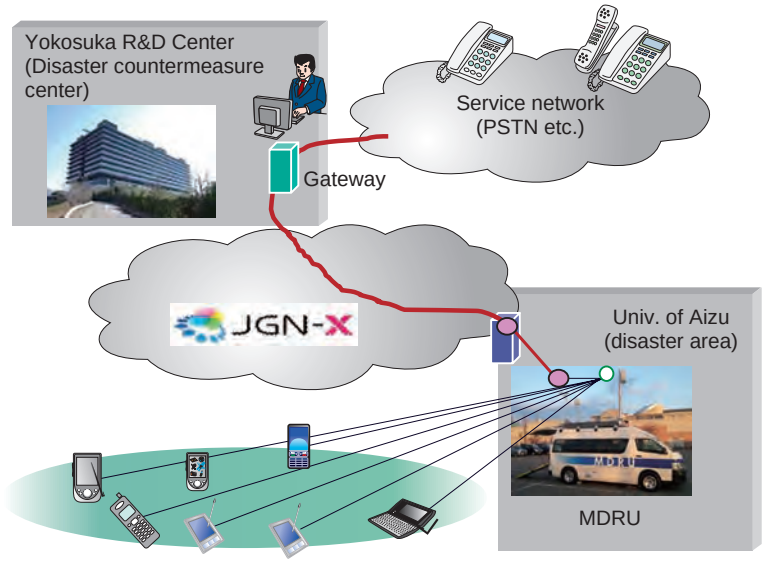


Fig. 10. Testbed constructed to evaluate proposed concept.

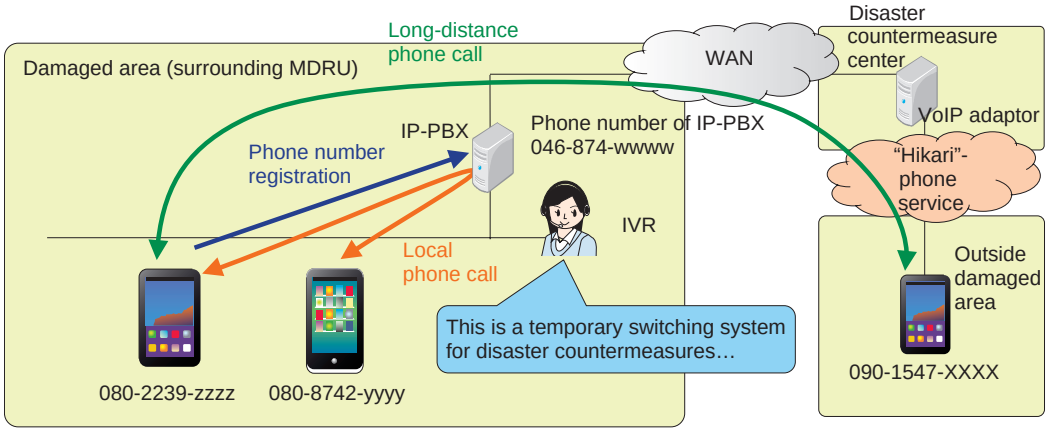


Fig. 11. Phone service offered by MDRU and evaluated in experiment.

HIKARI DENWA phone service.

7. Subjective evaluation experiment

We conducted a subjective evaluation experiment using the testbed (**Fig. 11**). Once the MDRU is activated, the phone service starts. Users who have smartphones register their smartphones to the user database using the pre-installed IP-PBX registration software. After registration, users can make local phone calls to registered smartphones. In the second phase, the MDRU was connected to the WAN through NTT's Yokosuka R&D Center. With this experimental setup, users in the test area could make long-distance calls. The main phone number of the IP-PBX system is written as 046-874-wwww in Fig. 11. A person dialing this number would hear the message: "This is a temporary switching system for a disaster countermeasure; please input the phone number of the telephone you intend to call." The user then inputs the desired phone number and reaches the telephone with the IP-PBX system.

We used the above setup to conduct a subjective evaluation experiment of the phone service with the

Fig. 12. Participants taking part in subjective evaluation conducted at University of Aizu.

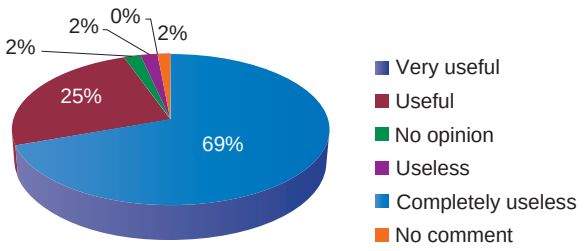


Fig. 13. Subjective evaluation results.

cooperation of the University of Aizu during a campus festival held in October 2013. A photograph of this event is shown in **Fig. 12**. About 300 men and women ranging in age from their teens to their 70s participated in the experiment. They were asked to evaluate the service's effectiveness on a 5-level scale. The results of the subjective evaluation are shown in **Fig. 13**. More than 95% of evaluators ranked the service as useful or very useful.

8. Conclusion

We proposed an emergency phone service system based on an extended IP-PBX. The system is installed on an MDRU that is transported to a damaged area after a disaster occurs. We greatly simplified the process of registering customer devices to the IP-PBX. A Wi-Fi based access network is formed to connect user devices to the IP-PBX. The proposed system can establish a local phone service once the MDRU is powered up in the damaged area. A prototype system was developed, and a subjective evaluation was performed. The evaluation results confirmed the effectiveness and feasibility of our proposed system.

Acknowledgement

This work is partly supported by the R&D project on "ICT Projects for resilient information and communication networks" and on "the movable ICT-Units for emergency transportation into disaster-affected areas and multi-unit connection," both by the Ministry of Internal Affairs and Communications (MIC) of Japan. The authors would like to express their appreciation to the project members from Tohoku University and Fujitsu Corporation for their collaborative work.

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A Brief Overview of Network Functions Virtualisation

Kazuaki Obana, Takeshi Kinoshita, and Katsuhiro Shimano

Abstract

Many network functions such as firewalls and intrusion detection systems have been implemented on specifically designed hardware. Today we are seeing a technological trend in which these functions are being implemented as software running on general purpose servers. The European Telecommunications Standards Institute has established an Industry Specification Group (ISG) to discuss and define the requirements for Network Functions Virtualisation (NFV). This article introduces the concept of NFV and summarizes the activities of the NFV ISG.

Keywords: NFV, network functions virtualisation, virtualisation

1. Introduction

The performance of central processor units (CPUs) and memories, basic components of a general purpose server, has been steadily improving in accordance with Moore's law*1. One core of today's multicore CPUs can handle a million packets per second. Therefore, sufficient performance may well be achieved even if network functions are implemented as software in a general purpose server. Virtualisation*2 presents an advantage in doing so because it enables execution of cloud computing capabilities such as flexible, on-demand deployment of network resources. Network Functions Virtualisation (NFV) is thus coming closer to practical use, and many network carriers have begun testing it for that purpose (**Fig. 1**). The NFV Industry Specification Group (ISG) was established by the European Telecommunications Standards Institute (ETSI) to address issues concerning the realization of the technology.

In existing network appliances, network functions are implemented with specifically designed, proprietary hardware. The performance of these appliances has been improved through the development of hardware that meets specific requirements while retaining carrier-grade reliability. To introduce a new service, newly designed appliances with the required functionalities must be installed at the carrier's buildings, which increases costs for the carrier. Operation and maintenance of the appliances is also an issue because different processes are involved for each kind of appliance, and managing them in an integrated way from a remote site is usually difficult.

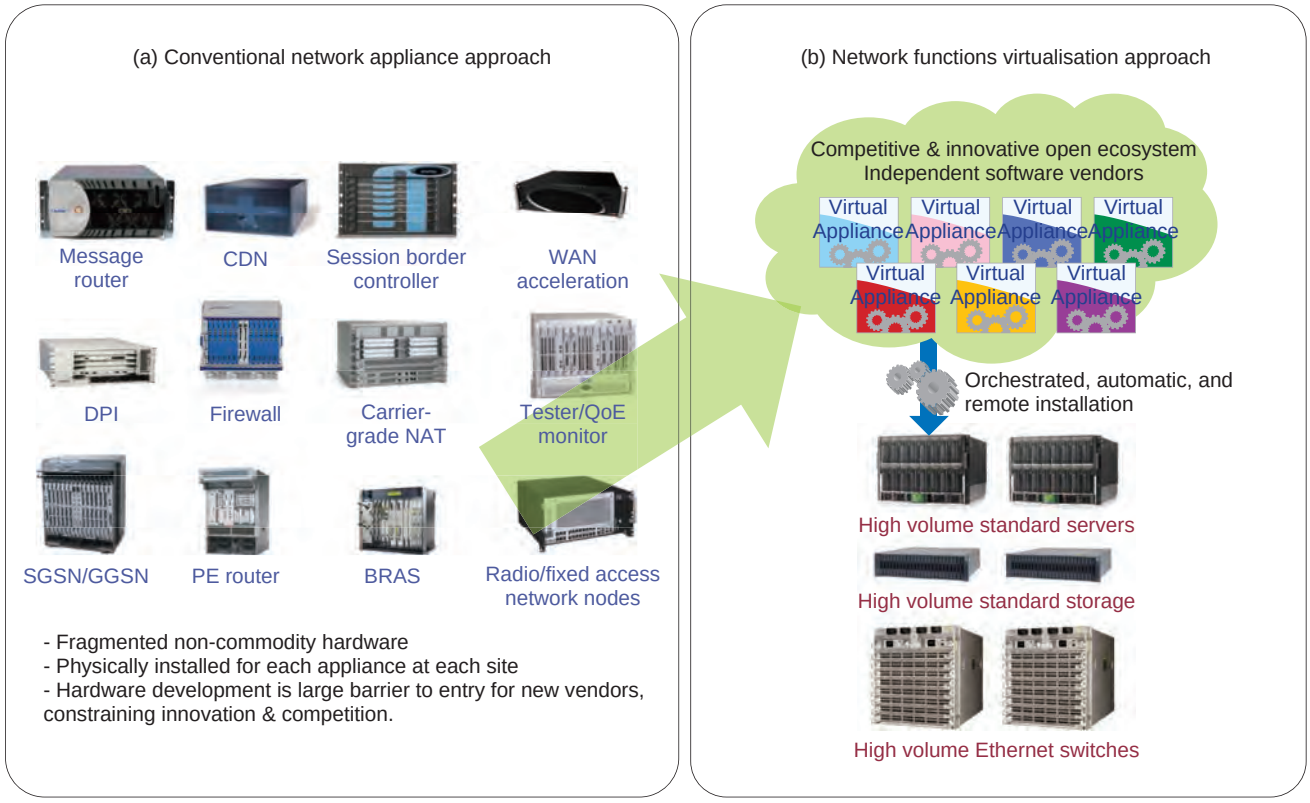
In contrast, the objective with NFV is to implement network functions on general purpose servers. The virtualisation allows the functions to be updated on demand, making it easier to achieve integrated remote maintenance. NFV thus reduces the OPEX (operational expenditure), while also reducing the CAPEX (capital expenditure) through the use of widely used servers, which are usually available at a lower cost.

2. Applications and use cases

The functions being discussed by the NFV ISG vary through the data plane and the control plane for both fixed-line and mobile networks. They include all the currently used network functions such as carrier-grade network address translation (NAT) and

*1 A computing term that originated around 1970; the simplified version states that processor speeds, or overall processing power for computers, will double every two years.

*2 The British spelling used by ETSI is retained throughout the article.



BRAS: broadband remote access server
CDN: content delivery network
DPI: deep packet inspection
GGSN: gateway GPRS (general packet radio service) support node
NAT: network address translation
PE: provider edge
QoE: quality of experience
SGSN: serving GPRS support node
WAN: wide area network

Fig. 1. NFV approach.

broadband remote access server (BRAS) functions implemented in a carrier's central offices; evolved packet core, IP (Internet protocol) multimedia subsystem (IMS), and eNode B functions implemented in mobile networks; functions of home gateways and set-top boxes located at a customer's premises; IPsec tunneling, deep packet inspection, and other traffic analysis or protocol handling functions; load balancer (LB), content delivery network (CDN), and other network control functions; and firewall, intrusion detection system, and other security functions.

Of these, nine use cases were selected as high level cases by the NFV ISG and were described in a recently published document [1]:

(1) Network Functions Virtualisation Infrastructure as a Service,
(2) Virtual Network Functions as a Service,
(3) Virtual Network Platform as a Service,
(4) VNF (Virtual Network Functions) Forwarding Graphs,
(5) Virtualisation of Mobile Core Network and IMS,
(6) Virtualisation of Mobile Base Station,
(7) Virtualisation of the Home Environment,
(8) Virtualisation of CDNs,
(9) Fixed Access Network Functions Virtualisation.

3. History of the NFV ISG

A number of carriers across the world recognized the need to establish a common forum for discussing NFV to lead the technological movement, and thus collaborated in preparing a whitepaper [2] intended to promote international efforts towards realizing NFV. They include AT&T, BT, CenturyLink, China Mobile, Colt, Deutsche Telekom, KDDI, NTT, Orange, Telecom Italia, Telefonica, Telstra, and

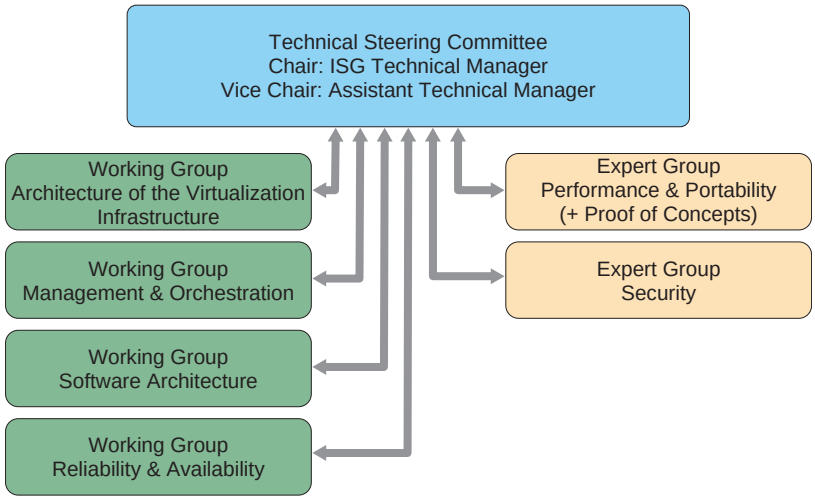


Fig. 2. WG/EG structure.

Verizon. In October 2012, at the SDN (software-defined networking) and Openflow World Congress held in Darmstadt, Germany, they announced the publication of the whitepaper as well as the establishment of the NFV ISG under the auspices of ETSI. (The second version of the whitepaper [3] was published at the conference in 2013.) Since the NFV ISG was officially formed in November 2012, its members have increased to more than 140 companies and organizations consisting of vendors of communications equipment, information equipment, and software. Some 200 to 300 people attend the periodic meetings, where they have active discussions. The NFV ISG does not specify technological details concerning implementation of NFV but presents its architecture and requirements so that they can be used as a basis for the technological specifications developed by other standards organizations. Many of the key persons are also members of other standards organizations, and they facilitate collaboration between organizations. Now that the NFV ISG has released official documents, it is highly expected that standardization processes underway at other organizations will advance further.

Inside the NFV ISG, each Working Group (WG) and Expert Group (EG) discusses issues concerning a specific theme (**Fig. 2** and **Table 1**). Representatives from WGs and EGs constitute a Technical Steering Committee (TSC), which coordinates and guides the activities of different groups. A Network Operator Council (NOC) was created to guide the organization as it was established. It also discusses strategic aspects of the activities (**Fig. 3**).

Plenary meetings are held every quarter, and all NFV ISG members are eligible to take part. Additionally, rapporteurs, who are responsible for completing documentation, can convene ad hoc meetings to discuss items in detail and improve the content of documents. Because only a limited number of members can attend these meetings, draft documents edited at the meetings are made accessible to all NFV ISG members before the next plenary meeting. The draft documents are subject to comments from members and are made ready for approval via an online meeting or at a plenary meeting.

At plenary meetings, WGs and EGs hold separate face-to-face sessions. In other cases, online sessions are often held. They include joint meetings, in which members from more than one WG gather to collect opinions from relevant WGs. People from different countries and regions throughout the world take part in these meetings, so it is often difficult to determine a suitable meeting date and time. The fact that many members belong to more than one WG or EG makes this even harder. The representatives of WGs and EGs thus make diligent efforts to coordinate meeting schedules.

The first plenary meeting was held in January 2013 at the Sophia Antipolis technology park in France, where the headquarters of ETSI is located. All of the plenary meetings up to and including the most recent one, the fourth, have been held in either Europe or the United States. It is likely that a future meeting will move to another region. If other standards organi-

Table 1. Areas focused on by Working and Expert Groups.

WG/EG	Description
Architecture of Virtualisation Infrastructure WG	Developing a reference architecture for the NFV virtualisation infrastructure. Working domains include: Compute, Hypervisor, Network Infrastructure, Interfaces & Abstractions, Test Access, Scalability, Portability, and Replicability.
Management & Orchestration WG	Defining a management and orchestration framework for virtual network functions and the infrastructure these functions run on. Scope includes requirements for orchestration and management, identifying gaps in current standards and best practices, and providing recommendations to fill in the gaps. Topics include: abstraction models and APIs, provisioning & configuration, operational management, interworking with existing OSS/BSS.
Software Architecture WG	Developing a classification system for network functions and defining the phases of network evolution towards a fully managed and orchestrated platform, including the impact on interfaces, legacy external functions, and management systems.
Reliability & Availability WG	Focusing on aspects related to robustness and resiliency in a virtualised network environment. The scope includes use case analysis and definition of the architecture framework, models, and requirements for network resiliency and service sustainability.
Performance & Portability EG (Proof of Concepts)	Assessing performance limitations of selected key virtualized network functions representative of different kinds of workloads. It will seek to identify best practices to optimize the performance of different workloads and investigate how to achieve predictable performance and isolation while assuring portability.
Security EG	Working to ensure that NFV designs in security from the start and that security accreditation bodies address NFV. Scope includes both information security and performance isolation. The group is working to engage accreditation institutions and those with global security expertise and will identify the security deltas introduced by NFV and assign activities to the relevant working groups.

API: application programming interface
BSS: business support system
OSS: operations support system

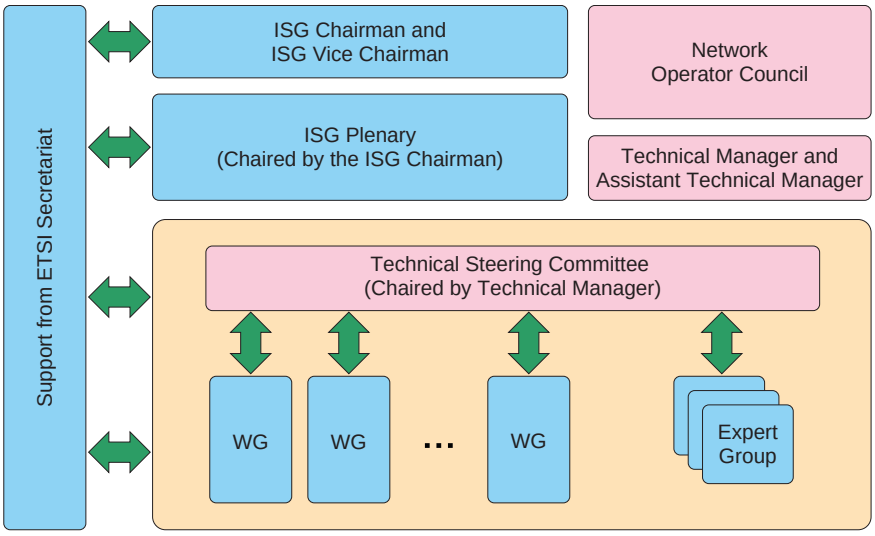


Fig. 3. ETSI NFV ISG organization and structure.

zations such as ONF (Open Network Forum) or IETF (Internet Engineering Task Force) are planning to have meetings around the same period as meetings planned by the NFV ISG, the schedule may be adjusted so that participants can attend all of the meetings, although the schedule is not always subject to change for this reason.

4. Procedures and current status

The documentation process in the NFV ISG is consensus based, meaning that all attendees need to

agree to the revisions for them to be included in a document. Otherwise, discussions will not go further until any objections are dropped. In these cases, the pending issues are described in the Editor's notes. The members who are most concerned with the issues are required to continue discussions at other opportunities and to later submit contributions intended to gather agreement. No voting has taken place in this process as of yet to determine which of various opposing proposals to adopt.

At the first plenary meeting, the NFV ISG agreed to form four WGs and two EGs. After each group initiated technical discussions, the members strongly recognized the need to have documents that would be used for reference in the discussions of each group. At the second plenary meeting, they decided to create reference documents, each of which describes one of the following four Work Items (WIs): NFV Use Cases [1], NFV Architectural Framework [4], Terminology for Main Concepts in NFV [5], and NFV Virtualisation Requirements [6]. The WGs and EGs continued their own discussions as long as the discussions did not relate to the WIs. For related technical issues, they halted discussions until the completion of the reference documents.

Documents of the NFV ISG are created as a Group Specification (GS) and then published upon being approved. These documents are made open and available to the public after the official publication.

The published documents are also sent to other standards organizations. It is highly expected that the discussions at these other organizations will go into further depth after the WGs and EGs release their respective GSs. So far, the four abovementioned WIs, as well as the WI titled Proof of Concepts (PoC), have already been documented as GSs, which are available on the ETSI NFV website.

5. Outlook

The publication of the five GSs will help promote the technical discussions held by each of the WGs and EGs, and more GSs will be published as they progress. We expect that the relevant standards organizations will deepen their discussions based on the GSs that the NFV ISG release. We also expect that the member companies and organizations of the NFV ISG will actively make PoC proposals because the PoC framework is formalized in the published GS. These activities are expected to strengthen the development of technology toward realizing commercial NFV services.

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He received the B.E. and M.E degrees in electrical engineering from Waseda University, Tokyo, in 1995 and 1997, respectively. After joining NTT Optical Network Systems Laboratories in 1997, he engaged in R&D of priority queuing by time and place information, a reverse proxy with a shaping function, and a fast transmitting system with multi-lanes. From 2008 to 2012, he worked on R&D of customer premises equipment in Promotion Project 1, NTT Cyber Solutions Laboratories. Since moving to NTT Network Innovation Laboratories in 2012, he has been engaged in R&D of programmable nodes.

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He received the B.E. and M.E. degrees in nuclear engineering from Kyoto University in 1994 and 1996, respectively. After joining NTT Optical Network Systems Laboratories in 1996, he studied optical fiber communications systems in access networks and their management. He then moved to the R&D center of NTT WEST, where he was responsible for developing and introducing commercial services, including broadband internet access, IP v4/v6 VPN, and wide area Ethernet. He also worked on reducing energy consumption of datacenter components such as servers, communications equipment, and air-conditioning systems. His current research involves virtualisation of network functions and its implementation.

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He received the B.S. degree in physics from Waseda University, Tokyo, in 1991 and the M.S. degree in physics from the University of Tokyo in 1993. Since joining NTT in 1993, he has studied optical networks and network management and related areas such as optical network management systems, GMPLS, and traffic engineering. He also spent time at the headquarters working on NGN network architecture from the first phase of construction. Recently, he has been leading the research on SDN and network virtualisation at NTT Network Innovation Laboratories.

External Awards

APNOMS 2013 Best Paper Award

Winners: Naoki Tateishi[†1], Mitsuho Tahara[†1], Naoyuki Tanji[†1], and Hikaru Seshake[†2]

†1 NTT Network Service Systems Laboratories

†2 NTT COMWARE

Date: September 27, 2013

Organization: The Asia-Pacific Network Operations and Management Symposium 2013 Committee

For "Method for Visualizing Information from Large-scale Carrier Networks".

With the increase in services such as telephone, video on demand, and Internet connection, networks now consist of various elements such as routers, switches, and a wide variety of servers. The structure of a network has become more complicated. Therefore, failure diagnosis of an affected area by using many alarms tends to be more difficult, and the time required to detect the causal point of failure increases. To improve quality of services, reducing the diagnosis time is essential. Alarm browsers and graphs are used to display the collected data from a network to determine the network's status. An operator manages a network by envisioning the network structure. However, the larger the network becomes, the more difficult it is for operators to do this. Therefore, a topology view with geographical information and a topology view with hierarchical information of equipment are used. However, these views degrade if the scale of the network is even larger and more complex. We propose a method for visualizing network information on space and time axes. This method can help network operators to recognize causal points of failure and affected areas. We also explain a prototype software implementation of this visualization method.

Published as: N. Tateishi, M. Tahara, N. Tanji, and H. Seshake, "Method for Visualizing Information from Large-scale Carrier Networks," Proc. of the 15th Asia-Pacific Network Operations and Management Symposium (APNOMS 2013), Hiroshima, Japan.

Papers Published in Technical Journals and Conference Proceedings

Wavelength Defragmentation Algorithm for Transparent Multi-ring Networks with Multiple Fibers per Link

A. Kadohata, T. Tanaka, F. Inuzuka, A. Watanabe, and A. Hirano

Proc. of the Optical Fiber Communication Conference and Exposition and the National Fiber Optic Engineers Conference (OFC/NFOEC 2013), OW3A.7, Anaheim, CA, USA.

We propose a scalable and effective wavelength defragmentation algorithm that considers multiple fibers per link. The number of fibers is reduced by more than 14% in multiring-like networks based on numerical evaluation.

Selective Beamforming for Inter-cell Interference Mitigation in Coordinated Wireless LANs

K. Ishihara, T. Murakami, Y. Asai, and M. Mizoguchi

Proc. of the 16th International Symposium on Wireless Personal Multimedia Communications (WPMC 2013), Atlantic City, NJ, USA.

In future wireless LAN systems, the transmission bandwidth will become wider and the number of access points (APs) will increase as wireless LAN systems become more widespread. As a result, the number of available frequency channels will decrease and inter-cell interference (lCI) among APs with the same frequency channel will become a serious problem. To address this issue we previously proposed an ICI mitigation scheme based on coordinated APs, where a transmit beamforming scheme used for multiuser MIMO is applied to avoid the ICI effect. In this paper, we propose a selective beamforming scheme for ICI mitigation in wireless LAN systems. The scheme uses ICI power as a basis for selectively determining whether to perform null beamforming for each station (STA) in overlapping basic service sets (OBSSs) according to the ICI power. Computer simulation results confirm that the achievable rate obtained with the scheme improves and is higher than that obtained with either time resource sharing or conventional ICI mitigation in an OBSS environment.

What is he/she like?: Estimating Twitter User Attributes from Contents and Social Neighbors

J. Ito, K. Nishida, T. Hoshide, H. Toda, and T. Uchiyama

Proc. of the 2013 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM 2013), pp. 1448–1450, Niagara Falls, Canada.

We propose a new method for estimating user attributes (gender, age, occupation, and interests) of a Twitter user from the user's contents (profile document and tweets) and social neighbors, i.e., those whom the user has mentioned. Our labeling method is able to collect a large amount of training data automatically by using Twitter users

associated with a blog account. Furthermore, we experiment with estimation methods using social neighbors with three adjustable levels of information and show that our method, which uses the target user's profile document and tweets and the neighbors' profile documents (not including tweets), achieves the best accuracy.

Channel State Information Feedback Method for Massive MIMO OFDM

R. Kudo, S. M. D. Armour, J. P. McGeehan, and M. Mizoguchi

Proc. of the 24th IEEE Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC 2013), pp. 1239–1243, London, UK.

MIMO-OFDM with a massive number of transmit antennas (Massive MIMO-OFDM) promises to increase the spectrum efficiency or reduce the transmission energy per bit. The performance of Massive MIMO-OFDM is strongly influenced by the method used to estimate the channel state information (CSI) at the transmitter. Given the massive number of transmit antennas, the many training frames needed for CSI estimation decreases MAC efficiency and increases the cost of estimating CSI at a user station (STA). This paper presents a CSI estimation scheme that reduces the training frame length by using a rank enhancement pilot design. This design assigns a different CSI estimation weight to each subcarrier. The STAs feed unitary matrices, which are obtained by multiplying the left and right singular vectors, back to the AP. The proposed CSI method enables the AP to obtain accurate CSI for limited signal spaces and less-accurate CSI for wider signal spaces for setting data transmission weights and CSI estimation weights, respectively. Simulations of an IEEE802.11n channel show that the proposed CSI estimation scheme with very short training frames obtains greater than 95% of the achievable bit rate of a full CSI estimation in Massive MIMO-OFDM systems with 32 transmit antennas, 2 receive antennas, and 3 STAs.

Angle Selective High Absorption by a Mushroom Metasurface at V-band

S. Nagai, A. Sanada, M. Kawashima, and T. Seki

Proc. of the 27th Asia Pacific Microwave Conference (APMC 2013), pp. 336–338, Seoul, South Korea.

A metasurface consisting of a periodic array of mushroom structures is designed and tested to demonstrate a strong angle selective absorption for TM (transverse magnetic) incident waves from free space at V-band. An absorption as high as 35.6 dB is experimentally obtained with the incident/reflection angle of $\theta = 7$ degrees at 67.3 GHz. Time domain measurements reveal that there exist reradiated waves with a longer decay than that of the direct specular reflection and the absorption is considered to be due to a cancellation of the direct specular reflected waves and the reradiated waves.

Study on Short-range MIMO Transmission Using Interference Cancellation by Antenna Directivities

M. Arai, T. Seki, K. Hiraga, T. Nakagawa, and K. Uehara

Proc. of the 27th Asia Pacific Microwave Conference (APMC 2013), pp. 395–397, Seoul, South Korea.

In this paper, a simple method for canceling interference by using antenna directivities is proposed for short-range transmission systems. For higher data transmission systems the millimeter-wave frequency bands are useful because of their wide bandwidths. Also, Multiple-Input Multiple-Output (MIMO) technology can be applied to these bands because the application enables channel capacity to be increased by using multiple antennas at the transmitter and receiver without expanding the frequency bandwidth. However, since MIMO transmission schemes are complicated we consider parallel transmission, a simple method for transmitting multiple data streams that is suitable for short-range MIMO transmission. We propose a simple method for canceling interference by using antenna directivities and improving channel capacity in parallel transmission. Numerical analysis shows that the method maximizes channel capacity at the optimal spacing Lopt = 2λ0. It is also found that the channel capacity of the method is 14% higher than that of Eigenmode beamforming (EM-BF) for two transmission streams and 12% higher for four streams.

Transmit Power Control Suitable for Interference-aware Channel Segregation Based Dynamic Channel Assignment

Y. Matsumura, K. Temma, K. Ishihara, B. A. Hirantha Sithira Abeysekera, T. Kumagai, and F. Adachi

Proc. of the 9th International Conference on Information, Communications & Signal Processing (ICICS 2013), Tainan, Taiwan.

Since the number of available channels is limited, the same channels need to be reused. However, co-channel interference (CCI) limits the transmission quality. The channels should be reused so that the CCI received at all access points or base stations is minimized. Our recently proposed interference-aware channel segregation based dynamic channel assignment (IACS-DCA) can form a stable channel reuse pattern which mitigates the CCI in a distributed manner. An additional use of transmit power control (TPC) can further reduce the CCI. In this paper, we propose a signal-to-interference power ratio (SIR) based TPC scheme suitable for IACS-DCA. We show, by computer simulation, that the IACS-DCA with SIR based TPC forms a stable channel reuse pattern and further improves the outage probability of signal-to-interference-plus-noise power ratio.

Next Generation Wi-Fi: High Efficiency Wireless LANs

Y. Inoue

Proc. of IEEE GLOBECOM 2013, Vol. IF29, No. 4, Atlanta, GA, USA.

In order to support the increasing demands for mobile data communications with cellular systems, the wireless local area network (WLAN) needs to be improved to offer high performance in densely deployed environments. The IEEE802.11 Working Group has created a new study group called High Efficiency WLAN SG for the purpose of improving the spectrum efficiency and area throughput. Assumed scenarios include both indoor and outdoor deployment. Both 2.4- and 5-GHz bands are included in the scope.

Report on the 3rd International Symposium on Network Virtualization

T. Kinoshita and M. Kiyokawa

IEICE Communications Society—GLOBAL NEWSLETTER, Vol. 37, No. 4, pp. 2–3, 2013.

The 3rd International Symposium on Network Virtualization was held on September 6, 2013, at the University of Tokyo. This year's symposium introduced the latest research activities in the areas of Software Defined Networking (SDN), Network Functions Virtualization (NFV), etc. In the symposium sessions, future directions of

research on programmability within networks were discussed from the viewpoints of various stakeholders from academia and industries across the world.

Implementation Method for Over 50-Gbit/s PC-cluster Based Stream Server System

H. Kimiyama, T. Ogura, and M. Maruyama

IPSJ Journal, Vol. 54, No. 12, pp. 2413–2426, 2013.

Recently, video production sites often exchange video data for video-production in which there are many sub-processes (e.g., 3D modeling, color conversion) since each sub-process requires unique high-level skills. Video production sites use general file servers to exchange their video data via high-speed networks. However, these servers do not have sufficient performance to smoothly handle such high-quality video such as uncompressed HD (high definition) and uncompressed 4K videos, which have rates of over 1 Gbit/s. Therefore, we researched a personal computer (PC)-cluster-based video stream server system to handle such high-quality video streams. We have developed a video server system with 24-Gbit/s maximum throughput by combining 16 PCs, 8 general storage systems, and a 20-Gbit/s InfiniBand inter-cluster network. To respond to demands for delivering video data streams to more video production sites, we propose a new communication method over an inter-cluster network that offers higher total throughput. We implemented the new communication method on a PC-cluster-based server system prototype and evaluated system performance. By combining 24 PCs, 12 storage devices, and one InfiniBand switch, we realized a 54-Gbit/s throughput video server system. In this paper, we describe the proposed communication method, the hardware and software implementation method on the PC cluster, as well as the evaluation results.

An SDM Method Utilizing Height Pattern Due to Two-ray Fading Characteristics

K. Hiraga, K. Sakamoto, M. Arai, T. Seki, T. Nakagawa, and K. Uehara

Antennas and Wireless Propagation Letters, IEEE, Vol. 12, No. 1, pp. 1622–1626, 2013.

A spatial division multiplexing transmission method utilizing the characteristics of two-ray fading without relying on the narrow beam of the antennas is introduced. This paper formulates the optimized array antenna arrangements and channel capacity as functions of the transmission distance and shows achievable channel capacity for two- and three-element antenna arrays. The paper also describes bandwidth dependency up to 15 percent bandwidth based on an assumed application to 60-GHz-band gigabit wireless systems. The proposed method provides increased capacity comparable to multiple-input and multiple-output (MIMO) transmission without the extra signal processing cost incurred when using conventional MIMO.

Experimental Demonstration of Simultaneous SPM and XPM Mitigation Using Combined Techniques of Optical Compensation and Multichannel Single-stage DBP

H. Kishikawa, T. Kawai, K. Shibahara, and M. Fukutoku

Electronics Letters, Vol. 49, No. 25, pp. 1627–1628, 2013.

A novel system mitigating self-phase and cross-phase modulation effects simultaneously using optical dispersion compensation at optical nodes and multichannel single-stage digital backward propagation (DBP) is proposed. Experiments demonstrate 2.4 dB Q-factor improvements with both self-phase modulation and cross-phase modulation compensation.

A Load Balancing and Replica Partitioning Method for Consistent Hashing

M. Irie, E. Iwasa, M. Kaneko, T. Fukumoto, and K. Ueda

IEICE Trans. on Communications, Vol. J97-B, No. 1, pp. 31–40, 2014 (in Japanese).

We choose session control servers as the objects of our studies on massively distributed systems. Systems such as session control servers must have a good load-balancing scheme. Characteristics such as scalability and fault-tolerance are also required. We propose a load-balancing method that fulfills these requirements. We apply consistent hashing as the load-balancing scheme for the session control servers. Existing node-ID allocation methods for consistent hashing have a wide range of load distributions, so they are not suitable for the load balancer of session control servers. We propose a node-ID allocation method that selects the longest range of ID space and allocates an ID to divide that range. In addition, we propose a technique to prevent conflicts between replicas of the virtual nodes. Lastly, we confirm the characteristics of our proposed method from the results of computer simulations and an experimental evaluation.

Proposal and Consideration of the Securitter which Tweets Behavior of Information Security

S. Hara, H. Miura, Y. Seki, and H. Suwa

IPSJ Journal, Vol. 55, No. 1, pp. 210–220, 2014 (in Japanese).

To increase the security level of the information society, it is important that end-users perform certain security actions. We think that if users can share information about familiar persons who carried out a certain action, they will be aware of security information and will act in a way that is related to their own behavior. In this paper, we propose Securitter, which is an information sharing method using Twitter. Securitter automatically extracts the logs that are left when users have carried out information security behavior. We consider the requirements and the functions of the Securitter and implement an application program in order to validate the feasibility of the system including the linkage with Twitter. We built a network environment using Twitter and conducted an experiment in which 47 users followed the tweets of 3 co-workers for a week. The results indicated that 30 users read the information about performing an information security related action, and 5 users actually did the action. Furthermore, we confirmed the effectiveness and acceptability of receiving tweets from the Securitter from structured interviews and questionnaires.

Using Phrase End Context to Predict Phrase Boundary Rise Labels from Text for Expressive Text-to-speech Synthesis

H. Nakajima, H. Mizuno, O. Yoshioka, and S. Takahashi

IPSJ Journal, Vol. 55, No. 1, pp. 553–562, 2014 (in Japanese).

Expressive speech shows a phrase boundary rise of fundamental frequency (F0) even if it is not an interrogative sentence. To synthesize expressive F0, tone labels such as phrase boundary tone label are known to be useful. Though conventional label prediction mainly uses many numerical features such as phrase length and phrase location in a sentence, conventional phonetic analysis reveals a complex

relationship between phrase semantics and phrase boundary tone label. Instead of using semantic processing, this paper proposes the use of phrase end context, which consists of several word surface strings and their part-of-speech in the phrase and the existence or non-existence of a pause at the phrase-final position. Experiments on Japanese expressive speech, Tokyo dialects, that target phrase boundary rise label prediction show that the proposed phrase end context attains performance equal to or better than that of conventional features, confirming the usefulness of the phrase end context proposal.

Editor's Message to Special Issue on Technologies and Network Services to Cooperate with Social Activities

Y. Seki

Journal of Information Processing, Vol. 22, No. 1, p. 18, 2014.

In this special issue, the editorial committee of the journal sought paper submissions on technologies and network services to cooperate with social activities. The editorial committee members are mainly from the Special Interest Group on Groupware and Network Services.

Theoretical and Experimental Analysis of Spatial Division Using Antenna Directivities in Short-range MIMO Transmission

M. Arai, T. Seki, K. Hiraga, T. Nakagawa, and K. Uehara

Electronics Letters, Vol. 50, No. 2, pp. 65–67, 2014.

A simple method is proposed for achieving short-range multiple-input multiple-output (MIMO) transmission without complicated signal processing. This is achieved by a spatial division that cancels interference between signal streams by using π-phase-shifted antenna directivities in high speed parallel transmission systems at 60 GHz. The method achieves spatial division transmission without MIMO detection even for antenna elements with wide beamwidths. This makes it easy to design antenna elements and reduces signal processing costs in the transmitter and the receiver. Moreover, the method provides almost the same channel capacity as that of the complicated MIMO transmission methods. The optimal antenna array length is derived to maximize the capacity, and the validity of the proposed method is confirmed through numerical and experimental analyses at 4.85 GHz.
