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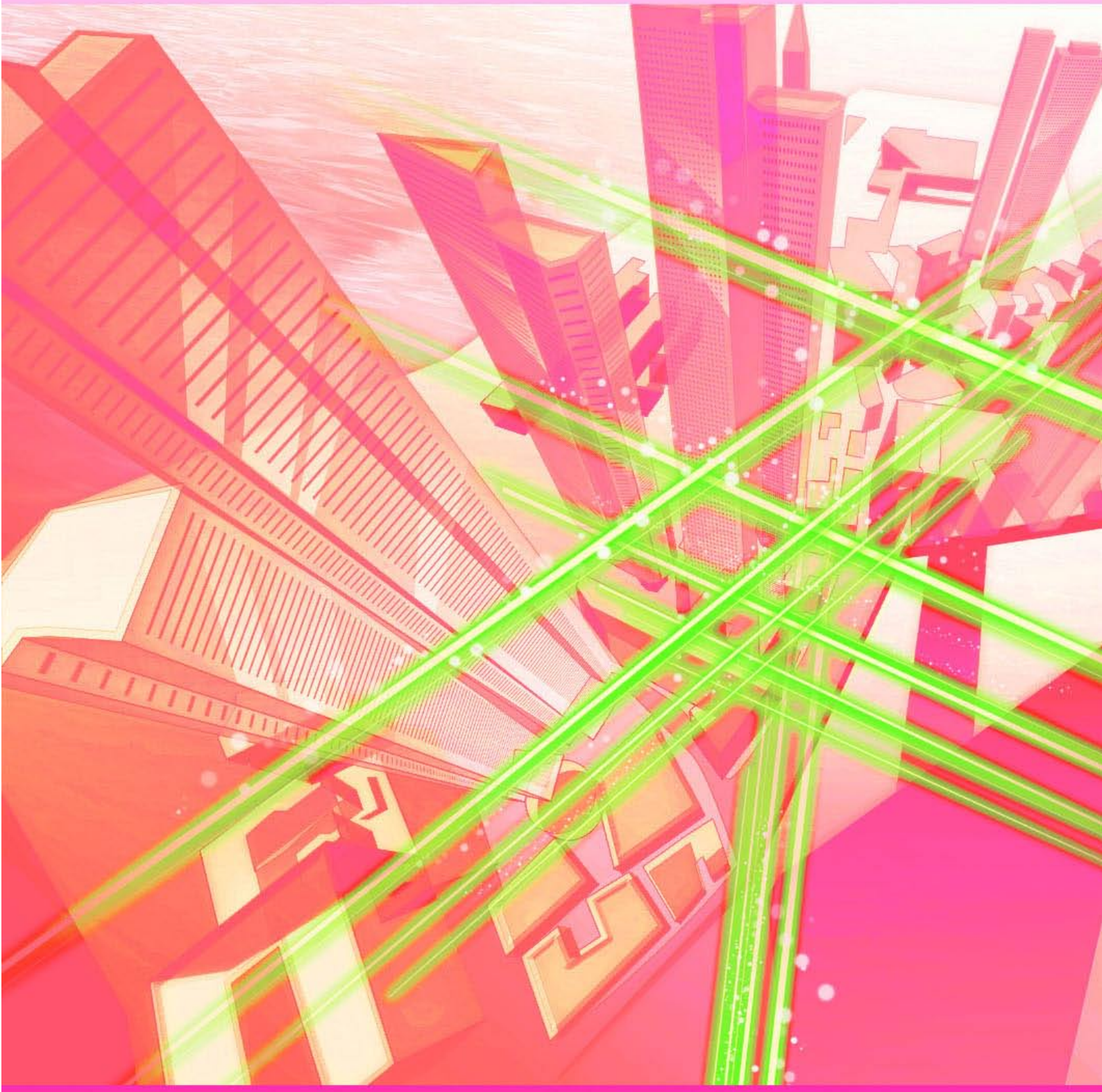

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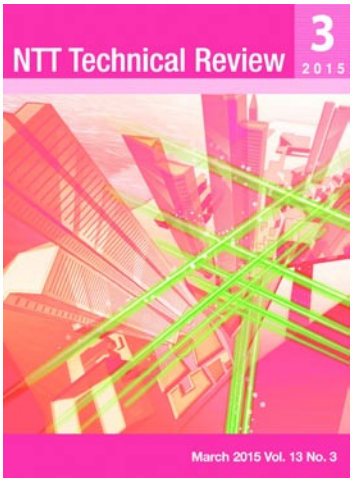

Time for a More Human Approach—Facing the Challenges of an Aging Society and Regional Revitalization through New Forms of Distance Education

Katsuhiko Shirai
External Board Member of NTT, Chairperson of the Foundation for the Open University of Japan

Overview

Japan is facing an aging society with a declining birthrate. How can distance education support our younger members of society, our future leaders? The Open University of Japan (OUJ) aims to provide new, high-quality courses through the introduction of cutting-edge ICT (information and communication technology). We asked Katsuhiko Shirai, External Board Member of NTT and Chairperson of the Foundation for the Open University of Japan, who has many years of experience in research and education, to tell us about OUJ's approach to education and regional revitalization. We also asked him to share his thoughts on the role of researchers.

Keywords: ICT, MOOC, speech research

Providing high-quality learning through ICT

—Mr. Shirai, please tell us about OUJ's approach towards education.

The Open University of Japan (OUJ) aims to provide university courses to a wide segment of society through television (TV), radio, and other forms of broadcast media. Thirty years ago when OUJ was first established, there were many people who could not attend university or college because of their economic situation or other reasons. Our objective then was to enable these people to receive a university education while working, to promote lifelong learning in society, and to provide people who could not easily attend a school of higher education because of a long-distance commute, with the opportunity to learn.

In the past, enrollment at OUJ was centered about students in their 20s and 30s, but today, most students are in the 30–60 age group, with about an equal number of students in each generation. However, there are also the elderly who, faced with retirement, have a strong desire to study again; this includes people in their 70s and up into their 90s who are very serious about learning.

Conversely, there are many young people who started out by entering a university only to quit soon after if their studies were not meeting their needs or personal goals. A system is therefore needed to enable them to continue their education. To support such a wide range of students, OUJ will be introducing online courses with interactive capabilities in fiscal year 2015.

The fact is, more than half of the students at OUJ are now participating in courses via the Internet. Today, there are more people than ever who are enjoying video and other media via the Internet using their smartphones or tablets as part of everyday life. It was therefore inevitable that OUJ would construct an environment for delivering courses via the Internet.

OUJ is presently delivering lectures and courses using TV channel 1+α and radio channel 1, but time constraints limit the number of courses that can be provided to about 300 per year. Using the Internet will eliminate such constraints on delivery time and will theoretically enable any number of courses to be offered. In this way, we will be able to provide more detailed, highly specialized courses.

—Internet delivery enables students to take classes whenever they want, but aren't you concerned that such a format will give students the freedom to put off their classwork if they so desire?

That problem exists even today. The current era is such that students take their classes during a time slot most convenient for them, whether it be via the Internet or TV. For people who are very serious about learning, the problem here is more about content.

I believe that there are people who have stumbled upon some of OUJ's programs on TV when randomly changing channels, so I think it is important to create programs that can attract the interest of these people too.

In addition, a key characteristic of OUJ is that students are always on the opposite side of the instructor's microphone or camera. Consequently, other than in face-to-face classes held at more than 50 Study Centers throughout Japan, instructors cannot directly perceive the reaction of students to the content of a lecture. For this reason, instructors are asked to undergo training not just in regard to lecture content but also on incorporating various techniques into their lectures involving their way of speaking, their body language and gestures, and the like.

On top of that, an increase in the number of courses offered incurs a proportional amount of preparations and funds. We are therefore leveraging our extensive experience in producing high-quality TV and radio content in dealing with the challenges of creating new programs. For example, we think that liberal arts courses should be delivered via TV and radio since there are probably many people who enjoy such lectures even if they are not OUJ students. On the other hand, we think that highly specialized courses such as those at the graduate level taken by a relatively small number of people should be delivered via the Internet. This type of management that makes use of the special characteristics of broadcast media is what I would like to pursue.

Playing a part in dealing with the aging society and regional revitalization

—What is the current state of MOOCs and higher education in Japan?

A massive open online course (MOOC) refers to a course given by a celebrated professor of a renowned university somewhere in the world that anyone can access via the Internet. However, participation in pure MOOCs by Japanese universities would present a language problem that would lessen their appeal. Against this background, the Japan Open Online Education Promotion Council established Japan Massive Open Online Courses (JMOOC) with the aim of providing courses in the Japanese language.

One official platform for JMOOC is *gacco*, which has the distinction of being Japan's first MOOC website launched in April 2014 in collaboration with NTT DOCOMO. It has been highly evaluated as a fine mechanism for enabling anyone to experience a

university level course free of charge, although course credits are not provided.

In terms of university education, the matriculation rate into four-year universities is above 50%, of which more than 80% is into private universities. If this matriculation rate remains unchanged while the birthrate declines, the number of students will inevitably decrease. Under these conditions, every university is trying to come up with ways of providing more attractive courses and facilities to attract and maintain students, but private universities, especially regional ones, appear to be in a difficult situation in terms of operations and management.

One may think that achieving enrollment goals may not be so difficult if social awareness of higher education increases and the matriculation rate rises by a few percentage points. However, the reality is that economic factors and changing values on the part of university candidates, such as in questioning the worth of a university diploma given its cost, means that universities cannot ignore the issue of whether they can truly provide high-quality courses when they are in an unstable financial position.

I myself believe that ordinary universities could use the courses and materials provided by OUJ. In fact, I believe that if universities were to exchange and provide some of each other's courses, the quality of course content would rise while easing the burden on instructors. It might also enhance the depth of courses without having to raise tuition fees.

—The concept here is that high-quality courses should be shared among everyone.

I call it a "cloud-type university," but from here on, I believe that the focus will be on two main styles of university education.

In the first style, the student places importance on the university brand and studies at only one university, finding value in tradition and other conventions. In the second style, the student discards such traditional values and studies by selecting high-quality courses from a variety of universities. In either case, I believe that one role of universities in the future will be that of a guide to help students navigate through a huge amount of available material.

It can be said that regional universities have the role of contributing to the revitalization of the regions where they are located. For this reason, the use of JMOOC online courses means more than just supplementing the courses provided by a university; it also holds the potential of educating and developing human resources that can contribute to the revitalization of their region. Many young and socially aware students in their 20s are enrolled in regional universities. If they do not simply complete courses—rather, they learn something valuable from those courses and become more intelligent and motivated—they can bring about real changes in their regions.

It looks as if high-quality courses will become increasingly open as we go forward. We are on the verge of an era in which an overabundance of content will make it difficult to decide just what to study. In the end, there will be a great need to organize this huge amount of material so that students can make sense of it.

There will be more universities like the Khan Academy that aim to improve education by creating a mechanism for studying at one's own pace anywhere in the world. Adopting this system will enable a university to provide each student with individual support tailored to his or her level of proficiency as opposed to supervising a few dozen students all together in one classroom. JMOOC has not yet reached this point, but some universities are in the process of incorporating this system in some of their courses. I think there will be a major movement in the future to adopt such a beneficial mechanism.

Time for a more human approach

—The speech research field that you were involved in for many years has progressed amazingly.

That's right. I worked in the field of speech research for over 50 years. During that time, studies were broadly divided into speech recognition and speech synthesis, and Europe, the United States, and Japan were vying for the top spot in this field. I was particularly involved in basic research in collaboration with Advanced Telecommunications Research Institute International (ATR), NTT laboratories, and other institutions. ATR is known for its high-level researchers on loan from top Japanese research laboratories such as NTT laboratories, and as the place that gave birth to the automatic interpretation telephone. ATR led the world in this area with its unique research results, and the basic idea or principle of this system can be said to have served as a model for NTT DOCOMO's "Hanashite Honyaku," its automatic voice translation application.

A major topic in the field of speech research today is interactive technology. With the coming of the 2020 Summer Olympics to Tokyo, there is a need for a practical function that can provide multilingual support. A good portion of this function has already been completed. However, while speech recognition and speech synthesis will be major components of this function, multilingual support will require linguistic elements and language data to serve as models. Up to now, the study of language models has been the reserve of linguists and grammarians; however, compared to the written word, the spoken word, i.e., everyday conversation, does not have to be as rigorously correct in terms of grammar or the language in general. Consequently, in addition to researchers, there is also a need here for a massive database of everyday conversation, referred to as a "corpus" in the linguistics field. It should be possible to create a function that provides multilingual support by statistically analyzing this corpus and creating stochastic models. In the past, there were no computers powerful enough to perform such an analysis, but advances in ICT (information and communication technology) have made it possible to handle such a huge corpus, which now needs to be analyzed as "big data." Companies and organizations in a wide variety of fields ranging from business science to traffic control, disaster prevention, and case analysis, have already begun to apply big data. I think that now is the perfect time for the field of speech research to do the same, especially by combining big data with statistical analysis and stochastic models, which have been the cornerstone of this field.

—Mr. Shirai, having witnessed all sorts of trends in speech research from its early days to the present, how do you think NTT laboratories and NTT researchers should face the future?

In the early days, broadcasters and telecommunication companies had their own research laboratories and carried out basic research in a step-by-step manner. Nowadays, however, companies are coming to question the necessity of in-house research—whether that be basic research or applied research—and are thinking about consigning their research needs to other companies or institutions. In addition, research institutions that have specialized in basic research and given society such amazing research results, for example, Bell Laboratories, have for the most part disappeared throughout the world.

At the same time, major enterprises such as Google, Amazon, and Microsoft are taking up the work of applied research, signaling a generational shift in the corporate world. Nevertheless, despite this trend, I believe that NTT's basic research laboratories are holding fast to its traditions when it comes to the need for basic research. Of course, the role of NTT laboratories in general has shifted from basic research to applied research to meet the needs of the times, but I believe that it still retains truly autonomous development capabilities.

I would like to see this core R&D (research and development) strength applied in a direction that can contribute to society in all kinds of ways. This, I believe, is NTT's social responsibility—it's not just what I want but also what society on the whole expects.

Today, there is huge competition in big data analysis techniques, which they call "recipes." Given the abundance of big data material in the world, the

important thing here is figuring out how to "cook" big data, so for researchers, the task is clear. However, the models that are coming to be used in big data analysis are not as simple as those used in the past. Today, they are highly detailed and involved. Statistical concepts are therefore becoming key elements in this work. Techniques for creating statistical models, carrying out analyses, and solving a variety of problems have been used in speech research. I believe that applying these techniques in combination with machine learning theory will reap a mountain of beneficial results in the years to come.

From here on, I think many researchers will be discussing the future and talking about what lies ahead. They may think about truly incredible matters such as whether intelligence and wisdom in the world can be brought together inside a computer to outdo humans and whether cosmic riddles can finally be solved. They may also talk about various structures and systems by considering, for example, that events that occur before our very eyes are, in the end, simply a question of human cognition. These topics may sound quite eccentric, but thinking in this manner is perhaps a human trait. I believe that cutting-edge research is generated by asking questions such as "What do people feel?" and "What do people think about?" and "How do people behave?" Major themes at NTT are communications and data processing, or in other words, the network and the cloud, which have become a major presence and influence in our lives. I myself am fascinated by the prospect of combining this human touch with machines such as computers, so you can see that my involvement in speech research has continued unabated.

Interviewee profile

■ Career highlights

Katsuhiko Shirai became an Executive Advisor for Academic Affairs at Waseda University in 2010 after having served as a Professor there since 1975 and as President of Waseda University since 2002. He has been the Chairperson of the Foundation for the Open University of Japan since April 2011 and an External Board Member of NTT since June 2012.

R&D Efforts to Reduce the Burden of ICT Services on the Environment

Nobuyuki Watanabe, Yoshiharu Akiyama, and Akira Sugiyama

Abstract

Providing telecommunications services requires a telecom infrastructure that comprises network equipment, air-conditioning systems, power supply equipment, access system equipment, and various other facilities. As a telecom provider, NTT manages the full range of such facilities. This article describes research and development efforts to reduce the burden placed on the natural environment by ICT (information and communication technology) services, focusing on what is being done by the NTT research laboratories and NTT Group companies as members of the Green and Sustainable Infrastructure Committee.

Keywords: energy and environment, sustainable, energy management

1. Introduction

In the face of global environmental issues such as global warming and depletion of natural resources, the NTT Group has for some time been working to achieve three goals in the use and application of information and communication technology (ICT) services: creating a low carbon society, implementing closed loop recycling, and conserving biodiversity. The use of ICT services involves massive consumption of power and resources including the operation of network equipment such as routers and servers and the air-conditioning systems needed to cool them, and access facilities such as utility poles and telecom lines. Network power consumption has been increasing along with network traffic, and the overall cost of power has been increasing because of the rising cost per unit of electricity. However, even when concerns about protecting the global environment are set aside, energy use is a growing problem for business operations in the NTT Group, which used nearly 8.6 billion kilowatt-hours of electricity in fiscal year 2013 (**Fig. 1**). Power consumption on this scale accounts for about 1% of all commercial power used in Japan. The carbon dioxide emissions associated with power consumption on that scale make up about 95% of all emissions attributable to the NTT Group, and that must be reduced as a step towards achieving a low-carbon society. Furthermore, we rely almost entirely on the commercial power supply. Japan currently depends on imported fossil fuels for power generation, and fuel costs are rising year by year. The effect of that situation on short-term revenue cannot be ignored by the NTT Group. What is more, traffic volume is increasing yearly with the increasing popularity of services that transmit large amounts of data such as video, and new services for smartphones and other such devices. The investment in facilities needed to cope with the increase in traffic is expected to also increase the power consumed to provide those services.

To solve the problem of rising energy costs and future problems related to the global environment, NTT Energy and Environment Systems Laboratories has been collaborating with NTT Network Service Systems Laboratories, NTT Access Service Systems Laboratories, NTT FACILITIES, INC. and other organizations in the research and development (R&D) of technology to reduce power consumption and technology to conserve resources and in drafting R&D strategies.

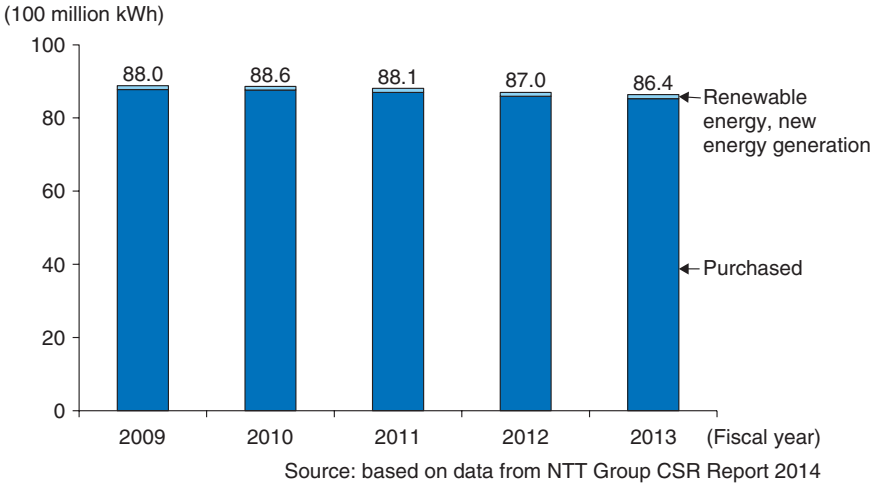

Fig. 1. Trend in power use by the NTT Group.

2. Six areas of technology related to environment and energy

The provision of ICT services requires a telecom infrastructure that comprises network equipment, air-conditioning systems, power supply equipment, access system equipment, and various other kinds of facilities. To reduce the environmental burden created by the telecom infrastructure, the Environment and Energy Technologies Committee was established in April 2013. (The name was changed to the Green and Sustainable Infrastructure Committee in November 2014.) The Committee serves as a strategic organization for cooperation among all facility-managing entities within the NTT Group, including the research laboratories and member companies, in the R&D of elemental technology in the six areas (**Fig. 2**) listed below.

(1) Power source related technology for raising the level of self-sufficiency and supplying power to network equipment
(2) Air-conditioning related technology for raising the energy efficiency of air conditioning systems for telecom buildings
(3) Technology for integrated operation of network equipment, power supply systems, and air-conditioning systems
(4) Technology for reducing power consumption, with network architecture and network equipment designed to contribute to overall network energy efficiency
(5) Green telecom infrastructure technology for resource conservation
(6) Technology for dealing with electromagnetic radiation, lightning, and other disturbances from the external environment.

These Feature Articles introduce R&D work on materials for energy production and storage [1] and high-voltage direct current (HVDC) power supplies [2, 3], which concern the first three items above. Other articles feature work on reducing power use of network equipment [4] and of optical access systems [5] (item 4), and work on conserving resources for the materials used in the telecom infrastructure [6] (item 5). We are also working on technology for quantitatively measuring the effects of ICT services on the environment [7].

3. Future development

NTT Energy and Environment Systems Laboratories has been collaborating with other NTT research laboratories and NTT Group companies through the Green and Sustainable Infrastructure Committee to develop technology for reducing the load placed on the environment by ICT services. We are continuously moving forward with R&D to improve energy efficiency and resource efficiency in the overall business activities of the NTT Group by responding rapidly to the needs of businesses and external trends.

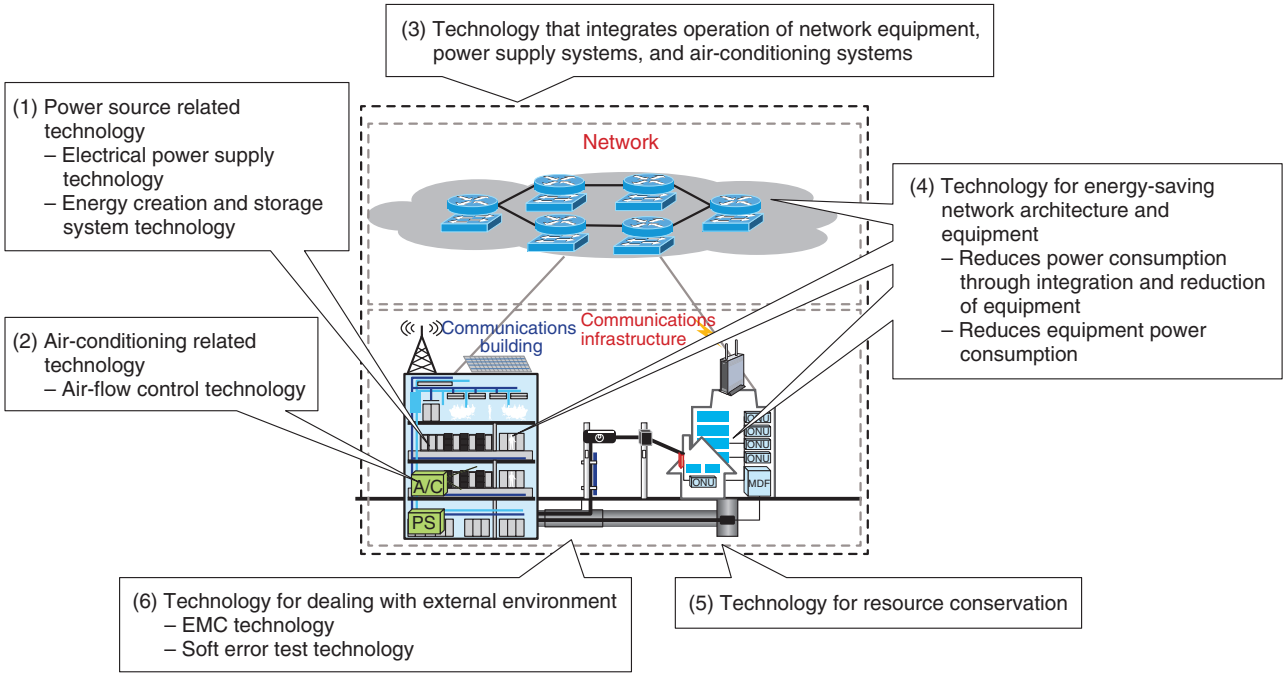

Fig. 2. Six areas of technology concerning energy and the environment.

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He received the B.S. in electrical engineering from Chiba University in 1982. Since joining NTT in 1982, he has mainly been engaged in R&D of digital switching systems, switching services, and call agent systems. He is a member of IEEE (Institute of Electrical and Electronics Engineers) and IEICE (Institute of Electronics, Information and Communication Engineers).

Yoshiharu Akiyama
Executive Manager, Research Planning Section, NTT Energy and Environment Systems Laboratories.

He received the B.E. and D.E. from the University of Electro-Communications, Tokyo, in 1990 and 2010, respectively. Since joining NTT in 1990, he has been researching methods of testing and measuring electromagnetic compatibility (EMC) of wireless communication and broadband communication systems. In 2013, he became manager of the Energy System Project and was engaged in developing the HVDC power supply system. He is now the Executive Manager of the Research Planning Section in Energy and Environment Systems Labs.

Akira Sugiyama
Senior Research Engineer, Research Planning Section, NTT Energy and Environment Systems Laboratories.

He received the B.S. and M.S. in computer science from Tokyo Institute of Technology, Tokyo, in 1994 and 1996, respectively. He joined NTT Basic Research Laboratories in 1996, where he was engaged in research on natural language processing. He moved to NTT Energy and Environment Systems Laboratories in 2004. He currently belongs to the Research Planning Section in Energy and Environment Systems Labs.

Evaluation Methods of the 'By ICT' Effect

Tomomi Nagao, Yuichiro Takei, and Shinsuke Hannoe

Abstract

As a step towards achieving the goals of THE GREEN VISION 2020, the NTT Group's environmental vision for the year 2020, the NTT Energy and Environment Systems Laboratories has developed various methods to evaluate the 'By ICT' effect as a means of evaluating the effect of reducing the societal load on the environment by using information and communication technology (ICT) at the enterprise level. Such evaluation makes it possible to easily calculate the total reduction in the environmental load that results from the ICT services provided by the NTT Group by using business indexes such as sales and number of contracts.

Keywords: Green by ICT, environmental load reduction, CO_2 emissions

1. Introduction

There are expectations that the use of information and communication technology (ICT) can reduce the overall load of society on the environment as a measure against global warming [1]. ICT can be used to increase the efficiency of energy use, reduce the production and consumption of products and make the processes more efficient, and reduce the movement of people and goods, and thus reduce CO_2 emissions stemming from those activities. Our name for these efforts to use ICT to reduce CO_2 emissions in society as a whole is "Green by ICT."

The NTT Group established THE GREEN VISION 2020 as our environmental vision for 2020 [2], which is based on the policies of *Green by ICT*, *Green of ICT*, and *Green with Team NTT*. The objective of Green by ICT is to expand the use of ICT and, specifically, to achieve a reduction in CO_2 emissions of 20 million tons by increasing the use of all ICT services offered to customers by all NTT Group companies in 2020. To manage and monitor the degree of attainment of the goal for this objective, a means of evaluating the total reduction in CO_2 emissions resulting from the use of ICT services provided by each company (the *By ICT* effect) is necessary.

2. Development of methods for evaluating the By ICT effect

The By ICT effect for individual ICT services is evaluated by comparing the amount of CO_2 emitted when ICT services are used with the same emissions produced when conventional, non-ICT means are used to provide the same functions, as calculated according to environmental efficiency guidelines [3] using the life cycle assessment (LCA) method [4]. The concept of these calculations is illustrated in **Fig. 1**. In the NTT Group, the By ICT effect of many ICT services is evaluated by using the Environmental Solution Certification System [5].

As the enterprise targets described above, all ICT services offered by an enterprise to customers are subject to evaluation of the By ICT effect. However, the number of ICT services at the enterprise level is very large, so it is difficult to evaluate all of the services individually and to sum them up with limited management resources. Therefore, the challenge was to establish methods for easily estimating the total By ICT effect at the enterprise level by using certain management indexes, such as sales results and numbers of contracts.

To meet that challenge, we developed a method for estimating the scaled, overall By ICT effect by

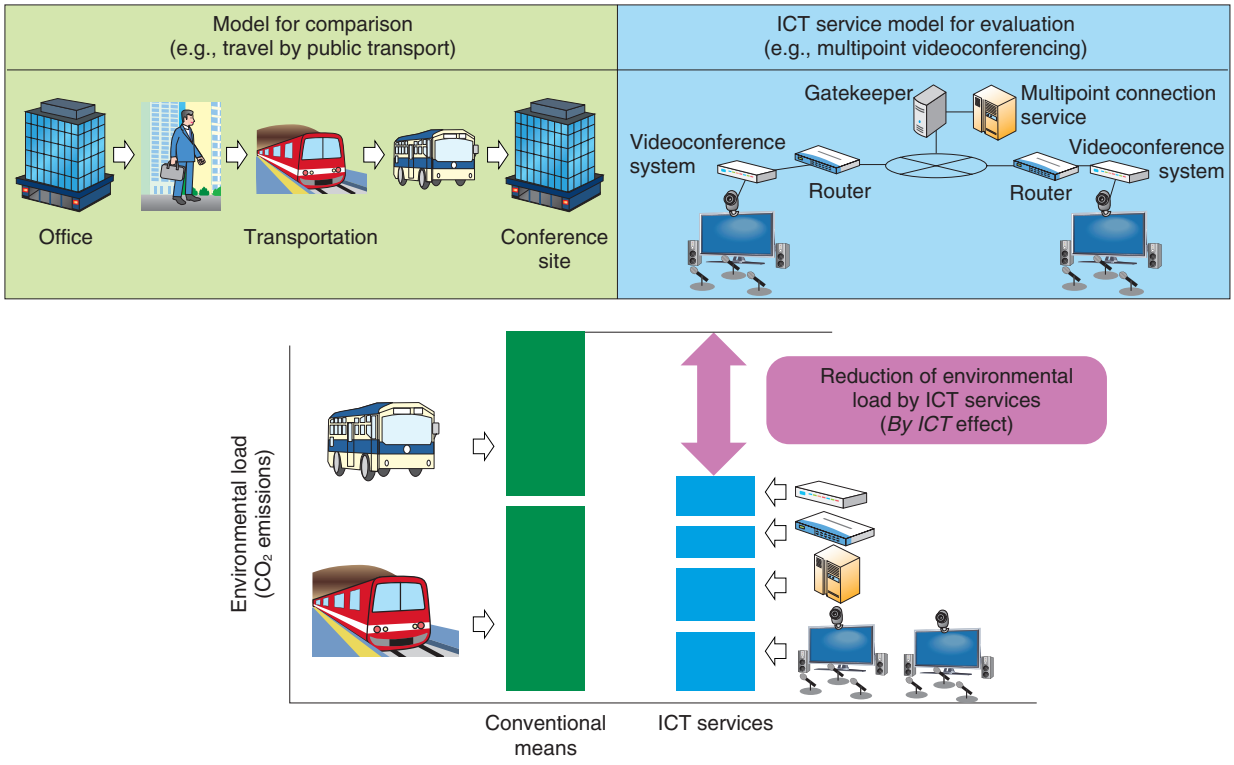

Fig. 1. Evaluation of *By ICT* effect of ICT services.

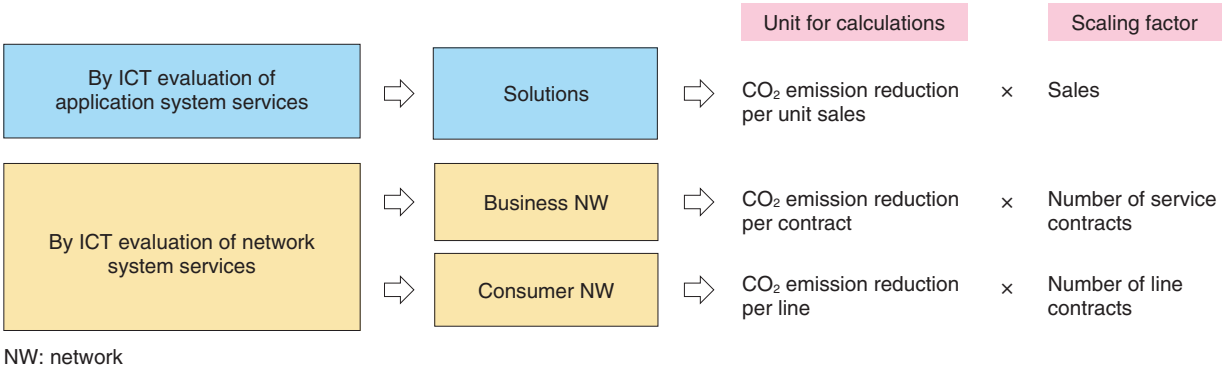

Fig. 2. Categories for evaluating By ICT effect.

multiplying the reduction in CO_2 emissions per unit by a scaling factor, under the assumption that the By ICT effect is proportional to a value that represents the number of ICT services offered by an enterprise (the scaling factor). We took the service hierarchy and users into consideration and divided the NTT Group services into *solutions*, *business network services*, and *consumer network services*, and developed evaluation methods for each category (**Fig. 2**). For the scaling factors, we used management indexes, specifically the sales of solutions and the number of network service contracts for network system services. The evaluation methods for the different categories are explained below.

2.1 Evaluation method for solutions

The solutions evaluation method [6] estimates the By ICT effect by multiplying the sales (scaling factor) and the unit for calculation. The unit for calculation is the amount of CO_2 emission reduction per one million yen of solution sales. We evaluated the By ICT effect for the solutions provided by each NTT Group company according to the guidelines for environmental efficiency, plotted the results against solution sales, and derived linear regression equations. The slopes of the regression lines serve as the units for calculation. Regression equations were derived for the government, finance and insurance, and information and communication industry categories of ICT solutions (**Fig. 3**). Grouping the solutions by industry confirms that a correlation between the By ICT effect and sales can be obtained. By multiplying the calculation units of each industrial category by the respective sales figures and then summing the values, the By ICT effect for all the solutions of an enterprise can be estimated (**Fig. 4**).

To share this approach with companies outside of the NTT Group and obtain social recognition, we established the ICT Business Organization LCA Study Group within the LCA Society of Japan in 2012. The Study Group is making progress in setting guidelines for the method of calculating the By ICT effect at the enterprise level. The calculation method provides a basis for setting quantitative environmental targets for companies, quantitative management of goal attainment, and disclosure of information to society. Our objective for the future is to establish a method for quantitatively calculating the By ICT effect on a national level in order to measure how the use of ICT contributes to improving the environment.

2.2 Evaluation method for business network services

The method for evaluating business network services applies to leased lines and Internet protocol virtual private network (IP-VPN) services. The By ICT effect for a model enterprise is evaluated according to the guidelines for environmental efficiency evaluation. Assuming a typical model enterprise that uses leased line services, we use the calculated amount of CO_2 emission reduction for the model enterprise as the calculation unit. That value is multiplied by the number of service contracts in order to

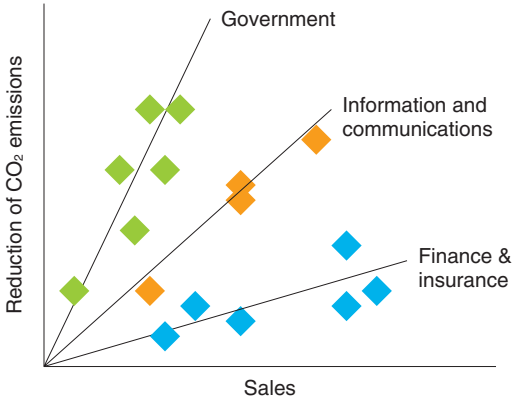

Fig. 3. Derivation of units for calculation.

Industry	Sales (millions of yen)					Unit for calculation (t-CO_2/million yen)
	Company A	Company B	Company C	Company D	Company E	
Finance & insurance						
Government						
Information and communications						
Manufacturing						
Transportation						
Health & social						
	Derived by using 'By ICT' effect evaluation methods		Derived from financial statements			Derived by using 'By ICT' effect evaluation methods

Fig. 4. Estimated By ICT effect of solutions.

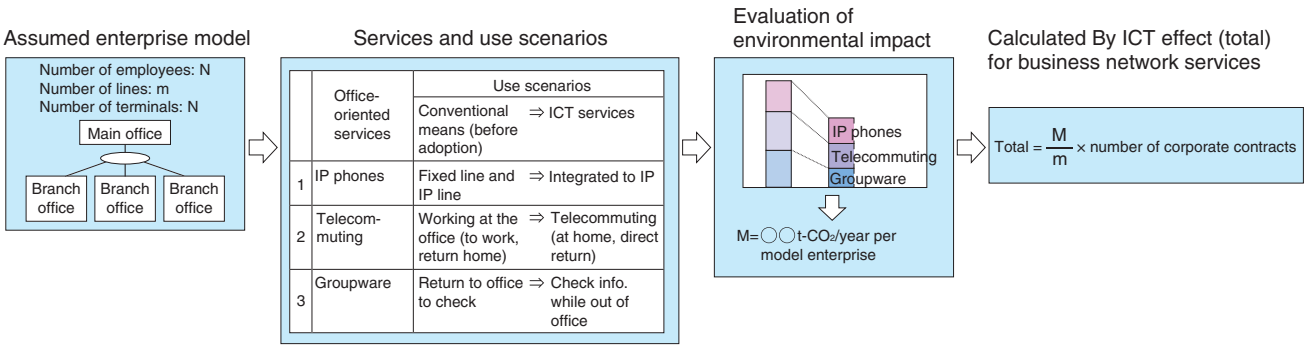

Fig. 5. Evaluation of By ICT effect for a model enterprise.

estimate the By ICT effect for typical leased line and IP-VPN services. The evaluation concept is illustrated in **Fig. 5**. The number of service contracts used is the number for the model enterprise obtained from the number of lines needed for the services and the number of corporate contracts. The By ICT effect for each model enterprise is obtained by multiplying the calculation unit and the number of service contracts, and those values are then summed to estimate the By ICT effect for all business network services.

2.3 Evaluation method for consumer network services

The method used to evaluate consumer network services [7] is based on the use of feature phones or smartphones on the mobile network and the use of personal computers on a broadband network. The By ICT effects are calculated by multiplying the calculation unit by the respective scaling factors (number of line contracts). The calculation unit is the amount of CO_2 emission reduction per line calculated from typical use scenarios for consumer network services and the corresponding values for conventional means. The use scenarios for broadband and mobile networks are diverse, so we selected use scenarios for which the user rates were 10% or more as typical scenarios after referring to statistical information (**Table 1**). We obtained the use frequencies for the scenarios and the conventional means that were used in the comparison from questionnaires, and we calculated the amount of CO_2 emission reduction according to environmental efficiency guidelines (**Fig. 6**). User questionnaires were obtained from 1160 people via the web. The calculated units for calculation were multiplied by the respective numbers of contracts to estimate the By ICT effect for consumer network services.

3. Trial calculations of the By ICT effect for 2013

We applied the evaluation methods described above in trial calculations of the By ICT effect for the NTT Group for fiscal year 2013 and reported the results in the NTT Group CSR (Corporate Social Responsibility) Report 2014 (**Fig. 7**). Those results include evaluations for solutions, business network services, and consumer network services, and they indicate that the reduction in the amount of CO_2 emissions increased from 10.37 million tons for fiscal year 2010 to 29.64 million tons for 2013. The large increase in the By ICT effect is due to the increase in use time for consumer network services, particularly for broadband networks and smartphones used on mobile networks. The hours of use per day for personal computers and smartphones have risen sharply since 2011, and this fact is reflected in the evaluation results.

Table 1. Typical use scenario selection for consumer network services.

Use scenario	Xi	FOMA	FLET'S HIKARI
	Feature phones	Smartphones	Personal computers
Voice calls	○	○	○
Email	○	○	○
Music (including ring tones)	○	○	○
Images	○	○	○
Games	○	○	○
Entertainment, sports, and news		○	○
Search and link aggregation	○	○	○
Bulletin boards		○	○
Personal websites		○	○
Blogs		○	○
SNS		○	○
Free video		○	○
Charged video		○	○
Dining information		○	○
Cell phone manufacturer sites	○	○	
Maps	○	○	○
Transportation info & time schedules	○	○	○
General news	○	○	○
Weather reports	○	○	○
Online banking		○	○
Online shopping		○	○
Auctions		○	○
Awards, questionnaires		○	○
Bargains, discount coupons		○	○
Stocks, market information		○	○
Miscellaneous info & culture		○	○

SNS: social networking service

4. Future development

The NTT Group will continue to work towards reducing the load placed by society on the environment in the future by further broadening the range of ICT use in various fields. By quantitatively assessing that work using the By ICT effect evaluation methods and announcing the results to the public, we will continue to demonstrate the environmental contributions of the NTT Group. We will also continue to expand the use of the By ICT effect evaluation methods, beginning with the work that is already underway to establish guidelines for evaluating solutions.

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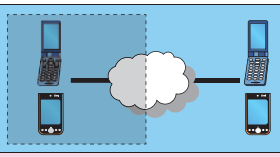
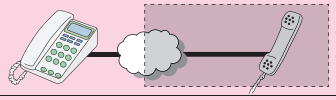
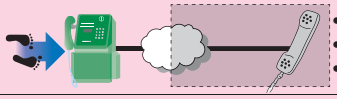
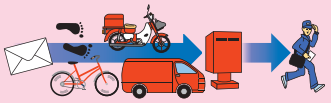
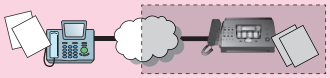
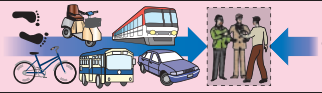
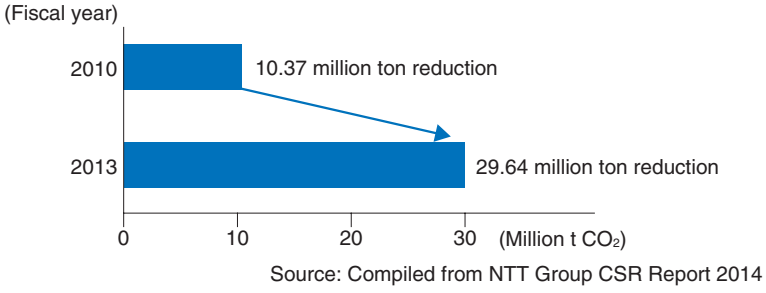
	Use scenarios	Evaluation model	Service use rate (%)	Use time (hours/years)	Percentage (%)	CO_2 emissions (kilograms of CO_2/year)
ICT services (Xi)	Email	 • Feature phone or smartphone • Mobile network	96.7	48.6	100	0.59
Conventional means (for comparison) Without Xi	Home phone	 • Fixed-line phone • Fixed-line network			58.5	115.7
	Public phone	 • Public phone or round-trip travel • Public phone • Fixed-line network			11.8	
	Letters	 • Letters • Posting or round-trip travel • Mail box • Mailing			6.9	
	FAX	 • Paper • Fax machine • Fixed-line network			4.3	
	Direct meeting	 • Round-trip travel			5.5	
	Nothing	 • None			13.0	

The parts within the broken lines are outside the scope of the evaluation.

The numbers are for Xi.

Fig. 6. Method for calculating CO_2 emission reduction for various use scenarios and conventional means (e.g., email).



Source: Compiled from NTT Group CSR Report 2014

Fig. 7. By ICT effect for NTT Group.

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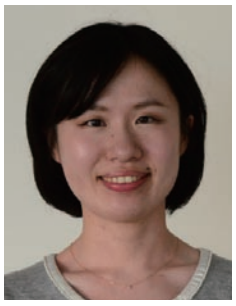

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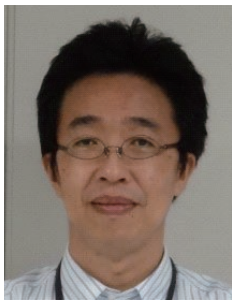

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R&D on Conservation of Material Resources in Telecom Facilities

Yasuhiro Higashi, Kazue I. Takahashi, and Takashi Sawada

Abstract

NTT Energy and Environment Systems Laboratories has been focusing on the material resources used in constructing telecom facilities and is pushing forward with research and development (R&D) of green infrastructure technology for conserving resources in the design of new facilities in order to achieve a long service life, extend the service life of existing facilities, and renovate old facilities. This article presents a technology for diagnosing and evaluating degradation of buried stay rods and anchors to extend the service life of existing facilities, and a resource visualization technology that is relevant to recycling of resources when discarding facilities.

Keywords: telecom facilities, material resources, resource conservation

1. Introduction

The NTT Group telecom line facilities that support information and communication technology (ICT) services include about 700,000 km of optical cable, about 1.1 million km of metal cable, about 12 million utility poles, and about 620,000 km of conduit. It is thus important for the NTT Group to move forward with resource conservation while maintaining the safety and security of such a huge amount of infrastructure. Resource conservation is often discussed in terms of 3R technologies: reduce, reuse, and recycle. In reducing materials used for deployed facilities, it is important to extend the service life of existing facilities as well as to design future facilities with resource efficiency considerations. For that purpose, proper methods of diagnosing and evaluating degradation in existing facilities are essential. In this article, we first describe a technology for diagnosing and evaluating degradation in the buried stay rods and anchors of utility poles. We then describe resource visualization technology that contributes to improving recycling through clarification of the amounts and types of resources contained in discarded telecom equipment.

2. Technologies for evaluating degradation of buried stay rods and anchors

Utility poles are supported by a strand wire that is connected to a stay rod and secured underground by either a block (block type) or an anchor (anchor type) (**Fig. 1**). The stay rods are treated with hot-dip galvanization, and in order to prevent further corrosion, they have been coated with polymer (coatings) since 1988. About one-third of all blocks and anchors (about 2.5 million) produced under the old specifications prior to 1988 are still in use and are subject to a high failure rate due to corrosion in soil. The need for renovation of such facilities depends on the degree of degradation, so the criterion for renovation of the rod is set such that renovation is required before the cross-section of the rod is reduced by 50%, which corresponds to a safety factor of 1 (compared to a safety factor of 2 for new products). However, although the above-ground portion of the rod can be inspected visually, there is currently no means of directly checking the underground part without excavating the rod. There is therefore a need to develop an evaluation technology that does not require excavation of the rod to determine if there is thinning or a defect in the underground part that poses a risk of

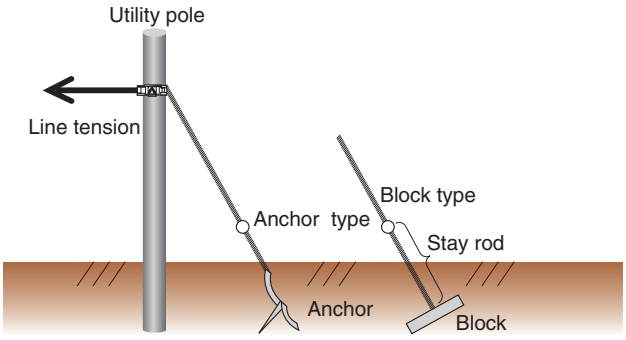


Fig. 1. Utility pole support: anchor and block types.

fracture. A method that uses ultrasonic guided waves to detect degradation in the underground part is described below.

2.1 Ultrasonic guided wave technology for underground rods

Ultrasonic guided waves[*1] differ from ordinary ultrasonic waves (bulk waves) in that their propagation is confined to within an object. There is less attenuation of guided waves over distance than for ordinary bulk waves, so they propagate over longer distances. For that reason, guided waves are being used in the development of diagnostic technologies for pipelines and other such structures [1]. However, there are some problems to be solved before guided waves can be applied to diagnose rods.

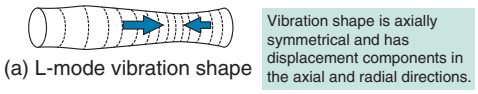
(1) In an underground environment, the energy loss of the guided wave outside the rod results in high attenuation.
(2) For rods that are in current use, particular probes are required that enable guided waves to be transmitted and received from the above-ground portion of the rod.
(3) Detection of the signal reflected from underground thinning or defects with good sensitivity (high signal-to-noise ratio: SNR) is difficult because noise that originates outside the underground part of the rod is generated.

As the first step in solving these problems, we investigated ultrasonic wave modes and frequencies. A guided wave propagating in a cylindrical, isotropic, homogeneous elastic body such as a metal rod may have one of three modes, depending on the vibration pattern. One of those modes is the L mode, which has the vibration shape illustrated in **Fig. 2(a)**. We calculated the dependence of the attenuation rate on frequency assuming that the propagation of the guided wave in the L mode had the vibration pattern shown in the figure in a rod buried underground. The results for a rod with a diameter of 13 mm obtained using ordinary soil characteristics are shown in **Fig. 2(b)** [2]. On the basis of these results, we selected a 60-kHz, L(0, 1)-mode guided wave as having a low attenuation rate.

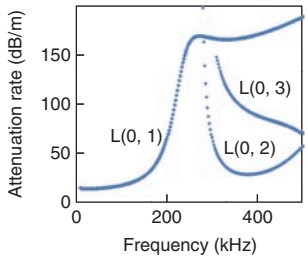
Next, we designed and fabricated compact probes that have built-in piezoelectric vibration elements that generate vibrations at 60 kHz for transmitting and receiving the guided waves from the side of a thin rod. In the measurements, we used pairs of probes that had the same performance, and we set the two probes in each pair on opposite sides of the rod. The probes are driven with the same phase, and the received signals are summed so that the L mode signal can be transmitted and received selectively. We further arranged multiple pairs of probes to enable control of the direction and directionality of the transmitted and received wave signals (**Fig. 2(c)**) to achieve a higher SNR and improve sensitivity [3].

We used the equipment configuration described above together with a new sample rod in which an artificial defect was formed to investigate the feasibility of detecting the defect under the same conditions as for an actual buried rod. The concept of defect detection by a guided wave is illustrated in **Fig. 3(a)**, and an example of the actual measured results for a buried rod (13 mm in diameter and 215 cm in length, with a 10-mm-wide artificial defect that reduced the

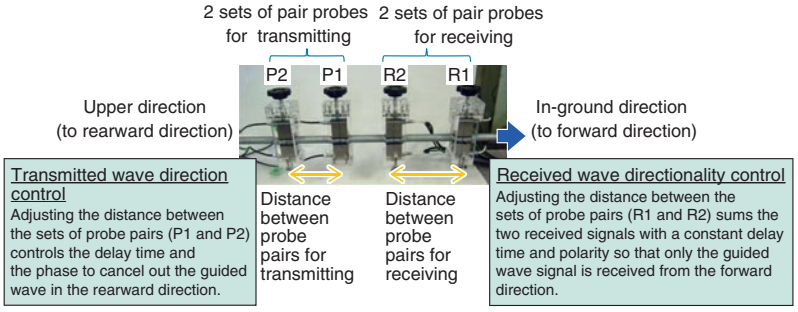
*1 Ultrasonic guided wave: An ultrasonic wave whose propagation is confined to within a solid object. Guided waves have multiple modes, and the speed depends on the frequency, which is in contrast to ordinary ultrasonic waves (bulk waves), which propagate in a medium that is sufficiently large relative to the wavelength.



(a) L-mode vibration shape



(b) Frequency dependence of L-mode guided wave attenuation in a buried rod



(c) Example of probe arrangement on rod

Fig. 2. L-mode guided wave vibration shape, attenuation, and probe arrangement.

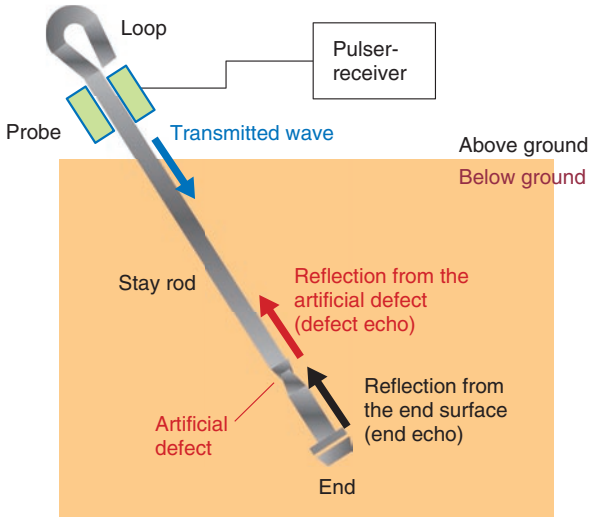
diameter by 40%) is presented in **Fig. 3(b)**. A clear echo from the artificial defect is observed in the result, confirming that it is possible to detect an underground artificial defect with this method. We are currently conducting field testing of this diagnostic technology to verify the feasibility of detecting actual degradation from corrosion thinning with the cooperation of NTT EAST and NTT WEST.

2.2 Investigation of method to estimate degradation in buried anchors

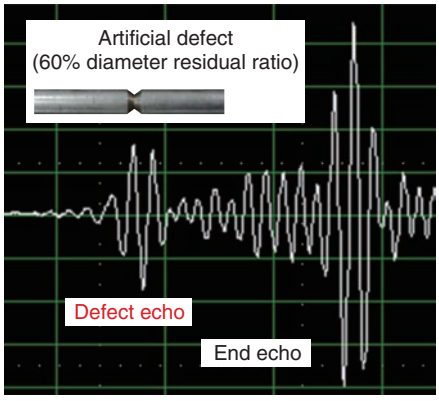
In addition to the ultrasonic guided wave diagnosis technology for stay rods, we are investigating a method for estimating the degree of degradation in underground anchors due to corrosion, since anchor types are used in far more facilities than block types, but the ultrasonic wave is not transmitted to the anchors. For anchors, the supporting force is obtained from the part that is driven into the ground. We are therefore investigating corrosion degradation in the underground part of the anchor over time and constructing a degradation model, which we will use to calculate strength in order to implement technology to determine when renovation may be necessary.

3. Resource visualization technology

Resource visualization technology is used to understand the types and amounts of resources contained in telecom facilities and to identify locations of uneven distribution of resources in order to provide information for advanced recycling of discarded equipment. Information on toxic materials such as lead and heavy metals has been available for some time because manufacturers are obligated by law to report the content of harmful substances in order to prevent any harmful effects on human health in the use and recycling stages. However, the contents of gold, silver, and copper, which can be recovered through recycling, are not reported because there is no obligation to do so on the supply side. Therefore, the discarding of equipment has generally been handled without information on the amount of resources contained in the equipment.



(a) Detection of artificial defect by guided wave (blocks etc. are omitted.)



(b) Measured results for artificial defect in a buried rod

Fig. 3. Detection of defect by guided wave and measured results.

3.1 Purpose of resource visualization technology

Used switching equipment accounts for the second-largest amount of waste generated by the NTT Group, after concrete utility poles. Many kinds of materials are used in switching equipment to achieve high performance, so the discarded equipment itself can be an important resource. We therefore consider the new node switches, which will be discarded in large numbers in the future migration of the public telephone network, to be a promising subject for research on technology for visualizing material resources. Analyzing and estimating the contents of resources are core technologies for resource visualization technology. Knowing the types and amounts of material resources of discarded equipment in advance will lead to better selection of an optimal recycling method. Moreover, knowing which parts contain the greatest amounts of rare metals would make it possible to concentrate those resources by collecting the appropriate parts and to increase the recovery efficiency. Improving recycling processes can be expected to reduce the cost of disposing them, thus accomplishing two goals at the same time.

3.2 Development of resource visualization technology

Material resource visualization involves the use of analysis and estimation technologies. The resource contents of typical components and circuit boards are analyzed, and the results are stored in a database, as shown in **Fig. 4**. With circuit boards for which the resource content is unknown, the types and numbers of components mounted on the board are input, and the content is estimated by obtaining data on parts information and/or content for similar parts from the database.

New node switches use many kinds of circuit boards, so we first investigated the various circuit boards used in the switches. We selected typical boards that are common to all switches and that are present in large numbers. Next, we selected material resources that have high economic value and a high risk of depletion. As a result, we selected eight elements for quantitative evaluation, including gold, silver, copper, and palladium.

The challenge in developing the analytical method was to find a way to analyze easily and circumstantially the target elements in circuit boards that contain plastics as well as various kinds of metals. We first tried the usual inductively coupled plasma (ICP) analysis[*2], but the preparation of samples in solution form requires a complex and expensive process. Therefore, X-ray fluorescence analysis[*3] was used together with ICP analysis because the preparation process is simple; the samples are prepared by pulverizing and compacting the boards. We are therefore investigating an analysis method using ICP and X-ray fluorescence accordingly as a method for simple

*2 ICP analysis (ICP-AES: ICP atomic emission spectroscopy, or ICP-MS: ICP mass spectrometry): A quantitative analytical method that can achieve highly accurate analysis of multiple chemical elements but has the disadvantage of a complicated sample preparation process.

*3 X-ray fluorescence analysis: A quantitative analysis method for chemical elements that is less accurate than ICP analysis but requires relatively simple sample preparation and can be used to analyze multiple elements at the same time.

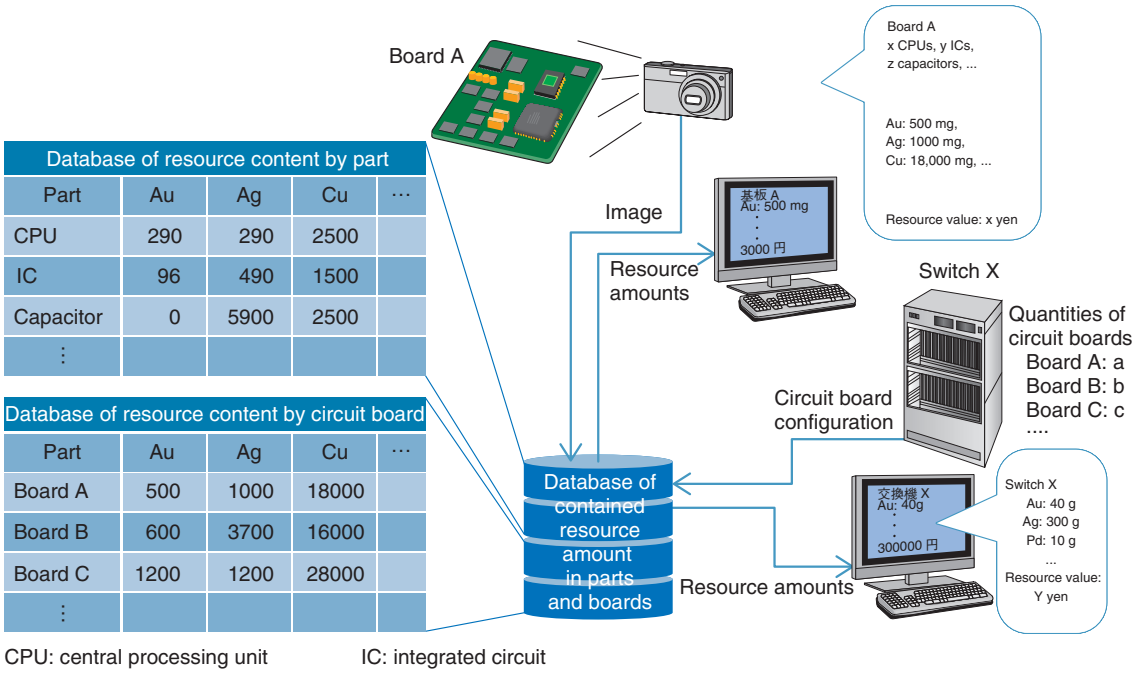


Fig. 4. Resource content estimation system.

Table 1. Comparison of resource contents.

(Weight, ppm)

	New node circuit boards*4	Personal computer [4]	Cell phone*5	Natural ore [5]
Gold	230	120	411	1.1
Silver	440	680	182	13
Copper	200,000	159,000	89,000	8400
Palladium	95	160	90	1.1
Chrome	400	33	900	230,000
Gallium	8	10	56	
Zirconium	170	110	230	3700
Antimony	3800	58	130	9900

*4 Average for three new node boards
*5 Average for 140 cell phones, excluding batteries

quantitative analysis within the permissible range of accuracy.

As an estimation method, we are investigating a summing method in which the amounts of resources contained in the components stored in the database are multiplied by the number of each type of component. An advantage of this method is that the amounts of resources contained in circuit boards for which resource content information is not available can be estimated without pulverizing the boards. We are also investigating the application of image processing technology for fast and easy automatic recognition of components from images rather than relying on visual counting by human workers alone. Such technology would be particularly effective for small and numerous components such as chip condensers, and for components that have many varieties and are difficult to classify such as IC chips. We have used this approach to clarify that new node circuit boards and cell phones contain many metals that have high economic value and a high risk of depletion as natural resources (**Table 1**).

3.3 Future work in resource visualization

Many valuable material resources are contained in telecom facilities. To provide safe and secure ICT services in the future, it is necessary to have a stable supply of resources and to optimize recycling costs. We believe that advanced recycling based on information on resource contents provided by resource visualization technology will contribute to achieving sustainable ICT services. Our objectives in the future include expanding the targeted equipment, expanding the database, and improving the estimation accuracy. We would also like to investigate methods of providing information that take into consideration future risks to the environment, economy, and society.

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Materials Technology for the Production and Storage of Energy

Jiro Nakamura, Takeshi Komatsu, and Masahiko Hayashi

Abstract

Slowing the progression of global warming is an urgent task, and the NTT Group recognizes the need to reduce the carbon dioxide emissions that come with our corporate activities. Another important requirement from the viewpoint of the business continuity plan is preparing backup systems in the event of power failures that result from large-scale disasters. For these reasons, NTT Energy and Environment Systems Laboratories has been researching and developing materials for producing electrical power and fuels from natural energy sources such as sunlight and materials for storing natural energy to serve as a backup source of power during power outages. We describe here clean energy systems (artificial photosynthesis, algae, and thermal power generation), which can be used as energy producing materials, and lithium-air rechargeable batteries, which can be used as an energy storage material.

Keywords: rechargeable batteries, artificial photosynthesis, algae and thermal power generation

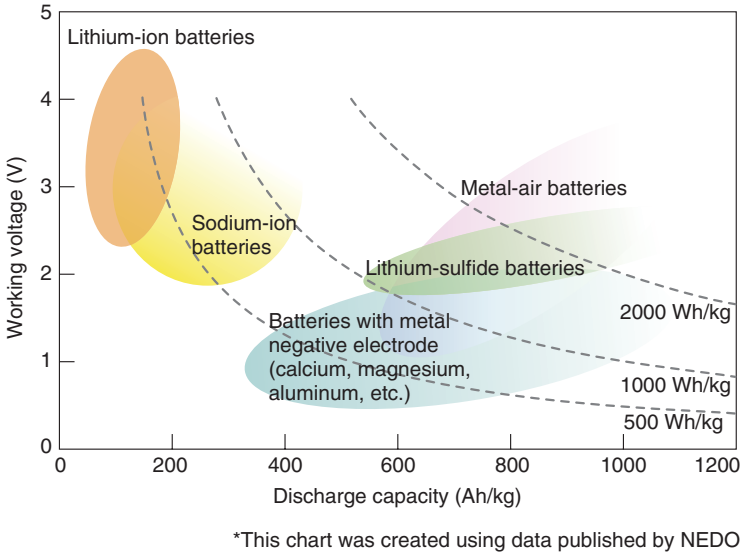
1. Introduction

There is renewed recognition of the need to achieve a sustainable society that does not burden society or the environment. Particularly in the aftermath of the massive destruction caused by the earthquake that occurred in eastern Japan in 2011, there is heightened interest in technology for energy-producing materials that make use of renewable energy and unused energy sources, and technology for energy-storing materials such as storage batteries (rechargeable batteries). While much research and development (R&D) is being done in the fields of materials for energy production and storage, and new technologies are being introduced, it will probably take some time to develop a market for such technology. This article describes R&D on next-generation materials technology that will contribute to achieving energy production and storage systems.

2. Energy-storing materials: trends and R&D

2.1 Expectations for high-performance rechargeable batteries

There is an essential need to install backup electrical power systems to maintain stable communication services during disasters and the ensuing power outages. Many communication facilities are equipped with motor-driven electrical power generators and lead-acid batteries as backup power supply systems. To provide sufficient power for large telecom facilities and datacenters, however, a large amount of stored fuel or as much as an entire floor of dedicated lead-acid storage batteries is required. These circumstances have created a need for a new type of rechargeable battery that has a higher energy density to provide the same amount of power with less volume and weight than lead-acid storage cells. One approach to solving this problem is to scale-up the lithium-ion batteries that were initially developed in a smaller form to power mobile phones [1]. Ultimately, however, there is no doubt that a new type of rechargeable battery that has even higher energy



*This chart was created using data published by NEDO

Fig. 1. Performance mapping of new types of rechargeable batteries.

density than lithium-ion batteries will be required in the future.

2.2 Lithium-air rechargeable batteries as a new form of rechargeable battery

A mapping of the performance of new types of rechargeable batteries, including lithium-ion batteries, provided by the New Energy and Industrial Technology Development Organization (NEDO) [2] is presented in **Fig. 1**. We can see from the figure that all the new types of rechargeable batteries have higher energy density than lithium-ion batteries. Of those new types, metal-air batteries have the highest energy density.

The structure and working mechanism of a lithium-air rechargeable battery is illustrated in **Fig. 2** as an example of a metal-air battery. Conventional batteries include the active materials of the positive and negative electrodes within the battery. In contrast, oxygen, which is an active material for the positive (air) electrode of the metal-air battery, is provided from the surrounding air. Because most of the metal-air battery is made up of the metal negative electrode, this type of battery features a very high energy density and a long discharge time. The negative-electrode materials used in metal-air batteries include zinc (Zn), iron (Fe), aluminum (Al), lithium (Li), and other metals. The battery voltage and energy density differ according to the metal that is used, and the lithium-air rechargeable batteries provide a high voltage on the 3-V level as well as a higher energy density than batteries using other metals.

NTT Energy and Environment Systems Laboratories has taken these advantages into account and is proceeding with research on lithium-air rechargeable batteries, which theoretically have a much higher energy density than lithium-ion batteries, with a view to using them in the future as an energy buffer for natural energy sources as well as for backup power supply systems.

2.3 Issues facing lithium-air rechargeable batteries

The main thrust in research on lithium-air rechargeable batteries began in the first decade of this century. Manufacturers and various research organizations are currently proceeding with basic research to verify the practicality of this technology, and that work has shown that lithium-air rechargeable batteries have low charge/discharge cycle performance, meaning that the discharge time after charging is short, and that it is difficult to obtain a large current. Another technical problem that has become clear is the effect of moisture in the air. Various approaches have been taken to solve these problems by developing battery materials, and in particular, NTT Energy and Environment Systems Laboratories has been researching catalysts that can enhance the reaction rate at the air electrode [3–7].

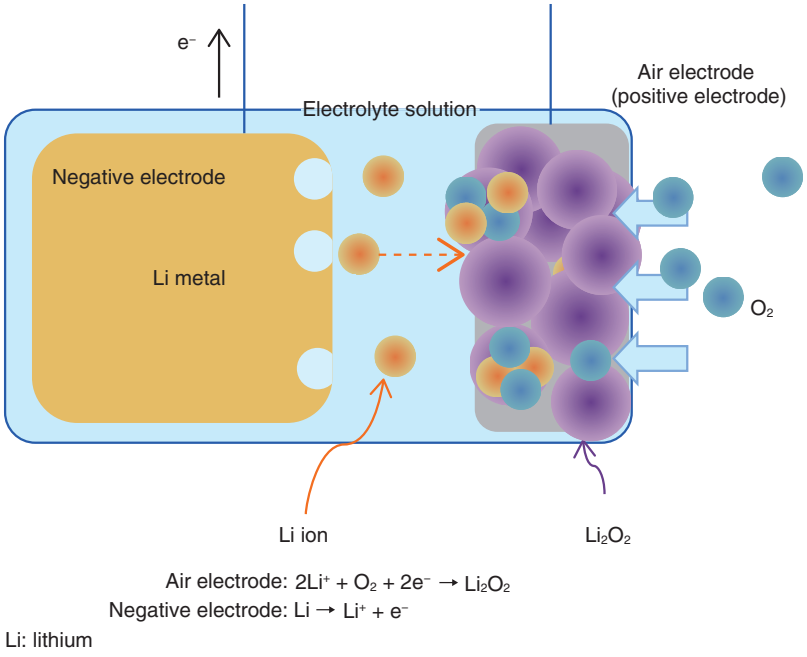


Fig. 2. Working mechanism of lithium-air rechargeable batteries (discharge reaction).

2.4 Higher charge/discharge performance through development of air electrode catalysts and electrolyte optimization

Our research shows that ruthenium oxide has higher activity than conventional catalysts. The initial charge/discharge curves of lithium-air rechargeable batteries that use a ruthenium oxide catalyst and a conventional manganese oxide catalyst are shown in **Fig. 3**. We can see that the ruthenium oxide catalyst has a higher discharge voltage and a larger discharge capacity, and that the charge voltage is low and the charge capacity is large. These results indicate that ruthenium oxide has higher catalytic activity than conventional catalysts.

The choice of electrolyte solution is another important factor in improving the cycle performance. A comparison of the charge/discharge performance for a lithium-air rechargeable battery that uses a conventional carbonate ester-based electrolyte and a battery that uses a newly selected di-ether-based electrolyte is shown in **Fig. 4**. We can see a clear improvement in the cycle performance with the di-ether-based electrolyte.

These results indicate that optimization of battery materials is important for improving the charge/discharge cycle and other aspects of battery performance.

2.5 A new future with high-performance rechargeable batteries

If high-performance rechargeable batteries that have high energy density can be made practical, it will be possible to greatly reduce the size and weight of backup power supplies, which are currently heavy and consume a lot of space. In telecom facilities that dedicate as much as an entire floor of the building to the backup power supply, that would free up a large amount of space that could be used for servers or other equipment. If batteries with sufficiently high cycle performance can be achieved, it would expand the range of applications beyond backup systems. For example, large rechargeable batteries introduced to private residences would allow power to be stored during the night when rates are relatively low, for use during the day. It would also allow homes that have solar panels but do not use much power during the day to store power for use at night. Such peak power cutting or shifting to reduce power consumption can help reduce carbon dioxide emissions.

3. Energy-producing materials: trends and R&D

Concerns about the problem of the contribution of carbon dioxide, methane, and other greenhouse gases

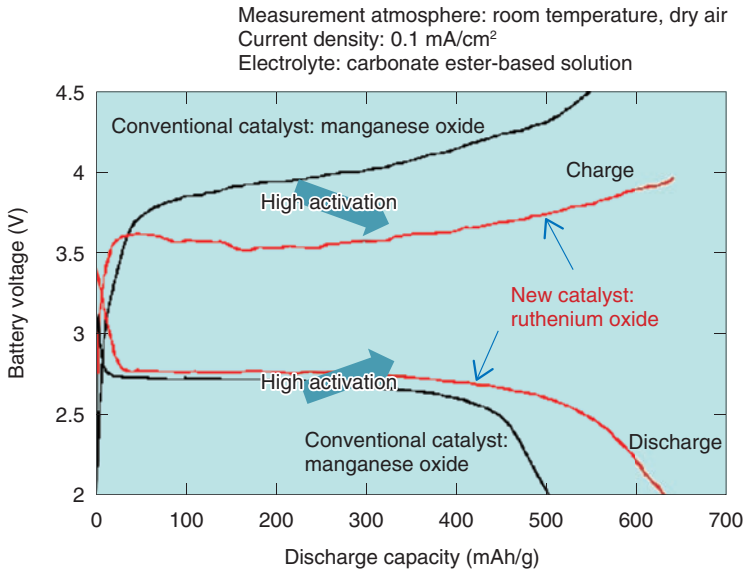
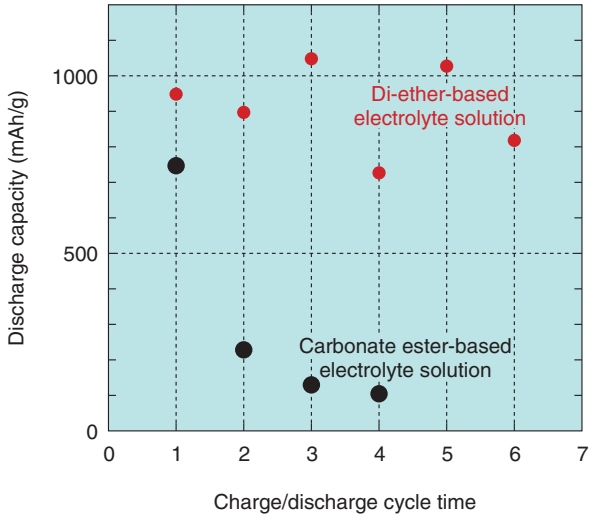


Fig. 3. Initial charge/discharge curves of lithium-air rechargeable batteries using a ruthenium oxide catalyst.



RuO_2: ruthenium oxide

Fig. 4. Dependence of cycle performance on electrolyte solution of lithium-air rechargeable battery using a RuO_2 catalyst.

on global warming, as well as the problem of dwindling fossil fuel resources have been increasing year by year. This has led to an increase in the demand for development of clean energy technology for utilizing renewable and unused energy. In contrast to energy that is derived from petroleum, coal, natural gas, and other fossil fuels, renewable energy exists in the natural world in the form of sunlight, wind, and geothermal heat, for example. Unused energy includes heat contained in rivers and drainage systems and the heat generated by power transformer substations. In particular, these forms of energy are characterized as non-depletable and present everywhere, and they do not emit greenhouse gases or increase the emission of greenhouse gases. Such energy sources therefore have the potential to be a radical solution to the problems mentioned above when used well. We have been focusing efforts on using these forms of energy in the development of green energy technology including green fuels, green power generation, and the capturing of carbon dioxide. We describe here a green fuel based on artificial photosynthesis, the use of microalgae to capture carbon dioxide, and thermoelectric conversion as a means of green power generation.

3.1 Research on artificial photosynthesis

Artificial photosynthesis is a process that mimics the photosynthesis of plants by using sunlight to cause a reaction between carbon dioxide and water in order to produce fuels such as hydrogen, carbon monoxide, formic acid, methanol, and methane (**Fig. 5**). The artificial photosynthesis process uses renewable energy from sunlight (non-fossil fuel) and consumes carbon dioxide, which is a cause of global warming. Currently, though, the efficiency of converting solar energy in the conversion of carbon dioxide to methane and other fuels is very low, and the process is

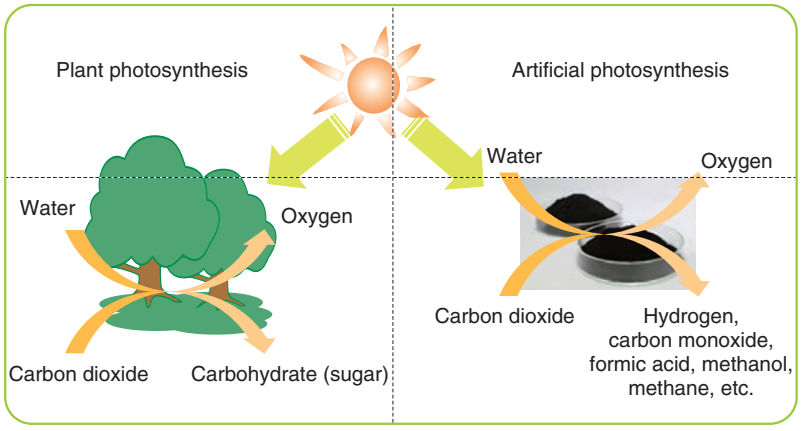


Fig. 5. Comparison of artificial and natural photosynthesis.

Fig. 6. Exposure to sunlight produces reaction gases (mainly hydrogen) on the electrode (rod).

inferior to natural photosynthesis. We are therefore investigating the use of photocatalytic thin films and a way to improve the performance by modifying the thin-film surface with promoters [8]. So far, we have used known photocatalysts for the thin-film, constructed a system for evaluating performance, and confirmed the generation of hydrogen, methane, and carbon monoxide by instigating a reaction between carbon dioxide and water (**Fig. 6**).

3.2 Research on microalgae

Algae, especially microalgae, are attracting attention as a fuel resource that does not compete with food sources. Microalgae have a very high rate of reproduction compared to terrestrial plants, as well as a high lipid content and a carbon dioxide capture capability about 10 times higher than a forest. We have been conducting R&D on a system for chemically capturing carbon dioxide using microalgae [9, 10]. We have also been investigating the effects of growth conditions such as the composition of the cultivation medium and temperature, and evaluating the growth rate of algae and the amount of carbon dioxide capture with the objective of optimally controlling the cultivation conditions (**Figs. 7** and **8**).

3.3 Research on thermoelectric conversion

Thermoelectric conversion is a process in which electrical power is generated when there is a temperature gradient within a thermoelectric element. The thermoelectric element comprises p-type and n-type semiconductors that are arranged in a π-type series (**Fig. 9**). The use of inorganic materials for thermoelectric elements is widely known, but there are problems with their widespread use in general society, as they contain rare or toxic metals, and are hard and heavy. For that reason, we are researching organic thermoelectric conversion materials. Organic materials offer the potential for lightness, workability, and flexibility. They are also less expensive and have less impact on the environment because they contain no rare metals. However, organic materials have lower thermoelectric conversion efficiency than inorganic materials, so there is a need to raise that efficiency. We have therefore been moving forward with the development of practical thermoelectric elements

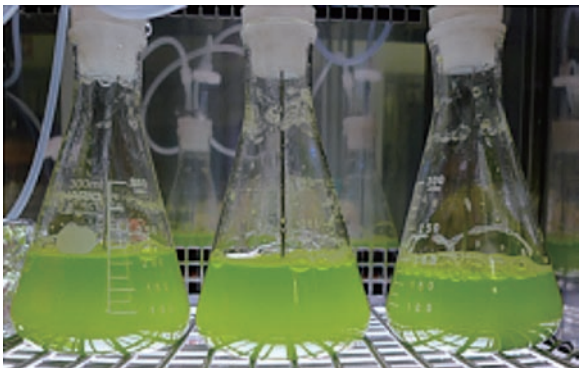


Fig. 7. Microalgae cultivation.

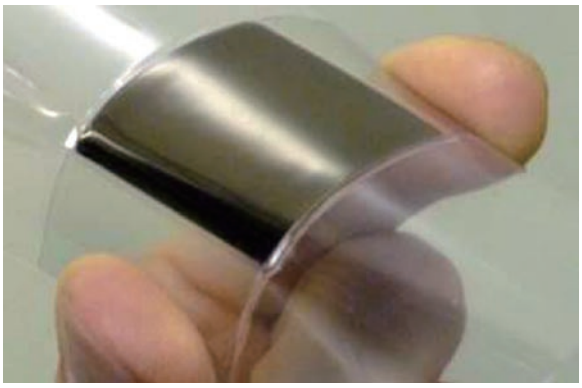


Fig. 10. Thermoelectric element (1 square inch).

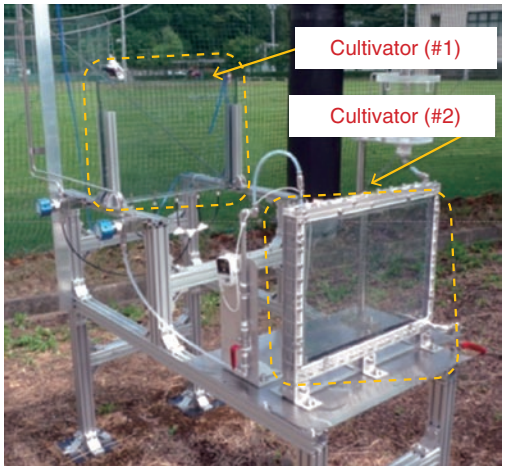


Fig. 8. Outdoor cultivators (on the grounds of the Atsugi R&D Center).

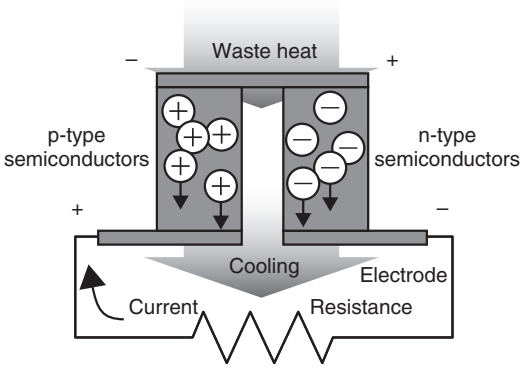


Fig. 9. Thermoelectric conversion principle.

with two objectives: raising the element performance and increasing the element surface area [11]. We have already achieved an element surface area of one square inch (**Fig. 10**).

4. Future prospects

Natural energy such as sunlight and unused energy such as waste heat can be found everywhere. It is important to collect these forms of energy efficiently and convert them into high-quality energy. By advancing the basic materials research, we aim to dramatically improve the efficiency of such processes.

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Efforts to Improve Energy Efficiency of Network Service System

Junichi Koga, Takashi Kurimoto, Takafumi Hamano, Atsushi Terauchi, and Masahiro Miyasaka

Abstract

NTT Network Service Systems Laboratories is developing network architecture and supporting technologies towards a *future network* that will enable a service-oriented platform and the creation of new value along with the Hikari Collaboration Model. This article describes our efforts in improving the energy efficiency of network service systems such as routers and servers.

Keywords: telecommunications carrier network, network service system, energy efficiency

1. Introduction

In 2014, NTT announced it would shift its business model to provide the world's first full-scale wholesaling of a fiber access service in order to stimulate the Japanese ICT (information and communication technology) market [1]. To accelerate the evolution of network and operation technologies to support the new business model, NTT Network Service Systems Laboratories has been carrying out research and development (R&D) towards achieving a service-oriented network in which network resources and functions are modularized in order to provide them quickly and flexibly according to a service player's request.

Building on the concept of the service-oriented network, we focus here on discussing the future network, which is intended to create new value in various ways, to provide network functions to meet diverse needs, and to provide a social infrastructure that is secure, stable, and economical. The objectives of the future network are to reduce capital expenditures (CAPEX) by drastically simplifying the network, and to reduce operating expenses (OPEX) by introducing virtualization for more flexible and efficient use of resources through integration of advanced operations across the entire network (**Fig. 1**). We are investigating network architectures and developing support technologies in order to achieve these goals. We are also researching system architectures of network service systems that increase energy efficiency.

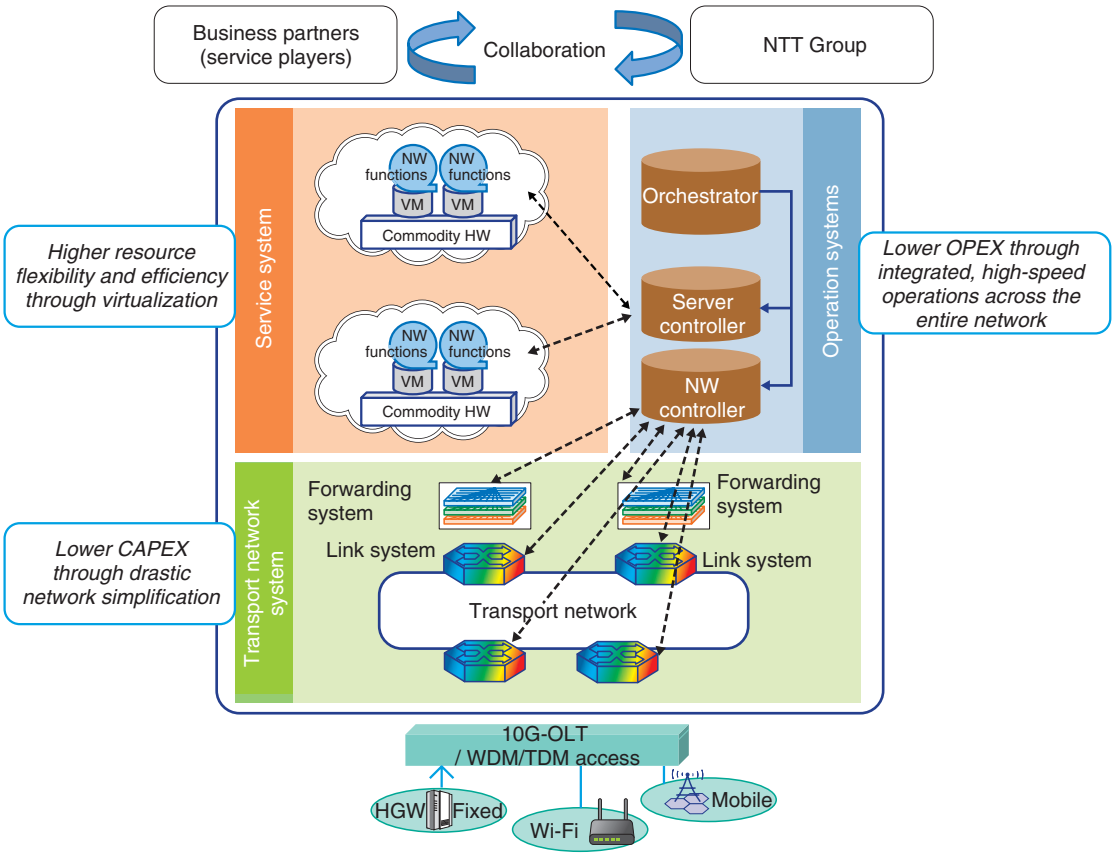
In this article, we describe our work on reducing power consumption for the transport network system, server system, and operation system.

2. Transport network systems

We aim to achieve a 50% reduction in power consumption in the transport network system through efforts focused on each part of the network.

For link systems, we are working on energy-efficient transmission methods to support a future increase in network capacity, and on a network control method that makes use of equipment with low energy consumption. For the core network, we are investigating terabit-class optical transport methods that can reduce the power consumption per bit under high-volume traffic by combining high-density wavelength path multiplexing with the use of energy-efficient devices. For metro networks, standardization is moving forward for short- to medium-distance optical transmission methods that are expected to be used with devices that have higher energy efficiency than those used for long-distance optical transmission. Our objective is to establish network control schemes that can reduce power consumption by using such energy-efficient transmission methods.

We are considering two steps to reduce the cost and



NW: network
HGW: home gateway
HW: hardware
OLT: optical line terminal
TDM: time-division multiplexing
WDM: wavelength-division multiplexing

Fig. 1. Future network architecture.

power consumption of packet forwarding systems. The first step is a drastic network simplification. We aim to aggregate the functions and shift them towards the network core. In the future network, we aim to develop large capacity edge routers that can accommodate more subscribers in order to reduce the total number of edge routers. In the next step, we aim to make greater use of general purpose products as network nodes. The concept of MSF (multi-service fabric) is an effort to reduce transport system cost and power consumption by enabling a shift from conventional ways of carrier network deployment. Instead of using high-performance, large-scale routers that have high per-bit power consumption, we aim to form a network with resources provided virtually by a set of commodity switches and servers. These switches and servers are handled as modules that can be combined in accordance with changing demands such as those for traffic load, launching new services, and failover.

3. Server systems

Server systems are aimed to be much more flexibly configured based on network function virtualization in order to maximize the advantages of resource sharing and to launch new services quickly.

Network systems for conventional telecommunication services consist of a wide variety of components, each of which has been developed as a separate unit to provide a specific function. To satisfy service quality and reliability with a set of such components, the capacity has been designed with a certain amount of

redundancy so that it can maintain the required performance and availability even in the event of a sudden traffic increase and equipment failure. The new server platform in the future network will adopt a distributed architecture that combines multiple general-purpose servers that are compact and inexpensive. In the proposed architecture, service quality will be maintained by adding or removing server resources as needed in order to cope with the load on the system, and the required reliability will be achieved without installing redundant systems by providing backup data storage in machines that are currently being used. By using resources efficiently in this way, we expect to be able to reduce the number of servers and the power consumption by one-half relative to the conventional network while maintaining service quality and system reliability.

4. Operation systems

For the future network, we are developing a new network management mechanism called an integrated management, operation, and orchestration system (MOOS) that enables us to achieve comprehensive network operation through the network layer to the service layer.

With current networks, a network administrator uses various operation systems (OpS) dedicated to specific network equipment or a specific network layer. In the future network, MOOS will make it possible to conduct integrated and advanced operations for the entire network. By using MOOS, we can expect to 1) reduce the operations workload by introducing real-time network configuration and automation failure recovery, and 2) increase the efficiency of remote and on-site operation by using network virtualization technology that can realize service management that is independent of equipment management. By achieving these two objectives, we can reduce the resources required for operations (for example, on-demand, on-site failure recovery will not be needed), and the overall electronic power consumption in network operations will also be reduced.

In regard to the power consumption by the OpS itself, achieving the first of the above two objectives can be expected to reduce the amount of OpS equipment such as by eliminating the need for a console. The accomplishment of the second objective will make it possible to reduce the number of servers and the network equipment to be managed, and the OpS facilities for such devices will also be reduced. As a result, we can achieve a great decrease in power consumption related to network operations by using MOOS.

5. Future plans

We have described our efforts to reduce the power consumption of the network service system. In moving forward with future network R&D, NTT Network Service Systems Laboratories will continue to take various approaches to energy conservation beyond the work reported here with the objective of reducing overall power consumption in the NTT Group.

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Issues and Solutions in Saving Energy of Optical Access Network Equipment

Hirotaka Ujikawa, Tomoko Shibata, and Ken-ichi Suzuki

Abstract

High-speed web browsing and high-resolution video content have become commonplace for end users with the help of recent high-performance user terminals. However, this results in continuous increases in both the use frequency and the volume of data traffic in the network, so an improvement in the capacity of the network is highly expected. However, the potential increase in power consumption of network nodes is a serious concern, as it is already at a significant level in current systems. Therefore, much effort is being focused around the world on finding ways to construct the next generation of network systems without increasing the power consumption. This article introduces issues specific to the optical access network, which represents a significant part of the power consumption in the entire network system, and describes the contribution of NTT Access Network Service Systems Laboratories in tackling these issues.

Keywords: optical access network, power conservation, cyclic sleep

1. Introduction

The architecture of the current 1-Gbit/s-capable FTTH (fiber-to-the-home) system, which is widely deployed for high-speed Internet services, consists of multiple network nodes, as illustrated in **Fig. 1**. The entire network can be roughly divided into two parts: the access network part, which is close to the end user, and the core network part. While the power consumption of one node in the core network is much larger than that of one node in the access network, the total consumption is greater in the access network because of the number of users each node is capable of serving [1]. Consequently, the per-user power consumption of the access network node is significantly larger. Therefore, tackling the issues related to the power consumption of the access network nodes will greatly contribute to reducing the total power of the entire network system.

2. Issues in power conservation of network nodes

There are several methods of reducing the power consumption of electrical devices, although some methods can affect the quality of service. Generally, the more a method reduces power consumption, the more adversely it affects network services. Moreover, some methods are only effective for specific types of nodes and are not effective on the others.

For example, user terminals such as personal computers (PCs) can accurately detect the usage of the end user by directly receiving user operations through input interfaces such as a mouse click. With this precise information about user operations, user terminals can control the power saving functions according to the usage. Unlike this example, the intermediate network nodes must control the power saving functions by monitoring the network traffic and estimating the usage so as not to induce adverse effects on the user application.

Another difficulty specific to the network nodes is

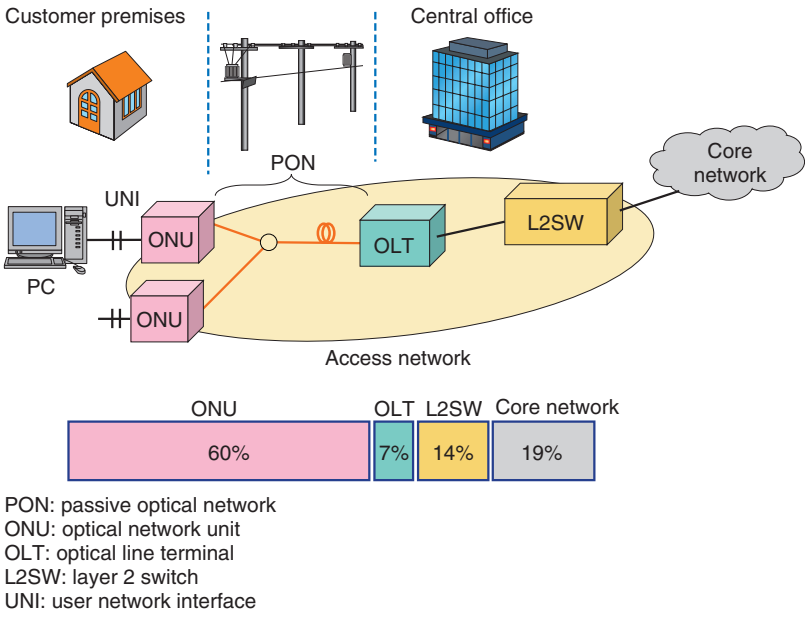

Fig. 1. Power consumption ratio in the entire network system.

their simplicity. The network nodes are basically equipped with only communication functions, which is different from the user terminals that have various rich functions. While user terminals can conserve power by turning off the unused functions, the network nodes' method of saving power is limited to temporarily suspending the communication function when there is no traffic. Furthermore, the components that take a long time to wake up cannot be turned off because that could induce an additional delay, which also restricts the power saving of the network node.

3. Issues specific to optical access networks

Moreover, there are further difficulties in power conservation of network nodes specific to optical access networks. The network nodes in the core network (e.g., servers and routers) accommodate traffic from a huge number of users. Because this aggregated traffic in the core network is expected to vary smoothly with time by the statistical multiplexing effect, effective power saving is also expected to be achieved at these nodes by reducing the number of active ports or packages of the processing unit. However, the traffic in the optical access network changes so drastically that it is difficult to estimate. Additionally, the nodes in the optical access network are often configured without redundancy such as that of a duplex system. Therefore, these power saving approaches are not applicable for optical access nodes that accommodate a small number of users. The appropriate power saving control technique for the optical access network should be able to precisely turn components on and off taking the bursty traffic into account.

4. Characteristics of traffic in the optical access network

We focus here in particular on Internet traffic via an optical access network because the other traffic generated by VoIP (Voice over Internet protocol) and IPTV (Internet protocol television) services can be logically distinguished from Internet services, and it is easier to determine whether they are in use.

While the amount of downloaded data from the Internet has been increasing year after year, it is much smaller than the potential capacity that the optical access network offers if we take unused time into account. For example, the most frequent value of the traffic volume in 2014 was reported to be 28 MB/day uploaded and 447 MB/day downloaded by one user [2]. Under the assumption that these data could be transferred in bulk, the upload and download would be completed in less than 4 s with an ideal 1-Gbit/s network. In theory, this indicates that most of the time in a day could be considered as resting time for the network nodes, as they do not have to transmit or

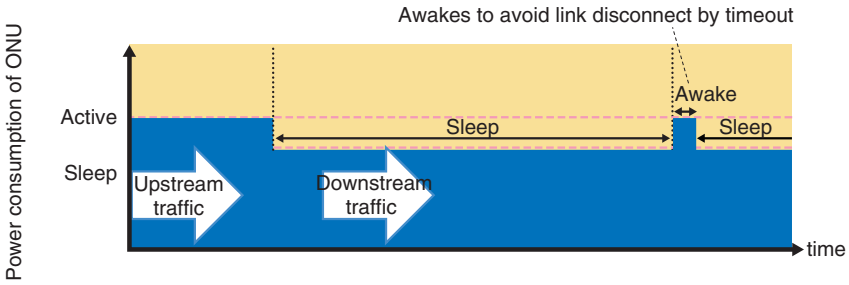

Fig. 2. Start and continuation of Tx sleep.

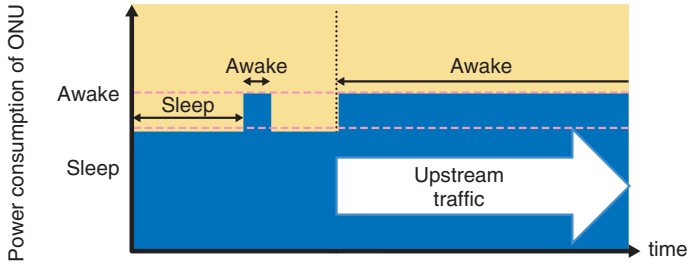

Fig. 3. Termination of Tx/TRx sleep caused by upstream traffic.

receive user data. In fact, however, the access nodes have to control the timing to apply power saving functions in order not to induce adverse effects on the user experience.

5. Effect of suspending communication functions

Specifically, the adverse effect induced by suspending the communication function of the access nodes is additional delay of the head packets, which are part of the packets successively generated by an application. It used to take several minutes for a PC to wake up from standby mode, so the head packets had to wait for the suspended devices to wake up. Because the actual delay would differ according to which components were suspended, we introduced sleep modes based on the standardized optical network unit (ONU) power saving of IEEE (Institute of Electrical and Electronics Engineers) Standard 1904.1-2013 [3]. There are two representative sleep modes, namely transmitter (Tx) sleep, which suspends the optical transmitter, and transceiver (TRx) sleep, which suspends the optical transceiver on the passive optical network (PON) side.

5.1 Tx sleep

Tx sleep is designed to suspend the functionalities in relation to the upstream data transmission of the ONU. Because the ONU has an Ethernet port on the user network interface (UNI) side, the ONU can immediately wake up by detecting the upstream input to the UNI even while the ONU turns off the optical transmitter on the PON side. The PON linkage between the ONU and the optical line terminal (OLT) at the central office is not disconnected by the timeout unless the ONU suspends the optical transmitter for a long time with no packet transmission. Therefore, the additional delay in applying Tx sleep would be limited to almost the same length of time as required to wake up the optical transmitter of the ONU regardless of the sleep duration while the sleep duration is less than 1 s (**Figs. 2** and **3**).

5.2 TRx sleep

In contrast, TRx sleep is designed to further suspend the functionalities in relation to the downstream data reception of the ONU. To detect the notification of downstream data arriving at the OLT, the ONU has to periodically turn on the optical transceiver. Therefore, the additional delay in TRx sleep would be lengthened according to the period in the worst case,

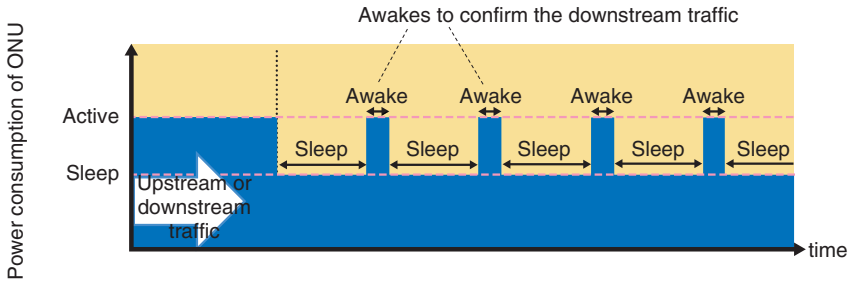

Fig. 4. Start and continuation of TRx sleep.

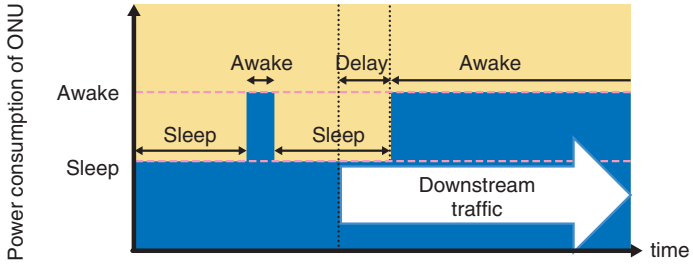

Fig. 5. Termination of TRx sleep caused by downstream traffic.

even if the wakeup time of the transceiver is short (**Figs. 4** and **5**).

6. Controlling the effect of ONU sleep

More effective power saving can be expected with TRx sleep than with Tx sleep by suspending a wider range of components in the ONU. Meanwhile, a conservative control that does not adversely affect the user application is necessary for TRx sleep. A typical control is to set a guard time so that the sleep period does not start for a certain period of time after a packet arrives, which would be effective for continuous packet generation while the application was in use.

However, a few types of traffic flow are automatically generated in the access network even while the user is not actively using an application. For example, some protocols periodically send packets to each other in order to detect a fault quickly in the communication path. In these circumstances, the ONU will not start the sleep during the guard time, which is constantly extended by the periodic arrival, and the effectiveness of power conservation would be significantly constrained.

Therefore, we have proposed an adaptive control method for TRx sleep that enables the length of the guard time to be changed (**Fig. 6**). When the number of arrived packets is so small that it can be assumed to be automatically generated traffic consisting of keep-alive messages, the controller reduces the guard time. When the number of arriving packets exceeds the threshold, the ONU extends the guard time to prevent the additional delay that directly affects the user experience, assuming that the user is actively using the applications. We confirmed in experiments that these proposed methods can reduce the average power consumption by 20 percent at maximum when the automatic keep-alive messages are frequently generated.

7. Future direction

In an era of IoT (Internet of things), where a variety of sensors would automatically communicate with the servers more frequently even without any human operations, the traffic characteristics would experience a drastic change. Because there is a close relationship between the power saving of network nodes and network traffic, especially in an optical access network, as introduced in this article, we have to pay constant attention to traffic trends in order to develop

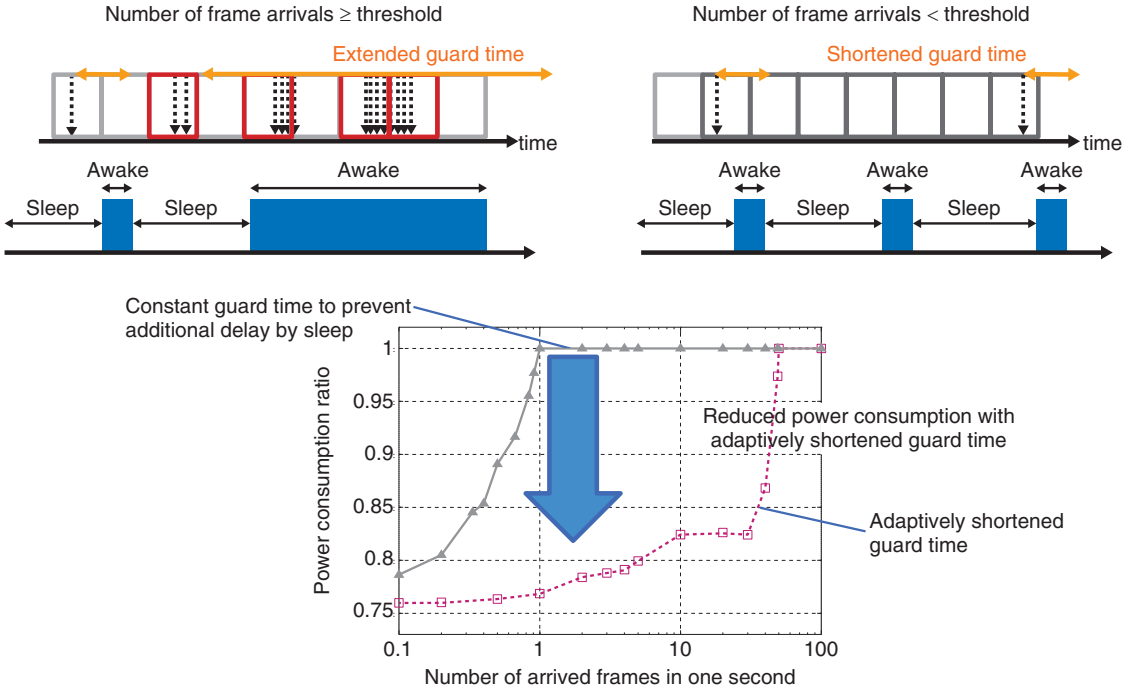

Fig. 6. Power reduction with proposed adaptive guard time control.

energy efficient network systems.

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HVDC Power Supply System Implementation

Toru Tanaka, Jun Kato, Atsushi Sakurai, Takeshi Iwato, Mikio Shintaku, Akiko Takahashi, Koki Asakimori, Naoki Hanaoka, Hiroaki Matsumori, and Nobuhiko Yamashita

Abstract

The high-voltage direct current (HVDC) power supply system is ready to implement and is expected to reduce energy consumption and costs in telecommunication buildings and datacenters. In this article, we explain the implementation status of this system and discuss standardization efforts. We also review the technical requirements and power supply system guidelines that were developed by the NTT Group to further promote HVDC systems.

Keywords: HVDC power supply system, technical requirements, power supply system guideline

1. Introduction

The NTT Group is working on various energy-saving measures for telecommunication buildings and datacenters. At NTT Energy and Environment Systems Laboratories, we have developed a high-voltage direct current*1 (HVDC) power supply system to supply power to information and communication technology (ICT) equipment in collaboration with NTT Group companies. It is the world's first such system, and we are now shifting to the introduction stage.

The HVDC power supply system uses DC 380 V, which is converted from commercial AC (alternating current) 200 V, and it supplies power to ICT equipment while charging the batteries [1]. If a power outage occurs, the battery directly supplies power to ICT equipment and acts as a backup to maintain the system until the upper engine generator starts and an engineer arrives.

A comparison of a conventional AC power supply system, 48 VDC power supply system, and our HVDC power supply system is shown in **Fig. 1**.

The AC power supply system is mainly used in datacenters. However, power loss is greater than in DC systems due to the many conversion stages. Also, a DC to AC converter is necessary between the ICT equipment and the battery. Therefore, system reliability is the lowest of the three systems in Fig. 1.

The 48 VDC power supply system is used in telecommunication buildings because it has a simple configuration and is highly reliable. However, the power consumption of ICT equipment has been increasing in recent years. Therefore, thick cables are needed, which causes problems in installation and system positioning.

Our HVDC power supply system is based on the concept of the 48 VDC power supply system. It is therefore highly reliable and efficient. In addition, the use of high voltage means that it does not require large-diameter cables.

We organized the entire configuration of the HVDC power supply system and developed various power supply devices such as rectifiers, power distribution frames, and power outlets in cooperation with NTT

*1 High voltage direct current: DC power supply systems in the ICT industry generally use 48 VDC. A voltage range of about 300–400 VDC is called high-voltage direct current.

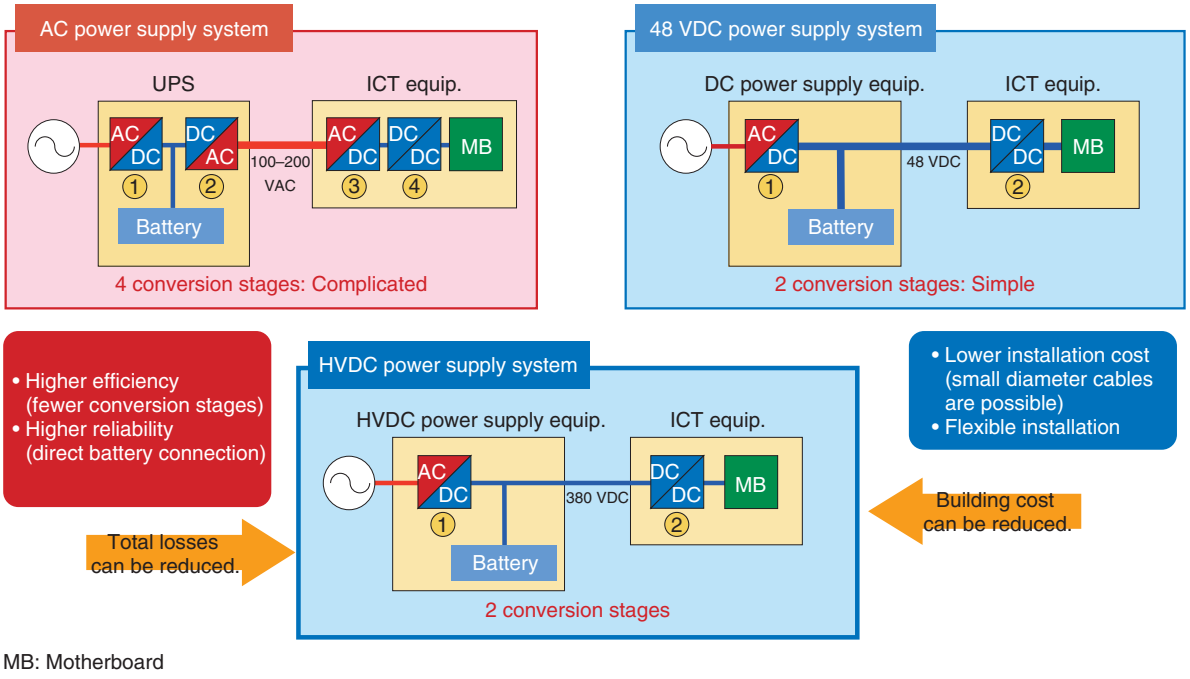


Fig. 1. HVDC power supply system.

Group companies.

To improve safety, we developed a non-exposed connector and an outlet to avoid the risk of electric shock. We also devised a grounding scheme so that even if an accidental electric shock occurs, the current flowing through the human body will be suppressed. We also developed a fuse and power distribution frame to ensure electrical stability during an accident such as a short circuit in ICT equipment. Even if a circuit breaker or a fuse trips or opens, the voltage fluctuation does not affect the other ICT equipment. The power supply devices and grounding scheme we developed are shown in **Fig. 2**.

2. International standardization

International standardization is necessary to promote our HVDC power supply system. Therefore, we are actively involved in standardization efforts in the International Telecommunication Union, Telecommunication Standardization Sector (ITU-T), and we have contributed to efforts to publish the requirements of the input port of ICT equipment (L.1200) and the power supply system configuration (L.1201) [2, 3]. These activities are expected to promote the implementation of the HVDC power supply system worldwide and to increase the lineup of HVDC-supported ICT equipment.

3. HVDC implementation in NTT Group

In the NTT Group, the HVDC power supply system has been installed at research and development centers in a trial experiment and also at NTT FACILITIES as a power monitoring system. NTT Communications has introduced our HVDC power supply system for large-scale systems. This system uses eight 500-kW systems (i.e., approximately a 4-MW system in total) and helps to reduce electricity and installation costs.

However, expansion of the HVDC-supported ICT equipment lineup and a reduction of the system cost are necessary in order to further promote HVDC implementation within the NTT Group. We have established the technical requirements (TR) as the technical documentation for procuring HVDC-supported ICT equipment in the NTT Group. We have also established guidelines (GL) that concern the development, procurement, design, and construction of the power supply system.

Through publication of the TR, the NTT Group has made it possible to support the promotion of HVDC-supported ICT equipment worldwide, boosting the commercial development of products by ICT

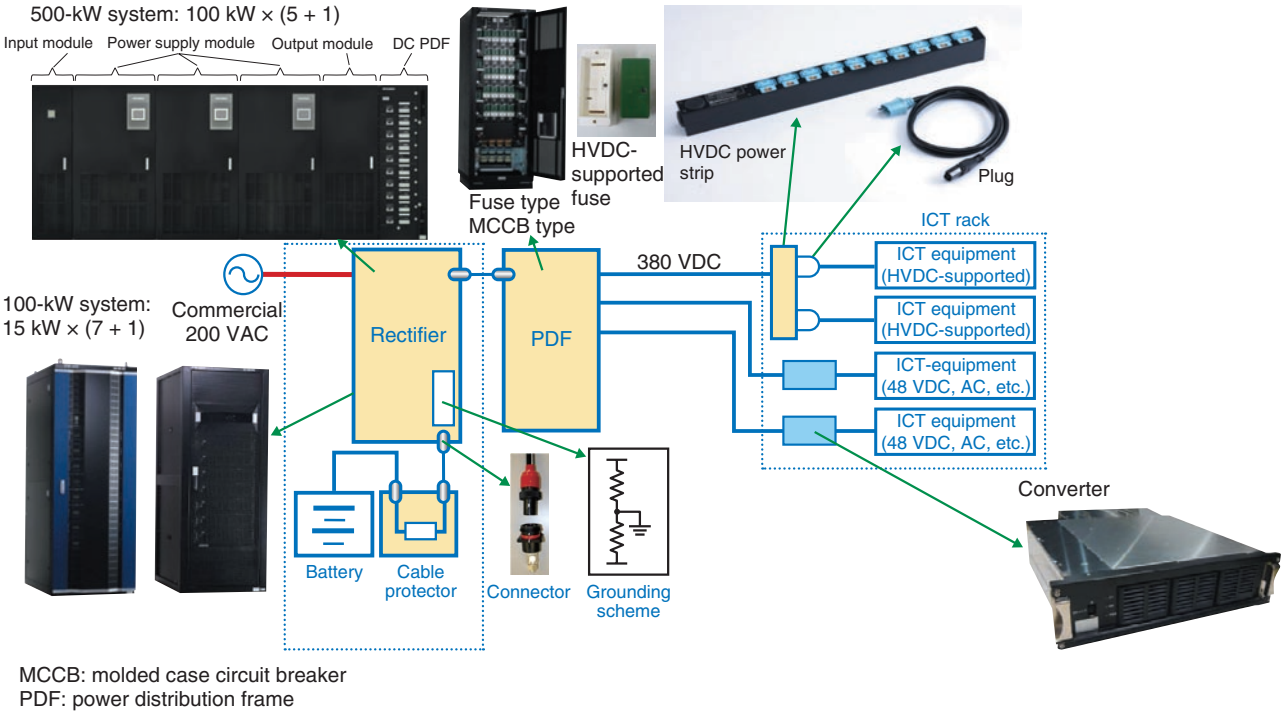


Fig. 2. Lineup of power supply components for HVDC.

vendors. The establishment of the GL makes the system manual more useful; for example, the design guidelines of the power supply system are specified. The establishment of a standard design and construction will help to reduce costs.

3.1 TR provision items

The TR consists of interface requirements of the ICT equipment. To ensure consistency with international standards, the TR incorporates the basic requirements of ITU-T L.1200 such as the operating conditions of the voltage range and abnormal voltage [4].

The specified range and the main provision items are respectively shown in **Figs. 3** and **4**. To start business operations, we incorporated additional provision items in TR other than those of international standard L.1200. To ensure safety and electrical stability, the TR establishes regulations such as the level of stored energy during an ICT equipment stoppage, maximum rated capacity, and rated voltage.

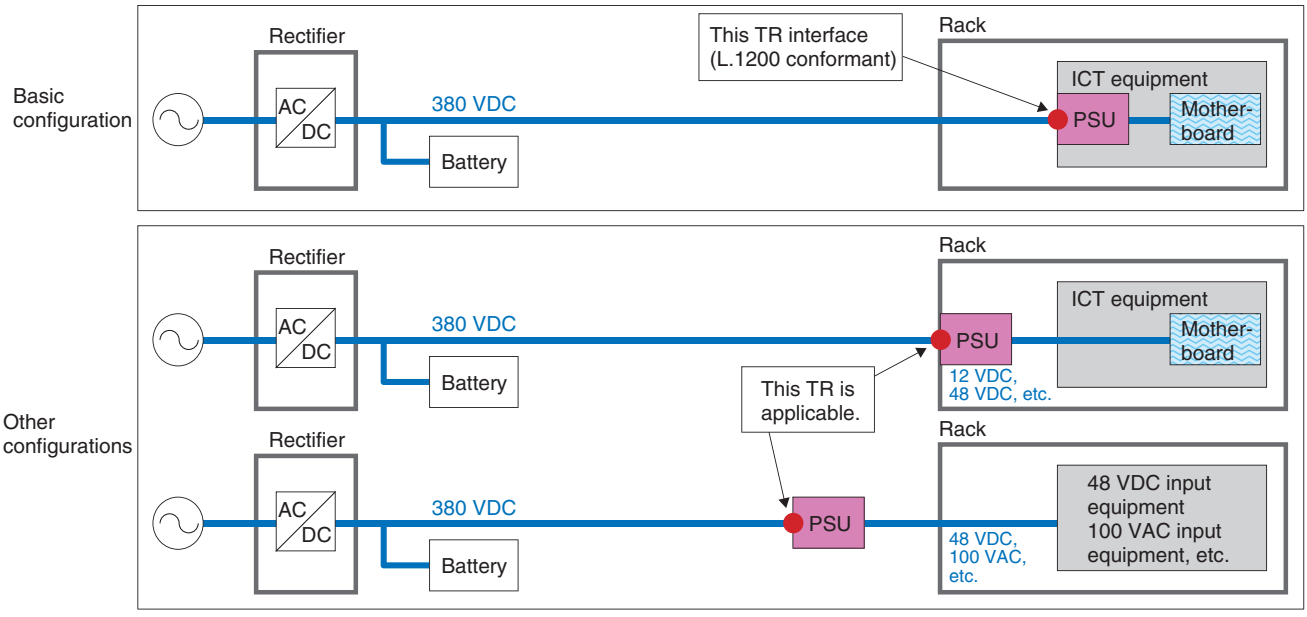
In addition, the risks associated with oscillation conditions and inrush current specified in the 48 VDC power supply system were evaluated with our HVDC power supply system and were found to be low.

This TR will enable ICT vendors to easily develop and sell HVDC-supported ICT equipment, while the NTT Group will be able to procure a wide range of HVDC-supported ICT equipment. In 2014, The NTT Group issued a press release announcing the full-scale introduction of the HVDC power supply system in 2016 [5].

3.2 GL provision items

The GL consists of guidelines for the overall power supply system. The 48 VDC power supply system guidelines have already been issued. However, they contain many complex provision items. In contrast, the HVDC power supply system guidelines have been issued as minimum required guidelines in order to apply it to telecommunication buildings as well as datacenters. The GL incorporates provisions for introducing and operating the HVDC system to ensure safety and reliability.

The specified range and main provision items of the GL are shown in **Fig. 5**. The existing strict regulations were deregulated while ensuring safety. For example, different floor power supply designs in the 48 VDC system, which provides energy from the rectifier floor to another ICT equipment floor, were prohibited due to possible risks associated with noise, stray current, and overvoltage from direct lightning strikes.



PSU: power supply unit

Fig. 3. Specified range of TR.

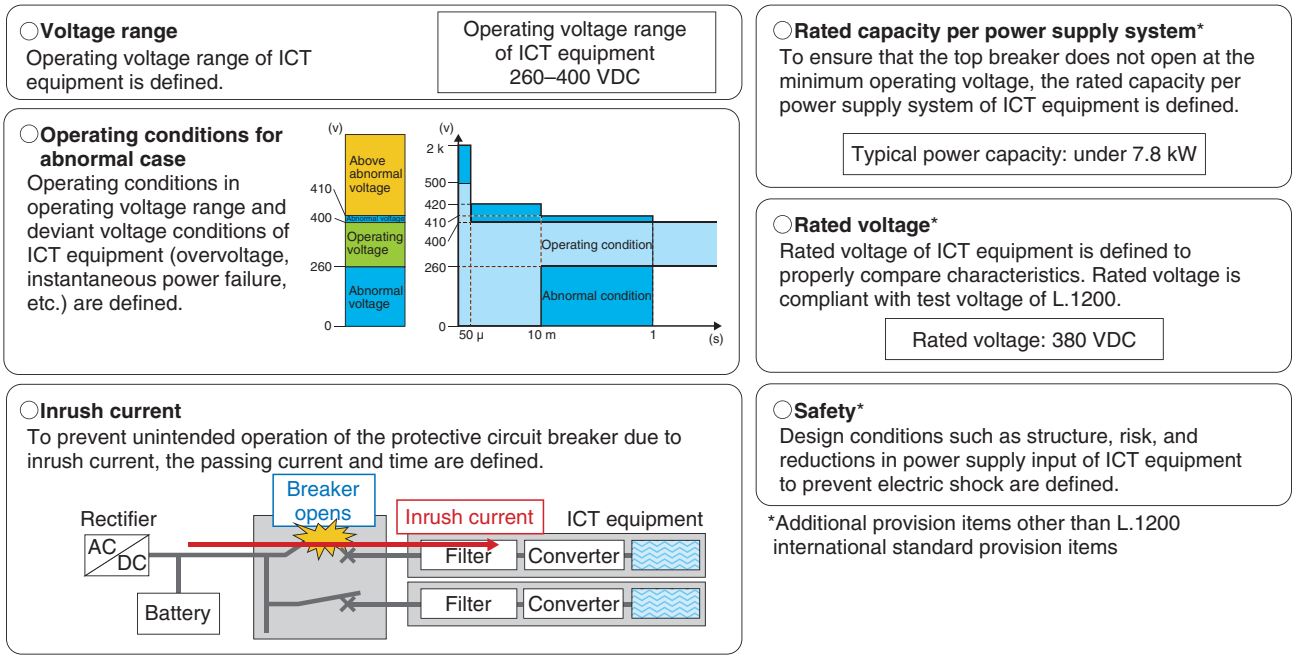
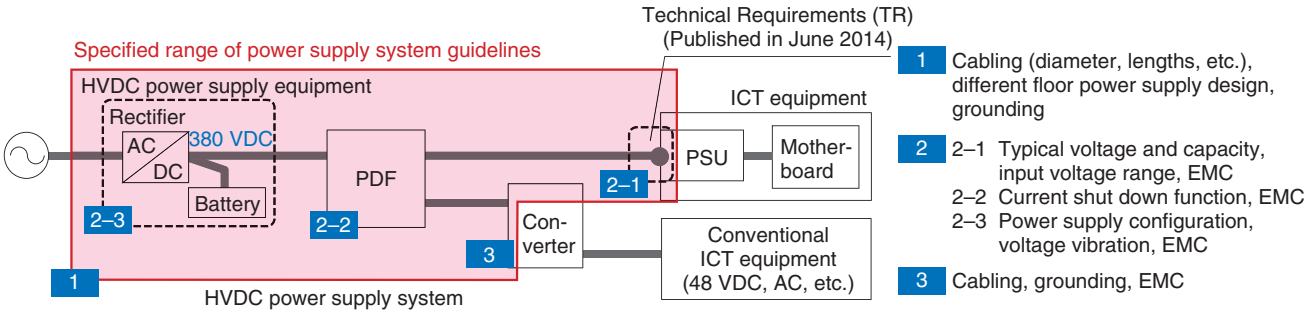


Fig. 4. Provision items of TR.

The HVDC power supply system can reduce noise and stray current risks because the grounding scheme is different. Therefore, we investigated measures to reduce the risk of overvoltage from direct lightning strikes.

In collaboration with NTT FACILITIES, we



EMC: electromagnetic compatibility

Fig. 5. Specified range and main provision items of power supply system guidelines.

developed a surge protection device (SPD) and clarified the inhibitory effect of overvoltage and the installation conditions of the SPD. We were able to come up with different floor power supply designs. We also evaluated the impact of transient voltage on other ICT equipment when the circuit breaker or fuse opens through experimentation and simulation of detailed models.

The use of fuses and a power distribution frame we developed keeps the transient voltage within the operating voltage range of ITU-T L.1200, which suggests that stable operation is possible.

4. Future development

The TR and GL have enabled the NTT Group to organize a full-scale introduction of the HVDC system and to plan a deployment strategy starting in fiscal year 2016; the objective is to have the system become standard by 2030. The implementation of our HVDC power supply system will make it possible to reduce electricity rates and installation costs.

In the future, in addition to strengthening relationships with stakeholders such as ICT vendors, we will expand HVDC-supported ICT equipment and reduce the total costs of the power supply system. Hence, we will accelerate the introduction of the system and continue to contribute to energy-saving strategies.

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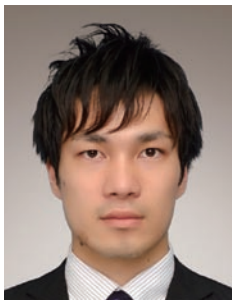

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Development of Equipment for HVDC Power Supply Systems

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Abstract

NTT FACILITIES is conducting research and development focusing on the introduction of high-voltage direct current (HVDC) power supply systems to telecommunication buildings, datacenters, and other such facilities. Future applications involving the direct integration of renewable DC energy sources such as solar panels into smart grids are also in view. This article describes our work on the development, construction, and maintenance of HVDC systems.

Keywords: high-voltage DC power supply system, HVDC rectifier, HVDC PDU

1. Introduction

Servers, data communication equipment, and other information and communication technology (ICT) equipment are in wide use in society and have been supporting substantial economic activity in recent years. ICT equipment is managed centrally in telecommunication buildings and datacenters, and as the use of such equipment spreads throughout society, its importance as a social infrastructure increases. The increasing use is accompanied by an increase in power consumption, however, and consequently, reducing that power consumption has become an issue.

Expectations are high worldwide that high-voltage direct current*1 (HVDC) power supply systems will conserve energy while still providing highly reliable power supplies. The NTT Environment and Energy Systems Laboratories and NTT FACILITIES have been doing basic research on HVDC as well as developing various types of equipment, which are described in the following sections [1].

2. HVDC rectifiers

The HVDC rectifier converts the commercial AC (alternating current) power supplied by power companies to 380 VDC [2]. There are 100-kW capable and 500-kW capable rectifiers, and the maximum conversion efficiency is a high 98%. Adopting a redundant configuration makes it possible to continue operation in the event that a failure occurs.

3. HVDC PDU

To counter the problem of arcing*2 when high-voltage direct current is interrupted, we developed a special HVDC power distribution unit (PDU) (**Fig. 1**).

The PDU has an internal mechanical switch that does not operate when the power plug of an ICT device is inserted into the socket. After insertion, the switch is slid to the 'on' position, and the internal contact points are closed, allowing current to flow. The switch is locked in position so that the plug cannot be removed. To remove the plug, the mechanical

*1 High-voltage direct current: In the ICT field, –48 VDC supply voltage is used for telecommunications throughout the world. DC voltages in the range from about 300 V to 400 V, on the other hand, are referred to as high-voltage direct current.

*2 Arcing: A sustained electrical discharge through the air between electrodes that occurs due to the electrical potential across the electrodes

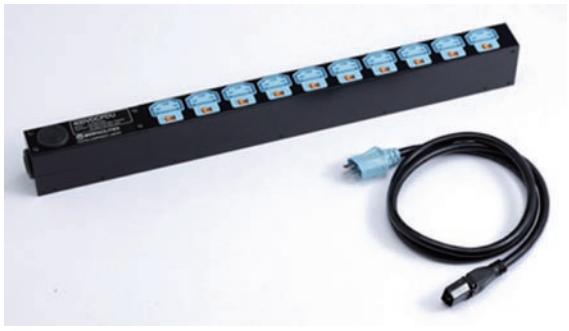


Fig. 1. HVDC PDU.

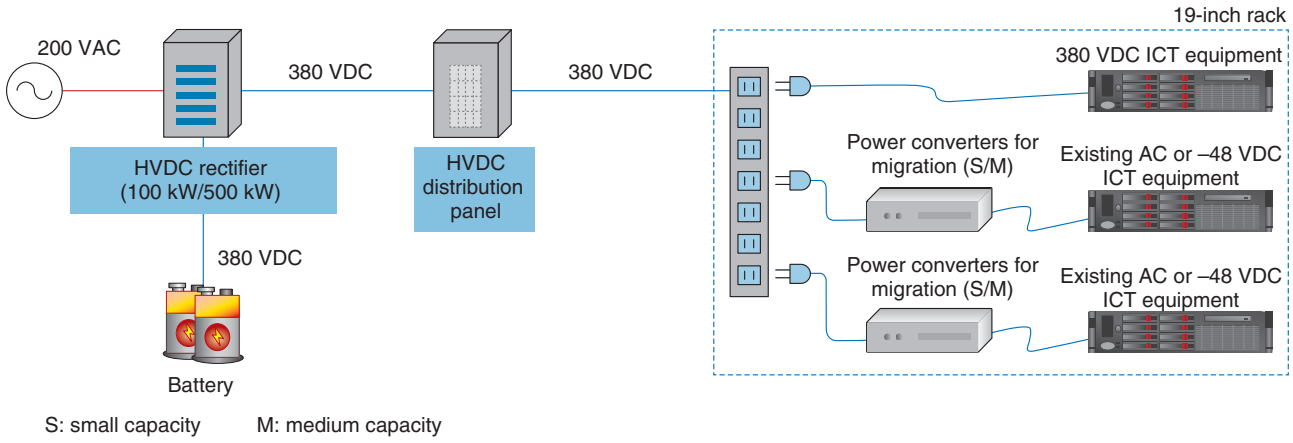


Fig. 2. HVDC power supply system configuration.

switch is slid to the 'off' position, opening the internal contact points. The arcing is interrupted, and the lock is released so that no arcing occurs outside the mechanism. That makes the plug insertion and removal operations safe for operators and maintenance personnel.

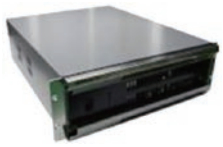
4. Power conversion equipment for migration

Introducing an HVDC power supply system involves procuring ICT equipment that is compatible with HVDC, as well as HVDC rectifiers and HVDC distribution panels. However, it is assumed that not all of the ICT equipment to be introduced will be HVDC-compatible in the initial transitional migration period. It is therefore necessary to use power converters that accept 380 VDC from the HVDC rectifiers and output 200 VAC, 100 VAC, and –48 VDC for the ICT equipment that operates on those voltages as provided by the previous power supply systems, without changing the general framework of the HVDC power supply system (**Fig. 2**).

We developed two power converters, a small-capacity type (S) and a medium-capacity type (M), to suit the equipment being supplied (**Fig. 3**). The S type was developed for equipment that consumes power on the level of several hundreds of watts such as monitors or other console systems. The M type was developed for ICT equipment that uses power on the level of several kilowatts.

5. Future development

We have described here work on introducing HVDC power supply systems to telecommunication buildings, datacenters, and other such facilities. Looking to the future, we will expand our field of view to include the development of HVDC smart

	Power converters for migration (S)		Power converters for migration (M)	
	AC output	DC output	AC output	DC output
External appearance				
Dimensions (mm)	W: 430 × D: 700 × H: 43 (1U)	W: 430 × D: 700 × H: 43 (1U)	W: 430 × D: 553 × H: 130 (3U)	W: 430 × D: 652 × H: 130 (3U)
Input voltage	Rating: 380 VDC			
Output voltage	100 VAC	–48 VDC	100 VAC, 200 VAC	–48 VDC
Output capacity	1.0 kW (500 W unit 2 + 1)		7 kW	
Unit efficiency	90% or higher	93% or higher	90% or higher	94% or higher

*M type dimensions are for the unit.

Fig. 3. Lineup of power converters for migration.

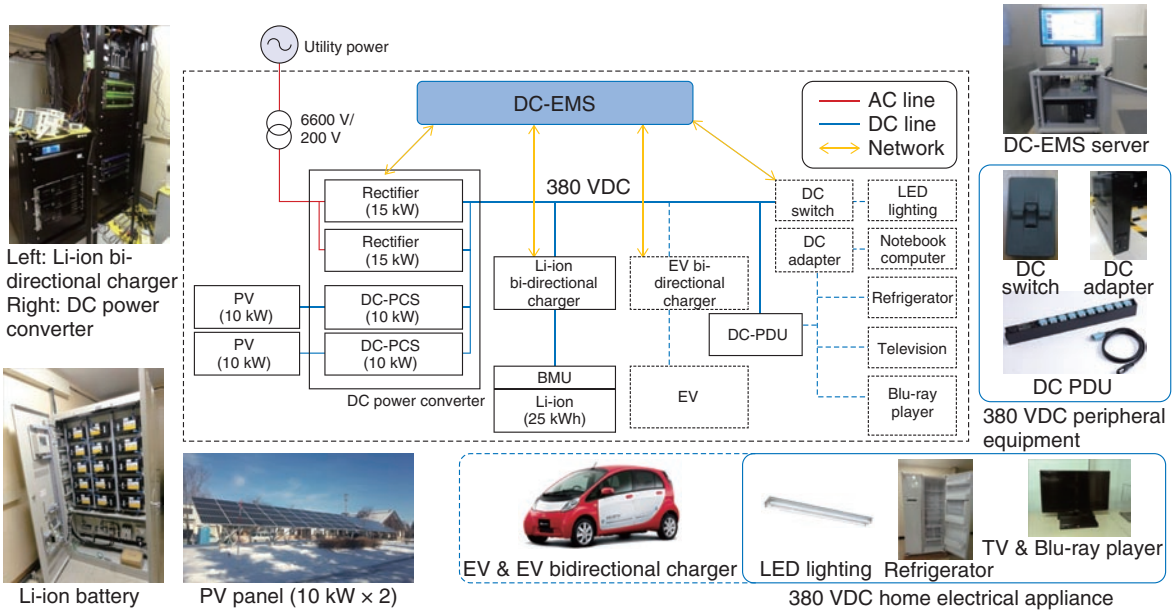


Fig. 4. Ministry of the Environment Field Testing System (Obihiro, Hokkaido).

grids that operate on renewable energy sources, combining distributed DC power generation by solar panels and other such sources with storage batteries [3]. We are currently involved in field testing in Obihiro City, Hokkaido and in Yamagata City, Yamagata as part of the Technology Development and Verification to Counter Global Warming Project of the Japanese Ministry of the Environment (**Fig. 4**), and we plan to actively apply the results from that work.

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Future Optical Access Technologies for Flexible Service Deployment

Akihiro Otaka

Abstract

The direction of technical development in optical access systems has mainly been towards achieving stable Internet access at higher speeds. However, we now recognize that technology for higher speeds alone is not enough to keep up with a changing market. Flexible use of resources is considered to be a requirement for the next generation of optical access. This article presents an overview of this problem and other upcoming challenges and describes examples of technology that NTT Access Network Service Systems Laboratories is working on in order to come up with solutions. These Feature Articles are based on presentations made at the Tsukuba Forum 2014 Workshop that was held on October 17, 2014.

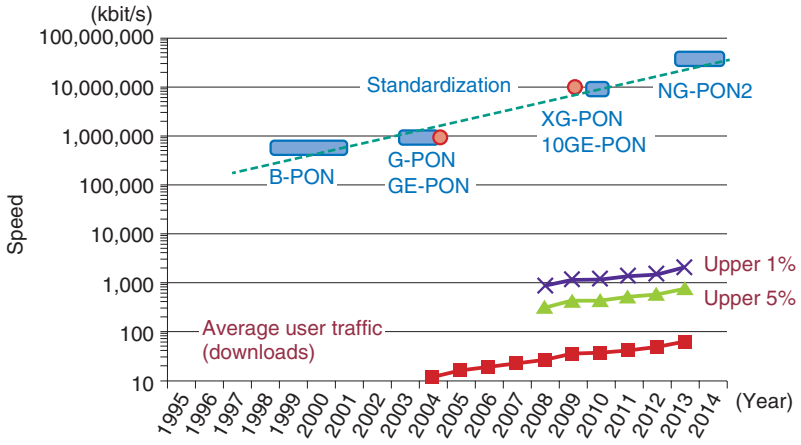
Keywords: access system, WDM/TDM-PON, mobile

1. Next-generation optical access challenges

Optical access systems have mainly been used for broadband Internet access. Fiber-to-the-home (FTTH) services began with the 50-Mbit/s passive optical network (PON), which was followed by B-PON (broadband-PON). The current Gigabit Ethernet (GE)-PON system can provide services at up to 1 Gbit/s. Statistics provided by the Ministry of Internal Affairs and Communications show that Internet traffic in Japan moves at approximately 2.9 Tbit/s over fixed lines (May 2014) and at approximately 620 Gbit/s over the mobile network (June 2014) [1, 2]. These figures represent an annual rate of increase of 30% for the fixed network and 50% for the mobile network. We can see that although traffic is steadily increasing, the increase in the number of optical lines has begun to taper off. In view of this situation, what is required of optical access in the future? The respective circumstances for fixed-line and mobile communications are reviewed in this section.

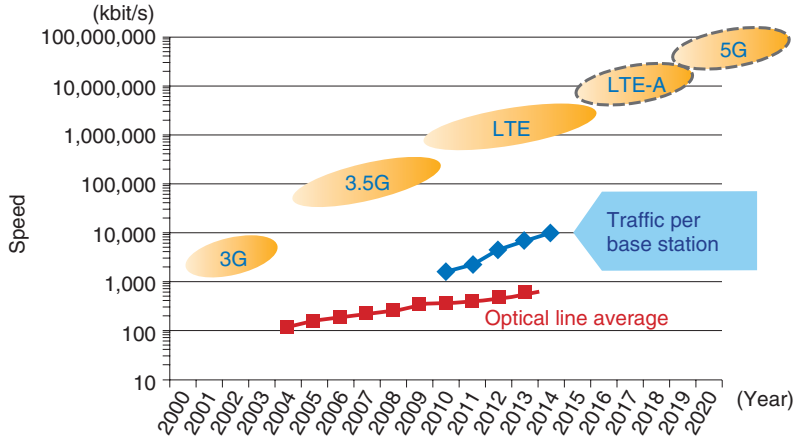
1.1 Fixed lines

From the change in traffic volume per fixed-line user over time (**Fig. 1**) [1, 3, 4] we can see that the traffic per user is only about 100 kbit/s, which is only about 10 seconds per day for a 1-Gbit/s line. Even for heavy users in the top 1%, the average speed is only several megabits per second, which is still far below the available access speeds. We can also see that the increasing trend in traffic volume is exceeded by the progress in technology for higher speeds. We should note here that this discussion concerns the average values, and so does not cover phenomena that occur rarely. On the scale at which a certain number of users share bandwidth in a single access system, such as PON, we cannot necessarily expect a statistical multiplexing effect. For this reason, an important point is whether or not services can be provided without any problem when rarely occurring phenomena are taken into account. An IP (Internet protocol) video service, for example, must be capable of providing the service even when all subscribers are using the service to the maximum extent when the total content bandwidth and number of simultaneously available channels for all users is within the total access bandwidth. In other words, that requires the access system to have a higher capacity than when bandwidth is considered in



G-PON: Gigabit passive optical network
XG-PON: 10-Gigabit-capable passive optical network
NG-PON2: next-generation passive optical network stage 2

Fig. 1. Trend in average traffic per user for fixed lines.



LTE: Long-Term Evolution

Fig. 2. Trend in average traffic per base station.

terms of average usage levels, which results in wasted resources. In the Hikari Collaboration Model [5], NTT's new business model in which a particular form of use or bandwidth is secured for partner providers, efficient resource allocation will be important to provide economical optical access.

1.2 Optical lines for mobile communication

Mobile communication base stations are connected to the network by optical lines, and the traffic on those lines is increasing because of the mutual amplifying effect of an increasing number of users and increasing communication volume per user. Optical line speeds are currently higher than wireless speeds, so the radio link is the bandwidth bottleneck.

The trend in traffic volume per base station, obtained by dividing the amount of mobile traffic by the number of base stations, is shown in **Fig. 2** [2–4, 6]. Just as with fixed lines, there is a sufficient margin in optical line speed. In contrast, speeds higher than wireless speeds are required for optical lines. Implementation of wireless speeds in excess of 10 Gbit/s is being studied for the future fifth-generation (5G) mobile communication, and speeds above the 1-Gbit/s

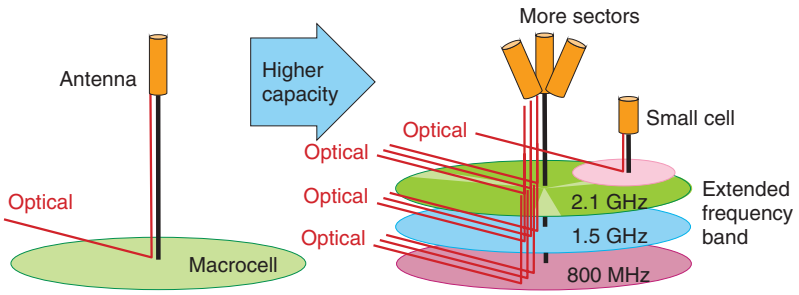


Fig. 3. Example of optical lines used with radio base station.

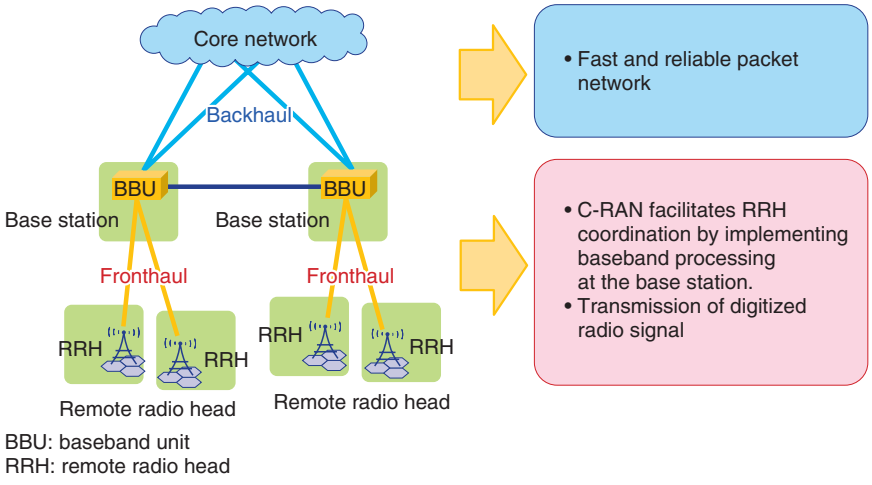


Fig. 4. Example mobile network configuration.

rate that is currently provided by optical lines will be required.

The direction of mobile communication technology as it progresses will be toward meeting the requirements for greater use of optical access as well as achieving higher optical line speeds. Increases in mobile capacity will come from the use of smaller cells, higher cell density, expansion of the radio frequency band, and other such factors, in addition to higher wireless transmission speeds. That will require more optical lines (**Fig. 3**).

There are also issues that are specific to mobile communication. Mobile networks are divided into the backhaul, which connects base stations to the core network, and the fronthaul, which connects base stations to remote radio heads (RRHs) (**Fig. 4**). The backhaul network is a high speed, highly reliable packet network whose speed depends on the traffic volume. The fronthaul network, on the other hand, uses a C-RAN (centralized radio access network) configuration, which facilitates coordination processing for multiple RRH towers that have overlapping signal areas. In that configuration, baseband processing and other processing is done at the base station, and only the high-frequency processing is done at the RRH tower, so the fronthaul part uses a CPRI (Common Public Radio Interface) signal, which is a digitized radio waveform. CPRI uses a fixed rate whether or not users are communicating, and requires a speed of about 16 times that of wireless transmission. With 150-Mbit/s LTE (Long-Term Evolution), for example, an optical transmission speed of 2.4 Gbit/s is required. If adopted in the present form for 5G mobile communication, the system would require an optical excess capacity of 160 Gbit/s per RRH tower, which is impractical.

Thus, the challenges for future high-speed mobile communication mainly concern the fronthaul system,

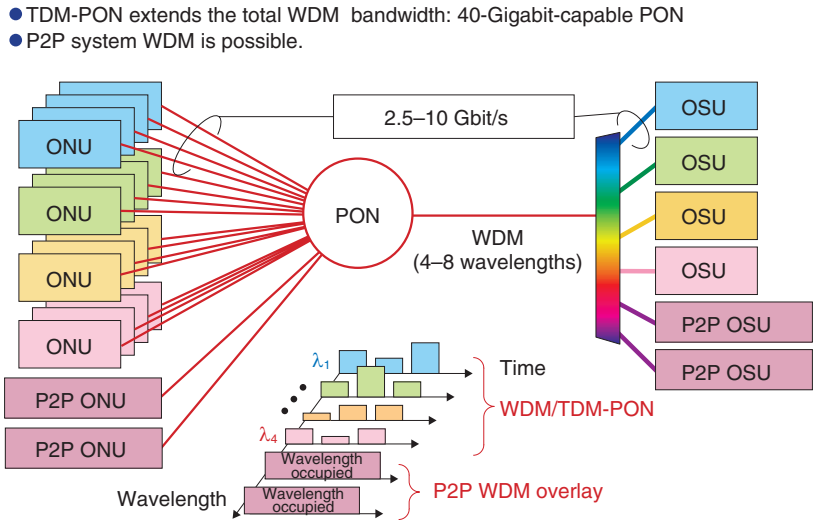


Fig. 5. NG-PON2 features.

specifically, the commitment of resources whether or not users are using the system, and the very large required bandwidth.

2. Implementing the next-generation optical access

We believe that the past trend of simply increasing speed is limited as a solution to the problems outlined above. We present here technology that NTT Access Network Service Systems Laboratories is working on that represents a different approach.

2.1 WDM/TDM-PON

WDM/TDM-PON uses wavelength division multiplexing (WDM) to superimpose multiple time division multiplexing (TDM) PON on a single fiber (**Fig. 5**). Currently, the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) is moving forward with standardization of 10-Gbit/s PON as the NG-PON2 (next-generation passive optical network stage 2) [7]. This is a 40-Gbit/s PON that multiplexes four typical 10-Gbit/s PON systems. This format also allows WDM for point-to-point (P2P) systems, which will be advantageous for mobile communication applications.

Although multiplexing four 10-Gbit/s PON systems on a single fiber quadruples the bandwidth, this WDM/TDM-PON is not simply a 40-Gigabit-capable PON system. The WDM technique has been used to achieve target communication speeds that are relatively low in the early stage of standardization, for which further speed improvements have been difficult. However, that was a transitional technology, and technical advances mean that it has since been replaced with high-speed serial communication.

In WDM/TDM-PON, WDM is not simply a technique for achieving higher speeds. The multiplexing of four 10-Gbit/s signals differs from a 40-Gbit/s serial signal in that the multiplexing provides flexibility in the use of wavelengths. The advantages of wavelength flexibility are described below.

The wavelength flexibility in a WDM/TDM-PON system is implemented by the ability to dynamically set the wavelength that is used by the optical network unit (ONU) for communication. That eliminates the need to provide an ONU for each wavelength, as shown in Fig. 5, which is an advantage in respect to the ONU management. The dynamic setting of the ONU wavelength also enables flexible bandwidth allocation and increases reliability. The improvement in reliability comes from being able to continue communication with a different optical subscriber unit (OSU) when an OSU fails during communication by switching the ONU wavelength [8].

When traffic volume is low, energy can be conserved by connecting all of the ONUs to a single OSU and placing all of the other OSUs into sleep mode (**Fig. 6**). Conversely, if it is known in advance that traffic will be low, service can be started on a single

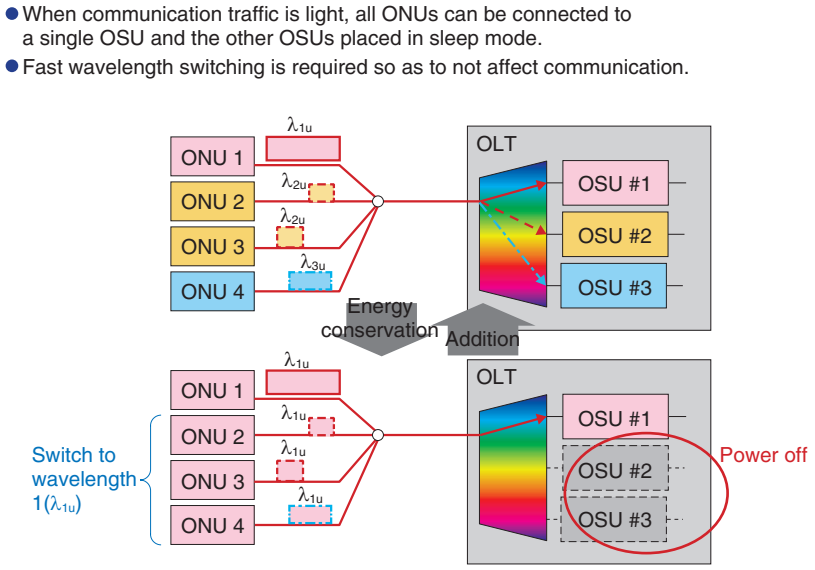


Fig. 6. Wavelength switching for energy efficiency and flexible bandwidth allocation.

OSU with more OSUs added successively as needed to accommodate increasing traffic. It is also possible to dynamically change connections between ONUs and OSUs, making it possible to switch to the appropriate OSU at any time in consideration of the user ONU resources needed to ensure bandwidth. The WDM technique can thus be used to avoid the current problem of configuring facilities for maximum capacity regardless of the amount of traffic.

In addition to moving forward with R&D on WDM/TDM-PON based on that approach, NTT Access Network Service Systems Laboratories is also using these results to contribute to standardization of NG-PON2 in ITU-T.

2.2 Compression technology and interface redefinition technology

For the mobile network, we are mainly working on developing technology to reduce fronthaul speeds. Here, we describe compression technology and interface redefinition technology for that purpose.

As mentioned earlier, the fronthaul system currently transmits radio waveform information, so optical transmission at a fixed speed is required, regardless of user traffic volume. NTT Access Network Service Systems Laboratories has developed compression technology for greatly reducing the radio waveform sample data by exchanging information on the user communication situation between the radio base station and the optical access system [9]. Also, processing for coordination of the RRHs is performed at the base station in the current fronthaul configuration, and only the high-frequency processing is performed at the RRH. NTT Access Network Service Systems Laboratories has shown that a new interface definition that reduces fronthaul bandwidth is made possible by revising that functional distribution and assigning appropriate functions to the RRHs to implement inter-RRH coordination (**Fig. 7**) [10].

We believe these technologies can be applied to create a mechanism in which bandwidth is allocated flexibly according to traffic level and only during communication to replace the conventional wasteful reserving of fixed optical access bandwidth.

3. Future development

The next generation of optical access systems is facing problems that the conventional approach of simply increasing speed cannot solve. Various research programs are underway based on the approach of allocating the required resources when required, such as that described here. In the future, it will probably be possible to shift bandwidth flexibly from the home to the business district during business hours and from the mobile network to the home during evening meal times. We are working on achieving such an efficient communication society.

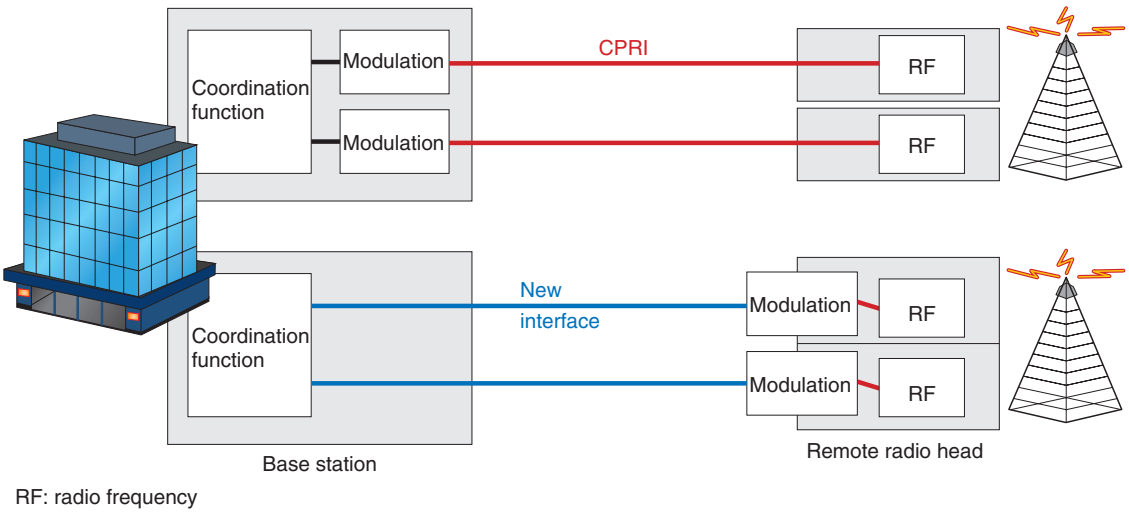


Fig. 7. Redefinition of the mobile fronthaul interface.

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■ Career highlights

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R&D Trends in Optical Fiber and Cable Technology

Kazuyuki Shiraki

Abstract

At NTT Access Network Service Systems Laboratories, we are engaged in research and development (R&D) of optical fiber and cable technologies that contribute to drastically reducing network costs. This article introduces the latest R&D in maintenance and operation technologies for effective maintenance and management of a massive number of optical facilities. It also reviews next-generation optical fiber technologies to handle the explosive future growth of data traffic.

Keywords: optical fiber and cable, maintenance and operation technology, next-generation optical fiber technology

1. Introduction

NTT has been involved in the development of optical fiber technology for over 40 years. A commercial optical fiber service was started in Japan in a trunk-line network in 1982, and the Japan longitudinal optical fiber network was completed in 1985. Since then, the transmission capacity has expanded year by year to meet the growing demand and to implement technical advances. In access networks, the full-scale fiber-to-the-home (FTTH) service called B FLET'S began in 2001. NTT laboratories have developed various optical components and systems to implement these commercial optical fiber services. In the recent decade, in particular, we have focused on improving fiber and cable technologies for optical access networks to further promote the FTTH service. A recent typical research and development (R&D) achievement is a bending-loss insensitive fiber we developed using holey fiber technology. A hole-assisted fiber, which is one type of holey fiber, has much higher resistance to optical bending loss compared to the conventional optical fiber and has been applied commercially as bending-free optical fiber cord, gap wiring indoor cable, and jumper cable for office buildings. These optical cords and cables may prevent an increase in accidental bending loss in customer homes and office buildings, where there are many opportunities to handle such cords and cables directly. In addition, these optical cords and cables make it possible to deliver optical cable into customer homes, where it was once difficult to wire conventional cable.

2. Future direction of R&D of optical fiber and cable technology

2.1 Target of optical fiber and cable technology

The transition in the number of FTTH subscribers can be divided into three phases (**Fig. 1**): an early stage, expansion phase, and mature phase. In the early stage, quick, mass installation was very important. In the expansion phase, it became important to construct optical facilities economically in order to expand service areas, especially where it was difficult to deliver service such as in rural areas. In the mature phase, however, it is becoming increasingly important to efficiently maintain and manage the huge number of existing optical facilities. In fact, our R&D focus has been shifting from how to reduce the construction cost, i.e., CAPEX (capital expenditure), to how to maintain and operate optical facilities

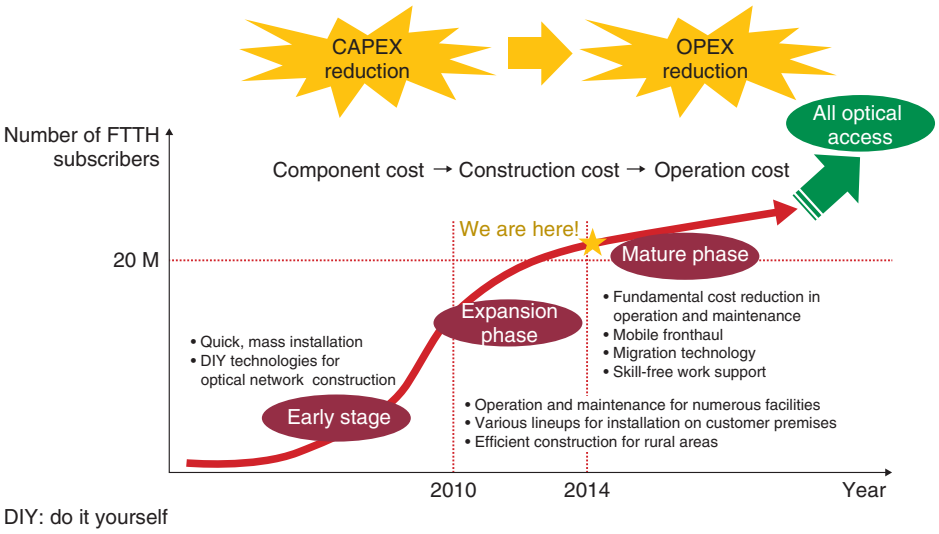


Fig. 1. Target for optical fiber technology.

effectively, i.e., OPEX (operating expenditure), as shown in the figure.

2.2 Two main objectives of R&D of optical fiber and cable technology

In view of the transition in the R&D target, we are conducting our R&D activities by focusing on two main objectives. First is the creation of new technologies for the operation and maintenance of optical network facilities as a short- to medium-term objective. To reduce the maintenance and operation cost of optical access networks, it is important to create new technologies by converging optical fiber technology and the latest information technology.

Second is the innovation of next-generation optical fiber as a medium- and long-term objective. It is expected that the conventional fiber will not be able to handle the explosive growth in traffic in the future. The limited transmission capacity of optical fiber is a continuous challenge that we also intend to tackle.

2.3 Direction of R&D of optical fiber and cable technology

The direction of R&D of optical fiber and cable is considered to have three axes: workability, operability/maintainability, and capacity/functionality. We are proceeding with our R&D activities having set the following four technology goals on these three axes.

(1) Easy and effective construction
- Cable design technology
- Optical connection technology

(2) Effective maintenance and operation
- Optical local injection/detection
- Fiber switching technology

(3) Precise and quick remote fault location
- High resolution and long distance measurement
- Measurement technique for PON (passive optical network) architecture

(4) Ultrahigh capacity fiber
- New structure fiber (holey fiber)
- Multi-core and few-mode fiber

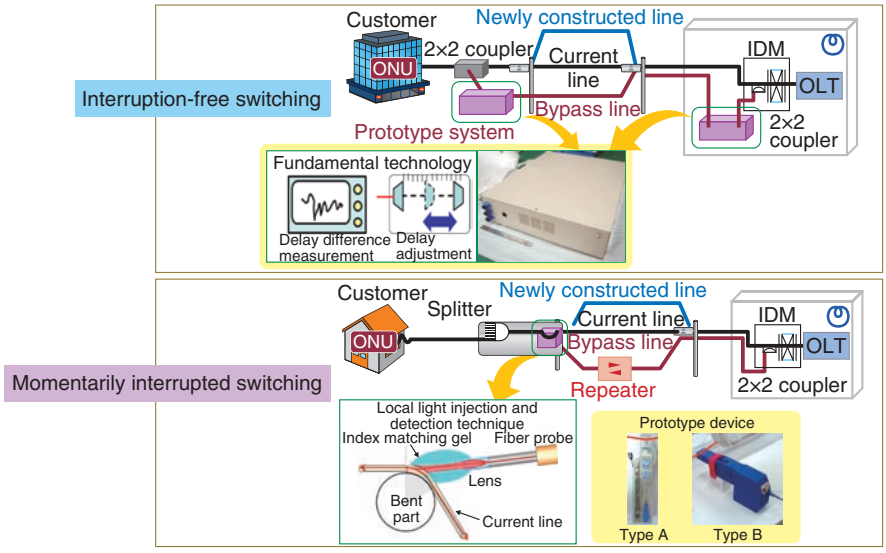
3. Recent R&D topics involving optical fiber and cable

We introduce here some of the R&D themes we have focused on recently.

3.1 Optical line switching technology

First, we introduce optical access line switching technology, which can minimize service interruption caused by fiber route changes. We have been studying this technology by focusing on two approaches. One is interruption-free switching, and the other is momentarily interrupted switching (**Fig. 2**).

In interruption-free switching, route switching is achieved without an interruption in service by preparing a bypass line, which is used temporarily to duplicate in-service lines. Finally, service is switched to a newly constructed line. The key technologies for this are *delay difference measurement* to precisely measure the signal delay between two different lines



IDM: integrated distribution module
OLT: optical line terminal
ONU: optical network unit

Fig. 2. Optical line switching technology.

(between the current line and the bypass line, and between the bypass line and the newly constructed line) and *delay adjustment* to control and adjust the signal delay. By improving this technology, we have been able to reduce the volume of equipment by 40 times (14 L) and to reduce the adjustment time by 1000 times (less than 3 seconds for a 1-km adjustment) compared to the original time. This improvement has enabled us to advance this switching technology to the practical use level.

Route switching in momentarily interrupted optical line switching technology is carried out by using a local light injection and detection technique in order to formulate a bypass line. In this scheme, bending is temporarily applied to the currently used line to switch an optical signal from the current line to a bypass line or from a bypass line to the newly constructed line. A very short service interruption occurs during switching, but this scheme is advantageous in that it can achieve switching with a very simple system configuration compared to interruption-free switching.

The local injection and detection technique is the key technology to realize this system. It enables input-output of signal light through the fiber coating without cutting the fiber. To detect very weak light signals leaking from the fiber and to input light signals into the fiber efficiently, it is necessary to adjust a fiber probe with a high degree of accuracy. We have developed a highly efficient local injection/detection system by designing an appropriate probe position to maximize the coupling efficiency and by devising an optical coupling scheme.

These two line-switching systems can be selected according to the work situation in the field. We believe that this new technology will make it possible to complete line-switching tasks more effectively and without service interruptions. We are now conducting a field trial by using prototype systems to identify practical problems, including those involving operation and procedures for line-switching work. We plan to further improve this technology taking the results of the field trial into account in order to establish it as a total solution for line-switching work.

3.2 Coated fiber connection technique

Next, we introduce our coated fiber connection technique, which makes it possible to cut and connect optical fiber without removing the fiber coating. The use of this technique eliminates the need to remove the fiber coating and to clean the fiber, and thus, the tools for this work (stripper, alcohol, paper, etc.) become unnecessary. Moreover, this connection technique reduces the risk of fiber breakage because it does not require field workers to handle bare fiber directly.

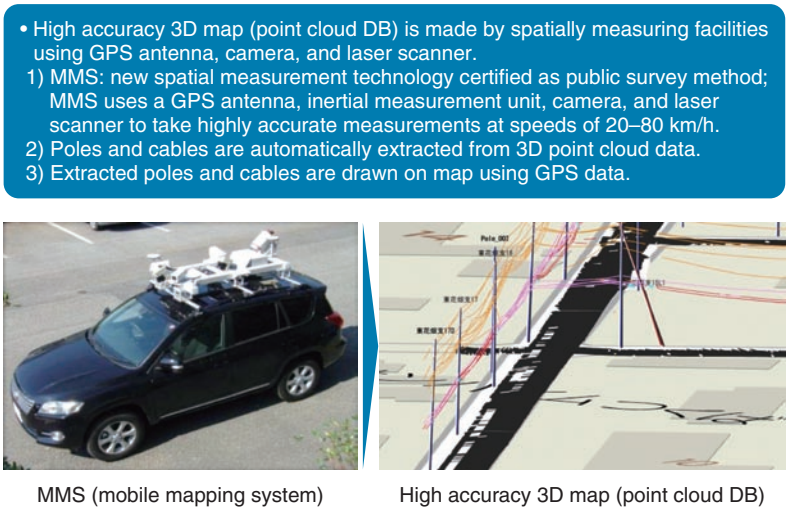


Fig. 3. 3D facility management technology.

This novel new connection approach incorporates two important key technologies. The first involves cleaving a coated optical fiber, and the second consists of removing the fiber coating in a connecting component. For the cleaving method, we found that a stretching method was suitable for cleaving the coated fiber over a wide temperature range. We also clarified that for the removal technique, improving the shape of the part of the connecting component the coating was removed from made it possible to remove the fiber coating more effectively over a wide temperature range. We will continue to improve this technique in order to reduce the cost of the cleaver device and increase the percentage of successful outcomes in almost every work environment.

3.3 3D facility management technology

We are working to reduce the total cost of outside facility management and make outside work more efficient by establishing outside facility databases (DBs) and business applications based on three-dimensional (3D) computer-aided design (CAD) technology. This technology is aimed at making design and maintenance work for outside facilities simpler and more effective by constructing a 3D CAD-based outside facility DB and business applications, instead of using the conventional 2D plant records (**Fig. 3**). This new technology is characterized by the use of a mobile mapping system (MMS) to build a highly accurate 3D map. MMS is a new spatial measurement technology certified as a public survey method; it is equipped with a GPS (Global Positioning System) antenna, an inertial measurement unit, a camera, and a laser scanner. It performs highly accurate measurements at speeds from 20 to 80 km/h. We are developing a 3D point cloud DB with MMS that can automatically extract outside facilities such as poles and cables from 3D point cloud data and identify extracted facilities by accessing an existing facility DB system.

One application example is automatic detection of pole deflection and the height of cables from the 3D point cloud DB. This enables us to select particular facilities that preferentially need to be inspected from a massive number of network facilities. Moreover, by analyzing changes in the 3D point cloud DB over the years, the system can be used to automatically indicate unsafe facilities on a map. This novel facility management system is expected to contribute to making inspection work of various facilities more efficient because it eliminates the need to dispatch workers to the field to inspect each piece of facility equipment.

3.4 Remote fault location measurement for PON architecture

PON technology has been widely adopted to deliver FTTH services to save the cost of cables and optical transceivers. One of the critical issues with PON configuration is how to monitor the faults in tributaries of the optical splitter, because conventional optical time-domain reflectometry cannot obtain accurate loss distributions beyond the optical splitter. We have devised a novel remote measurement technique that

enables us to obtain the loss distribution of each branched fiber below the optical splitter using a physical phenomenon called Brillouin scattering.

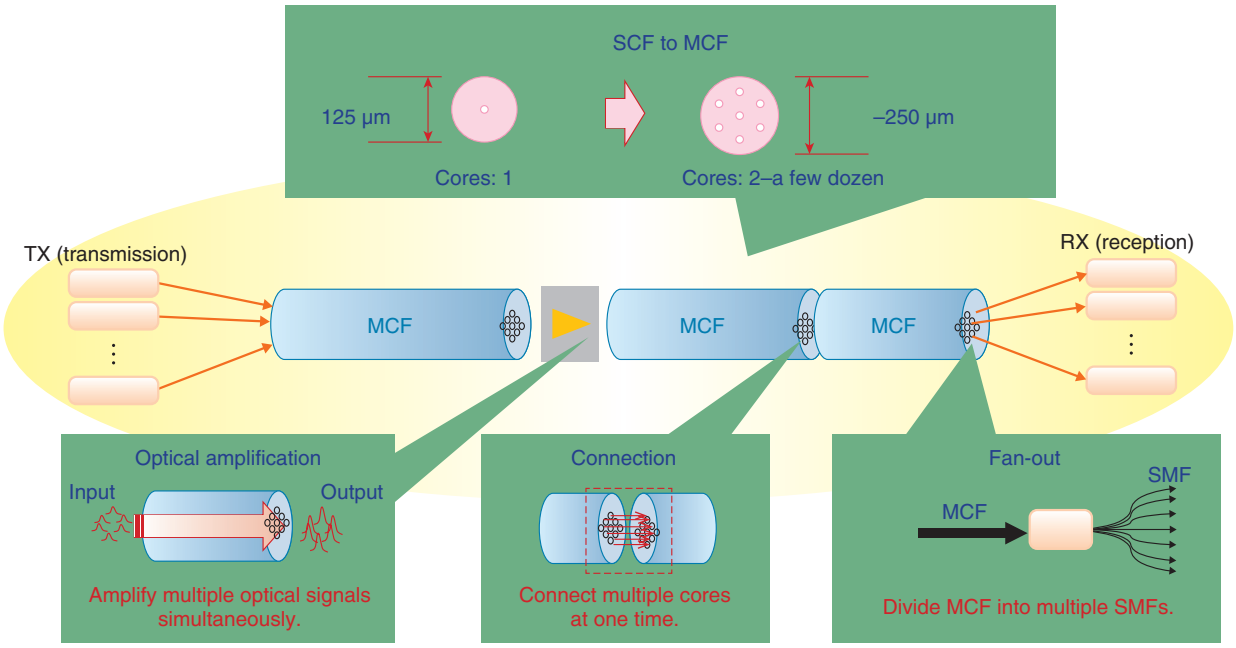
In this new measurement method, two optical pulses—a pump pulse and a probe pulse—are launched into an optical fiber with a time delay from an apparatus in the central office. The two launched pulses go into branched fibers through an optical splitter and are reflected at an optical termination filter installed in front of an optical network unit (ONU). Because the two pulses are injected with a time delay, the probe pulse, which is launched prior to the pump pulse, reaches the reflection point at the end of the branched fiber first, and it collides with the pump pulse, which is launched with a time delay, in the tributary fiber. The optical frequencies of the two pulses are set to have a difference between them that corresponds to a Brillouin frequency shift. When the two pulses collide, Brillouin scattering occurs in the fiber, which is when part of the energy is transferred from the pump pulse to the probe pulse. We can obtain the loss distribution of each tributary in order to analyze the returned probe pulses at the apparatus, while controlling the timing of the pulse launches. We confirmed that we were able to identify the faulty fiber and the accurate fault location in a PON configuration with an 8-branched splitter by using this method. This new method is therefore effective for identifying fault locations in fiber branches where failures tend to occur without having to dispatch workers to the field. If this approach can be implemented practically, it will help to overcome one of the major difficulties with PONs and will also reduce maintenance costs.

3.5 Next-generation ultrahigh speed and capacity fiber technology

The bandwidth of optical fiber communication systems that form the backbone for this communication is being increased yearly. So far, transmission capacity per optical fiber has increased by using time division multiplexing (TDM) and wavelength division multiplexing (WDM) and by increasing the multiplexing density and signal density based on various breakthroughs. However, as the density of signal multiplexing increases, the power density per cross section of fiber inevitably increases. High power density in optical fiber is known to cause nonlinear optical effects, which degrade signal characteristics, and fiber fuse, which destroys optical fiber thermally. When the power density threshold and the bandwidth of the optical amplifier are taken into consideration, it is said that the maximum transmission capacity of conventional single-mode fiber (SMF) is limited to around 100 Tbit/s. Space division multiplexing (SDM) is thought to be a potential candidate as the next multiplexing axis to break through the capacity limitation. Thus, new optical transmission technology is expected to meet the growing demand for transmission capacity. In terms of the transmission medium, two design concepts have been proposed for realizing SDM. One is multi-core fiber (MCF), which has multiple individual cores in a fiber, and the other is few-mode fiber (FMF), in which multiple different transmission modes can be transmitted within a single core. We are conducting research on the transmission medium for SDM technology in order to extend the transmission capacity to meet the future explosive increase in data traffic.

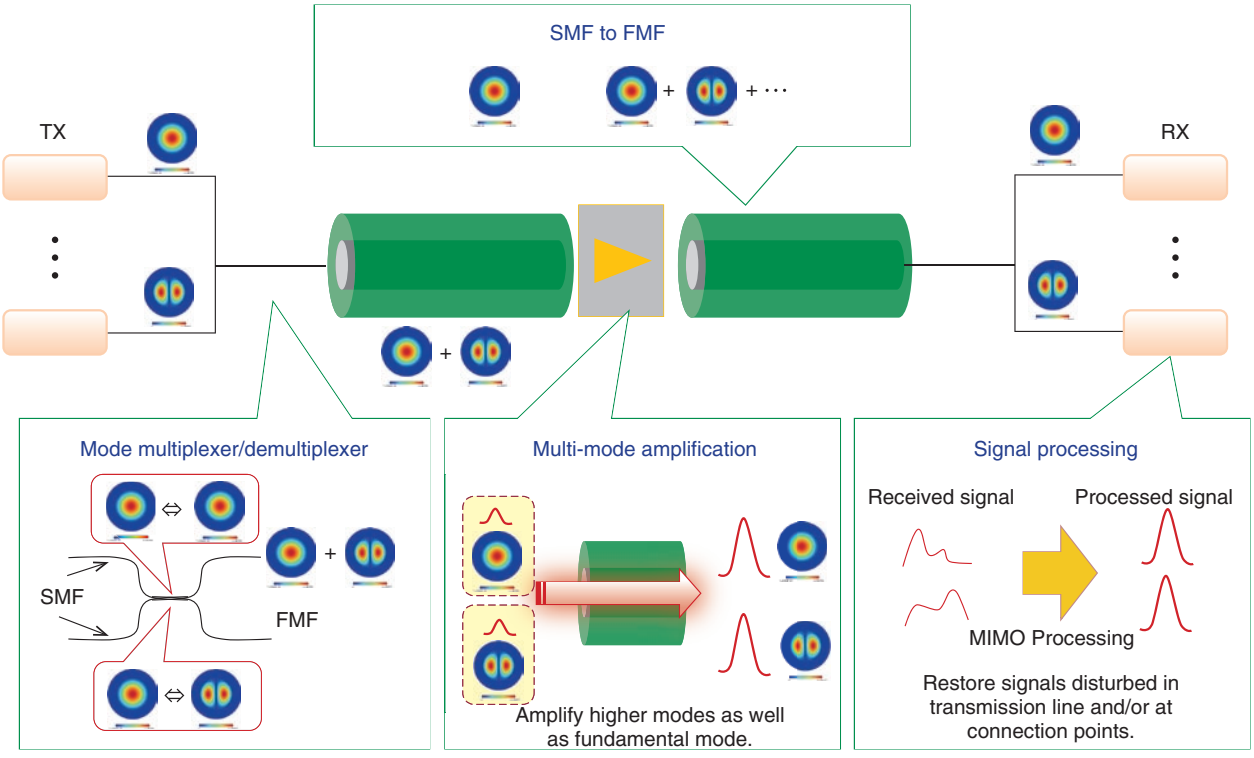
The MCF transmission system is illustrated in **Fig. 4**. The transmission system with MCF consists of some fundamental technologies as well as those for fiber design and manufacturing. These include optical amplification technology, which amplifies multiple optical signals simultaneously; connection technology, which connects multiple cores at one time; and fan-out technology, which divides MCF into multiple SMFs. We are now conducting research on MCF in a national project launched by Japan's National Institute of Information and Communications Technology (NICT), which has established an industry-academia research group. One of the achievements in this project is that we conducted the first trial of a multi-vendor interoperability experiment with MCF technology in 2013. We constructed a 100-km-long transmission line consisting of MCF with seven cores provided from five different fiber vendors, and other optical components such as amplifiers, connectors, and fan-out cords. We confirmed in the transmission experiment that transmission signals in the seven individual cores were successfully transmitted simultaneously without noticeable interference. We believe that this interoperability experiment is highly significant from a practical application perspective.

Fundamental technologies for mode division multiplexing transmission are shown in **Fig. 5**. Mode division multiplexing is a transmission scheme in which multiple optical modes individually modulated with signals are transmitted in a single-core optical fiber. The key technology with the multi-mode fiber used for SDM is the effective control of individual optical modes, in contrast to conventional multi-mode fiber. Mode division multiplexing systems are also based



Various fundamental technologies should be established to achieve the MCF transmission system.

Fig. 4. Fundamental technologies for MCF transmission.



MIMO: multiple-input, multiple-output

Fig. 5. Fundamental technologies for mode division multiplexing transmission.

on various fundamental technologies as well as fiber design and manufacturing technology, for example, mode multiplexer/demultiplexer technology, in which individual modes are multiplexed and demultiplexed; multi-mode amplification technology, in which higher modes as well as fundamental modes are amplified; and signal processing technology, which restores signals disturbed in the transmission line and/or at connection points. We successfully carried out the first ever mode division multiplexing transmission experiment, in which two modes that were modulated individually were transmitted in one fiber; this achievement was reported at the Optical Fiber Communication (OFC) Conference in 2011.

We have also reported world-leading data in the field of mode division multiplexing transmission technology such as multi-mode fiber with a trench-assisted graded index core in which six LP (linearly polarized) modes (ten modes if degenerate modes are included) can be transmitted with low differential mode dispersion and in a wide wavelength region, and a planar lightwave circuit (PLC) type mode multiplexer/demultiplexer, which can multiplex and demultiplex four individual modes in one PLC chip.

In terms of SDM technology, we will continuously strive to tackle the limitation in the transmission capacity of optical fiber and also to make progress in the practical use of SDM technology.

Author profile

■ Career highlights

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He received the B.E. and M.E. in physics and the Ph.D. in electrical engineering from Kyushu University in 1988, 1990, and 2000, respectively. He joined NTT Transmission Systems Laboratories in 1990 and studied low-loss optical fiber and nonlinear optical effects in optical fiber. He has over 20 years of experience in optical fiber and cable research, development, and standardization. He has served as a rapporteur of ITU-T SG15 Question 8. He is a member of IEICE (Institute of Electronics, Information and Communication Engineers) of Japan.

NTT R&D Activities toward Future Access Network Operation

Jun Nishikido

Abstract

The Access Network Operation Project of NTT Access Network Service Systems Laboratories is a research and development (R&D) undertaking targeting a future operation system in the access network. This article provides an overview of access network operation in a future network slated for implementation around 2020 and describes related R&D activities. It also introduces various R&D efforts focused on the use of navigation technology for streamlining the execution of business operations without affecting the existing operation system.

Keywords: future operations, future networks, navigation technology

1. Introduction

On May 13, 2014, NTT President and CEO Hiroo Unoura announced in a press conference that NTT EAST and NTT WEST would begin wholesaling fiber access services. By providing these services in a fair manner to a wide variety of market players in diverse industries, NTT is advancing a Hikari Collaboration Model [1] that signals a radical shift from its existing B2C (business-to-consumer) business to B2B2C (business-to-business-to-consumer) business. In this model, players such as telecommunication carriers, mobile virtual network operators (MVNOs), and Internet service providers (ISPs) provide services linking fixed and mobile communications. For example, the Hikari Collaboration Model could be applied to a total health support service in which medical institutions provide remote diagnosis and health consultations, electronics manufacturers provide devices for health monitoring, and fitness clubs suggest exercise plans for their members. In this way, market players in a wide range of industries collaborate to provide one-stop services supporting a healthy lifestyle.

The target access network operation scenario needed in order to achieve this B2B2C model based on the wholesaling of fiber access services is shown in **Fig. 1**. In this scenario, NTT will be an operations provider for service providers, who are represented by the second "B" in the B2B2C model. NTT will provide, in particular, one-stop operation and maintenance of network, cloud, and application services. This one-stop operation can contribute to the creation of new and attractive services in a wide variety of industries. Furthermore, end users in this scenario will be able to select from a variety of innovative services provided by diverse market players. At the same time, the operations provider (NTT), represented by the first "B" in the B2B2C model, must be capable of supporting diverse service levels and responding quickly to a huge number of service applications, so substantial labor savings will be needed to provide operations in this model.

NTT Access Network Service Systems Laboratories is currently examining five future directions of access network operation (**Table 1**). Of these, we will first introduce R&D activities surrounding Operations as a Service (OaaS) and Service Orchestration, which are strongly related to one-stop operation. We will then introduce Simple & Smart Operation (navigation technology) for reducing the operator's workload as a direction to be taken in parallel with

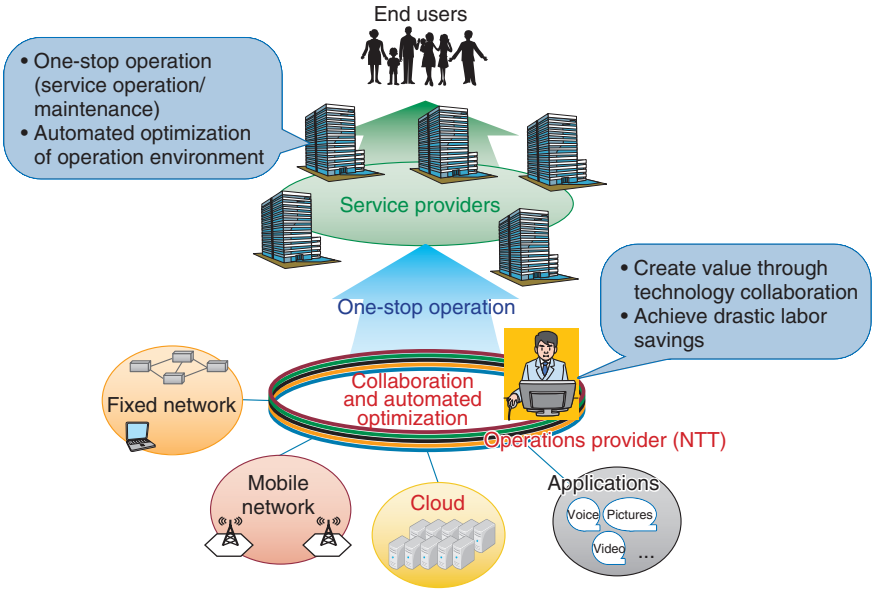

Fig. 1. Scenario targeted by access network operation.

Table 1. Future directions of access network operation.

OaaS	Provide operation functions as a service
Service Orchestration	Achieve service operations with no physical limitations through virtualization technology
Proactive Operation	Achieve a proactive form of operation by clarifying latent mechanisms driving changes in the network
Simple & Smart Operation	Save on labor by reducing number of operations and simplifying tasks
Sustainable Operation	Achieve management technology that enables secure and sustainable expansion that is robust to changes in the business and service environment

one-stop operation.

2. OaaS

The OaaS mechanism provides a portion of the operation functions for achieving efficient operation of network facilities to service providers as a service (**Fig. 2**). It enables over-the-top (OTT) and other types of service providers to use customer management functions that they formerly had to prepare themselves such as order processing, quality of service (QoS) and service level agreement (SLA) management, and billing management. The service providers can access these functions via an OaaS application programming interface (API) prepared on the NTT Group side. The OaaS mechanism also provides for automated collaboration in which service providers use the API to access a variety of operation functions that they formerly had to link to manually. This capability can dramatically shorten the time-to-market of a service. NTT aims to use this OaaS mechanism to provide an attractive network that service providers will continue to choose.

A beneficial effect of OaaS on the service-provider side is that an operation system can be used simultaneously with the network services (fixed and mobile) provided by the NTT Group, which means that information and functions on the NTT side and the

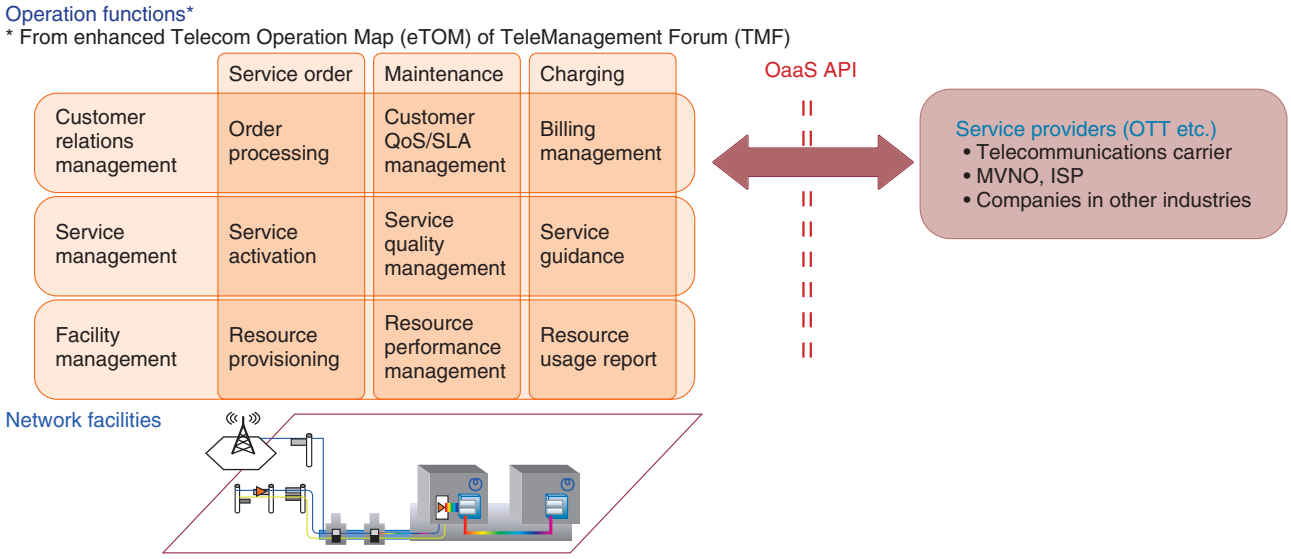

Fig. 2. OaaS mechanism.

service-provider side can be linked. It should therefore be possible to provide new services that merge communications with applications from diverse industries while making the best use of the key attributes of the service provider. As for end users, the provision of innovative services by a variety of service providers, each leveraging its core competence, should contribute to improved quality of life (QoL).

The main challenges and recent activities surrounding OaaS are listed in **Table 2**.

3. Service Orchestration

The Service Orchestration mechanism uses virtualization techniques to automate and streamline the process of making network settings that are needed for service provision but that straddle multiple layers (**Fig. 3**). In the network of the future, the cloud domain and the network domain must be seamlessly connected. The role of Service Orchestration will be to interlink legacy network equipment, network equipment that can be controlled by the new software-defined networking (SDN)[*1] technology, and network functions that have been virtualized by the network functions virtualization (NFV)[*2] technology provided on the cloud.

NTT is establishing three main goals for Service Orchestration: (1) end-to-end network service management to provide integrated control from the application layer to the physical layer; (2) separation of network services and equipment by applying virtualization techniques (SDN, NFV) to the network; and (3) advanced and automated operations through lump configuration of multiple network equipment and automatic recovery after failures. Service Orchestration should also reduce operating expenses while enhancing network value. We can expect Service Orchestration to achieve the former effect by simplifying remote tasks and consolidating on-site tasks and by identifying the causes and effects of failures associated with layer integration, and to achieve the latter effect by providing fast and efficient operations tailored to the request levels of diverse market players.

The main challenges and recent activities surrounding Service Orchestration are listed in **Table 3**.

4. Simple & Smart Operation

Simple & Smart Operation is introduced here as a direction to be pursued in parallel with the above R&D activities surrounding one-stop operation. Simple & Smart Operation focuses on the workflow

*1 SDN: A network that can dynamically set and modify the network configuration, functions, performance, etc., through software operations, or the concept of such a network

*2 NFV: A system for implementing the functions of a network-controlling communications device by using software and executing that software on an operating system (OS) that runs virtualized general-purpose servers

Table 2. OaaS: Challenges and recent activities.

Challenges	Recent activities
Clarify operations/ collaboration functions and associated information	• Establishing basic business patterns in the B2B2C model • Extracting user requirements through open innovation • Formulating a standard policy specifying a base API
Achieve collaboration between advanced applications and create collaboration variations	• Establishing technology for enabling collaboration according to service-provision conditions and user requests (big data analysis, security analysis, information virtualization, authentication and authorization technology, etc.)
Clarify OaaS architecture	• Specifying a general-purpose interface based on standard technology • Creating function/information models according to service grade

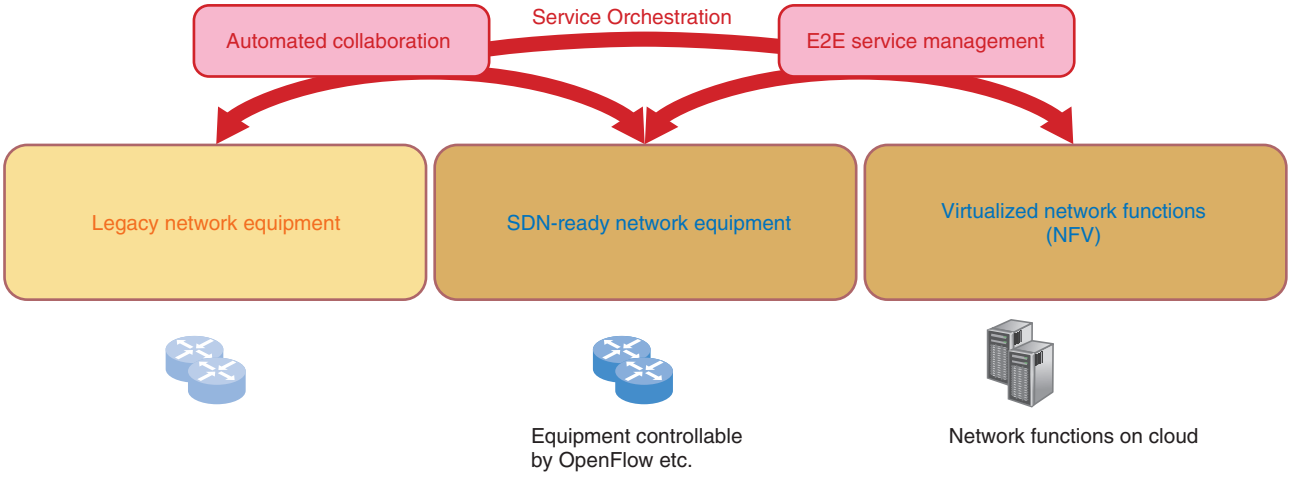

Fig. 3. Service Orchestration.

Table 3. Service Orchestration: challenges and recent activities.

Challenges	Recent activities
Clarify envisioned scenarios (scope of business)	• Clarifying business requirements and network function requirements • Studying use cases such as NFV
Create an information management model	• Studying a network/server resource management system • Studying standard management models such as TMF
Establish function mapping and interface provisions	• Deploying functions for achieving Service Orchestration (NMS, EMS, orchestrator, etc.) • Studying multi-grade management technology tailored to customers
Establish migration system	• Studying a migration system that considers migration from existing OSS
Assess range of use for market technologies and standardized technologies	• Studying orchestrator technology based on standardization trends • Assessing trends in virtualization studies of NFV/TMF

EMS: element management system
NMS: network management system
OSS: operation support system
TMF: TeleManagement Forum

in business operations (the portion of operations performed manually). This technology covers the range from simple operation support to drastic revision of processes; it addresses individual on-site environments that have been difficult to deal with in conventional system development and is intended to directly reduce the workload on operators. R&D efforts are underway in the Access Network Operation Project with the aim of creating a navigation framework that collects, consolidates, and processes individual-dependent know-how and materials used for decision-making in manual operations and feeds that information back to operators. Three specific technologies that are part of these R&D efforts are described in this section: Unified Management Support System (UMS) [2] for automating repetitive operations on a personal computer (PC); DataBridge [3] for transferring data securely between different networks; and annotation technology for overlaying various types of supplementary information on the operator's screen.

4.1 UMS

UMS software technology is designed to reduce the workload on operators by automating terminal operations performed on a PC. Its functions range from automatic recording of a sequence of operations to executing operations on behalf of the operator. UMS can automate relatively simple repetitive data-input operations performed on a Windows*3 OS and significantly reduce the operation workload on the operator. The main features of UMS are: (1) a function for automating operations and executing them on behalf of the operator; (2) a function that enables scenarios to be automatically generated by simply having the operator perform ordinary operations with respect to a certain application, and that enables those scenarios to be visually edited; and (3) simple implementation by copying the UMS file to the computer without having to modify the target system or perform a program installation. UMS software has already reached the practical stage and has been marketed by NTT Advanced Technology under the product name WinActor.

4.2 DataBridge

DataBridge is technology for smoothly linking systems at minimal cost while making use of existing security policies. Conventional practices for transferring data such as copying files between PCs using a USB (universal serial bus) memory stick or inputting printed information into a terminal on a different network would raise security concerns because of the possibility of losing physical media. DataBridge, in contrast, enables secure data transfer between detached networks without having to modify the existing system or network. In particular, it enables detailed security policies to be added such as allowing the transfer of PDF (portable document format) files but prohibiting the transfer of Excel files, or allowing the transfer of data for only specific users or specific time periods. In short, DataBridge can appropriately limit the types of information transferred between networks. It also preserves a record of the transferred information in the form of a log, thereby enabling operations that follow existing security policies. DataBridge has also reached the practical stage and is being marketed by NTT Software Corporation under the product name Crossway/DataBridge.

4.3 Annotation technology

Windows*3 includes a function for displaying help in the form of balloons when placing the mouse cursor over an item, but annotation technology facilitates user navigation through an application by enabling the user to add any type of supplementary information anywhere on an operation screen without having to upgrade the application (**Fig. 4**). In short, annotation technology enables a user to freely and directly display know-how anywhere on an operation screen. It can be used, for example, to display operation assistance after deploying a new system, to provide beginners with support in using an application that involves complicated terminal operations, and to display help information on the screen in the native language of foreign-language-speaking users. It also enables annotations to be edited easily by anyone via a GUI (graphical user interface) on an editing screen. Some of the functions of this annotation technology are now under development toward a prototype product.

5. Future outlook

Finding ways of responding to the diverse needs of service providers in a low-cost and rapid manner is essential to implementing the Hikari Collaboration Model. At the same time, the portion of operations run by people in meeting these needs must be made more efficient. NTT Access Network Service Systems Laboratories is committed to conducting ongoing research of access network operation in order to

*3 Windows is a registered trademark of Microsoft Corporation.

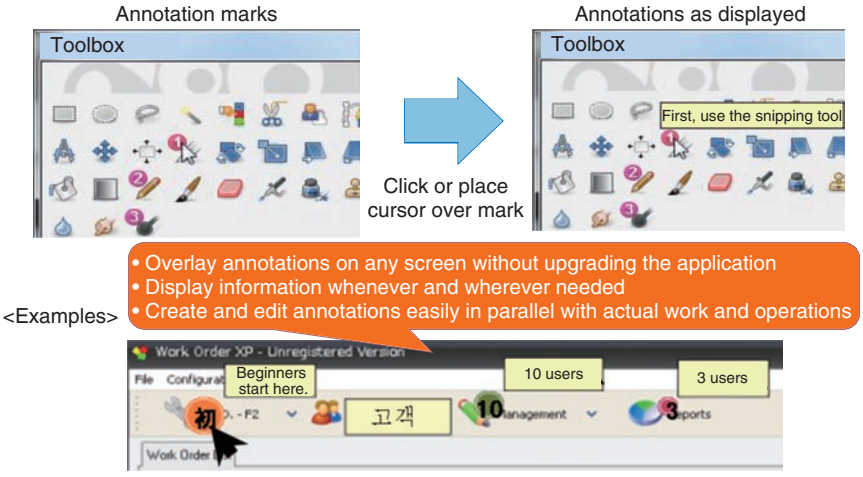

Fig. 4. Annotation technology.

respond optimally to these needs and to help create a prosperous and enriched society.

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Author profile

■ Career highlights

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Jun Nishikido received the B.E. in electrical engineering from Waseda University, Tokyo, in 1986; he joined NTT the same year. He received the 2000 Best Paper Award from the Institute of Electronics, Information and Communication Engineers (IEICE). He is currently engaged in strategy planning of operation system R&D and research on SDN/NFV in access networks. He is a member of IEEE (Institute of Electrical and Electronics Engineers) and IEICE.

Development of 100-Gbit/s Packet Transport System

Takeshi Kawasaki, Masaaki Inami, Yoshiaki Sasakura, Daisaku Shimazaki, Makoto Horiguchi, and Katsutoshi Koda

Abstract

A rapid increase in the amount of Internet traffic is expected in the core network of the NTT Group due to the growing popularity of mobile and cloud services. NTT Network Service Systems Laboratories has developed a 100-Gbit/s packet transport system (100G-PTS) in order to increase the network capacity cost-effectively. Moreover, 100G-PTS also improves the operability and reliability of the transport system, which is expected to reduce operational expenditures. This article presents an overview of 100G-PTS and its technical features.

Keywords: 100G, digital coherent technology, MPLS-TP

1. Introduction

The trend of steadily increasing Internet traffic means that transport systems with higher capacity are required in the carrier network. To provide sufficient capacity economically, NTT Network Service Systems Laboratories has developed a next-generation optical transport system called a 100-Gbit/s packet transport system (100G-PTS) that makes it possible to deliver 100-Gbit/s high speed data traffic using digital coherent technology and also to accommodate data traffic efficiently using packet transport technology. The goals for this development, in addition to enhancing the capacity, are to improve the operability and reliability of the system by integrating the equipment in different layers and by simplifying the network, and to reduce power consumption in order to reduce the total operational expenditure (OPEX). In the near future, we will be able to further save costs of Layer-3 equipment such as relay routers by using 100G-PTS (**Fig. 1**). Thus, 100G-PTS will be our key system in the NTT Group.

2. Overview of 100G-PTS and its key technical features

There are three key technical features in 100G-PTS, which bring certain advantages, as follows (**Fig. 2**):

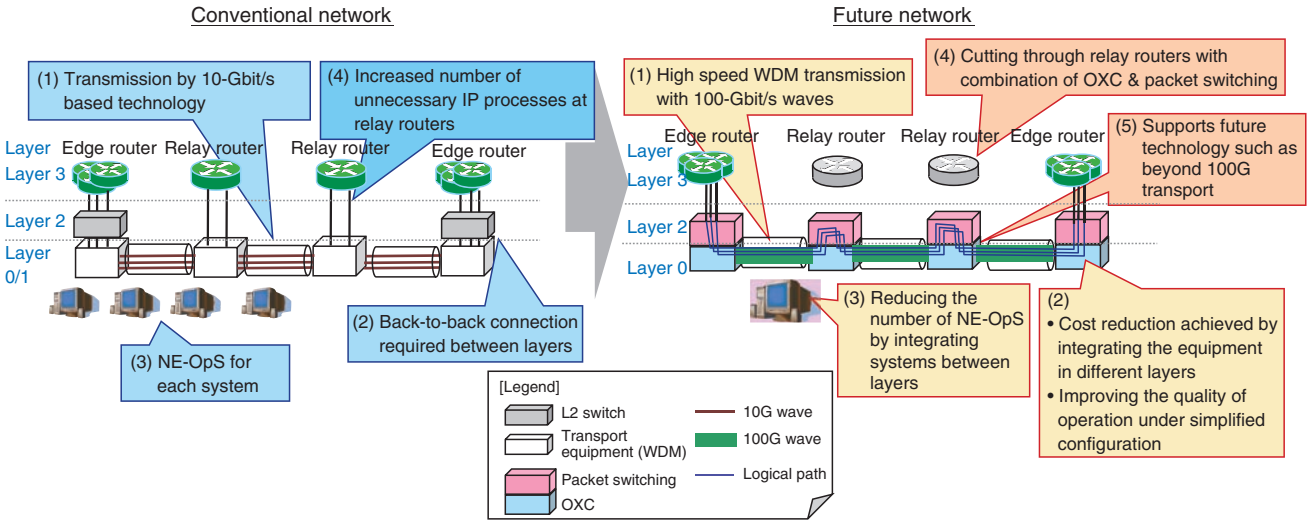
(1) Capacity enhancement by 100-Gbit/s digital coherent technology

(2) High operability and reliability by high performance optical switching technology that achieves compatibility between flexible bandwidth setting of the circuit and advanced operations, administration, and maintenance (OAM) functions through the use of MPLS-TP (Multi-Protocol Label Switch Transport Profile) technology

(3) Cost reduction by integration of both optical (Layer-0) and packet switching (Layer-2) in a single system

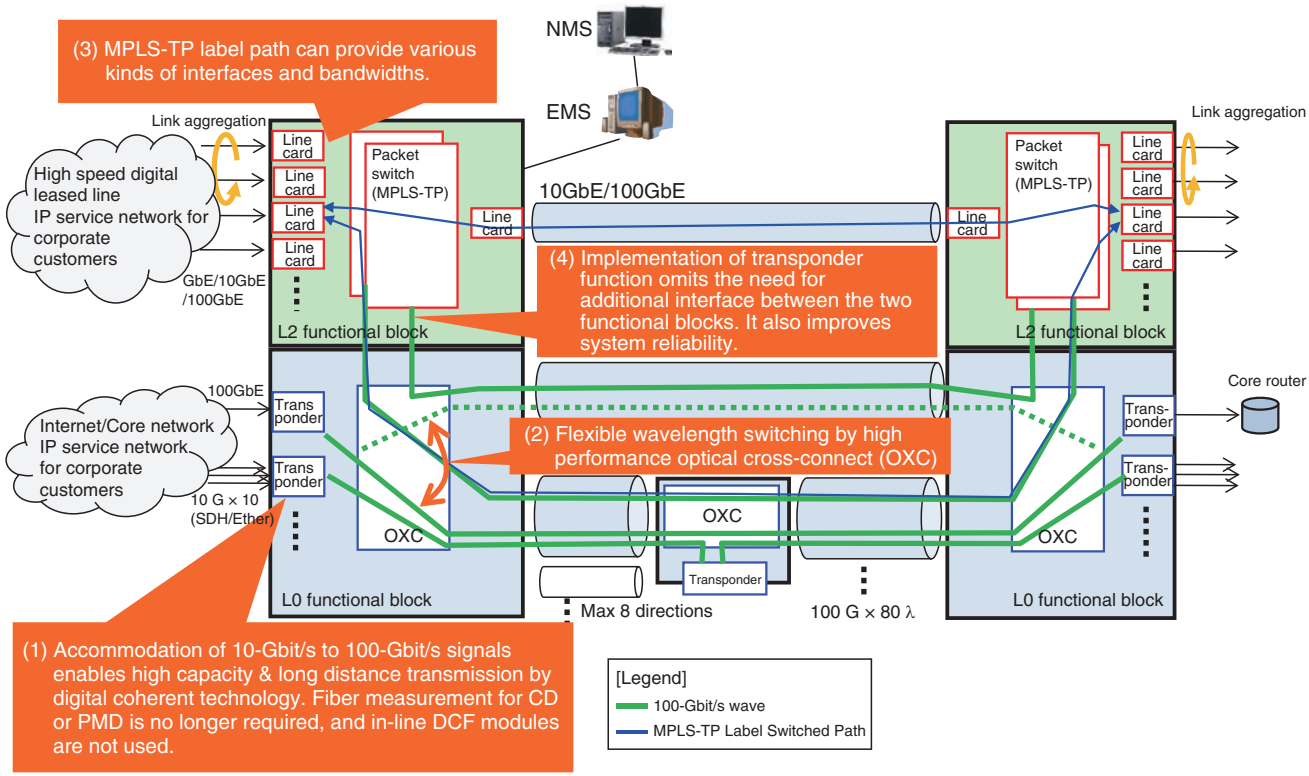
2.1 100-Gbit/s transmission with digital coherent technology*

* Digital coherent technology: Technology that uses high speed digital signal processing (DSP). It can drastically mitigate the limitations of transmission distance due to optical waveform distortion through the optical fiber cable.



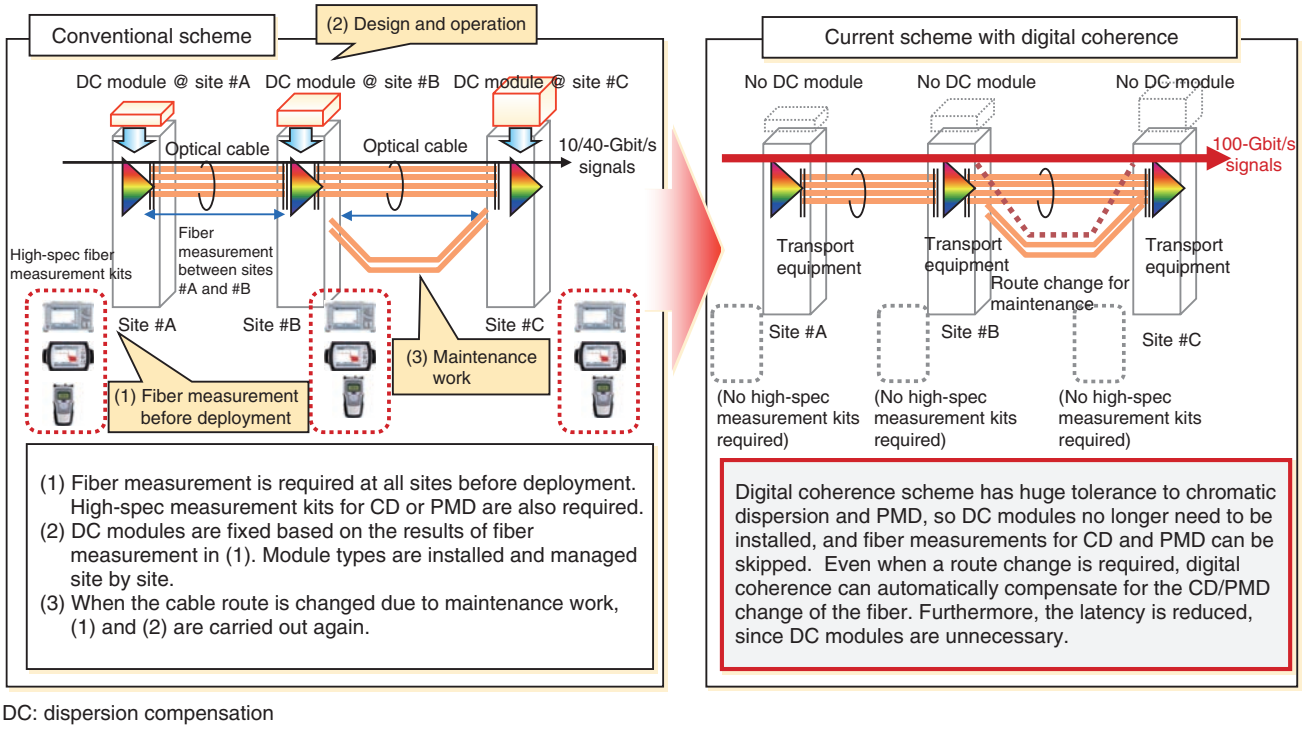
NE-OpS: network element operation system
OXC: optical cross-connect

Fig. 1. Advantages of integrating layers in transport network.



DCF: dispersion compensating fiber
EMS: element management system
L0: Layer-0
L2: Layer-2
NMS: network management system
SDH: synchronous digital hierarchy

Fig. 2. 100G-PTS key technical features.



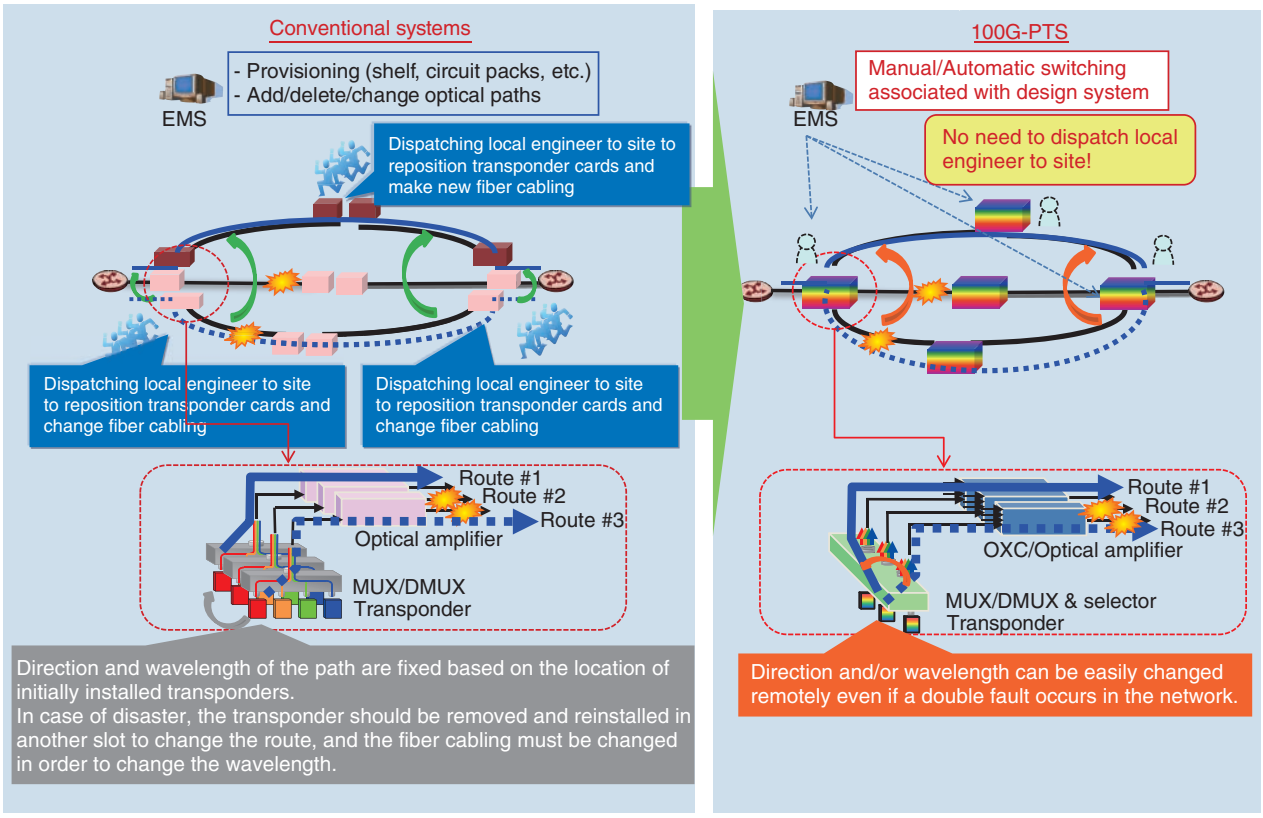
DC: dispersion compensation

Fig. 3. Benefits of digital coherent technology.

In conventional wavelength-division multiplexing (WDM) systems, the maximum speed is 10 Gbit/s or 40 Gbit/s per wavelength. However, using more 10/40-Gbit/s WDM equipment will not be sufficient to deal with the rapid increase in traffic, and therefore, a new transport system that can drastically enhance the capacity with higher speed data transmission is required. Digital coherent technology, which is a breakthrough technology in the industry, makes it possible to deliver 100-Gbit/s transmission per wavelength in 100G-PTS. 100G-PTS can achieve a maximum capacity of 8.0 Tbit/s by multiplexing 80 wavelengths of 100-Gbit/s signals.

To speed up the transmission rate (from 10/40 Gbit/s to 100 Gbit/s), spectral efficiency must be improved. We adopted a multi-level modulation/demodulation scheme that is widely used in the wireless communication field. However, long haul transmission still presented difficulties because multi-level modulation is sensitive to the noise generated inside the fiber during transmission. Polarization mode dispersion (PMD) and chromatic dispersion (CD) induced in the fiber are also factors that limit the transmission distance. The use of digital coherent technology resolved these difficulties, as its high speed digital signal processing (DSP) capability can compensate for or drastically mitigate distortion due to noise or PMD/CD during transmission.

Another major advantage of digital coherence is in deployment and operation (**Fig. 3**). In conventional systems, fiber measurements for loss, CD, and PMD need to be done using high-specification measurement kits before the installation work starts. On the basis of the results of such measurements, we have to install the appropriate CD compensation module site by site. Moreover, if the cable route is altered for maintenance purposes, we have to do the fiber measurements again for other fibers, which requires a lot of extra work. This is no longer necessary when using 100G-PTS with digital coherent technology, however, because CD and PMD can be generally compensated for by DSP. Thus, the measurement kits are no



MUX/DEMUX: multiplexer/demultiplexer

Fig. 4. Features of high performance optical switching technology.

longer needed, which reduces the OPEX for such work. Moreover, the delay of the system is improved because no CD module needs to be installed in 100G-PTS, which is an advantage for the carrier network.

2.2 High operability and reliability by high performance optical switching technology

In a WDM system, a transceiver called a transponder is necessary to generate the optical signal that is optimized in order to transmit signals a longer distance when it receives signals from external equipment such as service nodes. In conventional systems, the direction or wavelength of the path is fixed based on the position of the slot the transponder card is placed in. Therefore, when we have to change the route of the optical path or wavelength in the event of a disaster, we need to dispatch a local engineer to the site and manually change the slot in which the transponder card is placed. After that, we change the fiber connection and reconfigure the optical path via the network element operation system (NE-OpS) (**Fig. 4**). This requires a lot of planning for the route change. In 100G-PTS, on the other hand, we can remotely change the direction and/or wavelength via NE-OpS by using the high performance optical switch. Thus, we do not have to dispatch a local engineer to change the fiber connection and change the slots in which the transponder cards are placed, and this substantially reduces the OPEX of this task. A double fault case that might occur in a disaster is depicted in Fig. 4, in which we can repair a commercial circuit by switching to a third route remotely.

2.3 Compatibility between flexible bandwidth setting of the circuit and advanced OAM functions by MPLS-TP technology

In conventional systems, we have generally used the SDH (Synchronous Digital Hierarchy) format as an ITU-T (International Telecommunication Union Telecommunication Standardization Sector) standard to multiplex and accommodate legacy service traffic such as that from landlines or leased lines. In the SDH scheme, fixed time slots are allocated for each circuit/path, so the bandwidth is fully occupied even when

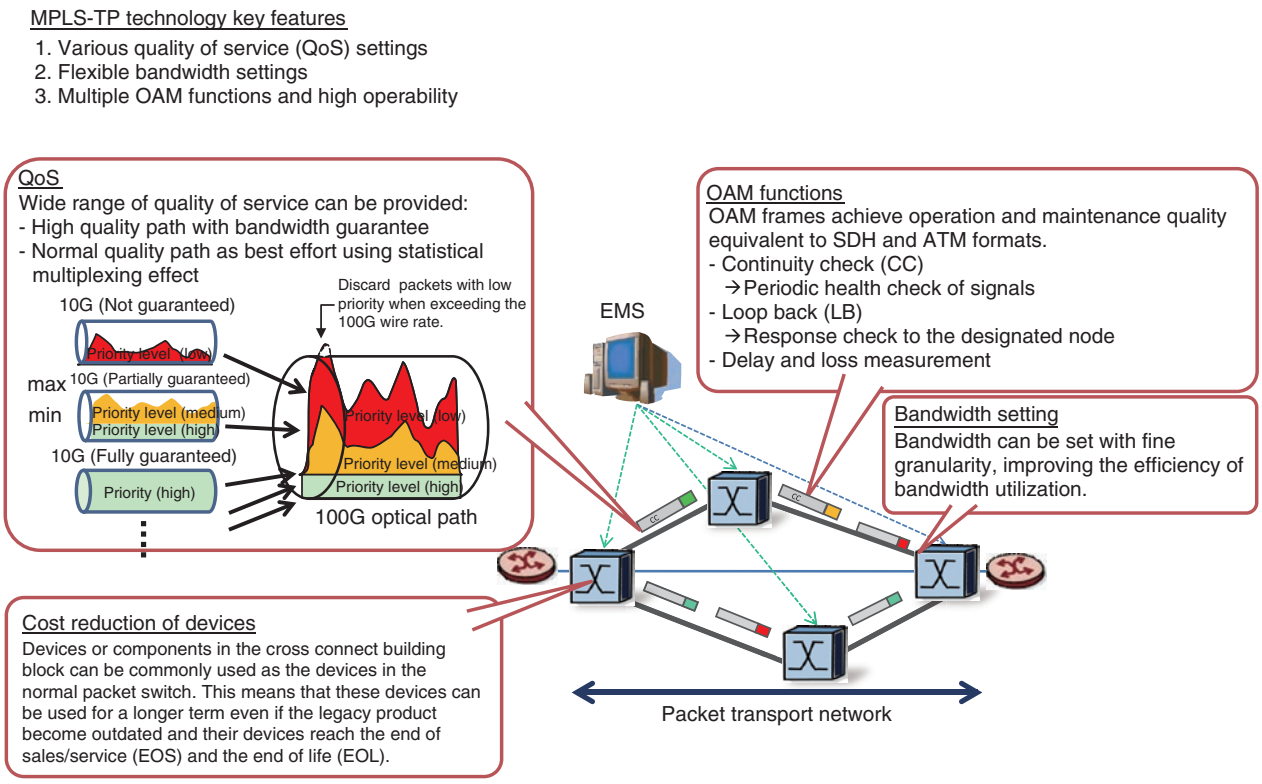


Fig. 5. Features of MPLS-TP technology.

there is no data traffic in the time slots.

In a packet system such as 100G-PTS, however, packets are generated only when there is some data traffic on the circuit. Additionally, we can set the path bandwidth with fine granularity by using packet multiplexing, and we can also set and manage an end-to-end label switched path (LSP) as well as set the SDH technology. When several LSPs are mapped onto the wavelength path, 100G-PTS can mix both types of LSPs (bandwidth guaranteed and non-bandwidth guaranteed) in order to effectively use the bandwidth. It can also configure the redundant LSP paths that achieve less than 50-ms protection switching, and moreover, it can provide hitless protection switching with no frame loss. Different types of protection paths are possible based on the operating conditions, so 100G-PTS assures high reliability of the network.

In terms of operation and maintenance, continuity check (CC) or loop back (LB) testing functions are available in 100G-PTS, which supports sufficient OAM functions to realize high quality operations and maintenance.

2.4 Cost reduction by integrating optical switching (in Layer-0) and packet switching (in Layer-2) in a single system

The equipment for WDM (as an optical transport system) and TDM (time-division multiplexing) (as an electrical MUX/DMUX (multiplex/demultiplex) switch) was generally released as separate units for transport systems, so an additional transponder was necessary to connect both pieces of equipment, and the cost was relatively higher. The 100G-PTS system can provide one system that combines the Layer-0 functional block (WDM) and Layer-2 functional block (packet switch), which reduces the interface cost by simplifying the connection between the two layers. It can also save the space needed for the equipment and the power consumption as well.

Because 100G-PTS supports many kinds of interfaces and a number of routes, it can be applied in various situations in the carrier network. For example, 100G-PTS can configure a multi-ring network, and it can also remotely switch to the third route in the event of a disaster, as shown in **Fig. 5**.

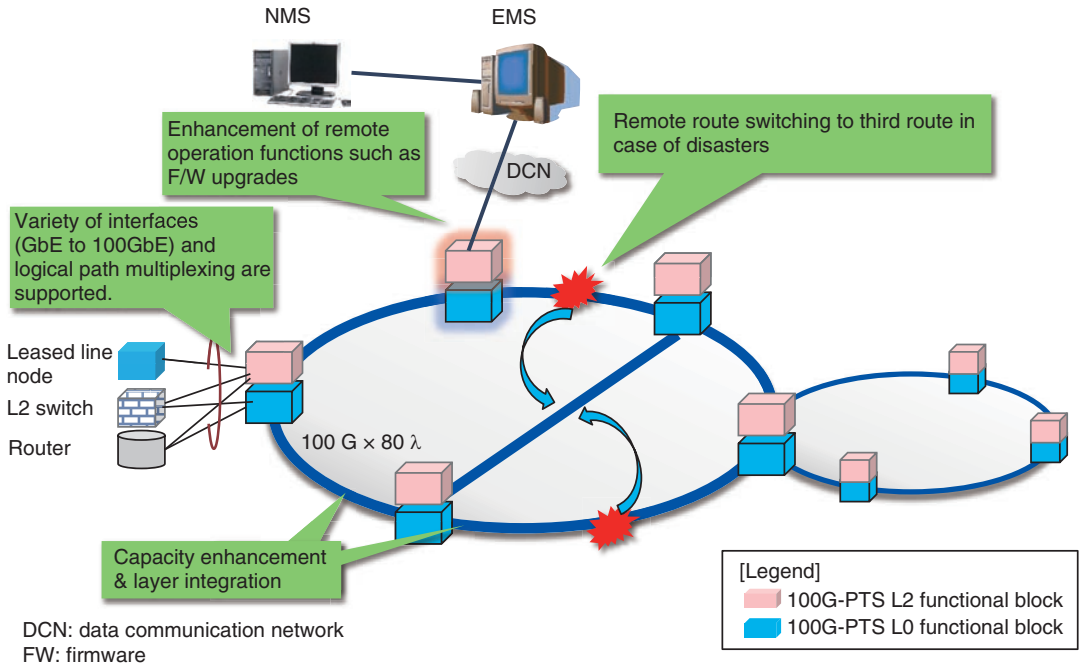


Fig. 6. Schematic of 100G-PTS network (summary).

3. Conclusion

Against the background of increasing demand for Internet traffic, NTT has developed 100G-PTS, which brings sufficient capacity and achieves high operability and reliability as summarized in **Fig. 6**. The demand for equipment that consumes less power has been growing in recent years because the rapidly increasing heat density (per rack) requires a powerful air cooling system, which drives up the cost of facilities. This in turn raises the CAPEX (capital expenditure)/OPEX. In the near future, we will focus on developing technology that can reduce the power consumption in 100G-PTS, and we will also continue to investigate further high performance technologies such as 400-Gbit/s transmission and SDN (software-defined networking).

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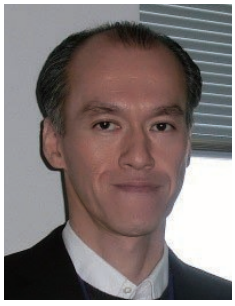

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Standardization Trends for Next-Generation Passive Optical Network Stage 2 (NG-PON2)

Kota Asaka and Jun-ichi Kani

Abstract

The FSAN (Full Service Access Network) Group and ITU-T (International Telecommunication Union-Telecommunication Standardization Sector) are actively working to develop new standards in order to achieve high capacity transmission, multiple service capability, and flexible network operation in future optical access network systems. This article reports on the standardization trends of NG-PON2 (Next-Generation Passive Optical Network Stage 2) systems that are being developed under a framework of the ITU-T G.989 series.

Keywords: ITU, optical access, NG-PON2

1. Introduction

To meet the large demand for high capacity transmission in optical access systems, a 10-Gigabit-capable PON (passive optical network) has already been standardized by IEEE (Institute of Electrical and Electronics Engineers) and ITU-T (International Telecommunication Union-Telecommunication Standardization Sector). To enable cutting-edge standardization of future optical access systems, the FSAN (Full Service Access Network) Group and ITU-T SG15/Q2 (Study Group15/Question 2) are currently discussing the specifications of a 40-Gigabit-capable PON, which employs wavelength-division multiplexing (WDM) technology, for the purpose of enabling cost-effective 40-Gigabit-capable transmission capacity and multiple service capability. The FSAN Group is a forum for discussing future optical fiber access networks, and FSAN member companies offer their contributions to ITU-T SG15/Q2 in order to promote the development of international standards for PON systems.

2. NG-PON2

In 2010, FSAN initiated discussions on a 40-Gigabit-capable PON known as NG-PON2 (Next-Generation Passive Optical Network Stage 2), which is going to be standardized in the ITU-T Recommendation G.989 series. **Table 1** lists the framework and standardization status of the G.989 series recommendations.

As the table indicates, the G.989 series consists of recommendations G.989, G.989.1, G.989.2, and G.989.3. The G.989 recommendation specifies NG-PON2 definitions, abbreviations, and acronyms and will be consented in July 2015. The G.989.1 recommendation, which covers the general requirements for NG-PON2, was approved in March 2013. The G.989.2 recommendation, which specifies the physical media dependent (PMD) layer including the wavelength plan and power budget of NG-PON2, was consented in December 2013 and approved in December 2014. The G.989.3 recommendation specifies particulars for the transmission convergence (TC) layer of NG-PON2 such as the wavelength protocol and bandwidth allocation, and is targeted for consent in July 2015. These achievements so far suggest that the standardization of the G.989 series will

Table 1. Framework and status of ITU-T G.989 series recommendations.

Recommendation	Title	Status
G.989	40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations, and acronyms	To be consented (Jul. 2015)
G.989.1	40-Gigabit-capable passive optical networks (NG-PON2): General requirements	Consented (Jul. 2012) Approved (Mar. 2013)
G.989.2	40-Gigabit-capable passive optical networks (NG-PON2): Physical media dependent (PMD) layer specifications	Consented (Dec. 2013) Approved (Dec. 2014)
G.989.3	40-Gigabit-capable passive optical networks (NG-PON2): Transmission convergence (TC) layer specifications	To be consented (Jul. 2015)

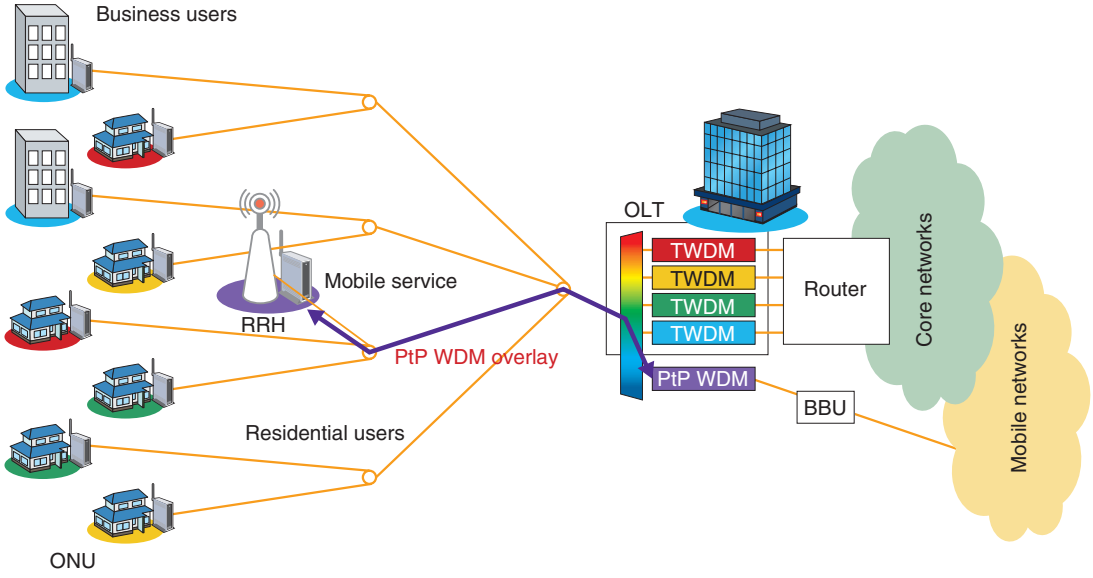

Fig.1. Example architecture of NG-PON2 system.

be completed in 2015 or 2016.

2.1 System architecture

An example of NG-PON2 system architecture is shown in **Fig. 1**. Although the previous PON systems offer broadband service only for residential users, NG-PON2 systems are expected to accommodate business users and mobile users in addition to residential users. The primary NG-PON2 solution is called TWDM (time and wavelength-division multiplexing)-PON, which is a hybrid of conventional TDM (time-division multiplexing) and WDM technologies. Optionally, NG-PON2 also supports Point-to-Point (PtP) WDM overlay, which is expected to be suitable for mobile services that require low latency. In NG-PON2, colorless optical network units (ONUs) are mandatory for reducing system operating expenses because they can eliminate the complicated inventory management of ONUs.

2.2 General requirements

Table 2 lists the general requirements for NG-PON2 that are specified in G.989.1 [1]. In TWDM-PON there are four (optionally eight) multiplexed wavelengths for upstream and downstream, respectively. In an NG-PON2 network there are three types of line rates (per wavelength) of 10-Gbit/s symmetry, 2.5 Gbit/s and 10 Gbit/s for upstream (US) and downstream (DS), respectively, and 2.5-Gbit/s symmetry. Therefore, the transmission capacities for each line

Table 2. General requirements for NG-PON2.

System	TWDM-PON (primary) PtP WDM overlay (option)
Capacity*1	DS*2 40G (10G × 4λ), US*3 40G (10G × 4λ) DS 40G (10G × 4λ), US 10G (2.5G × 4λ) DS 10G (2.5G × 4λ), US 10G (2.5G × 4λ)
Logical split ratio	1:256
Distance*4	40 km (without repeater)
Co-existence	All legacy PONs (RF video included)
Service	Residential and business users, mobile backhaul, and other applications

*1 For 4 wavelengths (λ)
*2 Downstream
*3 Upstream
*4 The maximum split ratio at this distance will depend on the budget class.

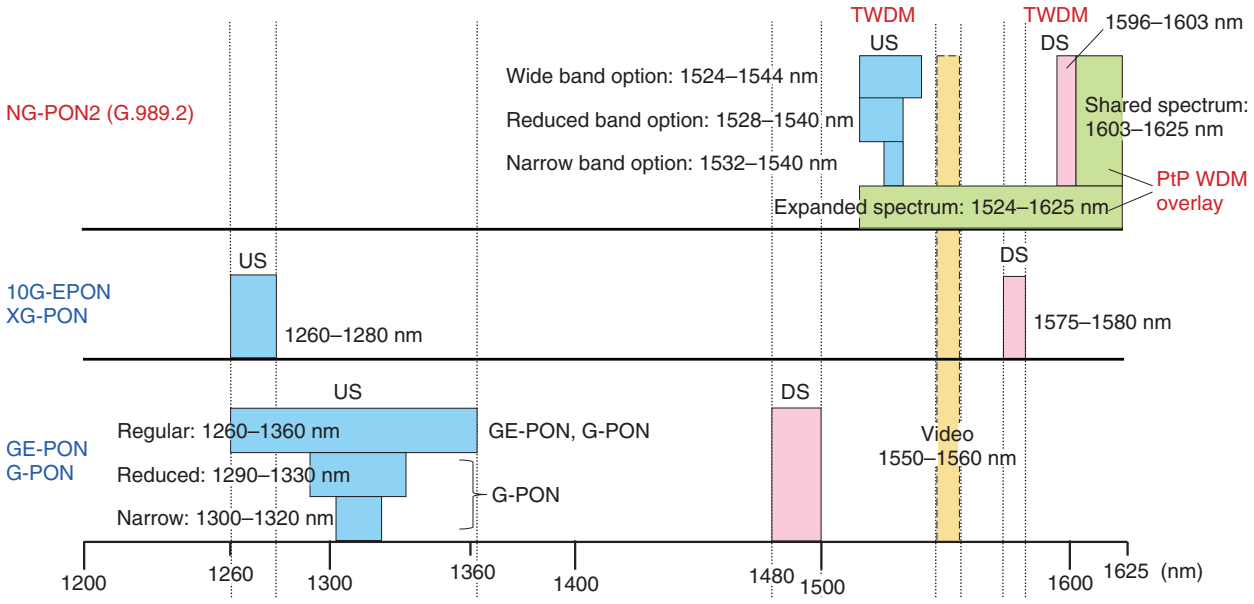

Fig. 2. Wavelength plan for NG-PON2.

rate are 40-Gbit/s symmetry, 10 Gbit/s (US) and 40 Gbit/s (DS), and 10-Gbit/s symmetry. The 40-Gbit/s symmetric capacity is expected to be applicable to business users, and the 10/40-Gbit/s asymmetric capacity to residential users. In G.989.1, the logical split ratio and the transmission distance are specified as 1:256 and 40 km, respectively. However, the optimum capacity, split ratio, and distance may depend on the NG-PON2 system services or applications. Therefore, G.989.1 shows combinations of these to be supported, for example, a 40-Gbit/s optimum capacity (DS), 20-km distance, and 1:64 split ratio.

2.3 Wavelength plans

The NG-PON2 wavelength plan specified in G.989.2 [2] is shown in **Fig. 2**, along with other system plans for comparison. To support co-existence with legacy PON systems that include an RF (radio frequency) video system, G.989.2 specifies 1524–1544 nm (wide band option) and 1596–1603 nm for US and DS, respectively. Two other options are also specified for the US plan: a reduced band option (1528–1540 nm) and a narrow band option (1532–1540 nm). These three options are specified by taking

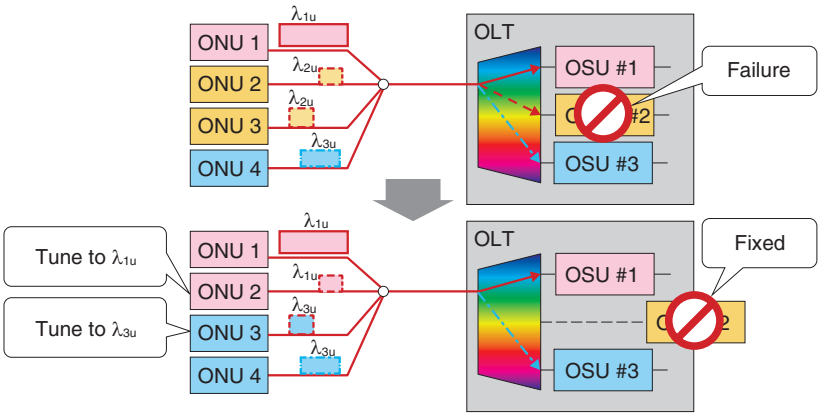

Fig. 3. Example of OLT protection technology using wavelength tuning in ONUs.

into account the wavelength channel spacings (min. 50 GHz, max. 200 GHz) and the tunable components implemented in ONUs. Since the C band is to be used for US in NG-PON2, a dispersion compensation technique would be necessary for a line rate (per wavelength) of 10 Gbit/s. For the wavelength plan for PtP WDM overlay, shared spectrum (1603–1625 nm) usage is specified for co-existence with legacy PONs. Expanded spectrum (1524–1625 nm) usage is also specified for greenfield applications. As mentioned above, G.989.2 specifies the wavelength band for PtP WDM overlay, but it does not specify the number of wavelengths or the wavelength allocation for US and DS.

The contents of G.989.3 are currently being discussed in FSAN and ITU-T. Basically, G.989.3 may be specified on the basis of G.987.3, which is the TC layer specifications for a 10-Gigabit-capable PON, with supplementary contents related to the wavelength assignment protocol.

3. Expected network function by in-service wavelength tuning

In developing colorless ONUs for NG-PON2, it is essential for the ONU transmitter and receiver to have wavelength tunability. Therefore, it is expected that using the in-service wavelength tuning technique in ONUs will enable NG-PON2 systems to have advanced network functions. In addition, cost-effective tunable components are important for practical deployment. The term *in-service tuning* means that an ONU can tune its wavelength during service operation in addition to the ONU's initialization process. An example of an advanced network function called OLT (optical line terminal) protection is illustrated in **Fig. 3**. As shown at the top right, the OLT is composed of three OSUs (optical subscriber units), and different wavelengths are assigned to each one. In a normal state, OSU #1, OSU #2, and OSU #3 communicate with ONU 1 (λ_{1u}), ONU 2 and ONU 3 (λ_{2u}), and ONU 4 (λ_{3u}), respectively. Upon assuming a failure in OSU #2, ONU 2 and ONU 3 immediately tune their wavelengths to maintain communications with other OSUs. As shown at the bottom left, ONU 2 changes its wavelength from λ_{2u} to λ_{1u} in order to be connected to OSU #1, while ONU 3 changes its wavelength from λ_{2u} to λ_{3u} to be connected to OSU #3. One of the advantages of the OLT protection is that ONUs with the in-service tuning technique can easily provide a protection function without additional equipment, such as a backup OLT and an optical switch. Another example of in-service tuning is an OSU sleep function, which is also attractive as a means of reducing power consumption in the OLT. With this function, all ONUs are connected to one (or fewer) OSU(s), and the other OSUs can be forced to sleep. This function is also implemented by using wavelength tuning during service operation. For these advanced functions, a tunable component is required to have a short tuning time in order to avoid any signal frame loss even during a tuning process. On the other hand, such a fast tunable component is not needed if an operator requires wavelength tuning only for ONU initialization. In accordance with the aforementioned background, G.989.2 specifies tuning time classes, which are categorized into class 1 (<10 μs), class 2 (10 μs–25 ms), and class 3 (25 ms–

1 s). The categorization is specified by taking into account the requirements from expected network functions in NG-PON2 and the current technologies of tunable components.

4. Future prospects

This article reviewed NG-PON2 as the latest standardization trend for future optical access networks. In the near future, FSAN and ITU-T will focus on discussing PtP WDM overlay specifications as an amendment to the G.989 series. It is also expected that further evolution of optical access network technologies will be discussed in FSAN and ITU-T.

References

[1] ITU-T Recommendation G.989.1:40-Gigabit-capable passive optical networks (NG-PON2): General requirements.
[2] ITU-T Recommendation G.989.2:40-Gigabit-capable passive optical networks (NG-PON2): Physical media dependent (PMD) layer specifications.

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External Awards

2014 Specially Selected Paper

Winner: Akihiro Miyata, Shunichi Seko, Ryosuke Aoki, Ryo Hashimoto, Tatsuro Ishida, Takashi Isezaki, Masahiro Watanabe, and Masayuki Ihara, NTT Service Evolution Laboratories
Date: January 15, 2015
Organization: Information Processing Society of Japan (IPSJ)

For "An Information Display System Using Digital Signage and Mobile Devices for Multiuser Environments."

We propose a digital signage system by which multiple users can access different content at the same time, and we report the results of a field evaluation. Some existing digital signage systems display multiple content in the beginning, then expand the detail of one type of content over the entire screen in response to requests from users. However, this method has the potential to fill only one user's need since the details of only one content selection occupy the entire screen. Our method enables several users to control her/his pointer to select certain content on the digital signage screen and browse details of the content on the mobile device immediately. This design also allows users to know which content is being watched by many others. The field evaluation (105 subjects) in Kumamoto City proved that our system is easy to use and acceptable for general users.
Published as: A. Miyata, S. Seko, R. Aoki, R. Hashimoto, T. Ishida, T. Isezaki, M. Watanabe, and M. Ihara, "An Information Display System Using a Digital Signage and Mobile Devices for Multiuser Environments," IPSJ Journal, Vol. 56, No. 1, pp. 106–117, January 2015 (in Japanese).

IEICE Electronics Society LQE Young Researchers Award

Winner: Kengo Nozaki, NTT Basic Research Laboratories
Date: December 19, 2014
Organization: Technical Committee on Lasers and Quantum Electronics (LQE), Electronics Society (ES), The Institute of Electronics, Information and Communication Engineers (IEICE)

For "InGaAs Photodetectors Based on Photonic Crystal Waveguide Including Ultrasmall Buried Heterostructure."

Ultrasmall InGaAs photodetectors based on a photonic crystal waveguide with a buried heterostructure (BH) were demonstrated for the first time. A sufficiently high DC (direct current) responsivity of ~1 A/W was achieved for the 3.4-μm-long detector. The dynamic response revealed a 3-dB bandwidth of 6 GHz and a 10-Gb/s eye pattern. These results were thanks to the strong confinement of both photons and carriers in a small BH and will pave the way for unprecedented nano-photodetectors with a high quantum efficiency and small capacitance. Our device potentially has an ultrasmall junction capacitance of much less than 1 fF and may enable us to eliminate electrical amplifiers for future optical receivers and subsequent ultralow-power optical links on a chip.
Published as: K. Nozaki, S. Matsuo, K. Takeda, T. Sato, T. Fujii, E. Kuramochi, and M. Notomi, "InGaAs Nano-photodetectors Based on Photonic Crystal Waveguide Including Ultrasmall Buried Heterostructure," Technical Report of IEICE. OPE, Vol. 113, No. 394, pp. 307–310, January 2014 (in Japanese).

Papers Published in Technical Journals and Conference Proceedings

Synergistic Effect between Image and Sound in 3D Audio/Visual Communication System

H. Takada, M. Date, Y. Kurokawa, Y. Honda, and A. Kojima

Proc. of EVCP 2014 (the 37th European Conference on Visual Perception), p. 36, Belgrade, Serbia, August 2014.

We developed a natural telecommunication system from a realistic spatial composition made with a high-fidelity position representation. This position representation is induced using three-dimentional (3D) imaging and acoustic technology. An image was produced using a stable 3D image generated by an edge detection method in the depth-fused 3D (DFD) visual perception. The sound was produced using acoustic wave field synthesis. The system provides realistic, natural, and comfortable communication by reproducing the distance and position of the image and sound without inconsistency. Using our system, we evaluated how images and sound together influence the relation between vision and hearing. The experiment varied the 3D position and timing of an image and sound, and the results showed that eye movements were pulled in the direction of the sound. In the future, we will develop an innovative hyper-reality communication system in which 3D sounds can guide the gaze-point on 3D images.

Efficient Virtual Network Optimization across Multiple Domains without Revealing Private Information

T. Mano, T. Inoue, D. Ikarashi, K. Hamada, K. Mizutani, and O. Akashi

Proc. of ICCCN 2014 (the 23rd International Conference on Computer Communications and Networks), pp. 694–701, Shanghai, China, August 2014.

Building optimal virtual networks across multiple domains is an essential technology to offer flexible network services. However, existing research is founded on an unrealistic assumption that providers will share their private information including resource costs. Providers, as is well known, never actually do that to remain competitive. Technically, secure multiparty computation, which is a computational technique based on cryptography, can be used to secure optimization, but it is too time-consuming. This paper presents a novel method to optimize virtual networks built over multiple domains, with great efficiency but without revealing any private information. Our method employs secure multi-party computation but only for masking sensitive values; it can optimize virtual networks under limited information without requiring a time-consuming technique. It is solidly based on the theory of optimality and is assured of finding reasonably optimal solutions. Experiments show that our method is fast and optimal in practice even when concealing private information; it finds nearly optimal solutions in just a few minutes for large virtual networks with tens of nodes. This is the first work that can be implemented in practice for building optimal virtual networks across multiple domains.

Convex Object Surface Mapping for Wide-field of View Video Representation

D. Mikami, D. Ochi, and A. Kojima

IEEJ Transactions on Electronics, Information and Systems, Vol. 134, No. 10, pp. 1451–1457, October 2014.

This paper proposes a new video representation method for videos capturing events held in a wide field. Such events can be captured with high resolution thanks to the recent development of video capturing technologies. Despite the development of these technologies, progress in representation methods for wide field-of-view (wide-FOV) video is quite limited. Some methods prioritize ease of overviewing, and forgo detailed observations; other methods put a high priority on detailed observations while sacrificing overviewing. Our work is aimed at simultaneously achieving (1) high visibility for regions of interest (ROIs), (2) easy overviewing, and (3) intuitive comprehension of the relative positions of video objects. Because of these advantages, the proposed method is especially suitable for showing wide-FOV videos on small display devices such as tablets and smartphones. To achieve the abovementioned aims, this paper propose a convex object surface mapping technique that provides high ROI visibility and easy overviewing. In addition, by selecting an elliptic cylinder or an oval as a convex object, the convex object surface mapping enables intuitive comprehension of the relative positions of video objects. The efficacy of the proposed method was verified through objective and subjective experiments.

Low-power Liquid Crystal Driving Technique Based on Capacitors for 1-Pixel Displays

H. Manabe, M. Date, H. Takada, and H. Inamura

Proc. of IDW 2014 (the 21st International Display Workshops), pp. 1343–1346, Niigata, Japan, December 2014.

Liquid crystal displays (LCDs) are suitable as elements for wearable and ubiquitous computing, thanks to their low power consumption. A technique that drives LCDs with lower power is proposed. It harvests charges on the LCD and stores them in an additional capacitor for reuse when the polarity changes. A simulation shows that the technique reduces the charge requirements by up to 50%. An experiment on a prototype shows that the reduction is only partially offset by the overhead of micro-controller operation. Overall, a 30% reduction was achieved with large 1-pixel LCDs. With a small 10 × 10-mm LCD, the overhead matched the reduction and no improvement was measured.

Sodium-ion Insertion/Extraction Properties of Sn-Co Anodes and Na Pre-doped Sn-Co Anodes

Y. Yui, Y. Ono, M. Hayashi, Y. Nemoto, K. Hayashi, K. Asakura, and H. Kitabayashi

Journal of the Electrochemical Society, Vol. 162, No. 2, pp. A3098–A3102, January 2015.

The electrochemical properties of Sn-Co were investigated to show the correlation between the cycle performance and the binders of electrode component materials. Sn-Co electrodes with polyacrylic acid (PAA) exhibited a better cycle property (about 300 mAh/g up to 30 cycles) than those with polyvinylidene difluoride (PVdF). This better cycle property with PAA was due to the slight change in the volume of the electrode that occurred during cycling as revealed by in-situ light microscopy. In addition, Na pre-doping in Sn-Co electrodes improved the average coulombic efficiency from 95.4% to 99.9% at 2–10 cycles.

Recognizing the Use of Portable Electrical Appliances Using Battery-shaped Sensor Node

T. Maekawa, Y. Kishino, Y. Yanagisawa, and Y. Sakurai

IPSJ Journal, Vol. 56, No. 1, pp. 229–238, January 2015 (in Japanese).

This paper proposes a battery-shaped sensor node that can monitor the use of an electrical device into which it is inserted by sensing the electrical current passing through the device. We live surrounded by large numbers of electrical devices and frequently use them in our daily lives, and so we can estimate high-level daily activities by recognizing their use. Therefore, many studies on ubiquitous and wearable sensing devices have attempted to recognize the use of electrical devices by attaching sensor nodes to the devices directly or by attaching multiple sensors to a user. With our node, we can easily monitor the use of an electrical device simply by inserting the node into the battery case of the device. We also propose a method that automatically identifies which electrical device the sensor node is inserted into and recognizes electrical events related to the device by analyzing the current sensor data.

Recognizing the Use of Portable Electrical Appliances Using Hand-worn Coil

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This paper describes the development of a new finger-ring shaped sensor device with a coil of wire for recognizing the use of handheld electrical devices such as digital cameras, cellphones, electric toothbrushes, and hair dryers by sensing time-varying magnetic fields emitted by the devices. Recently, sensing the usage of home electrical devices has emerged as a promising area for activity recognition studies because we can estimate high-level daily activities by recognizing the use of electrical devices that exist ubiquitously in our daily lives. A feature of our approach is that we can recognize the use of electrical devices that are not connected to the home infrastructure without the need to equip them with sensors. We evaluated the performance of our approach by using sensor data obtained from real houses. The

evaluation revealed that our approach can successfully recognize the use of appliances with motors.
