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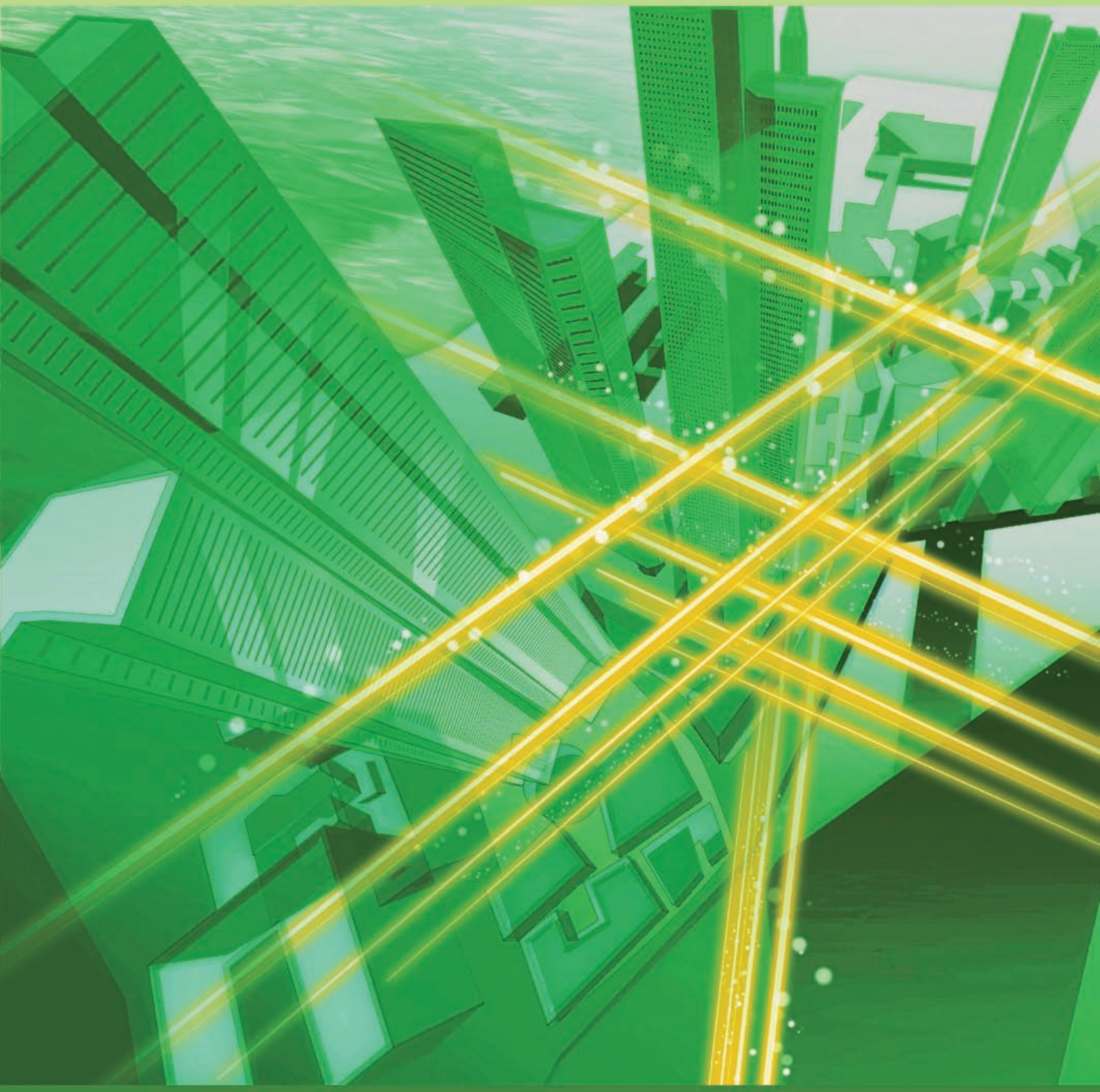

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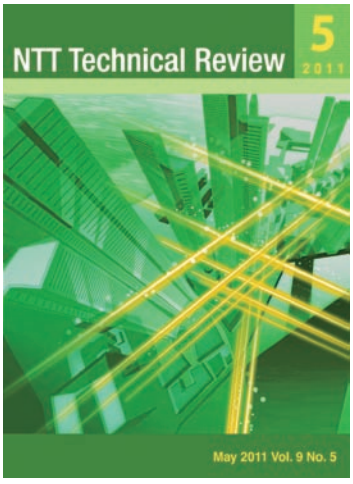

Motivated, Persistent, and Resolute—Taking on the Challenges of New Technologies and Customer Needs with a Broad Perspective

Shinichi Yamada
Executive Vice President & Representative Director, CTO, NTT DATA CORPORATION

Overview

NTT DATA CORPORATION is known for promoting cloud computing technology, which is now attracting considerable attention, and the further globalization of Japanese enterprises. Wondering how top executives at the company with their many years of technical experience view present conditions, we asked Shinichi Yamada, Executive Vice President and Representative Director, to tell us about current business efforts at NTT DATA and the role that the company should play in society.

Combining advanced technologies and extensive knowledge to look ahead to the future

—This year marks the halfway point of NTT DATA's Medium-Term Management Policy. How do you assess its progress?

NTT DATA seeks to become No. 1 in customer satisfaction as a leading-edge innovator in line with its Medium Term Management Policy, which targets sales of 1.5 trillion yen in fiscal year 2012, and the goal of becoming one of the top-five global IT (information technology) service companies. In this regard, our efforts are achieving results, as reflected by an increase in overseas sales, but if we turn our attention to the Japanese market, I feel that the IT industry itself is slightly contracting as customers become more concerned with cost reductions. I don't think that we can simply blame the economy for our problems here, but it is true that new IT investment by customers has not yet recovered in Japan and that even at NTT DATA we are doing our best to just maintain current business levels. Sometimes it feels like we will never get back to a growth trend, but despite these difficulties, we are getting some results thanks to the hard work of our employees.

—What areas do you feel are contracting?

One good example is hardware, where technical innovation is raising performance and lowering prices. This trend toward commoditization is also happening to networks, where prices likewise seem to be dropping every year. In the past, network scale would inflate every time a system was upgraded, which drove up sales. Nowadays, however, these networks are simply being maintained, which results in a contracting environment.

To give another example, NTT DATA has also been involved in software development, and the developers here have been Japanese engineers. However, once Chinese engineers enter this field, we can expect prices to collapse the same as they did in the manufacturing industry. This lack of IT investment and sluggish market expansion in Japan is making for severe price competition, and even when orders are received, it is not uncommon for them to come with very harsh conditions.

Expanding sales under these conditions is therefore difficult to say the least, but nevertheless I want to set the targets and take on the challenges of overcoming these difficulties.

—Is there any approach that could lead to a breakthrough?

Yes, of course, and we are actually working on this from many angles. One way is to lower costs such as by expanding offshore development. And it is also important that we not only convert our customers' businesses to IT but also help them to expand their businesses through optimal use of IT. In other words, it is vital that we create added value and new markets. Key tools here are cloud computing, machine-to-machine (M2M) communication, and business intelligence from a technical viewpoint and outsourcing from a business-model viewpoint.

In terms of organization, robotics and business intelligence are being pursued by the Robotics Integration Promotion Office and Business Intelligence Promotion Center, respectively, set up in NTT DATA's Research and Development Headquarters. Today, smart grids and structure monitoring are attracting attention as social infrastructures making use of information and communication technology (ICT). We should think of robotics as a technology that is essential to the construction of these social infrastructures since it can be used to collect and analyze all kinds of information from sensor networks and feed the analysis results back to the real world. In other words, robotics can merge cyber space and real space. For example, it can be used to monitor traffic and control signals and measure structural fatigue in bridges in real time and establish a repair plan. We are working to open up this field of controlling the real world through ICT. Of increasing importance here is business intelligence as a means of analyzing and utilizing the huge amount of information obtained from such systems and providing useful output.

I am getting good reactions to the use of robotics,

and our employees keenly feel that we must do something. This also holds true for M2M. However, in Japan, customers often view ICT only in terms of cost, without realizing that it can be a valuable tool for expanding business and even for changing society. In the past, ICT was often approached in the context of "How can we develop it?" but from here on, I believe that we must think of it in the context of "How can we use it to best effect?"

—What are your thoughts on cloud computing?

As you know, the NTT Group is a service creation enterprise, and it is well aware that the cloud is a crucial factor in the future expansion of services.

NTT was originally involved in services that provide access to mainframe computers over the network (DRESS/DEMOS), even as far back as the Nippon Telegraph and Telephone Public Corporation era, which ended with its privatization in 1985. These services themselves contracted as technical innovation brought the cost and size of computers down, but NTT has nevertheless continued to provide shared-use systems to financial institutions. What I'm trying to say here is that, while the technology itself may change, our experience with the cloud model runs deep. On the other hand, the services that NTT DATA has long been providing have been directed toward particular groups, and we have yet to tackle cloud services for the general public as provided by Amazon.

—As you have been involved with the cloud model longer than most, you probably have some visions.

Yes, I think our experiences and know-how are very

valuable for NTT DATA's efforts to expand its business in cloud computing. One idea is a cloud directed toward a group of enterprises with common interests as in the case of a supply chain. In short, we envision clouds directed toward specific communities. I believe that coordinating the needs of many stakeholders and incorporating them in services is a particular specialty of NTT DATA.

Another idea is to convert the assets of the NTT DATA Group into a cloud platform to give us a competitive advantage. For example, NTT DATA Intramart is the No. 1 workflow platform in Japan; this was achieved through tie-ups with business application vendors and sales partners. In this way, NTT DATA provides a space called an Intramart cloud, and by having our partners develop a variety of services and applications, we can achieve a win-win-win relationship among NTT DATA, partners, and users. And in the mainframe field, we are also converting NTT DATA's assets into a cloud. Migration to a cloud can be promoted by providing a base called a COBOL* cloud and preparing a migration path from the legacy system to the cloud platform. In addition to the above, NTT DATA was quick to make use of Hadoop open source software for distributed processing of large quantities of data. This software framework is attracting interest in the business intelligence field as a means of providing new added value to a customer's business, and we are providing it as a cloud service. From the viewpoint of the NTT Group, however, the *cloud* has an additional meaning. The main role of ICT so far has been to make the processing of business forms and exchanges with customers more efficient, but there is now a big movement toward using ICT to achieve a better society in a variety of areas such as medicine, education, social welfare, and traffic control in the manner of, for example, cyber-physical systems.

From here on, as this role of ICT rapidly expands, it will become increasingly important to make application creation more efficient and make application creation mechanisms easier to access. The cloud looks to become a key mechanism for creating these new applications. We have also been saying to our colleagues at NTT Laboratories in strategy meetings held over the last few years that cloud computing will become increasingly important in the years to come, and we are beginning to collaborate with them in this regard.

—Please tell us about NTT DATA's approach to OSS.

There are three reasons for our involvement in open source software (OSS).

The first reason, of course, is lower costs. Although hardware performance is rising as the cost of hardware is dropping, as I mentioned earlier, the cost of software is not dropping all that much. Using OSS to construct software products can reduce costs below those of using commercially available software. This license-free advantage takes on even more value in the case of cloud computing. Reducing costs, however, is not the main reason for using OSS.

The second and more important reason is to avoid vendor lock-in. From the start, NTT DATA has advocated a multi-vendor approach and has been praised for doing so. Here, the use of OSS is indispensable to a truly vendor-free environment. At the same time, we must set up our own system to support the analysis and correction of software faults, at least for major OSS products. Doing so will provide a number of advantages, including the long-term, reliable use of a system not only for us but also for customers and lower costs over the system's lifetime. We have been working with the NTT Holding Company at the NTT Open Source Software Center on this, but I would like to expand the scope of this collaboration.

The third reason, which is actually more of a

* COBOL (common business-oriented language) is one of the oldest programming languages, but it is still widely used.

secondary effect, is the training provided to NTT DATA engineers by reading and understanding the source code themselves. The most important asset (resource) in an IT firm is its people. Open source software represents the fruit of the skills and intellect of software developers around the world, which is why it can progress so rapidly. Catching up in this way or making a contribution to OSS is more useful than anything else for improving the skills of our software engineers.

Looking forward, I would like to promote collaboration in OSS use between NTT DATA itself and overseas companies in the NTT DATA Group.

Exploiting our strengths and advancing together

—How is NTT DATA approaching globalization?

As I touched upon earlier, overseas sales have reached the 100-billion-yen level mainly through mergers and acquisitions. The NTT DATA Group already has 20,000 employees working overseas. The number of global projects is actually increasing with a focus on Japanese customers, and the opportunities for providing consultations on global support are increasing steadily.

To meet our customers' expectations in this environment, I believe that we must standardize and unify the work processes and quality level among the group companies. Of course, each company has its particular forte and it would not be beneficial to overdo this and prune off its strong points. Nevertheless, it is important to share the NTT DATA Way, as both implicit and formal knowledge, among the companies so that a customer whose business spans a number of countries can feel at ease entrusting its work to the NTT DATA Group.

My responsibilities also include offshore development companies. Our emphasis up to now has been the provision of offshore services to Japanese firms, but we now need to set up a mechanism for global delivery that can perform development work at optimal locations throughout the world.

There is also a need to create solutions and products that can be sold on a global basis. In technology development, we have begun to share information about the skills, solutions, and products of each group company and to pursue global research and development (R&D). The aim here is to consolidate the ideas coming out of the various companies so that we can move forward as the NTT DATA Group. Our global R&D promotional base will be moving to North America (Silicon Valley) next fiscal year. Of course, we will continue to cooperate with NTT Laboratories of the NTT Holding Company more than ever, but we will move forward while maintaining a balance between both approaches to R&D.

Incidentally, we have begun research in collaboration with NTT Laboratories on a high-accuracy multilingual machine translation system for automatically translating Japanese manuals and design specifications into English, Chinese, and other languages.

Needless to say, it is important that we connect these new endeavors to results. Although we are also tackling R&D with a view to the future, obtaining results will be difficult unless we reassess our R&D targets every year or even every quarter. In a world of constant change, I believe that it is more important to accurately assess what is right in front of our eyes than to look three years into the future.

Seeing the big picture

—Under these circumstances, it appears that you need the ability to change systems in response to changes in the business world as well as foresight in research.

At present, no one really knows whether the projects that we are undertaking are the right projects, so honestly speaking, it is extremely difficult to say what viewpoint or approach is the best.

The history of IT is said to be in its infancy, but it's already been several decades since the mainframe era, and technical innovations keep on coming. In the past, NTT conducted multimedia experiments on an Information Network System (INS), video-on-demand, and other new systems; today, we have reached the point where optical fiber can reach homes

and TV can be viewed over optical fiber cables. Trials such as these were carried out not only in Japan but also overseas. It is said that life goes in cycles, and trends like these can be found just about anywhere, so if we study past cases, I think we can surmise that the future will evolve in a similar manner and make predictions to some extent.

In this way, we pursue various types of business while pondering whether we fully understand what the customer is thinking and whether the test phases for new products and services are advancing efficiently. To continue growing, NTT DATA must gain a foothold in new markets while efficiently constructing and operating systems in the current market. Both are essential and achieving a balance between the two is important.

However, it is not always possible to move forward with good balance between these two requirements; there will sometimes be a bias toward one or the other, but it may not hurt to go back and forth between these two modes of action. What is important here is not giving up!

Moreover, advancing together as a team requires frequent discussion. When I served as manager of the Research and Development Headquarters, I made an effort to set aside time to talk to employees. Everyone would like to do the things they want to do, but that is not always possible. That's why talk is crucial to objectively perceive, clarify, and share the why, when, and what of work. In research in particular, one tends to think in terms of what it is that one personally wants to accomplish, but aligning oneself with other people can broaden one's horizons and lead to great results. About fifteen years ago, I had the opportunity to spend two years in Silicon Valley in California, and I noticed that the people I encountered there behaved much in this way. They conducted joint research with the people that needed technology, that is, with customers, and solved problems together, which I think is a great shortcut to results. *Open innovation* is a trendy phrase nowadays, but I would like to see researchers approach their work in this way.

Interviewee profile

■ Career highlights

Shinichi Yamada entered Nippon Telegraph and Telephone Public Corporation (now NTT) in 1977. Since the founding of NTT DATA CORPORATION in 1988 as a spin-off company, he has held various positions including Director of Business Development Sector (2004), Director and Senior Vice President of the System Platforms Sector (2005), and Executive Vice President of the System Platforms Sector and Research and Development Headquarters (2007). He has served as Executive Vice President, Representative Director, and CTO of NTT DATA CORPORATION and President of the Solutions & Technologies Company since June 2009.

Creating a Vigorous Society and a Richer Future with ICT—Innovations in Lifestyle and Business

Coordinator:

– *Waichi Sekiguchi, Editorial Writer, Nikkei Inc.* [1]

Panelists:

– *Tetsuro Tomita, Executive Vice President and Director General, Corporate Planning Headquarters, East Japan Railway Company*[2]
– *Kaori Sasaki, President & CEO, ewoman, Inc.* [3]
– *Noritaka Uji, Representative Director and Senior Executive Vice President, CTO, and CIO, NTT*

Abstract

During the NTT R&D Forum 2011, a panel discussion entitled "Creating a Vigorous Society and a Richer Future with ICT" was held (ICT: information and communications technology). Noritaka Uji, Senior Executive Vice President, participated as a panelist. This article reports on the discussion between the coordinator and panelists.

1. Introduction

Sekiguchi: I believe that we are all fully aware of how the Internet and new information technology called social media, such as Twitter and Facebook, gave impetus to the current movements toward democracy that are taking place in certain Middle Eastern countries. The challenge we face today is how to make the most of this new technology.

Today, we intend to discuss that challenge under the theme of "Creating a Vigorous Society and a Richer Future with ICT" (ICT: information and communications technology). We are fortunate to have three panelists who are eminently qualified to discuss this topic. We will start with a brief presentation by each panelist and then move on to a panel discussion.

2. Presentations

ICT as a powerful driving force for dramatic evolution of enterprises

Tomita: The railway industry has long been a leading-edge ICT industry. I'm sure you're familiar with railway signals. They show whether there is a train ahead of you or whether it is safe to proceed. This is a core technology for ensuring safety. It is the culmination of a progression of painstaking efforts that have been made since the inception of rail transport in Japan, in 1872. This is truly an ICT.

The latest example of ICT use in railway operations is an IC (integrated circuit) ticket called Suica. [4] To date, 33 million Suica cards have been issued. Of these, 31 million can also be used as electronic

Waichi Sekiguchi, Coordinator

Tetsuro Tomita, Panelist

Kaori Sasaki, Panelist

Noritaka Uji, Panelist

money, and some 2.3 million e-money transactions take place every day. To ensure further development of Suica, we believe that it is important to achieve interoperability with the IC tickets issued by other railway companies throughout Japan (**Fig. 1**). We are also planning to expand Mobile Suica services, which enable Suica functions to be used with a mobile phone, by the summer of 2011 with a view to linking with Android smartphones that are compatible with Osaifu-Ketai (an electronic wallet scheme for mobile phones [5]) so that payment for Internet shopping can be done using Suica. The linking of Suica with Android smartphones will enhance Suica's capability as a convenient payment facility for online shoppers.

We are considering exploiting ICT to create a railway system that does not rely on signals. Currently, a train's location is identified by sending an electric current along the rails to create a track circuit and measuring the current in that circuit. Signals are then controlled on the basis of the identified train locations, and train operation relies on those signals. It will soon be possible to use wireless technology, instead of track circuits, to determine train locations. Instructions about the running speed and direction of each train can be sent using wireless communication. This will make it possible to dramatically reduce both facilities on the ground and maintenance costs. The energy consumption and overall costs of operating the railway system can also be reduced and safety will probably be further enhanced. We want to achieve a breakthrough in railway operation by using such technologies.

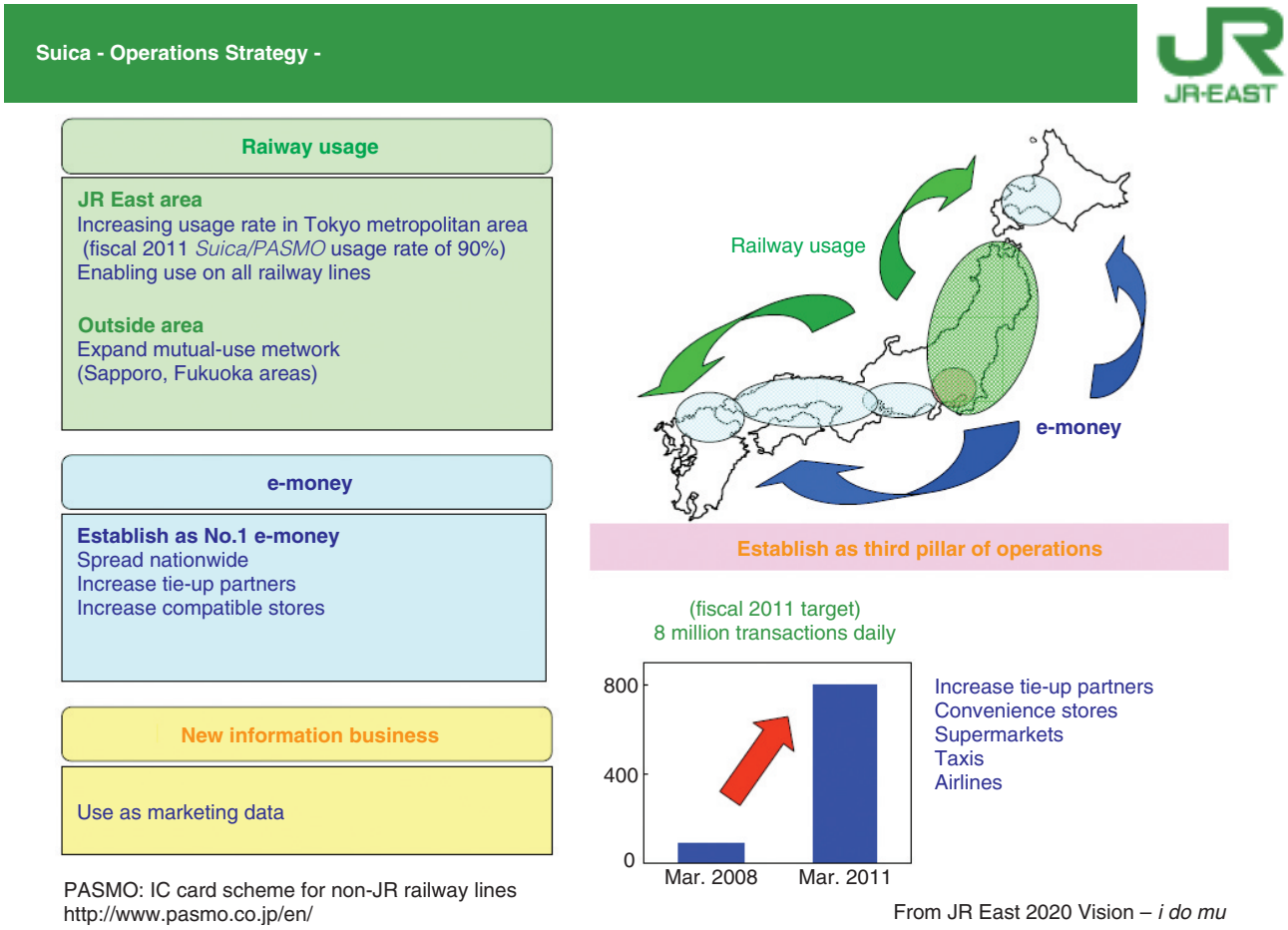

Fig. 1. Suica—Operations strategy.

Opportunities for people to learn various viewpoints

Sasaki: In 2000, we created a website called *ewoman*, which serves as an information hub. We believe that ICT is not just about convenience but about helping people to develop. The Internet is more than a tool for disseminating information; it's a tool for building a knowledge database. Users can search the database for information and consider how to make appropriate use of the obtained information. For example, the ewoman site provides *ewoman's online roundtable discussion*. This is not a bulletin board for posting information; there is a chairperson to coordinate a four-day discussion in each round table, and the resulting information is rearranged for readers. Users can access past discussions in order to learn about the subject matter discussed from various perspectives. To make the database really useful for readers, we have introduced what we call the *I-statement* rule. Participants must limit their statements to matters that directly concern them. In other words, instead of presenting general statements, they are required to discuss their own specific views and experiences. The intention is to eliminate hearsay and generalized discussions and to enable readers to understand a range of perspectives. I believe that forums of this type will be necessary in the coming age of diversity. We can create new value by integrating technology and knowledge.

What can we do with ICT? How should we use it? It is important that ICT goes beyond merely providing convenience; it must enable people to learn and grow. To create a true knowledge database, it is important to ensure interactivity and encourage participants to think in the first person. It is not enough that people can access the database. The database should enable them to broaden their options, make life more fulfilling, and enhance their sense of ethics.

ICT supports socio-economic growth, resolution of social problems, and pursuit of fulfilling lives

Uji: In this forum, a variety of ways of exploiting the latest technology are being exhibited. Let me talk about our fundamental approach to ICT.

We think that ICT is a cord linking different segments of society, industries, and organizations. For example, in an enterprise, ICT links different departments, such as sales, development, and general affairs. It also links different industries, or different ministries and agencies of the national government. It plays the role of holding things together. Linking different segments can enhance productivity and expedite transactions in business, for example. As we face various social issues, such as the declining birthrate and aging society, we urgently need to make full use of ICT in the fields of medical care, education, and administrative services in order to enhance the quality of these services. In this way, ICT can contribute to economic growth and the resolution of social problems. Another role for ICT is making possible a variety of lifestyles. We believe that ICT can support fulfilling lives by making it possible to strengthen the bonds within families and within communities (**Fig. 2**).

The latest keywords these days are *clouds* and *smartphones*. For example, studies are underway on a collaboration model whereby video coverage of work being conducted in the field can be recorded on a smartphone and sent to a remote office, which can then give visually oriented instructions to workers in the field in real time. This could dramatically enhance work efficiency. A new mechanism can be developed whereby a cloud manages smartphones in such a way that losing your phone is not longer a major inconvenience. The previous panelist talked about a knowledge database. I believe that the accumulation of large volumes of data in clouds can lead to the creation of new value for society.

Need for an ICT policy that emphasizes better use of information

Sekiguchi: As mentioned by one of our panelists, it will become common for terminals, such as tablet terminals, to be connected to clouds. The user will store his or her data in clouds and access the clouds to retrieve data via any available terminal. The advent of clouds and smartphones is making such a lifestyle possible. The time is coming when data clouds will be provided as a utility service like electricity, gas, and water. Faced with this prospect, people are expressing concern about how to ensure security and privacy. We need to ask ourselves how we should deal with these issues.

If we pause to look around, we can observe many changes taking place in the world, and we realize in what respects Japan is lagging behind. I think that there are three stumbling blocks that may impair our ability to achieve innovation.

The first of these is what some Japanese refer to as the *Galapagosization* of Japan, meaning that certain technologies used in Japan are unique, like the species whose habitat is confined to the Galapagos Islands, so they can never become global standards. It is true that Japan has had many good technologies. However, that is meaningless unless they are actually used. If our technologies are not well accepted globally, we will never get past a sense of being somewhat isolated.

The second stumbling block is people's general misgivings regarding the protection of personal information. To fully exploit information technology for the benefit of people's lives, we must have a common infrastructure. The idea of assigning an ID (identity number) to every Japanese citizen has never advanced beyond the discussion stage. I believe that Japan urgently needs to put this idea into practice.

Third is the tendency to demand excessive protection of copyrights. It is, of course, important to protect intellectual property rights, but I believe that we now need to adopt an ICT policy that places more emphasis on enabling people to better use copyrighted information than on rigorously protecting copyrights.

3. Discussion

How to promote globalization of Japan's technologies and services

Sekiguchi: At this point, I would like to ask the panelists to discuss what type of information society we should aim at creating. Although I think that Suica is an excellent technology, when I go abroad, I find completely different systems in use. Suica would seem to be one of those Galapagos species. Do you have a strategy for expanding its application overseas and, if so, could you share it with us?

Tomita: Now that Suica is well accepted in Japan, we are exploring ways to expand its use overseas. However, there are a couple of issues to consider.

The first is the data transmission speed. Commuters in Japan walk very fast. They pass through a ticket gate at about 1.5 m/s, probably the fastest rate in the world. Therefore, the Suica system must also operate

Fig. 2. NTT's understanding of the role of ICT.

very fast. It both reads and writes data in less than 200 ms. In Europe and the USA, such high-speed operation would be regarded as over-specification.

The second issue is reliability. Suica ensures system reliability by storing data in three different places—in the central equipment, in the ticket gate machine, and in the Suica card—so that any lost data can be found in a backup. Potential customers overseas regard such an intensive backup system as unnecessary.

Even where we have an excellent technology in Japan, when we attempt to transfer it to another country, we need to examine whether or not the technology is appropriate for the specific situation of the target country. I often feel that we should not be complacent about having an excellent system.

Sekiguchi: I think that we should make greater efforts to have Japanese technology accepted globally as a de facto standard. What do you think?

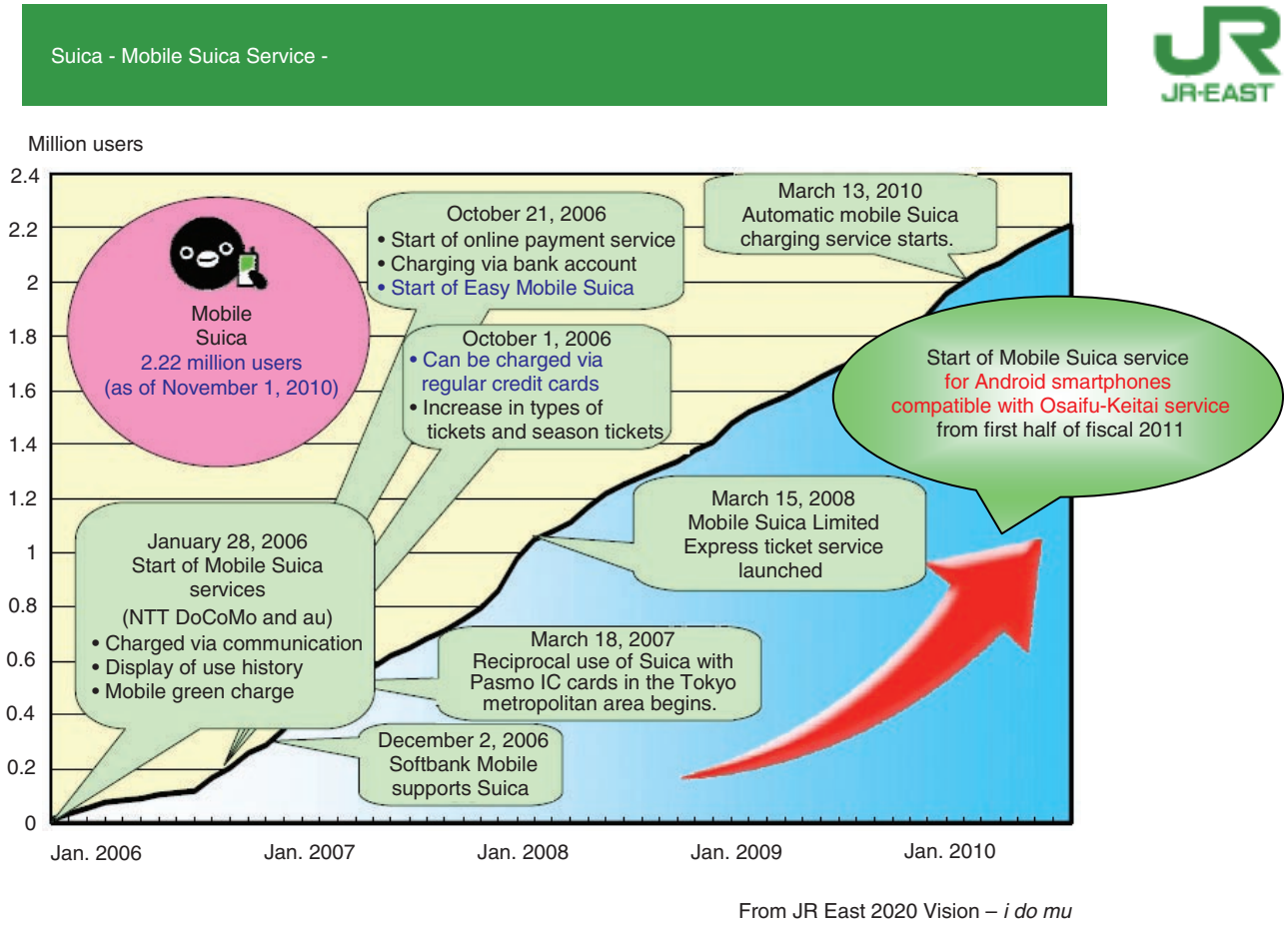

Fig. 3. Suica—Mobile Suica Service.

Tomita: We should not be the only ones to bear the burden of those efforts. We cannot make any progress in that direction unless the whole country becomes involved in thinking about how we should develop smartcards and the systems that use them. Unfortunately, there seems to be a gap in perception between Japan and other countries about the value of the convenience provided by smartcards. How to bridge that gap is another difficult issue. However, I believe that, by linking the Suica system with smartphones (**Fig. 3**), you can develop cards and terminals that are suitably tuned to individual users' needs. Provision of such sophisticated services can create new value.

Uji: I think it is great that Suica is built into a mobile terminal and enables user identification to be used in setting up communication. Initially, a single smartcard cost about 10,000 yen. Over time, the price has dropped dramatically. That is also great. The smartcard used to authenticate a cigarette vending machine user has fewer functions than other smartcards because it was paramount to reduce the price of this type of card. The capabilities built into a smartcard should be closely linked to how and where it is to be used. It is necessary to consider whether there is greater demand for less expensive cards or for highly secure cards. A highly sophisticated card cannot be a panacea for all needs.

Sasaki: I recall a conversation that I had with some local people during a recent visit to Switzerland. I showed them how my mobile phone receives information about what time my son passed through which exit of which station because he used his student commuter pass smartcard at a ticket gate. Their reactions surprised me. "What are you doing?" "That's wrong." When I raised the issue of children's safety in public places, they responded: "Your way of thinking is wrong." We then had a lengthy discussion.

This demonstrates that service needs vary depend-

ing on the specific environment and sense of values. What is required of a system can vary depending on whether you are targeting only the Japanese domestic market or aiming for global market acceptance.

Sekiguchi: I agree that, while technology may be global in nature, the services that people want will have a very local character. So, it would seem that the question we need to consider is how to intelligently balance the global and local aspects of a particular technological offering.

Use of social media in enterprises

Sekiguchi: As I noted at the outset, we are witnessing a surge in the use of social media. However, in Japan, enterprises in particular seem to take these media channels with a grain of salt. What's your perception?

Sasaki: I think that the potential power of individuals being able to speak out is clearly an extraordinary development, as evidenced by events in the Middle East. Previously, a person's opinion travelled slowly. Today, individuals access the Internet to post a variety of information from wherever they happen to be. Social network services (SNSs) on the Internet, for example, have developed into powerful tools. What is important in this Internet era is that individuals have a sense of ethics, a sense of responsibility in expressing their opinions, information literacy, and the ability to use and combine information.

Japanese enterprises are not even ready to experiment with SNSs. They are still watching these systems from a distance with suspicious eyes. Some enterprises are reluctant to set up inquiry links on their websites. The moment some of them did, they received a flood of complaints and had to shut down the links because they could not deal with the volume. I suspect that, if enterprises feel threatened by the notion of setting up inquiry links, they simply wouldn't know what to do if their employees were to begin speaking out via an SNS.

What enterprises should do is enhance employee satisfaction and train their people in public relations and communications so that they can serve as company spokespersons. Instead of restricting their employees' opportunities to speak out, enterprises would do better and enjoy enhanced brand perception if they were to train their employees to become good publicists.

Sekiguchi: A case in point is what happens when a train service is resumed after a period of temporary service suspension. It is Twitter users who transmit, ahead of all other media, the news that the trains are running again. Leaving aside the matter of whether or not such information is accurate, social media transmit information earlier than any official service. How does JR East deal with this issue?

Tomita: This is a major issue. In principle, information about an accident or delay should be disseminated through the mass media. If we do not notify reporters in the mainstream press first, our good relations with them will suffer. So, we must be careful when issuing information. Although the idea you mention is one possible way of sending information, it involves a difficult problem.

It is true that social media can transmit information faster. They can be effective tools. JR East has some 60,000 employees. A social network could be effective for mutual communication and exchange of information between employees.

Sekiguchi: What is the position of the ICT service provider on this issue?

Uji: Although we are a provider of ICT services, we are also users of these services. So, let me speak from the user perspective. NTT DATA has a web page for disseminating internal information. It also operates an internal social media mechanism through which employees can communicate freely across different departments and across different ranks. The mechanism is used effectively to communicate employees' opinions about understanding user needs and to provide mutual support.

NTT Laboratories also has an SNS called *chie-nowa*, which operates across the boundaries between organizations within the Laboratories. It is very useful for exchanging technical information and unearthing new ideas.

In addition, employees in the Public Relations Department of NTT Holding Company are tweeting for the public. This is highly rated as a new approach to public relations.

The NTT Group has some 200,000 employees and the number of overseas employees will increase. We will need to study, on the fly, how to use social networks while also seeking to ensure compliance.

How to deal with privacy and security in the age of high utilization of information

Sekiguchi: The technology research company Gartner conducts an annual survey of chief information officers (CIOs). It asks them to define the most important issue for their respective companies. Responses naturally include such considerations as cost reduction, improved efficiency in the supply chain, and quick decision-making, but the one that is

attracting growing attention is greater use of social media. CIOs are increasingly concerned about how to facilitate information exchange with customers, employees, and other stakeholders.

However, if we look at what is happening in the Middle East and at the WikiLeaks story, we can see that efforts to facilitate communication are, in a way, rebounding on those who have promoted such efforts. Even though you might have completely protected yourself against external attacks, you may not have taken sufficient measures to prevent information leakage from the inside. While the sharing of information is important, I think it is necessary to control information wisely. What do you think?

Tomita: That is an issue that we need to address seriously. JR East currently has some 100 companies in its group. Each company has its own website and its own system for exchanging information over the Internet. We have begun to check the levels of security and information management of these systems. We are exhaustively checking whether adequate defensive steps are being taken to protect servers and terminals against not only attacks from outside the company but also information leakage from the inside and whether or not logs are kept.

Sekiguchi: While system developers need to take this issue seriously, I think that each employee or each individual should also ensure that he or she takes measures to prevent his/her personal information from being disclosed in an undesirable manner.

Sasaki: When I read the blogs or twitters of well-known figures, I am puzzled when they write "I'm on the platform of such and such station" or "I am going into the restaurant of such and such hotel." Are they inviting people to come over or informing people that here is a chance to attack them? I am always careful to avoid risk when I tweet.

Today, with so many people able to post information and access each other's information, it is necessary to enhance users' behavior and their ability to judge what is confidential and whom they need to protect in addition to implementing advanced security technology. Risk management and security education for users is just as important as security technology.

Security policy that considers active utilization of information

Sekiguchi: Japanese companies tend to treat all kinds of information as confidential or classified. This results in a situation where you can no longer tell which information really is sensitive.

Uji: The higher the barrier to information access, the harder it is to make good use of that information and ensure that it is widely used. On the other hand, if access to information is not controlled at all, there is a risk of information leakage. I think that it is the role of enterprise security policies to clarify these issues. We have established a security policy and provided tools and a mechanism for implementing the policy, such as requiring employees to hold their employee ID cards close to a contactless card reader, which reads the IC in the card, when they start up their personal computers in the office and classifying information in terms of the required security level. While we undertake research and development of technologies to enhance information security, our recognition that it is important to classify information has led to establishment of the security policy.

While it is necessary to protect the confidentiality of information, it is also important to promote active use of information. For example, an NTT Group company provides an online question answering service called *Oshiete, goo!*. When someone submits a question on this website, he or she gets answers. As people discover the convenience of this service, the number of users is increasing and more and more information is being accumulated, creating a virtuous cycle. This is indeed a database of knowledge. I think that the provision of such a service represents the cloud concept in its broadest sense. The time has come for us to benefit from such convenient services. Technology has come a long way.

Sekiguchi: So, the two mainstays are construction of watertight systems and establishment of a watertight security policy. Even so, problems can occur. There can be pitfalls anywhere in the information society. This is a risk management issue. Given the security and privacy issues that we are faced with, how can we build a trouble-free system?

Uji: I believe that mechanisms in which appropriate security and privacy measures are implemented will increasingly find their ways into enterprises and everyday living. For example, service characteristics required in the medical, educational, and administrative fields vary from service to service. Some services can be provided on a best-effort basis. Some require rigorous authentication of users. Some cannot tolerate temporary service interruption. The NTT Group has declared that it will provide clouds that serve as safe and secure social infrastructures. In this respect, I believe that we must broaden their utilization in services of the Next Generation Network (NGN), which combines the convenience of the Internet with

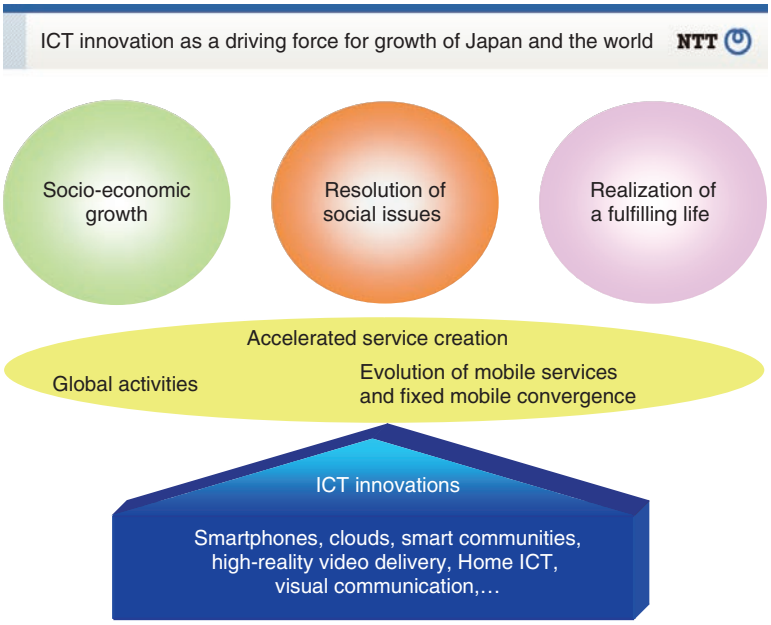

Fig. 4. ICT innovation as a driving force for growth of Japan and the world.

the reliability of the telephone network.

Need for interpreters to facilitate communication

Sasaki: I think that we now need interpreters to facilitate communication between those who know systems and those who know business processes. While we want to hear feedback from users, we sometimes fail to understand what they are telling us.

Here's an interesting anecdote. When female users said that they wanted a *cuter product*, the developer assumed that they meant the product should be pink. In fact, to the women, *something cute* meant a product with rounded edges. Enterprises need to recognize that proper interpretation is very important.

Now that it's so easy for individuals to post information, as in the case of SNSs, media training for consumers is also important. Our company provides media training to enterprise executives. It will also become necessary to provide media training to employees so that they can communicate their business processes and advanced technologies in a manner that users find easy to understand and so that they can determine for themselves what information is confidential.

Sekiguchi: My daughter tends to describe almost anything she likes as cute. I guess I need to be more careful to determine whether she means the shape or the color. This anecdote could apply to how we should write and read purchase specifications. It is important to understand what the users really mean.

Future ICT innovation

Sekiguchi: What measures should enterprises take in the near future?

Tomita: I think that the safety levels of systems in Japan are relatively high because we have learned from the experiences of various incidents. In the railway world, safety means that trains stop immediately whenever a problem occurs. Railway operation is a fail-safe system. The system design is aimed at ensuring safety without fail. However, since even this level of safety does not necessarily satisfy our customers, we need to aim higher.

Corporate executives need to further raise their ICT literacy. There have been cases where good proposals were not adopted by corporate executives simply because they were poorly presented. I want ICT engineers to explain their technologies in a more easily understandable manner.

Uji: When a new service is to be introduced, those who actually use it, those who know the required business processes, and those who develop the service need to collaborate with each other. System providers should not stop at explaining what can be done or what a thing means technically; they need to

continue to exchange opinions with actual users.

Right now, broadband networks are ready to be used by 99% of the Japanese population, but Japan is lagging behind internationally in active utilization of ICT.

Through ICT innovations, including the creation of clouds and other services, fixed mobile convergence, and global ICT activities, we are aiming to help achieve socio-economic growth, resolve social problems, and realize fulfilling lives (**Fig. 4**).

Sekiguchi: Today, we have heard some valuable insights from our three panelists regarding our stance on ICT, policy issues, system design issues, and operational issues. The world of ICT is steadily advancing, and information innovations are constantly emerging. There is no such thing as enough. We have learned that there is virtually no end to the security and other measures we need to take because new technologies always arise. I hope that our audience has found today's discussions useful. In declaring the session closed, I would ask the audience to give our three distinguished panelists a big round of applause.

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[5] Osaifu-Keitai.
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Profiles of the coordinator and panelists

■ Waichi Sekiguchi

Editorial Writer, Nikkei Inc. [1]

Serves as a member of the ICT Policy Task Force of the Ministry of Internal Affairs and Communications and also sits on the Council on Computerization of School Education of the Ministry of Education, Culture, Sports, Science and Technology.

■ Tetsuro Tomita

Executive Vice President and Director General of the Corporate Planning Headquarters, East Japan Railway Company [2]

Previous positions include Manager of the General Corporate Planning Headquarters and Director of the Life-style Business Development Headquarters.

■ Kaori Sasaki

President & CEO, ewoman, Inc. [3]

Serves as a member of the Government's IT Strategy Headquarters and is also on the Legislative Council of the Ministry of Justice.

R&D toward "Access Networks—Building Trust, Connecting People"

Yukio Akiyama†

Abstract

Researchers at NTT Access Network Service Systems Laboratories are engaged in research and development of the access network under the theme of building trust and connecting people. This article describes the current state of the access network and associated issues and introduces the five main approaches at NTT Access Network Service Systems Laboratories. The Feature Articles in this month's issue are based on lectures given at the NTT Tsukuba Forum 2010 workshop held on October 21, 2010.

1. R&D at NTT Access Network Service Systems Laboratories

At NTT Access Network Service Systems Laboratories, we are involved in the following four fields of research and development (R&D):

(1) Optical access network technology to provide high-speed, diverse, and inexpensive communication services by optical access
(2) Wireless access technology to provide high-speed, broadband, and seamless communication services to diverse locations and areas by wireless access
(3) Media network technology to achieve an economical access network, rapid service provision, and efficient operation of facilities
(4) Infrastructure technology to achieve long-lasting and efficient use of primary communication facilities such as conduits and manholes

In short, NTT Access Network Service Systems Laboratories deals with a wide array of technologies for making connections from NTT central offices to users' households.

† NTT Access Network Service Systems Laboratories
Yokosuka-shi, 239-0847 Japan

2. Trends surrounding the access system

As of the end of June 2010, the number of subscribers to broadband services in Japan had risen to 33,550,000. Among these, subscribers to fiber-to-the-home (FTTH) access accounted for 18,570,000 or 55% of the total. In terms of national broadband penetration (total number of subscribers divided by population of the country), these figures mean that Japan comes in second behind Korea, but in terms of total number of subscribers, they indicate that Japan occupies first place, far ahead of other countries, reflecting its commitment to increasing the penetration of FTTH and being a world leader in this field.

Within the NTT Group, the number of FTTH subscribers as of the end of June 2010 came to 13,840,000 for NTT EAST and NTT WEST combined. This figure is forecast to exceed 15 million by the end of fiscal year 2010. Needless to say, the NTT Group is not just aiming to increase the number of subscribers—it is also working to increase high-speed and advanced services so that even better products can be provided. When they were first deployed, FTTH services had a maximum transmission speed of only 10 Mbit/s. Now, up to 100 Mbit/s is normal, and since 2009, services with a maximum transmission speed of 200 Mbit/s or even 1 Gbit/s have been available.

It is also important for social issues such as the

aging society and changes in the global environment to taken into account when new technology for the access network is being developed.

An aging society means a decrease in the working population. Japan's workforce in 2010 made up 63.9% of the population, but from here on, it is expected to drop by 5 points every 20 years. NTT is not exempt from this problem: the aging of its employees is also a major issue. For NTT, this makes it all the more urgent to develop do-it-yourself (DIY) facilities, simplify installation work, and make maintenance work more efficient.

At present, the amount of human-induced CO_2 discharge is more than double the amount that can be naturally absorbed. The effects of global warming such as rising sea levels and desertification are of serious concern, prompting NTT to actively promote measures to protect the environment. Access-system equipment and components are used in the section up to the user's home and even inside the home, and in addition to being deployed in great quantities, they tend to be quite diverse in makeup in line with the diversification of services. Reducing the power and resource consumption of these products can therefore have a major effect toward preserving the environment.

3. Access network R&D activities

On the basis of the following external trends, NTT Access Network Service Systems Laboratories is taking up the following challenges in developing technology for the access network:

- Provide cheaper and more convenient broadband services to more people
- Make operations more efficient and skill-free as highly skillful personnel retire and the labor pool shrinks
- Incorporate measures to protect the global environment and reduce CO_2 emissions
- Disseminate and support technology and form partnerships to help accelerate the deployment of FTTH overseas

To achieve the above, we are undertaking five specific measures, which are discussed below: constructing a high-reliability and economical network, creating new network services, expanding the broadband service area, promoting green R&D, and expanding globally.

3.1 Constructing a highly reliable and economical network

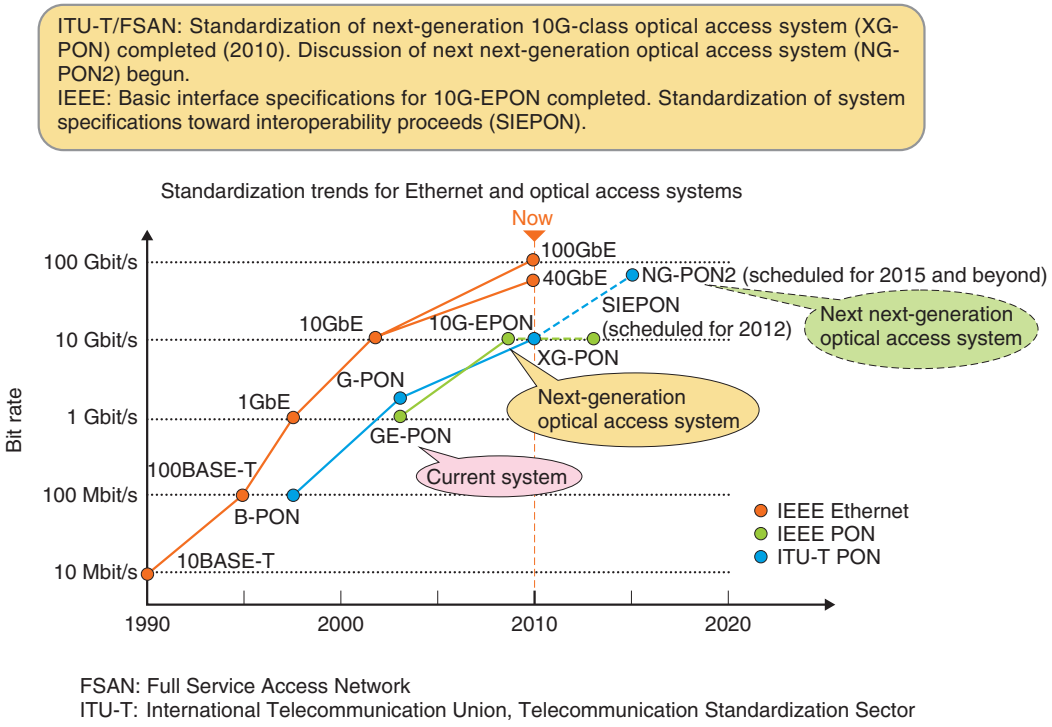
To reduce capital expenditure (CAPEX), we are working to optimize aggregation appropriate to user dispersion, construct facilities applicable to rural areas, promote the use of existing facilities, and simplify the work of installing new circuits and deploying new services. We are also working to reduce operating expenditure (OPEX) in relation to maintenance/operations and fault repair. Here, to supplement operations support technology based on existing operations systems, our plan is to simplify installation work through DIY facilities and skill-free procedures and introduce technology like remote fault troubleshooting and remote switching to make maintenance operations even more efficient. At the same time, we are working to make network facilities more reliable and to achieve long-life infrastructure facilities. The three technologies described below reflect these expenditure-reducing efforts.

(1) Small-diameter, low-friction indoor optical fiber cable

To promote the provision of optical services in multi-dwelling units and especially in existing structures, it became necessary to lay many cables using the spare space in existing conduits that already house telephone cables. In response to this need, we developed a small-diameter, low-friction indoor optical fiber cable having half the cross-sectional area and one-fifth the dynamic friction coefficient of existing products. More than 20 of these new cables can be deployed in the free space in existing conduits compared with only a few cables of the current type. Thus, optical services that could not be provided in the past owing to insufficient space in conduits can now be offered. This newly developed cable was also given an optimal amount of bending rigidity so that it could be installed in the conduit using the push-in method instead of the conventional pulling method using a pulling wire. The end result was a reduction in cable deployment time.

(2) Optical-media maintenance and operations technology (traffic monitoring tool)

We developed a traffic monitoring tool for monitoring signals from an optical network unit (ONU) and displaying service status. This tool enables on-site personnel to check the link status between optical fibers and an ONU. With this tool, the user's usage conditions can be checked in real time and the media access control (MAC) address can be verified when fibers are switched to ensure that the user has been connected. This prevents erroneous cutoffs or



FSAN: Full Service Access Network
ITU-T: International Telecommunication Union, Telecommunication Standardization Sector

Fig. 1. Progress and standardization of optical access systems.

connections in fiber switching activities while also reducing installation time.

(3) Operations visualization technology

This technology aims to make operations more efficient and improve security by systematizing business know-how possessed by individual employees. This know-how can be extracted from work logs that record the daily actions of operators and accumulated in a database so that it can be reflected in future operations. We can compare this approach to a high-performance car navigation system that uses a record of routes travelled by veteran drivers to advise novice drivers which roads to take or to guide a driver along an optimal route by means of an auto-cruise (auto-pilot) function.

Although this function could have been achieved in the past by embedding it in the system, the advantage of this technology is that information from work logs can be collected without having to revamp the base operations system. In this way, we aim to achieve functions such as automatic execution of routine operations, operation navigation, and controls on certain operations.

3.2 Creating new network services

NTT Access Network Service Systems Laboratories is researching and developing a high-reliability, next-generation access network to promote the creation of new network services.

3.2.1 10G-EPON

The demand for a faster optical access network is growing as broadband services spread and the Next Generation Network (NGN) expands.

The standardization of optical access systems tends to lag behind the Ethernet standardization process by a few years (**Fig. 1**). The GE-PON (Gigabit Ethernet passive optical network) optical access system, which is the one now in use, was standardized in 2004, while specifications for the physical layer and data-link layer of 10G-EPON (10-Gbit/s Ethernet PON) were standardized in 2009. In addition, discussions on NG-PON2 as the next next-generation optical access system providing several tens of gigabits per second have already begun.

At present, work is proceeding on standardizing interoperability between GE-PON and 10G-EPON at the system and network levels. Coexistence with the current GE-PON system is essential to the adoption and expansion of 10G-EPON. We are studying a

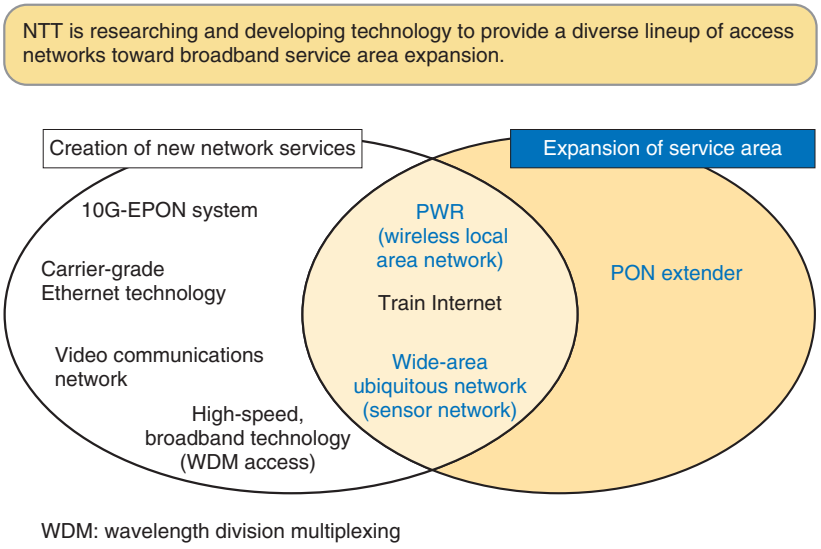


Fig. 2. R&D for expansion of broadband service area.

system that has a 1G-10G dual-rate optical line terminal (OLT) to accommodate GE-PON ONUs (1G upstream, 1G downstream) and 10G-EPON ONUs (1G or 10G upstream, 10G downstream) connected to the same splitter. Such interoperability will enable users who desire faster speeds to migrate to new services smoothly.

3.2.2 Carrier-grade Ethernet technology

To achieve high reliability, maintainability, and operability, we are developing the following three network technologies as well as an operations system that can implement those technologies and applying them to commercial services (NTT's Business Ether Wide).

(1) Ethernet OAM technology: Generates maintenance signals in communication circuits so that faults can be discovered in real time and troubleshooting performed immediately (OAM: operations, administration, and maintenance).
(2) Ethernet ring protection technology: Prevents collisions from occurring during ring-switching at the time of a fault in a ring-based network.
(3) Redundant access technology: Duplicates circuits in the access interval and performs high-speed switching at the time of a fault to improve reliability.

3.3 Expanding the broadband service area

NTT Access Network Service Systems Laboratories is working to expand the broadband service area by providing a diverse lineup of access networks. There are many technologies that can link the creation of new network services with the expansion of the service area (**Fig. 2**).

3.3.1 Optical-amplification PON repeater (PON extender)

The maximum transmission distance of the current PON system is 20 km, which means that some sort of distance-extending technology is needed to provide services to rural areas. In response to this need, we are developing a PON repeater to achieve wide-area service coverage (with long-distance, multi-branching capabilities) through optical amplification. This repeater can be installed outdoors on poles so that transmission distances can be increased in rural areas and the number of branches and accommodated ONUs can be increased in urban areas.

3.3.2 Wireless technology

A personal wireless router (PWR) will enable a variety of devices equipped with wireless local area network functions to be automatically connected to the most optimal network (3G, Wi-Fi, optical access, etc.) without user intervention.

A wide-area ubiquitous network (sensor network) will make possible services for automatically collecting information over a wide area by attaching wireless terminals to all kinds of things. Various service concepts are now being studied: one application would be to enable gas and electricity meters to be read wirelessly from an office instead of visually by a person in the field.

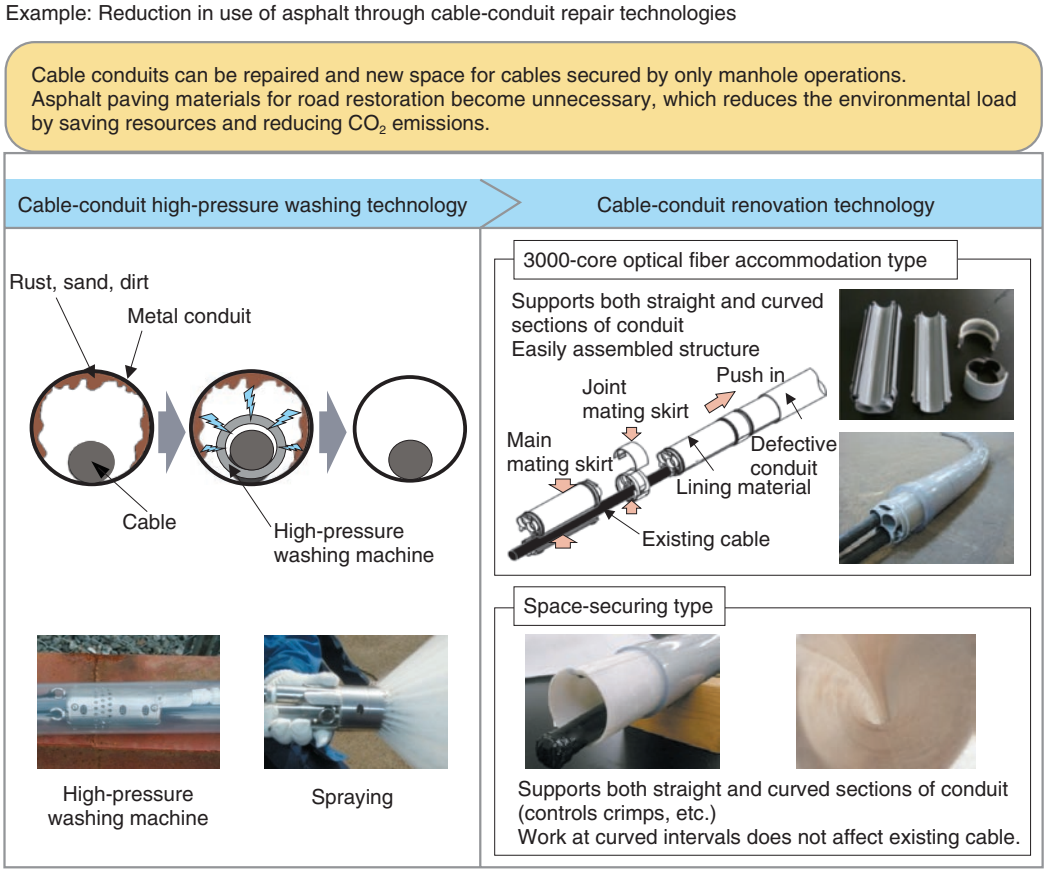


Fig. 3. Resource-saving technologies.

3.4 Promoting green R&D

3.4.1 Activities toward preserving the global environment

At NTT Access Network Service Systems Laboratories, our R&D efforts follow the "NTT Group Energy Efficiency Guidelines" conforming to the "ICT Ecology Guidelines" established by the Telecommunications Carriers Association (ICT: information and communications technology). We are working to reduce power consumption in access-network equipment by steering our long-term research in the following three directions.

- Reduce power in devices and components
- Reduce power through a method/system approach
- Reduce power through a network-architecture approach

We are also developing cable-conduit repair technology, design technology for concrete poles, and optical-splitter compact housing technology to save resources including recycling access-network facilities.

3.4.2 Power-savings technology for PON systems

To reduce power consumption in the access network, we are researching the application of mechanisms like automobile idle-stop systems to PON systems. A sleep function will deactivate some ONU functions according to current operating conditions and a link-rate switching function will switch the link rate between OLT and ONU according to current traffic conditions. Achieving these mechanisms will require protocol for controlling communications between the OLT and ONU, and standardization activities to this end are proceeding.

3.4.3 Resource savings by cable-conduit repair technologies

These technologies make it possible to repair cable conduits though operations performed only in a manhole. This enables conduits to be reused while also reducing the use of asphalt conventionally required in cable-conduit excavation work and cutting down on earth, sand, and other waste (**Fig. 3**). Cable-conduit

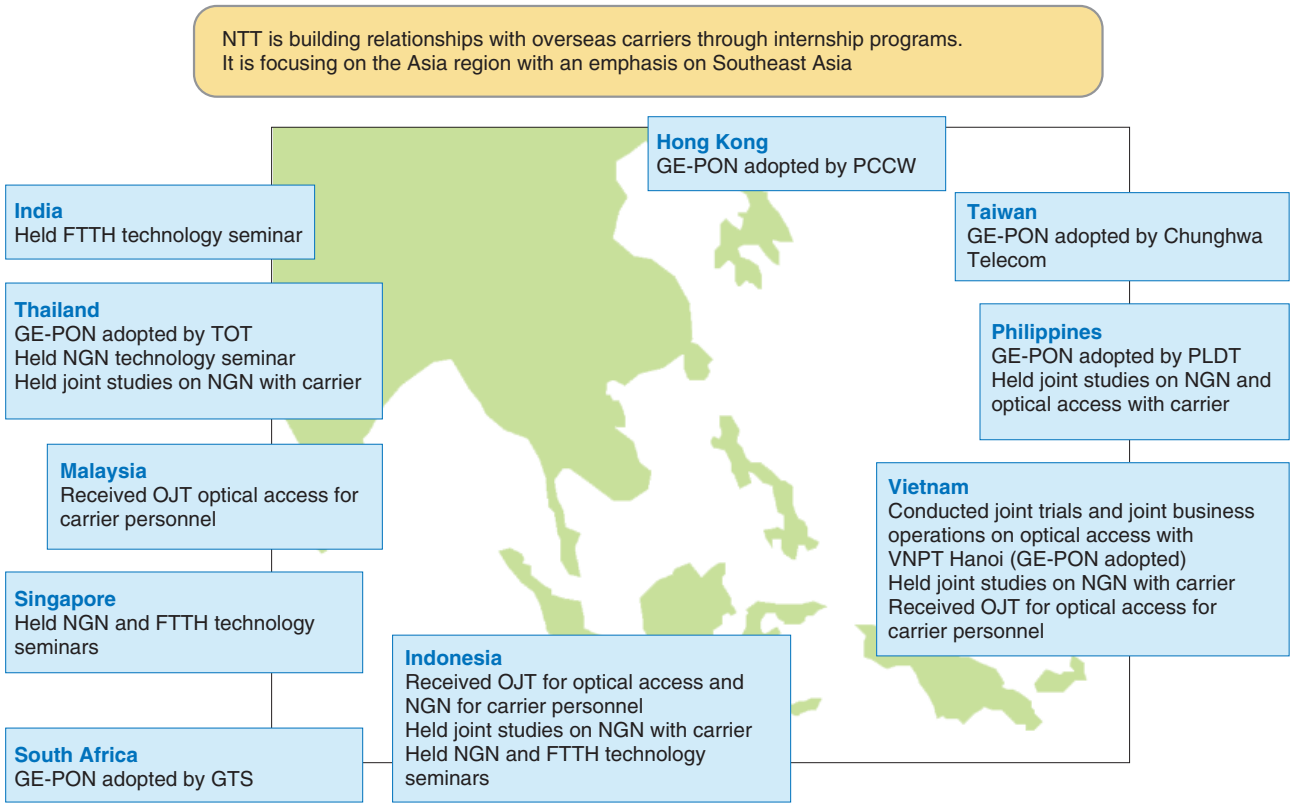


Fig. 4. Relationship building with overseas carriers.

high-pressure washing technology removes rust and dirt inside a conduit by high-pressure washing without requiring the cable to be pulled out. Cable-conduit renovation technology secures space for accommodating additional cables by inserting lining material inside a conduit after it has been washed.

Up to now, the repair of a degraded conduit required excavation of the road surface, backfilling after completion of the repair, and the application of a new asphalt coating. Our new no-dig technologies, however, eliminate the need for roadwork to excavate and repair conduit cables. Once these technologies are fully implemented, the use of asphalt paving materials is forecast to drop by about 300,000 tons over a five-year period.

3.5 Expanding globally

To become more competitive on the world stage, NTT is actively promoting its researched and developed technologies and their products to a number of countries overseas. It is also involved in international standardization activities and relationship building with an eye to expanding business on a global scale. Three specific R&D achievements of NTT Access Network Service Systems Laboratories are contributing to the global expansion of the Japanese ICT industry.

(1) Free-bending optical fiber cord and small-diameter, low-friction indoor optical fiber cable: NTT was the first in the world to commercialize these products, which are now being sold overseas by Japanese manufacturers.
(2) Optical connectors: These have been internationally standardized (by IEC: International Electrotechnical Commission) and hold a world share of about 50%.
(3) High-speed optical access system (GE-PON): This system has been internationally standardized (by IEEE) and adopted by Chunghwa Telecom (Taiwan), TOT (Thailand), PCCW (Hong Kong), and other overseas carriers.

In addition to providing technologies and products, NTT is also building relationships with overseas telecommunication carriers by receiving interns and holding technology seminars (**Fig. 4**). The initial focus here was Southeast Asia, but tie-ups with carriers in Central and South America have recently begun.

4. Conclusion

Under the theme of building trust and connecting people, NTT Access Network Service Systems Laboratories will continue to research and develop technology toward achieving a sophisticated communication environment and a safe, secure, and reliable information sharing environment for the betterment of society.

Profile

■ Career highlights

Executive Manager, Senior Research Engineer, Supervisor, Access Service and Network Architecture Project, NTT Access Network Service Systems Laboratories.

Yukio Akiyama received the M.S. degree in mathematics from Hokkaido University in 1987. After joining NTT in 1987, he engaged in research on operations support systems for the access network, failure analysis of LANs, huge data analysis, and R&D product promotion. He is now engaged in strategy planning of access network R&D and research on the architecture of operations systems. He is a member of the Information Processing Society of Japan and the Japanese Society for Artificial Intelligence.

Current and Future Research on Optical Fiber and Cables

Shigeru Tomita†

Abstract

This article introduces the organization, research group topics, and R&D directions of NTT Access Network Service Systems Laboratories, which is researching and developing a full range of access-system technologies with a focus on optical fiber and cables.

1. Introduction

NTT Access Network Service Systems Laboratories is fully engaged in the research and development (R&D) of access-system technologies. In particular, the Access Media Project extracts core technologies from themes selected through strategic studies, researches and develops those technologies, and passes on the R&D results to various promotion projects. In short, it exclusively handles the R&D of core technologies considered necessary for future systems. The Access Media Project consists of four groups. Some of the topics they are working on are described in more detail in section 2.

(1) Media Utilization Group: next-generation outdoor optical line technology

(2) Media Maintenance Group: optical line testing technology, media network management and operation technology, and preventive maintenance technology

(3) Advanced Media Research Group: new optical fiber structures

(4) Media & Equipment Monitoring Group: media measurement technology

† NTT Access Network Service Systems Laboratories
Yokosuka-shi, 239-0847 Japan

2. Research topics by group

2.1 Bending-loss insensitive fiber (Media Utilization Group)

One consequence of the rapid penetration of fiber-to-the-home (FTTH) services is that many unskilled workers have came to be involved in the deployment of optical fiber. As a result, optical fiber bending loss became a frequent occurrence in the field. This problem led to active development of bending-loss insensitive fiber.

Standardization of optical fiber insensitive to bending loss is progressing as Recommendation G.657 in ITU-T (International Telecommunication Union, Telecommunication Standardization Sector). There are two categories according to compatibility with existing optical fiber specifications (G.652): Category A having full compatibility and Category B having partial compatibility (**Table 1**).

There are two approaches to decreasing bending loss: control the refractive-index distribution (optimal-refractive-index-distribution type of fiber) and form air holes (microstructured fiber). The former method controls the refractive-index distribution of existing single-mode fiber (SMF) to suppress bending loss, but its suppression effect is smaller than that of the latter method. The microstructured type, on the other hand, achieves large differences in refractive index within the optical fiber, which enables considerable design freedom. NTT has been using microstructured fiber for some time. It comes in various kinds such as hole-assisted fiber (HAF) and this type

Table 1. Development and standardization of bending-loss insensitive fiber.

G.657 Low-bending-loss optical fiber for access networks	Minimum bending radius		
	10 mm	7.5 mm	5 mm
Category A Fully compatible with G.652	A1 Specified	A2 Specified	A3 Under discussion
Category B Partially compatible with G.652	B1 No standard product	B2 Specified	B3 Specified

G.652: standard for SMF

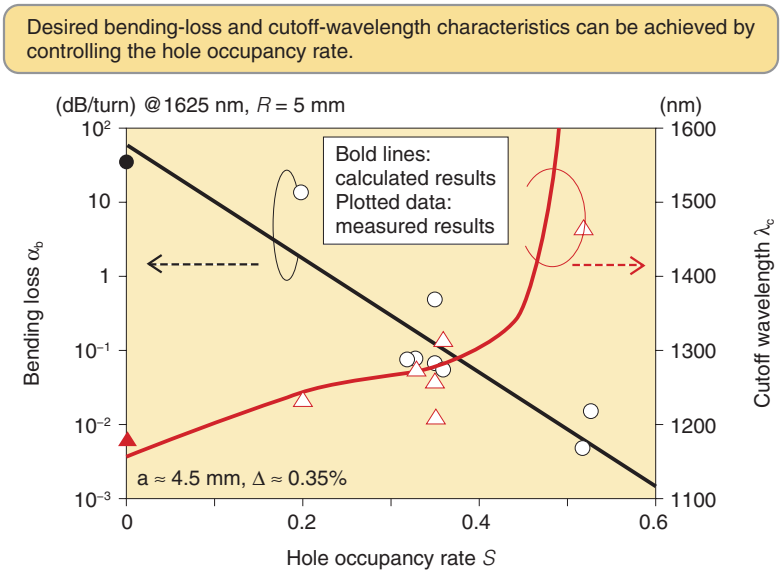


Fig. 1. HAF hole occupancy rate and transmission characteristics.

also includes nanostructured fiber.

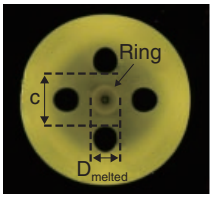
NTT has developed single-mode HAF design technology that simultaneously achieves single-mode transmission characteristics equivalent to standard SMF and low bending loss characteristics that greatly surpass the G.657.B.3 standard. The transmission characteristics of HAF can be easily determined from the area ratio of the hole section in the annular region of HAF (hole occupancy rate) and the core structure (core radius and refractive index). Bending loss decreases as the hole occupancy rate increases, but at the same time, the shortest single-mode wavelength (cutoff wavelength) increases, which prevents single-mode transmission from being achieved. Setting a hole occupancy rate of 0.3–0.4 yields optimal transmission characteristics for maintaining the cutoff wavelength while suppressing bending loss (**Fig. 1**).

An example of HAF that can simultaneously achieve single-mode transmission characteristics and low bending loss has the following properties: hole occupancy rate of 0.41, bending loss (at 1625 nm, R=5 mm) of 0.04 dB/turn, cutoff wavelength of 1126 nm, and loss (at 1550 nm) of 0.19 dB/km.

NTT is already providing free-bending optical fiber cord using HAF with a large bending-loss suppression effect. This cord can be deployed by ordinary people within their homes. Moreover, there are plans to extend single-mode HAF to NTT office facilities and other indoor and outdoor facilities with the aim of achieving even higher levels of transmission quality and reliability.

2.2 Single-mode HAF optical cord (Media Maintenance Group)

A distribution frame can be found at the point where NTT office cables connect to outside cables. In



- The fiber-fuse propagation phenomenon depends on the relationship between diameter c of the circle inscribing the holes and the diameter of the melted area (D_{melted}) [1].
- D_{melted} is assumed to be nearly the same as the diameter of the plasma region.

Fiber fuse propagation versus D_{melted}/c

	P_{in} (W)	D_{melted} (μm)	D_{melted} /c	Fiber fuse
HAF-A	15.6	23.5	0.77	Propagate
HAF-B	15.6	23.5	1.37	Not propagate
HAF-C	13.5	22.8	2.39	Not propagate
PCF	14.3	23.2	2.35	Not propagate

Source: K. Takenaga, S. Tanigawa, S. Matsuo, M. Fujimaki, and H. Tsuchiya, "Fiber Fuse Phenomenon in Hole-Assisted Fibers, Proceedings of the 34th European Conference and Exhibition of Optical Communication ECOC2008, P.1.14

Fig. 2. Relationship between fiber fuse and D_{melted}/c.

the work of connecting these cables, there are many places where workers can come into direct contact with optical fiber. Applying low-bending-loss optical fiber to those places can be an extremely effective measure for maintaining quality. Shock-resistance experiments have shown that, while SMF can be greatly affected by shocks, single-mode HAF exhibits no shock-induced frame errors. Therefore, the use of single-mode HAF in a distribution frame can eliminate worries about transmission quality loss even if optical fibers should be accidently bent or pulled.

2.3 Fiber fuse studies (Advanced Media Research Group)

Increasing the amount of incident light in an optical fiber can raise the fiber's internal temperature and create a plasma in which discharge phenomena occur. This flash of light can propagate back toward the light source and damage the optical fiber in a process called fiber fuse. In SMF, this can occur at an optical power of about 1.3 W (at a wavelength of 1480 nm). By contrast, in holey fiber, this fuse-propagation threshold is very high. We have found that fiber fuse does not occur in photonic crystal fiber (PCF) or HAF for input power below 9.0 W (at 1060 nm) and 8.1 W (at 1550 nm), respectively. In the latest reports, the phenomenon can be controlled for light sources with power in excess of 10 W in PCF and HAF at wavelengths of 1480 nm and 1550 nm, respectively.

Fiber fuse was found to terminate at the connection point between ordinary optical fiber and holey fiber. In an experiment in which SMF and HAF were connected, a flash propagating from the SMF side created many harmful cavities in the SMF but lost its momentum and disappeared after crossing the connection point. The reason for this fuse propagation termination is considered to be that the density of the propagating plasma suddenly decreased once its expanding breadth reached the air holes in the holey fiber.

Various types of HAF and PCF were used to compare propagation phenomena and clarify the relationship between fiber fuse and hole structure. It was found that the relationship between the diameter of the circle inscribing the holes (c) and the diameter of the area melted by the fiber fuse (D_{melted}) determines the propagation characteristics (**Fig. 2**). Specifically, if D_{melted} is less than c, that is, if the ratio D_{melted}/c is less than 1, the fiber fuse propagates, but if it is greater than 1, no propagation occurs.

This finding suggests that plasma propagation might be suppressed upon reaching air holes. To test this idea, a fiber fuse was propagated in HAF having a structure in which D_{melted} and c were nearly equal. The manner in which the core was destroyed was found to differ greatly from that in ordinary SMF. In SMF, cavities caused by core melting appeared sequentially at very short intervals (10 μm) while in HAF, cavities opened up at relatively long intervals (330 μm) and destroyed the core. When the section of destroyed core was analyzed, it was found that D_{melted} broadened gradually and came to a stop near to the air

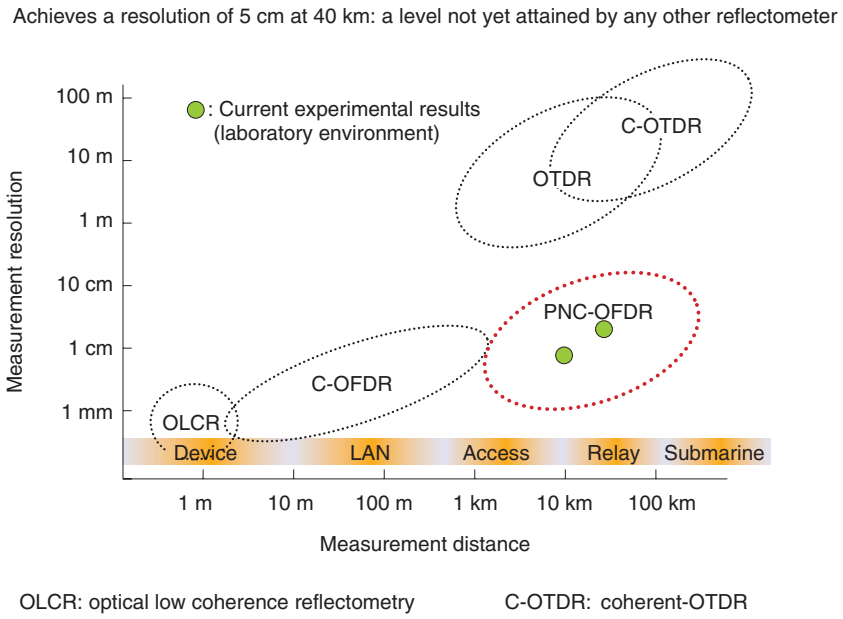


Fig. 3. PNC-OFDR for long-distance, high-resolution measurements.

holes. It was also observed that energy concentrated after propagation stopped and that a fiber fuse reoccurred, producing a repeating propagation phenomenon. Although the reason for this could be inferred to be the occurrence of boundary phenomena, a detailed explanation has not yet been given.

2.4 Phase-noise-compensated optical frequency domain reflectometry (Media & Equipment Monitoring Group)

Coherent optical frequency domain reflectometry (C-OFDR) is a technique for locating fault points and making distortion-distribution measurements in the longitudinal direction of optical fiber. This technique has superior resolution characteristics but is limited to measurement distances of 2–3 km owing to the influence of phase noise from the light source. On the other hand, optical time-domain reflectometry (OTDR), which makes measurements within an optical fiber by injecting optical pulses to minimize the effect of phase noise, is capable of long-distance measurements but suffers from low resolution.

Phase-noise-compensated OFDR (PNC-OFDR) achieves both long-distance and high-resolution measurements by monitoring phase noise with an auxiliary interferometer and removing its effect. It can therefore maintain accuracy even at long distances (**Fig. 3**). The auxiliary interferometer compensates for phase components by electrically storing phase noise data in memory and superposing components. This technique does not suffer from measurement disablement due to excessive phase noise at long distances. PNC-OFDR can achieve a resolution of 5 cm from 40 km away, which exceeds those of all other reflectometry methods.

PNC-OFDR is very effective for detecting spans with high polarization mode dispersion (PMD). In optical fiber, PMD, which arises from optical birefringence, is one factor limiting transmission speed. It has come to be controlled in recent optical-fiber products but not in older products. To maintain transmission quality in the system, high-PMD spans must be located and replaced with new optical fiber. In a high-PMD span, short-period fluctuations in polarization occur in the transmission direction, and such fluctuations can be used to identify high-PMD locations. However, the fluctuation period is less than a few tens of centimeters, which means that detection requires a high resolution of 5–10 cm.

Moreover, as the relay interval on transmission paths can currently be up to 80 km, a measurement-distance performance of at least 40 km is needed when making measurements from both ends of the interval. In an experiment to assess PNC-OFDR-

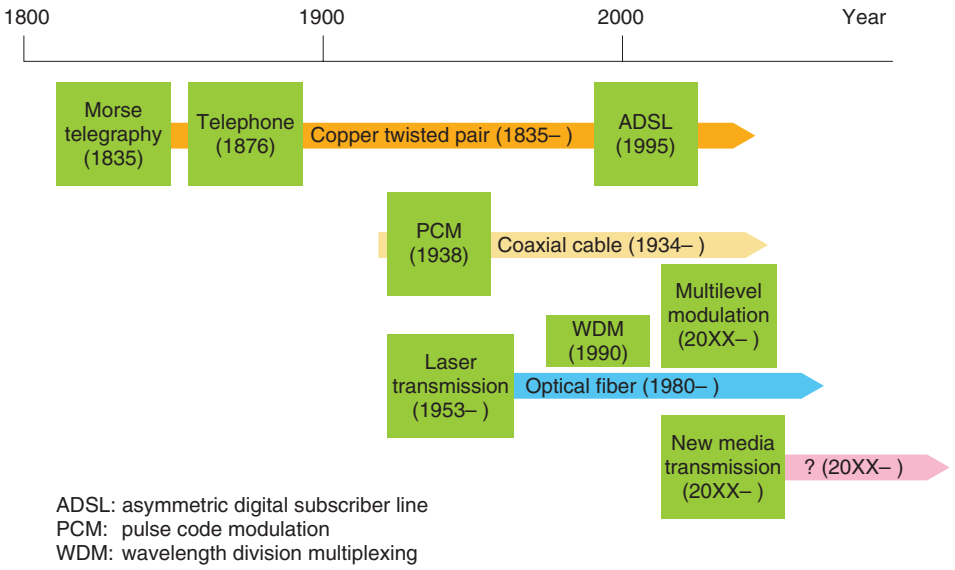


Fig. 4. History of wired transmission media

based measurement, a high-PMD fiber taken from the field was installed at the end of about 40 km of SMF and PMD was clearly identified at that location.

3. Directions of future optical fiber research

3.1 Overview

The history of wired transmission media began with copper twisted pairs in Morse telegraphy and progressed to coaxial cable and then optical fiber in the 20th century, resulting in the development of new transmission systems (**Fig. 4**). The development of optical-fiber technology brought a huge leap in transmission capacity, but as demand for even higher capacities grew, capacity limits for conventional SMF began to be observed. Improved or new forms of transmission media are being eagerly sought. Two optical-fiber-based candidates for improved transmission media are multicore optical fiber and multimode optical fiber. The former has multiple cores within one clad, which can improve the spatial density and achieve high-capacity transmission. The latter has a structure capable of multiple-input multiple-output (MIMO) transmission and can achieve high-capacity transmission through multichannel propagation. Next-generation studies on the possibility of achieving transmission media for carrying terahertz-band and ultraviolet light signals are also being performed.

3.2 Higher cable density

Small-diameter high-density optical cable technology increases transmission capacity by increasing cable density. A 1000-core optical fiber cable of the latest slot-type design in current use has an outer diameter of 23 mm and a weight of 0.45 kg/m, while the new small-diameter high-density optical cable currently under development is designed to have an outer diameter of 15.8 mm and a weight of 0.19 kg/m. Thus, the new cables will lead to very compact installations. A number of foreign firms are involved in making cables thinner and lighter and the most advanced research product from these firms has a density more than 1.5 times existing levels. Nevertheless, the pursuit of higher fiber densities is approaching inherent limits and we can expect the objective of future cable R&D to shift toward functional enhancements.

3.3 Manpower shortage solutions

The number of employees involved in cable deployment and maintenance is forecast to decrease by around 60% in seven years time as aging workers retire. Replacing those employees with younger staff is one countermeasure, but there will still be a great shortage of staff with the appropriate skill set. There is therefore an urgent need for navigation-based support systems and equipment that can be operated by unskilled staff.

Profile

■ Career highlights

Senior Research Engineer, Executive Manager of the Access Media Project, NTT Access Network Service Systems Laboratories.

Shigeru Tomita received the B.S. and D.Eng. degrees from Nihon University, Tokyo, in 1983 and 1993, respectively. After joining the Ibaraki Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) in 1983, he engaged in research on optical fibers and optical fiber cables. From 1995 to 1996, he engaged in development of outside plant planning tools in NTT's Outside Plant Planning Division. After returning to the laboratories, he worked to develop optical components such as connectors and cords for use indoors. From 2008 to 2010, he was the leader of the Advanced Media Research Group. He is a member of IEEE and the Institute of Electronics, Information and Communication Engineers.

Trends in Wireless Access Technologies toward Expansion of Broadband and Ubiquitous Services

Toshihiro Manabe†

Abstract

This article introduces wireless technologies being studied in the Wireless Access Systems Project at NTT Access Network Service Systems Laboratories. To achieve flexible access networks that meet various needs or demands, the coexistence of optical fiber and wireless systems is indispensable. It also mentions electromagnetic wave propagation technology and technology for increasing frequency utilization as core technologies of wireless systems and eco-related activities that began in 2010.

1. Overview of wireless systems

1.1 Comprehensive view of wireless technology R&D

NTT is conducting research and development (R&D) of wireless systems and deploying a variety of wireless access services to satisfy different objectives and accommodate different types of service areas. In satellite communications, for example, we are developing technology for compact earth stations that can apply the wide-area capability of satellite communications to circuit restoration in disaster areas and technology for mobile-multicast satellite communications systems for application to maritime communications in places where the laying of optical fiber is impossible. And for rural areas, we are providing communication services using the combination of an optical fiber system (from an NTT building to a certain point) and a fixed wireless access (FWA) system (from that point to end users). At the same time, we are working on the development of a triple-play FWA system that can support quality of service (QoS) and provide video and telephony functions conforming to 0AB-J specifications (where 0AB-J refers to a 10-digit phone number starting with 0).

Meanwhile, for urban areas, NTT is developing nomadic wireless access (NWA) and cognitive-radio systems that can provide high-speed wireless local area network (LAN) services in designated public areas such as airports, train stations, and cafes. Expanding the service area while keeping costs down is a problem common to FWA and NWA, but it is being solved by multihop technology that uses wireless repeaters to broaden the service area. The application of multihop technology has made it possible to easily expand wireless LAN areas that have, until now, been just spots.

In addition to the above, we are developing personal wireless router (PWR) technology that enables terminals equipped with a wireless LAN function to make connections over a broad region instead of just a limited area. As a wireless LAN router that can be carried anywhere, a PWR enables a wireless LAN terminal to be used seamlessly at outside locations or at home. We are also developing ubiquitous systems (wide-area sensor network systems) for gathering information about various types of machines and facilities situated over a wide area such as automobiles, transport vehicles, and vending machines.

† NTT Access Network Service Systems Laboratories
Yokosuka-shi, 239-0847 Japan

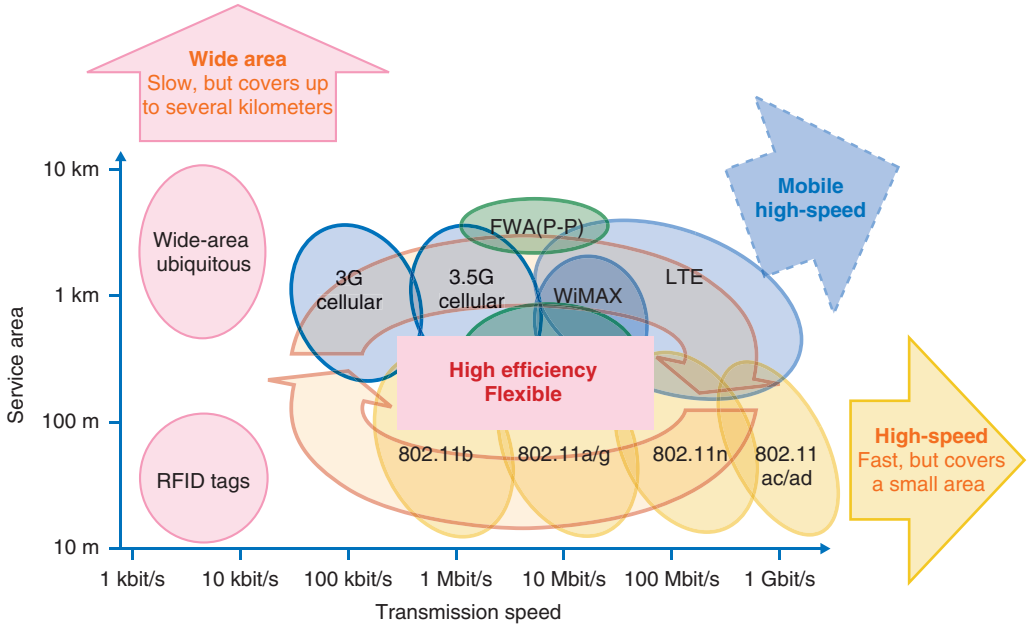


Fig. 1. Directions of wireless technologies.

The Wireless Access Systems Project is also researching and developing fundamental technologies in support of the above wireless transmission technologies.

1.2 Future directions of wireless technologies

The development of wireless technologies has traditionally focused on increasing transmission speeds. The wireless LAN standard IEEE802.11, though supporting only a small area, initially specified transmission speeds of only about 1 Mbit/s but now specifies speeds in excess of 100 Mbit/s and speeds above 1 Gbit/s are under study. Greater speeds for mobile devices over broader service areas have also been pursued in system development from 3G (third-generation) cellular to Long Term Evolution (LTE). In addition, FWA has come to provide service areas several kilometers in size for point-to-point (P-P) connections and several hundred meters in size for point-to-multipoint (P-MP) connections at transmission speeds of about 10 Mbit/s in both cases.

More recently, studies have been progressing on wide-area ubiquitous systems that emphasize wide-area coverage as a new technology direction separate from the pursuit of higher speeds. The wide-area ubiquitous system was born from the idea that a sensor network could be constructed by enhancing radio-frequency identification (RFID) tags and extending transmission distances. Although supporting speeds of only several kilobits per second, it features a service area several kilometers in size (**Fig. 1**).

2. Activities toward expansion of broadband and ubiquitous services

2.1 Satellite communications systems

NTT is currently providing the following satellite communications services.

- Infrastructure satellite communications system (for disaster response): maintains public lifelines in disaster areas (NTT EAST and NTT WEST)
- Infrastructure satellite communications system (for remote islands): provides universal service (NTT EAST and NTT WEST)
- Maritime broadband system: provides broadband communications to ships at sea (NTT Communications)
- WIDESTAR & WIDESTAR II: provide satellite mobile communications (NTT DOCOMO)

For each of these services, improved functionality is required to meet a high demand for smaller and more economical equipment, greater mobility, higher bandwidth and capacity, improved security, extremely wide coverage at low bit rates, and so on. To meet these needs, NTT laboratories are investigating the extension of existing services, the renovation of

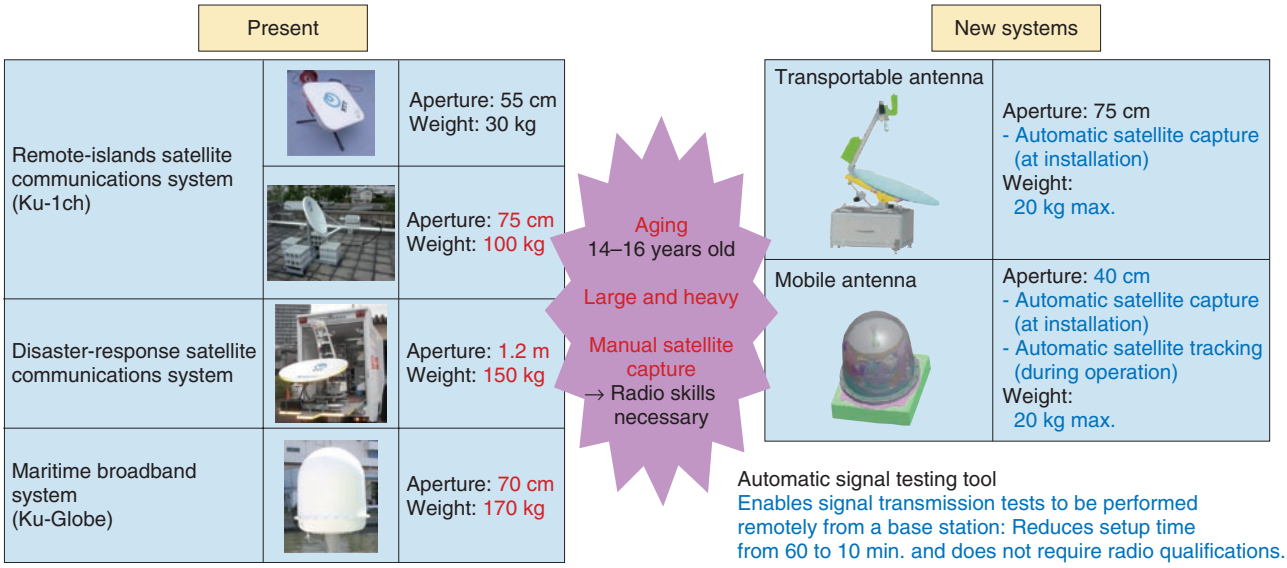


Fig. 2. Development of compact earth stations for satellite communications.

services, and the development of new services.

(1) Compact earth station

One key advantage of satellite communications is that a lifeline can be secured by simply setting up earth stations at a number of points and then connecting them via satellite. However, most of the facilities for existing earth stations are 14–16 years old while also being too large and heavy to be easily transported. Moreover, their operation requires skilled radio technicians to orient the antenna in the direction of the satellite (manual satellite capture). In response to this situation, we have developed new systems (transportable type and mobile type) that are significantly smaller and lighter. The transportable type has an automatic satellite capture function and the mobile type has automatic satellite capture and tracking functions to improve operability (**Fig. 2**).

The field of wireless communications is not immune to the problem of a dwindling number of technicians as the numbers of licensed radio operators is on a downward trend. As one countermeasure to this problem, we are developing an automatic uplink access testing tool. This tool enables uplink access tests to be performed remotely so that earth stations can be put into commission even by unlicensed personnel and setup time can be greatly shortened from 60 minutes to only 10.

(2) Multi-domain signal processing technology

The frequency band of a satellite transponder is extremely limited. In addition, as a result of the setting and releasing of channels having different bandwidths, unused frequency slots are scattered across the transponder's bandwidth and these prevent the entire band from being used. To make effective use of such unused frequency slots, the spectrum of the modulated signal is divided into subspectra, some of which can then be purposefully removed or superposed to reduce the bandwidth required. The vertical and horizontal polarization axes can also be shared so that subspectra can be assigned as desired.

The purpose of the above techniques is to improve spectrum utilization efficiency, but these techniques also have a positive side effect from the viewpoint of security. Because the spectrum of the modulated signal is broken down into fine sections before transmission, the signal cannot be correctly demodulated by a third party even if a portion of the band can be observed.

This multi-domain signal processing technology enables a single satellite transponder to be shared by a disaster-response infrastructure satellite system, a remote-islands infrastructure satellite system, and a maritime broadband satellite system and enables a wide-area large-capacity system to be compact and economical while also having improved security.

2.2 FWA system

On the basis of the current Wireless IP Access System (WIPAS (IP: Internet Protocol)), we are developing an FWA system supporting triple-play services

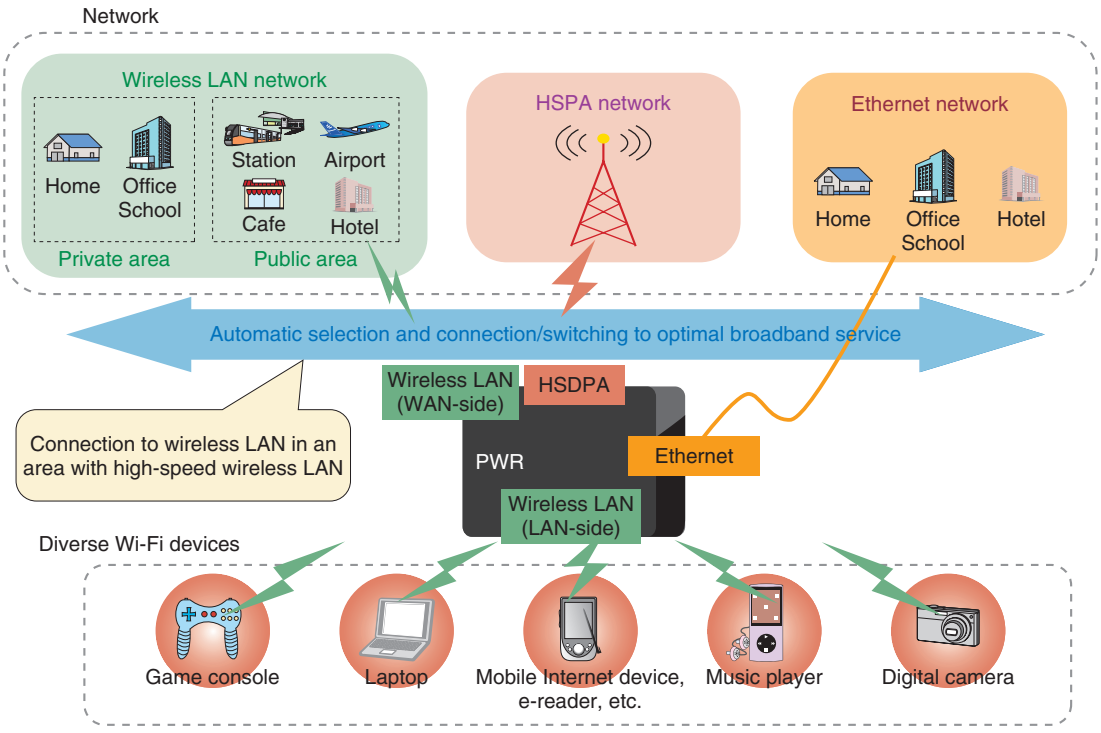


Fig. 3. PWR: core terminal of NWA and cognitive radio.

equipped with a QoS control function including 0AB-J support and a multichannel video delivery function. For P-P (one-to-one) connections, this system will provide a maximum transmission distance of about 1.3 km and a transmission capacity of about 180 Mbit/s (total for uplink and downlink). Moreover, for P-MP (one-to-n) connections, the system will have a multicast function enabling the simultaneous provision of Internet, voice over IP (VoIP), and video services.

When wireless LAN was first introduced, terminals equipped with Wi-Fi were basically limited to laptop computers and personal digital assistants (PDAs). Since then, however, Wi-Fi-certified terminals have come to be installed in a wide variety of products for diverse applications, from business to personal needs and from indoor to outdoor use. However, places where wireless LANs can be used are still basically limited to one's home, train stations, trains, offices, and cafes. Consequently, Wi-Fi-only terminals without 3G wireless access functions cannot connect to the network from other locations.

In the light of this situation, NTT Broadband Platform, Inc. has undertaken the development of a PWR as a key device for connecting to the network at any time. It can accommodate various types of Wi-Fi devices on the LAN side and features wireless LAN, high-speed packet access (HSPA), and Ethernet on the wide area network (WAN) side. It can automatically select and connect to the broadband service depending on the user's current location (**Fig. 3**).

It might appear at first glance that there is no need for a wireless LAN function on the WAN side. However, including wireless LAN here, even in a terminal equipped with 3G wireless access, means that the terminal will be able to use a service that is faster than 3G wireless access when connecting at public wireless-LAN hotspot access points. In other words, it is desirable to offer wireless LAN as an optional wireless access method.

Moreover, another benefit of the PWR is that it has an authentication agent function. A terminal without an authentication agent function cannot make use of a public wireless-LAN service that requires authentication. Furthermore, even if a terminal has an authentication function, the user must still follow a troublesome procedure for inputting an ID and password. The PWR eliminates this bother and enables the terminal to be used anywhere and anytime regardless of whether it implements an authentication function.

2.3 Wide-area ubiquitous systems

Contrary to recent network technology trends where high-speed and large-capacity features are dominant, wide-area ubiquitous systems, though small in capacity, have been attracting attention as distinctive wireless systems that can cover a wide service area. These wide-area ubiquitous systems have the following features.

- A wireless area with a radius of several kilometers
- Transmission and reception of information between various types of sensors/actuators and IP terminals
- Low information capacity (a few hundred bytes to several kilobytes per terminal per month) and low rates (about 100 yen per month)
- Accommodation of an extremely large number of terminals (10–100 times the population)
- Extremely small terminals with long lives (battery exchange required once every 5–10 years).
- High security (not currently achievable by the Internet and RFID tags)

Ubiquitous terminals, which excel in operability, utility, durability, and cost efficiency, can be attached to people, vehicles, measuring devices, and information appliances, and the information obtained from them can be consolidated and controlled in the system. Application examples are the reading of gas and electricity meters, stock inventory of vending machines, location recognition, determination of traffic conditions, route selection, measurement of CO_2 emissions, and assessment of green measures.

NTT has been holding verification trials in Special Ubiquitous Zones [1] within Tokyo as part of a three-year project beginning in 2008. In these trials, NTT collaborated with gas companies to test network connectivity (telemetry and safety) and with telecommunication operators to test terminal mobility and location accuracy (mobility and signal reachability).

A wide-area sensor network consists of application servers on the user side (gas companies and telecommunication operators as joint participants in these trials), a master base station, (at Kyojima in Sumida-ku), remote base stations (Kyojima in Sumida-ku, Kanamachi in Katsushika-ku, and Chuo in Edogawa-ku), and network management equipment (NTT Musashino R&D Center) linked via an optical network. In the trial communication system, packets transmitted from wireless terminals, each about the size of a business-card case, are transferred through the optical network and the sensor network. The transmission power of these wireless terminals is very low, but the reception system composed of three remote base stations can maintain communication quality (site diversity technique).

2.4 Electromagnetic wave propagation technology

Electromagnetic wave propagation is a very important research theme in terms of equipment design, radio zone design and the establishment of core competence. In this area, questions that should be studied change as transmission speeds of wireless communication systems increase. Studies during the 1990s (1st- and 2nd-generation cellular systems) focused on receive-level characteristics, while those during the 2000s (dominated by wireless LAN and 3rd-generation cellular systems) analyzed the temporal spreading of incoming waves (differences in signal arrival times due to reflection and scattering) in addition to receive-level characteristics. Looking forward, future systems applying multiple-input multiple-output (MIMO) technology now under study (for next-generation wireless LAN and other systems) will be able to achieve high-speed and high-reliability communications by sending and receiving signals using multiple antennas and making use of complex electromagnetic wave propagation conditions in which signals arrive spatially not just from one direction but from many directions. It will therefore be necessary to analyze and model electromagnetic wave propagation characteristics that include spatially spreading characteristics in addition to studying receive levels and the temporal spreading of incoming waves as in the past.

The frequency bands used for wireless communications also broaden as systems become diverse, so the propagation characteristics in various frequency bands must also be studied. Furthermore, in broadband wireless access, rainfall can cause electromagnetic waves to fade and scatter when millimeter-wave bands are used. Therefore, consideration must be given to such rainfall-related attenuation.

2.5 Technology for increasing frequency utilization efficiency

Spectrum resources are limited, and effective use of the radio spectrum has been an incessant problem in wireless systems. Moreover, the 6-GHz band and below, which is suitable for mobile communications, is seriously congested and there is no way of easing this congestion other than by increasing utilization efficiency by having multiple systems share the same frequencies. The means adopted so far to enable such

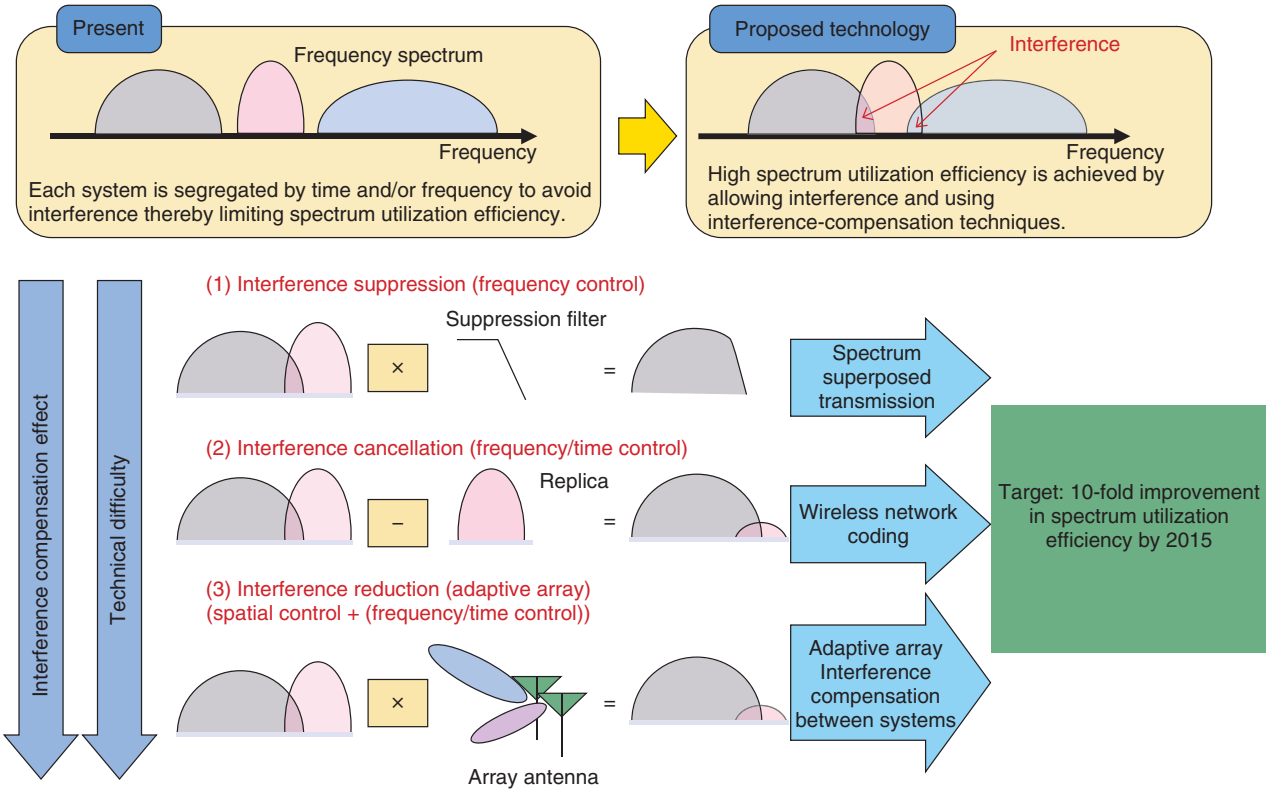


Fig. 4. From interference avoidance to compensation: interference compensation techniques.

frequency sharing is to detect the surrounding environment and take measures to avoid interference (interference avoidance technology), which has been implemented in carrier sense multiple access/collision avoidance (CSMA/CA) and cognitive radio. However, such an interference-avoidance type of approach requires each system to be segregated in terms of time and/or frequency, which itself is limited in increasing frequency utilization efficiency.

In a current study, we are looking at methods that take an aggressive approach to interference by allowing for interference in frequency sharing but removing any interference that may occur (interference-compensation frequency sharing system). There are several interference-compensation techniques as summarized below (**Fig. 4**).

- Interference suppression: cuts off interference power by using a suppression filter, but also reduces the power of the original spectrum resulting in slight deterioration
- Interference cancellation: generates a replica of interference to subtract it from the received signals.
- Interference reduction: sets up an antenna array to make an antenna beam pattern and does not receive signals in the direction of arriving interference

The technical difficulty of these techniques rises in the order of suppression, cancellation, and reduction but so does the interference-compensation effect. Our aim is to achieve a ten-times increase in frequency utilization efficiency by 2015 by applying these methods.

2.6 Green wireless

We are also working on reducing power consumption and CO_2 emissions in wireless systems. One example of our efforts here is the virtual base station, which can be created by interlinking many wireless LAN access points connected by optical fiber with the aim of lowering power consumption at the system level.

It is also instructive to consider that a wireless system, while providing information transfer by wireless means, must be fed power by wired means. Achieving independent power supplies for wireless systems has

been said to be difficult, but we are investigating the following two techniques.

(1) Wireless power transmission: Power is transmitted to wireless equipment via radio waves from a remote location, which makes power supply lines unnecessary and provides more flexibility for the equipment installation location.

(2) Energy harvesting: Radio waves emitted through space such as broadcast waves are concentrated and converted into electric power for use as a power supply for wireless equipment. Alternatively, natural energy such as sunlight can be used to generate power.

3. Conclusion

The mobility, flexibility, and extendibility of wireless systems have made wireless access essential to the diverse development of access-network services. The development of wireless technologies is as crucial and significant as that of optical access technologies in the construction of a seamless network environment.

Reference

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Profile

■ Career highlights

Executive Manager of the Wireless Access Systems Project and the Third Promotion Project, NTT Access Network Service Systems Laboratories.

Toshihiro Manabe received the B.E. and M.E. degrees from Kyushu Institute of Technology, Fukuoka, in 1985 and 1987, respectively. After joining NTT in 1987, he engaged in research on 26-GHz microwave systems. From 1990 to 1992, he was with NTT Network Systems Development Center, where he developed microwave systems connecting cell sites of mobile phone systems. From 1996 to 2002, he worked on R&D of the Advanced Wireless Access system at NTT Laboratories. From 2002 to 2006, he was with NTT Broadband Platform, Inc. developing public wireless LAN systems and services. After returning to NTT in 2006, he engaged in R&D of wireless access systems and services using wireless LAN. His activities are currently focused on the development of wireless access systems and research on wireless core technology. He is a member of the Institute of Electronics, Information and Communication Engineers.

Monolithic Integration of Silicon Photonics Devices for Telecommunications Applications

Tai Tsuchizawa†, Hidetaka Nishi, Rai Kou, Toshifumi Watanabe, Hiroyuki Shinojima, Koji Yamada, and Sei-ichi Itabashi

Abstract

This article introduces our recent progress in silicon photonics device integration for telecommunications applications. We have developed new processes for selective epitaxial growth of Ge on a Si waveguide core and for low-temperature deposition of silica waveguide film. Using these processes, we have managed to monolithically integrate Si variable optical attenuators (VOAs) with a Ge photodetector and Si VOAs with a silica arrayed waveguide grating. These integrated devices exhibit sufficient performance for application to future telecommunications systems that combine wavelength-division multiplexing and burst-mode packets.

1. Introduction

The rapid and huge increase in telecommunications traffic requires highly integrated photonic devices, which make possible high-functionality, low-power, and low-cost telecommunications modules. Recently, photonic integration has been intensively pursued by applying silicon (Si) photonics technology because photonic devices made of Si have many advantages, such as ultrasmall size, low cost, and convergence with electronic devices. A more detailed review of recent R&D trends in Si photonics is given in [1].

Various passive and dynamic devices, such as wavelength filters and modulators, have already been developed using an ultracompact Si wire waveguide, which is a promising platform for photonic integration [2]–[7]. Moreover, some active devices, such as photodetectors (PDs) and light sources have recently been developed on a Si wafer by using heteroepitaxy technology for germanium (Ge) and wafer bonding technologies for III-V materials [8]–[11]. We can now make various individual photonic devices on the Si platform, and some devices, such as filters, modulators, and PDs are already at a level suitable for practical application. As device integration on a chip is the most important advantage of Si photonics, research on Si photonics is now shifting to the integration of devices having various photonic functions.

In this article, we describe two optical device integrations for telecommunications applications. One is the integration of a Si variable optical attenuator (VOA) and a Ge PD and the other is the integration of Si VOAs and a silica-based arrayed waveguide grating (AWG) filter. The VOA-PD integrated device allows high-speed optical level control, which is very important for suppressing fast gain transients and equalizing gain variations. The VOA-AWG integrated device provides wavelength demultiplexing and high-speed power-level adjustment in individual channels. These integrated devices should be applicable to future telecommunication systems that combine wavelength-division multiplexing (WDM) and burst packets.

† NTT Microsystem Integration Laboratories
Atsugi-shi, 243-0198 Japan

2. Fundamental characteristics of Si wire waveguide

Cross-sectional structures of Si wire waveguides are shown in **Fig. 1**. We have developed two types of Si wire waveguides: the single-mode channel type and the rib type. Both types consist of a Si core and silica-based cladding and are fabricated on a silicon-on-insulator (SOI) wafer with a buried SiO_2 layer of 3 μm. The thickness and width of our waveguide core are roughly in the ranges of 200–300 nm and 300–600 nm. The rib-type waveguide is mainly used for dynamic devices such as attenuators and modulators based on carrier injection because the p^+ and n^+ regions can be formed in the slab areas. The channel-type waveguide is used for passive devices such as wavelength filters. The Si wire waveguide has a very high refractive index contrast. This is advantageous for high-density integration because it allows the core to be less than a micrometer wide and the bending radius to be just a few micrometers.

Transmission characteristics of our Si wire waveguide for 1550-nm infrared light are shown in **Fig. 2**. To reduce the coupling loss to an external fiber, our waveguides have spot size converters (SSCs) at both ends. Each SSC consists of a Si inverse taper and a low-index waveguide with a large core covering the taper [2], [13]. For the measurement, high-numerical-aperture fibers with a 4.3-μm field diameter were butt-coupled to the SSC's low-index waveguide. The slope of the line in the figure shows propagation loss, which is typically around 1 dB/cm. This is for transverse electric (TE) polarization, but the propagation loss for transverse magnetic (TM) polarization is rather lower. The loss of the Si wire waveguide depends largely on the sidewall roughness of the Si core. Improvements in the fabrication technique have greatly reduced the loss due to sidewall roughness [12]. In Fig. 2, the transmittance corresponding to waveguide length = 0 shows the coupling loss for two converters; one coupling loss is about 0.5 dB. The superior performance in propagation and coupling will satisfy the severe telecommunication standards for insertion loss.

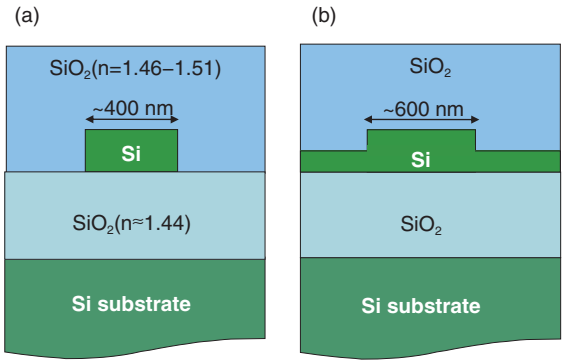


Fig. 1. Cross-sectional structures of (a) channel- and (b) rib-type Si wire waveguides.

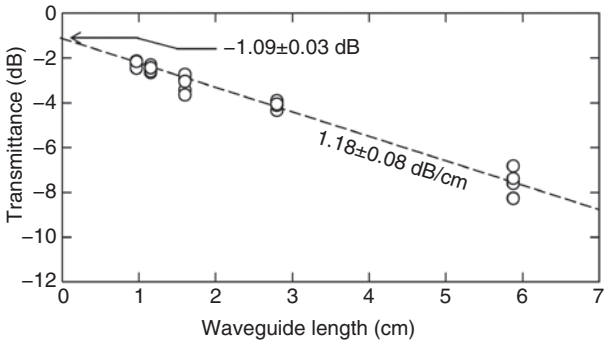
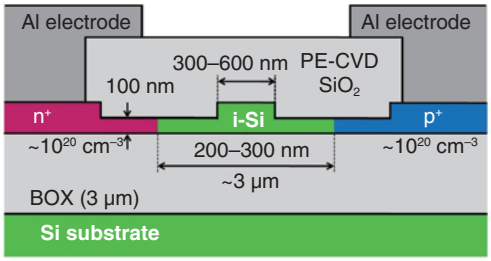


Fig. 2. Measured propagation loss of a silicon photonic wire waveguide with SSCs.

3. Monolithic integration of Si VOA and Ge PD

3.1 Device structure and characteristics

Since Si has semiconductor characteristics, we can easily implement various electronic device structures, such as PN (positive, negative), PIN (positive, intrinsic, negative), and MOS (metal oxide semiconductor) structures [5], [14]–[16], which give optical modulation ability through the carrier plasma effect. We have developed a Si VOA with PIN-type carrier injection structures in the rib-type Si wire waveguides [16]. The cross-sectional structure of the Si VOA is shown in **Fig. 3**. The rib-type Si waveguide has a 600 nm × 200 nm core and 100-nm-thick slab. The p^+ and n^+ regions are 1 mm long and defined in the slab section, and they are about 3 μm apart. The VOA based on Si wire waveguides has the following advantages. The smaller the core is, the faster the device works. Moreover, because of its ultrasmall core, the carrier density, which determines the optical absorption, can be easily increased, so the size and injection current, or power consumption of the device, can be reduced. We have already demonstrated these advantages in our fabricated devices. For example in a 1-mm-long VOA, the 3-dB frequency bandwidth is over 100 MHz, which is about ten times higher than that in



BOX: buried oxide layer
PE-CVD: plasma enhanced chemical rapor deposition

Fig. 3. Cross-sectional view of the Si VOA.

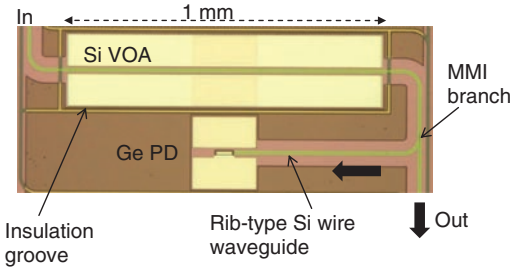
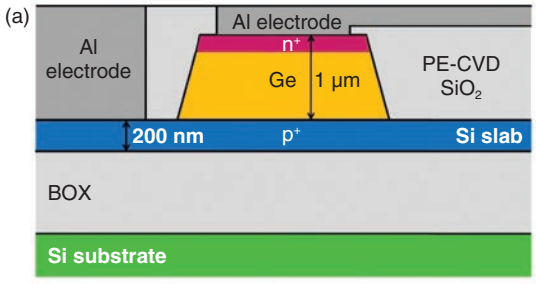


Fig. 4. Top view image of monolithic integration of Si VOA and Ge PD.



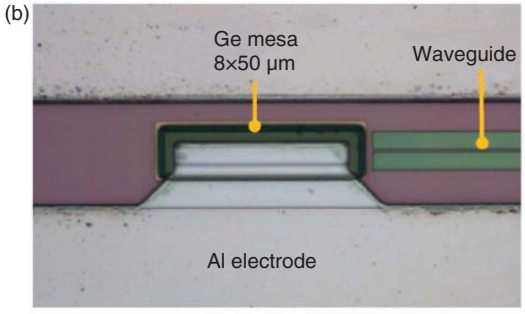


Fig. 5. (a) Cross-sectional structure of the Ge PD and (b) its top view image.

conventional devices. Operation with 30-dB attenuation in a 1-cm-long device requires about 55 mW, which is about half the power consumption of conventional rib-type devices [17]. As this fast VOA is based on a simple structure, a polarization-independent VOA can be achieved just by optimizing the Si core size [18].

PDs made from Ge are preferred in Si photonics because Ge has process compatibility with Si as well as a large absorption coefficient at telecommunication wavelengths. Recently, we have successfully integrated PIN-type Si VOAs and Ge PDs [19], [20]. A schematic of a fabricated VOA-PD integrated device is shown in **Fig. 4**. The device consists of a Si VOA, a 3-dB multimode interferometer (MMI) branch, and Ge PD. The MMI branch was placed between the Si VOA and Ge PD to route light to the outside for device evaluation. The vertical cross-section of the Ge-PD and its top view are shown in **Fig. 5**. The Ge PD is based on a vertical PIN photodiode. A Ge mesa was grown on a Si waveguide by selective epitaxial growth in an ultrahigh vacuum chemical vapor deposition (UHV-CVD) chamber [21]. A SiO_2 film that acts as the overcladding of the Si waveguides was used as a mask for the Ge selective growth. The thickness and size of the Ge mesa were fixed to 1 μm and 8 × 50 μm^2, respectively. To prevent electrical crosstalk between each VOA and PD through the Si layer, an insulation groove is made around the VOA. For device characterization, we injected 1560-nm-wavelength light with a TE-like mode through a lensed fiber into the waveguide with a 3-μm-expanded core at both edges. The infrared light input into the VOA was split by the MMI branch at the VOA's exit waveguide. One of the outputs was fed to a Ge PD on the chip and the other to an external fiber. The propagated optical power was attenuated by carrier absorption when carriers were injected into the waveguide.

The current-voltage (I-V) curves of a Ge PD in dark and illuminated condition are shown in **Fig. 6**. Dark current (I_{dark}) was as low as 60 nA at 1 V of reverse bias, corresponding to a dark current density of 15 mA/cm^2. Such a low I_{dark} can guarantee sensitivity as high as -41 dBm in the detectable minimum light power. When light was injected into the waveguide, a photocurrent was generated as shown in Fig. 6. The estimated responsivity was around 0.8 A/W at reverse bias of 1 V. The 3-dB frequency bandwidth of the Ge

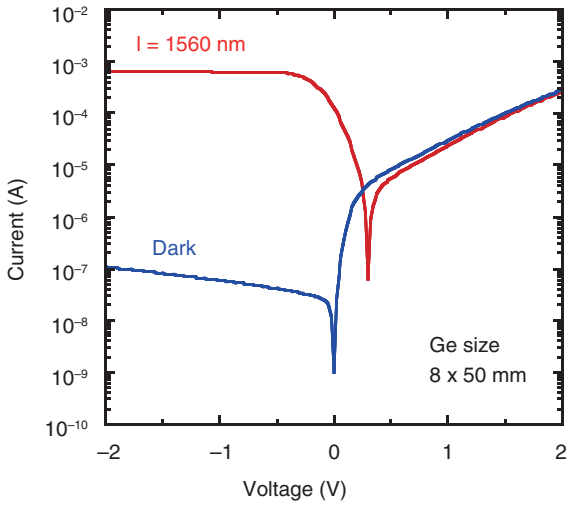


Fig. 6. Current-voltage curves of a fabricated Ge PD with and without light guided to a waveguide.

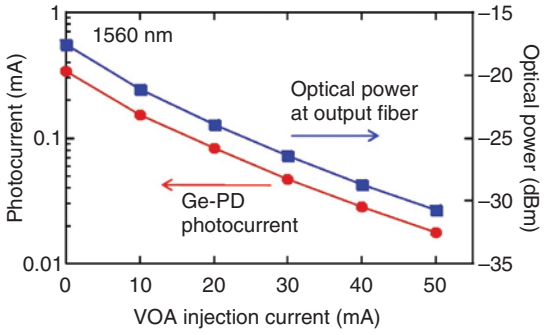


Fig. 7. Photocurrent of the Ge PD on chip and the optical power detected off chip when the VOA was operated with various injection currents.

PD was a few gigahertz, which is limited simply by the RC time constant.

The photocurrent detected at the Ge PD on-chip and optical powers monitored at the output fiber under the condition of VOA current injection are shown in **Fig. 7**. Since attenuation is linearly proportional to carrier density in the intrinsic region of a VOA, the attenuated optical power in decibels decreased linearly with respect to the injection current. The change in photocurrent corresponds well to the optical power. This indicates that the PD precisely detected the light intensity attenuated by the VOA. Leakage current between the two devices was not

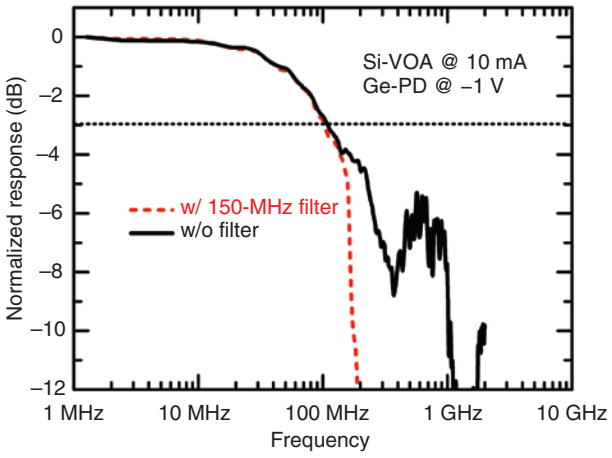


Fig. 8. Frequency responses for synchronous operation between the VOA and PD.

observed in synchronous operation because of the insulation groove made around the VOA. We confirmed that both devices fabricated in monolithic integration worked synchronously with good performance. The frequency responses of the VOA-PD integrated device are shown in **Fig. 8**. Regardless of the reverse bias at the PD, the 3-dB cut-off frequency in VOA-PD synchronous operation was about 130 MHz. The 3-dB cut-off frequency of the VOA was around 130 MHz, while that of the PD was in the gigahertz range. The frequency response of an integrated VOA-PD device is limited solely by the VOA.

3.2 Application to optical power equalization

One of the most promising applications of the VOA-PD integration is fast optical power equalization for burst optical packets. For example, power equalization of bursty upstream optical packets can enhance the dynamic range of receivers [22]. Since the response time should be a few hundred nanoseconds in a 10-Gbit/s passive optical network (PON) system [23], the 130-MHz frequency response of our integrated VOA-PD is sufficient for this fast power equalization. To confirm the feasibility of the fast optical power equalization, we attempted optical intensity equalization using our VOA-PD device and an off-chip electrical feedback circuit [24]. The feedback circuit was a simple linear system. The photocurrent of the Ge PD was converted into a voltage signal through a transimpedance amplifier (TIA). The output voltage of the TIA was amplified by a differential amplifier with respect to a voltage reference, which represented the target power level for optical output.

Then, the signal was guided to the VOA driver, where injection current proportional to the control voltage signal was generated. The feedback circuit covered a frequency bandwidth from DC to 180 MHz.

The output optical power versus input power in DC feedback operation is shown in **Fig. 9**. The output power stabilized within a deviation of 2.7 dB even when the input power varied by 22 dB. For 10-dB input variation, output stabilization within a deviation of 0.8 dB was accomplished. The VOA injection current exhibited a monotonic increase with no irregular behavior. This indicates that the feedback circuit worked very stably even for a large dynamic range of more than 25 dB in optical input. The temporal response of the output for a step-wise increase in the input level is shown in **Fig. 10**. When the input optical power suddenly increased by 16 dB, the output power was quickly recovered and stabilized within a 1.5-dB residual error. The 3-dB recovery time was about 90 ns, which will satisfy the timing criterion for burst optical packets in a 10G-EPON (10-Gbit/s Ethernet PON) system. The recovery time includes a 40-ns insensitive cable delay, which could be eliminated by mounting an application-specific integrated circuit on the VOA-PD chip.

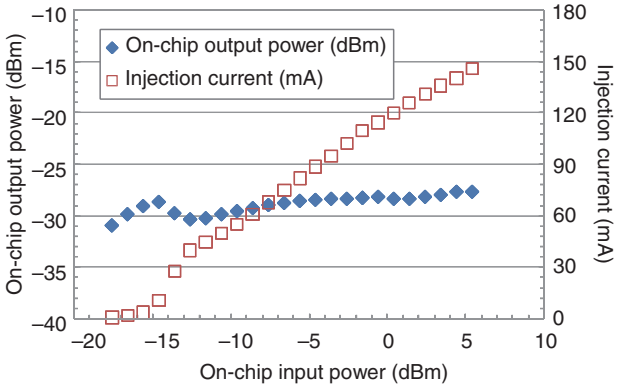


Fig. 9. Results of optical power equalization in DC operation.

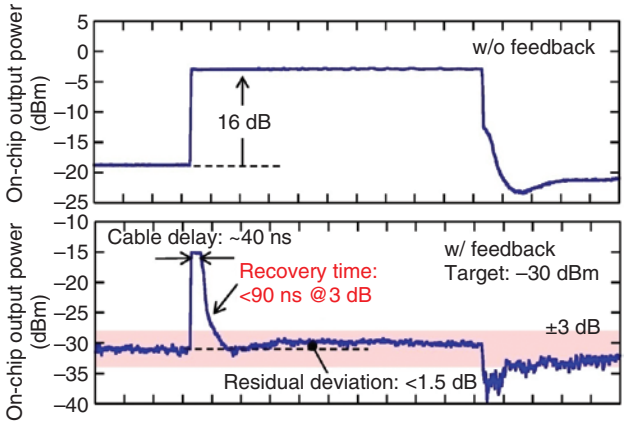


Fig. 10. Results of optical power equalization in pulse operation.

4. Monolithic integration of silicon-based dynamic and silica-based passive devices

4.1 Low-temperature deposition of silica waveguide films

Silica-based waveguides are very attractive for constructing high-performance passive photonic devices, such as AWG wavelength filters and interferometers for receiver circuits because low propagation loss and small polarization dependence are expected [25]. On the other hand, Si wire waveguide devices have other excellent features, such as very fast operation, low power consumption, and high integration density. Therefore, integrating a Si waveguide device with a silica waveguide device should lead to high-performance practical devices for telecommunications applications.

A serious obstacle to the integration of Si and silica is the thermal degradation of the Si devices during the fabrication of a silica waveguide. Silica waveguide fabrication generally involves a high-temperature process at over 1000ºC in silica film deposition [26]. Such a temperature oxidizes the Si waveguide core and destroys the PIN structures for Si modulation devices and Ge PDs. For Si and silica device integration, we need a low-temperature silica film deposition method. We have recently developed one based on electron-cyclotron-resonance plasma enhanced chemical vapor deposition (ECR-PECVD). The ECR plasma easily dissociates gas molecules and provides moderate energy to the substrate. This enables fast deposition of high-quality silica and silicon-rich silica (SiO_x) films at low temperatures. The refractive index and deposition rate of silica film by ECR-PECVD with a mixture gas of SiH_4 and O_2 are shown in **Fig. 11**. In this experiment, the SiH_4 flow rate was maintained at 25 sccm and the O_2 flow rate was changed. The results indicate that the silica film refractive index can be controlled over a wide range from 1.47 to 1.60 by forming SiO_x (Si-rich oxide), which is achieved simply by adjusting the flow rate of oxygen. The deposition rate is about 150 nm/min,

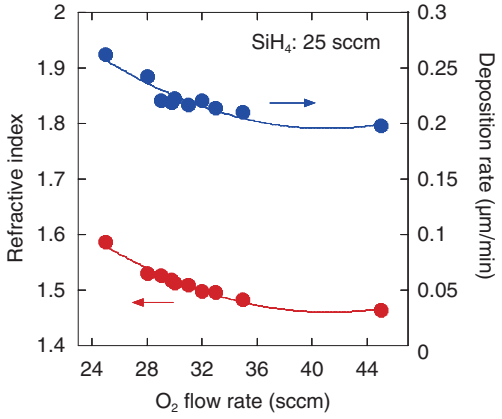


Fig. 11. Refractive index and deposition rate of silica film versus O_2 flow rate with constant SiH_4 flow rate of 25 sccm.

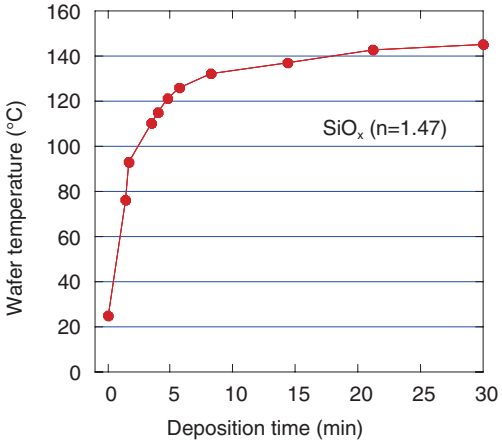


Fig. 12. Wafer temperatures during ECR-PECVD of silica film.

which is high enough for waveguide films that need a thickness of a few micrometers. The wafer temperatures during the ECR-PECVD of silica film, which were measured with thermosensitive tape put on the wafer surface are shown in **Fig. 12**. Although the wafer was not cooled purposely, the wafer temperature was below 150ºC throughout the deposition time of 30 min, which corresponds approximately to a 2-μm-thick deposition.

To evaluate the optical loss of SiO_x made by ECR-PECVD, we made SiO_x waveguides with a refractive index contrast of about 3%. The core was made of SiO_x, whose refractive index is 1.515, and the size was 3 μm square. The overcladding was SiO_2, whose

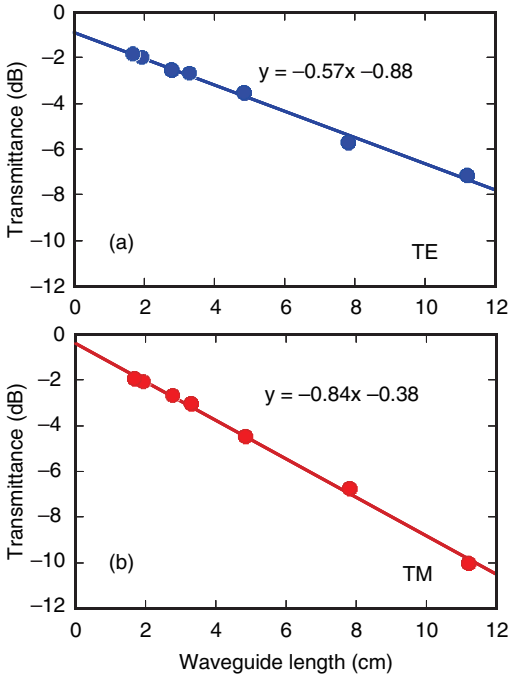


Fig. 13. Transmittance of SiOx waveguides for (a) TE and (b) TM modes as a function of waveguide length.

refractive index is 1.47. These films were formed on 3-μm-thick thermal SiO_2 on a Si wafer because the SiO_x waveguides were integrated with Si waveguides on an SOI wafer with 3-μm buried SiO_2. The transmittance of SiO_x waveguides for TE and TM modes as a function of waveguide length is shown in **Fig. 13**. From the slope of the fitted line, we obtained propagation losses of 0.57 dB/cm for the TE mode and 0.82 dB/cm for the TM mode. These values are low enough for making a practical device on a small chip. The larger loss of the TM mode is probably due to leakage of the propagated light to the Si wafer. The minimum bending radius of this waveguide is 0.5 mm, which will significantly reduce the device size.

4.2 Si VOA and SiO_x AWG integration

Using the low-temperature silica deposition technique, we have fabricated an integrated variable attenuator multiplexer/demultiplexer (VMUX/DEMUX) [27], which is an important component for photonic networks, such as a reconfigurable optical add/drop multiplexing (ROADM) system. The VMUX/DEMUX consists of VOAs for optical power-level control, PDs for power-level monitoring, and an AWG for WDM. An optical microscope image

of the fabricated device is shown in **Fig. 14**. The device was made by the monolithic integration of Si-VOA and SiO_x AWG on an SOI wafer with a 3-μm-thick buried oxide layer. The AWG was made with SiO_x waveguides of Δ 3% and enables wavelength demultiplexing of the C-band signal in 16 channels with 200-GHz spacing. The Si VOA is 5 mm long and its structure is based on the PIN carrier injection described in section 3.1. The AWG provides wavelength demultiplexing and the VOAs quickly adjust the power level in each channel.

The silica and Si waveguide have very different dimensions. The SiO_x waveguide, which composes the AWG, has a cross section of 3 × 3 μm^2. The Si wire waveguides, which compose the VOA, have a 0.2-μm core height, 0.6-μm core width, and 0.1-μm slab thickness. The large difference in core size causes a large coupling loss between two waveguides. This is another problem in the integration of Si and silica waveguides. We used an SSC to compensate for the mode-size mismatch and connect them with low loss. Each output port of the AWG is connected to a Si pin-type VOA through SSCs. An SSC consists of a Si inverse taper and a low-index waveguide with a large core covering the taper [20]. The taper, which gradually becomes thinner toward the end, is 300 μm long and the tip is 80 nm wide. A low-index waveguide over the Si taper is made from a SiO_x waveguide, which has an about-3-μm-square core and index contrast of about 3%. In this device, the same SiO_x layer is used for the cores of the AWG's waveguides, the cores of the low-index waveguide over the Si taper of the SSCs, and the overcladding of the Si wire waveguide. The sharing of SiO_x layers for different purposes simplifies the fabrication process.

First, we examined the performance of the integrated Si VOAs. The relationship between attenuation and injected current is shown in **Fig. 15**. In these experiments, the DC source was connected to the electrode pads of the VOAs. The Si VOA exhibited linear operation as a function of injected current and had a dynamic range up to 30-dB attenuation with an injected current of 70 mA. The power consumption for 20-dB attenuation was 45.8 mW (44.0 mA, 1.04 V). These characteristics are almost the same as those of the stand-alone VOA, indicating that the ECR-PECVD process did not affect the PIN structure in the waveguide. The measured frequency response is shown in **Fig. 16**. The VOA had a 3-dB bandwidth of about 50 MHz. This frequency bandwidth is sufficient for level equalization for burst optical packets in a 10-Gbit/s PON system. Next, as a demonstration of

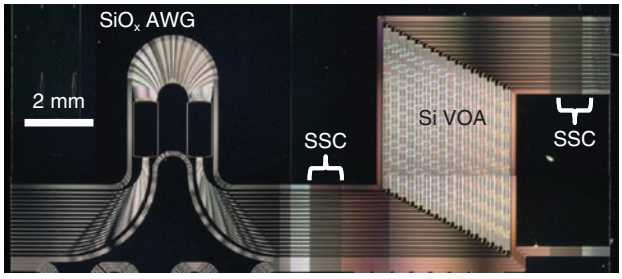


Fig. 14. Optical microscope image of a fabricated VOA-AWG integrated device.

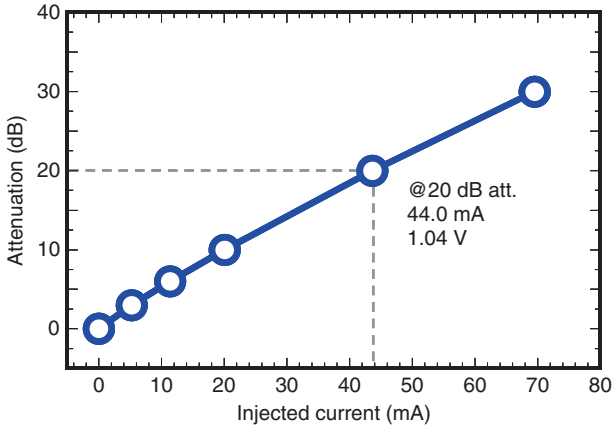


Fig. 15. Relationship between injected current and attenuation of Si VOA in integrated device.

multichannel power equalization using the VMUX/DEMUX, we operated the VOAs individually and measured the transmission spectrum of each channel. The measured spectra are shown in **Fig. 17**. We separated the channels into groups of four and drove the VOAs so that all the channels in a group had the same intensity. We can see that the VOAs independently set the optical level in a group. We verified that all of the integrated VOAs operated, and we drove them so that the transmission level was equivalent every four channels. This device exhibits wavelength demultiplexing owing to the AWG and high-speed power-level adjustment in individual channels owing to the Si-VOA, which has a 3-dB bandwidth of about 50 MHz. The fast level control on each wavelength channel will be useful in future burst-mode WDM telecommunications networks.

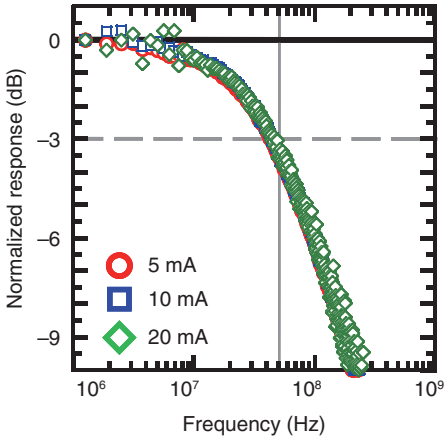


Fig. 16. Frequency response of an integrated Si VOA measured under injected currents of 5, 10, and 20 mA.

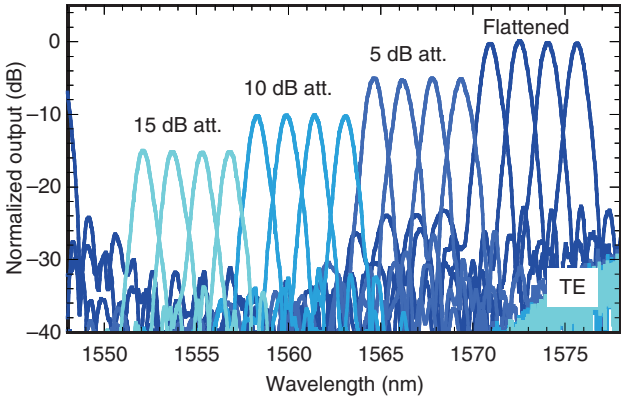


Fig. 17. Demultiplexing and intensity adjustment for every channel using the integrated VOA-AWG device.

5. Conclusion

We demonstrated the monolithic integration of a Si-wire-based VOA, Ge PD, and SiO_x-based AWG. To integrate photonic devices made of different materials, we developed new processes, including selective epitaxial growth of Ge on a Si core, and a low-temperature method of silica film deposition. The Si VOA and Ge PD integrated device showed good synchronous operation with a bandwidth of around 100 MHz, which is limited by the VOA. We demonstrated that this device can work as a fast intensity equalizer for burst-mode packets in optical network systems. The Si VOA and silica AWG integrated device showed wavelength demultiplexing and fast power optical power control of each wavelength channel. Although the integration of many more devices is necessary for practical use, we believe that the integration of Si photonics devices will enable us to make low-cost, high-performance devices for telecommunications.

Acknowledgments

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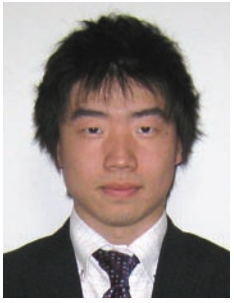
Tai Tsuchizawa
Senior Research Engineer, NTT Microsystem Integration Laboratories.

He received the B.S. and M.S. degrees in physics from Sophia University, Tokyo, and the Ph.D. degree from the University of Tokyo in 1984, 1986, and 1990, respectively. Since joining NTT Laboratories in 1990, he has been engaged in studies on ECR plasma technology and its application to an etching process for microfabrication. His current research interest is fabrication technologies for silicon-based optoelectronics devices. He is a member of the Japan Society of Applied Physics (JSAP).

Hidetaka Nishi
NTT Microsystem Integration Laboratories.

He received the B.S. and M.S. degrees in mechanical science and engineering from Tokyo Institute of Technology in 2005 and 2007, respectively. In 2007, he joined NTT Microsystem Integration Laboratories, where he has been engaged in research on silicon-based optoelectronics devices. He is a member of JSAP.

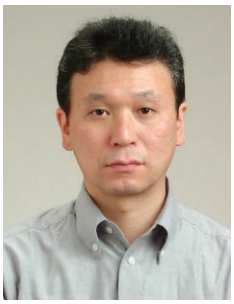


Rai Kou
NTT Microsystem Integration Laboratories.

He received the B.E. and M.E. degrees in applied physics from Waseda University, Tokyo, in 2007 and 2009, respectively. From 2007 to 2009, he was a visiting researcher at the National Institute for Materials Science (NIMS), Tsukuba, Japan, where he worked in the field of nonlinear optics and its related materials. He joined NTT Microsystem Integration Laboratories in 2009. His current research interests are integrated silicon photonic devices. He is a member of JSAP and the Institute of Electronics, Information and Communication Engineers (IEICE). He received the JSAP Young Scientist's Award for the Presentation of an Excellent Paper in 2009.

Toshifumi Watanabe
Senior Research Engineer, NTT Microsystem Integration Laboratories.

He received the B.S. and M.S. degrees in applied physics from Tokyo Institute of Technology in 1982 and 1984, respectively. Since joining the Musashino Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) in 1984, he has been engaged in layout processing studies for electron-beam pattern writers and for computer-aided design data modulation for large-scale integration and photonic circuits. His current research interests include robust processing algorithms for very complex pattern layouts.

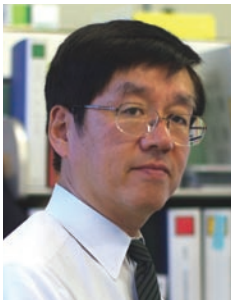


Hiroyuki Shinojima
Senior Research Engineer, NTT Microsystem Integration Laboratories.

He received the B.S. and M.S. degrees in applied physics from Tokyo Institute of Technology and the Ph.D. degree from Muroran Institute of Technology, Hokkaido, in 1984, 1986, and 2009, respectively. Since joining NTT Laboratories in 1986, he has been engaged in studies on material physics and nonlinear optics in semiconductor microcrystals. His current research interests include coherent control in silicon, material physics in low-dimensional semiconductors, and the origin of homochirality in terrestrial bioorganic compounds.

Koji Yamada
Senior Research Engineer, NTT Microsystem Integration Laboratories.

He received the B.E., M.E., and Ph.D. degrees in nuclear engineering from Kyushu University, Fukuoka, in 1986, 1988, and 2003, respectively. Since joining NTT Laboratories in 1988, he has been engaged in theoretical and experimental studies on beam dynamics in electron synchrotrons. Recently, he has been engaged in research on silicon-based nanophotonic structures. He is a member of the Physical Society of Japan, JSAP, the Atomic Energy Society of Japan, the Particle Accelerator Society of Japan, IEICE, and IEEE.



Sei-ichi Itabashi
Senior Research Engineer, Supervisor, NTT Microsystem Integration Laboratories.

He received the B.S. and M.S. degrees in physics from Tohoku University, Miyagi, and the Ph.D. degree from Hokkaido University in 1982, 1984, and 1998, respectively. Since joining the Musashino Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) in 1984, he has been engaged in experimental studies on X-ray and EUV sources. He has also been engaged in theoretical and experimental studies on highly reflective X-ray mirrors and multilayers. He is currently engaged in studies on silicon photonics technology. He is a member of JSAP.

IPTV Interoperability Events at ITU-T

Masahito Kawamori†

Abstract

This article reports the results of the first Conformance and Interoperability Testing event for IPTV (Internet protocol television) hosted by ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) in Geneva (July 2010), the second event in Singapore (September 2010), and the third event in Pune, India (December 2010).

1. Background

IPTV (Internet protocol television) is expected to become a promising service and global standardization is making progress. IPTV standards produced by ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) are based on various services including NTT Plala's Hikari TV service, which started in March 2008. Many Japanese companies, including NTT, are participating in ITU-T's IPTV-GSI (Global Standards Initiative), which is contributing greatly to the global standardization of IPTV. This was much appreciated by ITU, which decided to hold events that would promote conformance to Recommendations and interoperability among the implementations of those Recommendations in order to enhance the quality of ITU-T's IPTV standards. This is a remarkable decision in ITU-T's long history of standardization, and the first Interop event was considered especially significant. This article reports the results the first Conformance and Interoperability Testing (CIT) event for IPTV hosted by ITU-T in Geneva (July 2010), the second event in Singapore (September 2010), and the third event in Pune, India (December 2010).

At the World Telecommunication Standardization Assembly (WTSA), held in October 2008 in Johannesburg, the Republic of South Africa, a resolution was proposed and adopted as Resolution 76 "Studies related to conformance and interoperability testing, assistance to developing countries, and a possible future ITU Mark Program" at the request of the developing countries. It states that ITU-T Study Groups should develop the necessary conformance testing Recommendations for telecommunication equipment as soon as possible and that ITU-T Recommendations to address interoperability testing shall proceed as quickly as possible. On the basis of this resolution, Japan proposed to develop a draft Recommendation for CIT. This contribution was discussed in Study Groups SG11, SG13, and SG16 and resulted in the creation of Joint Coordination Activities of Conformance and Interoperability Testing (JCA-CIT). Following this move, during the IPTV-GSI events, Question 13 of SG16 (Q13/16) drafted CIT Recommendations. At the IPTV-GSI event held in January 2010, it was agreed that the first CIT event (called Interop) would be held in July 2010 in Geneva. At the IPTV-GSI event in May 2010, companies were invited to participate in the upcoming event. To prepare for the first Interop event, Q13/16 had an electronic meeting almost every week until July 2010 to facilitate progress on the CIT Recommendations.

2. 1st Interop in Geneva

After six months of preparation, the first Interop event for testing conformance and interoperability for IPTV Recommendations was held on July 20 to 23, 2010, as scheduled, at the ITU headquarters building in Geneva, Switzerland (**Photo 1**). This was the first ever interoperability event organized by ITU, and much attention was paid to this *historic event*, as it was called by Malcolm Johnson, the Director of ITU-T's Telecommunication Standardization Bureau (TSB).

The Interop event itself consisted of two parts: the

† NTT Cyber Solutions Laboratories
Yokosuka-shi, 239-0847 Japan

first two days were devoted to conformance and interoperability testing (CIT event). This testing was not open to the public, but only to those companies that registered as event participants. The remaining two days were an open showcasing event, to which many individuals and companies were invited to witness the implementations of ITU-T IPTV Recommendations. Special provision was made for regulators and government agencies that had requested and registered beforehand for one-on-one discussions with the presenters at the showcasing event to enable them to have a special tour of the showcased solutions. NTT participated in the closed CIT event as well as the open showcasing event.

2.1 Conformance and interoperability testing (CIT event)

The Recommendations tested in Geneva are listed in **Table 1**.

H.721 is a Recommendation for IPTV terminal devices, initiated by an official contribution from Japan and based on specifications for IPTV terminals actually implemented and deployed for IPTV services in Japan. It defines the requirements for the basic IPTV services, which include video on demand, Linear IPTV (also known as channel service), and interactive applications (IPTV portal).

H.750 specifies metadata. Many of the metadata elements defined in this Recommendations are already used in Japan. H.750 also includes metadata specified by ATIS (Alliance for Telecommunication Industry Solutions) IPTV Interoperability Forum (IIF).

H.762 (Lightweight Interactive Multimedia Environment; LIME) is a Recommendation in the MAFR (Multimedia Application Framework) series, which enables interactive applications and IPTV portals. This Recommendation was also based on contributions from Japan. The technology defined in H.762 is currently used in Hikari TV, NTT's IPTV service.

H.770 specifies how an IPTV terminal device can discover service providers and services, an essential mechanism for a standard IPTV service. It was initiated by contributions from Europe, but many contributions were also made by Japanese and Korean companies. As a result, H.770 is harmonized with service discovery specifications of IPTV Forum Japan and ATIS-IIF as well as those of digital video broadcasting (DVB).

At the first CIT event, Sumitomo Electric Networks, OKI, NEC, Mitsubishi Electric, and NTT were represented. These companies tested conformance to the requirements of the abovementioned Recommendations and interoperability among the implementations of those Recommendations on the basis of those Recommendations themselves and the newly created CIT Recommendations. Although the Japanese companies simply brought servers and terminals that are already deployed in Japan and implement those Recommendations for IPTV, the results of the conformance testing were excellent and interoperability was well proven. This shows the accuracy of their implementations as well as the quality of their

Photo 1. "Dr. Hamadoun Touré, ITU Secretary-General, addressing at the first ITU-T Interop event on IPTV in ITU Headquarters".

Table 1. Recommendations tested at the Interop event in Geneva.

	Recommendation title	Rec. no.	Approving SG	Completion date
1	Content delivery error recovery for IPTV services	H.701	SG16	Jan. 2008
2	IPTV terminal devices: Basic model	H.721	SG16	Jan. 2008
3	High-level specification of metadata for IPTV services	H.750	SG16	Mar. 2009
4	Lightweight Interactive Multimedia Environment for IPTV service (LIME)	H.762	SG16	Nov. 2009
5	Mechanisms for service discovery and selection for IPTV services	H.770	SG16	Aug. 2009

products. It also shows the maturity of the Recommendations themselves. Sumitomo Electric Networks, in particular, stood out in testing its products against all of the abovementioned Recommendations and achieving excellent results. This was truly a remarkable feat.

The checklists used in the testing were collected and made into test templates, which in turn will be used to improve the quality of Recommendations, as deemed necessary. Some of the abovementioned Recommendations were amended on the basis of the results of the first CIT event. This shows that CIT events are not just a showcase, but also an important part of the standardization process, which ensures the quality of standards, as well as providing the practical benefits of a test center.

Photo 2. LIME application for e-health on ITU-T IPTV showcased by NTT (copyright: I^2R and NTT).

2.2 Showcasing event

The remaining days, July 22 and 23, were dedicated to the showcasing and exhibition of IPTV products based on ITU-T standards to publicize and promote the general understanding of what ITU is doing with respect to IPTV standardization.

In addition to the previously mentioned Japanese companies, Cisco System (USA), TVSTORM (South Korea), and the Pontifical University of Rio de Janeiro (Brazil) participated in the showcasing event.

Photographers and TV crews at the Interop event site recorded the event and provided promotional content on YouTube.

Government agencies as well as companies from China, Japan, Indonesia, Singapore, Kenya, India, Turkey, Tunisia, Cote d'Ivoire, Italy, France, Germany, Australia, etc. around the globe came to see the demonstrations of standards-based IPTV. Interest among the developing countries was especially impressive. European companies, for whom it was the first time ever to see ITU-T's IPTV standards, were also impressed by the demonstrations, so much so that some of them started discussing how to deploy IPTV services using the showcased products.

On July 22, we had the honor of receiving Dr Hamadoun Touré, the Secretary General of ITU, who made the welcome address to all the participants and visitors at the event. During the address, he emphasized ITU's seriousness concerning CIT events in general, stating that this IPTV Interop event was a historic occasion, being the first event of its kind, and will be followed by CIT events for the Next Generation Network (NGN) and other topics.

One of the most important things to note about this IPTV Interop event is that many international organizations, some part of the United Nations, were invited. Especially significant was the participation of the Deputy Director of the European Broadcasting Union (EBU) and the Director of Intellectual Property at the World Intellectual Property Organization (WIPO). EBU is influential in various matters, including standardization, regarding the broadcasting world of Europe, and the fact that EBU recognized ITU-T's Recommendations as the first global standard on IPTV gives them considerable weight. With this event, EBU and ITU-T have agreed to even closer collaboration, which resulted in the joint workshop on accessibility for IPTV in November 2010. WIPO is a United Nations agency that is influential in copyright management, and it was very significant that WIPO recognized for the first time ITU-T IPTV as a legitimate medium for broadcast content.

NTT demonstrated interactive content created in cooperation with the Institute for Infocomm Research (I^2R) in Singapore and compliant with H.762 (LIME) on an H.721-compliant TV set already available on the market. This was the first time ever for an application complying with H.762 (LIME), which was approved in 2009, to be demonstrated in Europe, where digital TV sets with IP connections are not yet popular. Since there is no standard interactive platform widely used in Europe, LIME applications (**Photo 2**) were received with interest. Moreover, many observers from developing countries were impressed with LIME, which they saw for the first time.

The guest visitors were all impressed by the level of implementations, especially those of the Japanese participating companies, and it was truly significant

Table 2. Newly created CIT documents based on Interop results.

	Document title	No.	Approving SG	Completion date
1	Technical Paper: Conformance Testing Specification for H.721 (formerly H.IPTV-CONF.2)	HSTP.CONF-H721	SG16	July 2010
2	Technical Paper: Conformance Testing Specification for H.721 (formerly H.IPTV-CONF.6)	HSTP.CONF-H762	SG16	July 2010
3	Technical Paper: Conformance Testing Specification for H.770 (formerly H.IPTV-CONF.7)	HSTP.CONF-H770	SG16	July 2010

that the companies participating in the CIT event were able to demonstrate the maturity of ITU-T Recommendations for IPTV as well as the high quality of the implementations from an international viewpoint, in Geneva, one of the major centers in Europe.

2.3 Relationship between Interop event and Recommendations

The Geneva Interop results will be reflected in the CIT documents for Recommendations H.721, H.762, and H.770 and in those Recommendations themselves (**Table 2**). The changes to the Recommendations received consent at the SG16 Plenary meeting on July 30, 2010. Thus, the CIT event has been instrumental in improving the quality of current Recommendations for IPTV, a point that was well emphasized by ITU-T.

3. 2nd Interop in Singapore

3.1 Overview

The second IPTV Interop event took place on September 20 through 27, 2010, in Singapore as part of the IPTV-GSI event. The venue was provided by I^2R, which belongs to the Agency for Science, Technology and Research (A*STAR) at Fusionopolis next to Biopolis, which is famous as the center of Bioscience research in Singapore. Conformance testing took place there on September 23 and 24, while the 27th was dedicated to an open showcasing.

Fusionopolis and Biopolis were created by A*STAR with the aim of making Singapore into a global hub for research on information, telecommunications, sciences (such as physics, chemistry, and biology), and engineering. Biopolis and Fusionopolis are world-renowned research institutes, as witnessed by the fact that they have been featured in an NHK TV program. The venue was in the academic center of Singapore. Biopolis is next to the National University of Singapore and the Nanyang Technical University, while Fusionopolis is next to the Singapore campus of INSEAD, a famous European business school. More and more developments are expected in this area, which will certainly become the *brains* of Singapore. NTT R&D laboratories have been engaged in collaborative research with A*STAR, and the result of the joint work was also demonstrated at the Interop event.

The Singaporean government expressed strong interest in this event and gave essential support. At the open showcasing event on September 27, Leong Keng Tai, Director-General (Telecoms and Post) of the Infocomm Development Authority (IDA), welcomed participants and took a tour of the exhibition and observed the quality of ITU-T Recommendations for IPTV. This tour was also joined by Philip Heah, who heads the work on Next Generation Nationwide Broadband Network (NGNBN), and Raymond Lee, who is in charge of standardization at IDA.

Participants in this Interop event included Sumitomo Electric Networks, OKI, NEC, Mitsubishi Electric, and NTT from Japan, Panasonic Singapore and two other companies from Singapore, and two Korean companies.

Testing was conducted mainly on H.721 (IPTV terminal devices: Basic model) and H.701 (Content delivery error recovery for IPTV services). All the Japanese companies performed very well, showing their high quality. One Korean company also participated in the testing for the first time, in testing for H.770 (Mechanisms for service discovery and selection for IPTV services).

The main purpose of this Interop event was quality of experience (QoE) for IPTV services. Sumitomo Electric Networks, who led the discussion on H.701, the basic Recommendation for QoE, showed an end-to-end solution for IPTV service. They especially emphasized the high quality of Hikari TV IPTV service. Mitsubishi Electric also showed high-definition content. In Singapore, there is currently strong interest in the quality of content, as can be seen from the articles in newspapers that daily report on the quality

of service of their current IPTV service. The Interop event and its stress on quality was very relevant and well received by the guests to the event, including the government.

NTT demonstrated LIME content again, this time choosing an e-health application on the ITU-T IPTV platform. In the demonstration, data collected by devices for measuring body weight and blood pressure through the FLET's Phone as a gateway was graphed on the fly by the LIME application on an IPTV compliant with ITU-T standards. These measuring devices are already available on the market, and the participants from the Singaporean government seemed to be impressed with the demonstration. As the Singapore government has been emphasizing the importance of e-government, and IPTV in particular is considered to provide the user interface for such services, it was good for NTT to be able to demonstrate such a solution by using retail products. The fact that this demonstration was also based on collaborative work between NTT and A*STAR made it more meaningful to the local audience.

3.2 Results

As a result of the Interop event in Singapore, H. IPTV-CONF.1, the conformance and interoperability document based on H.701 was updated.

4. Third Interop Event in Pune, India

The third Interop event was held in Pune, near Mumbai, in India on December 15–17, 2010. It was co-located with ITU-T Kaleidoscope and IPTV-GSI. It was partially supported by the Indian government. Important representatives from major companies in India, such as the chairman of BNSL and representatives from Bollywood studios, came to the open showcasing event on December 17 and saw ITU-T's standard IPTV in action. The event was videoed by Bloomberg TV and broadcast to more than a million subscribers. It was notable that during the event the representative of the Indian government stated that they are considering ITU-T Recommendations as the national standard for IPTV in India.

5. Conclusion

ITU, led by TSB Director, Malcolm Johnson, has been vigorously working on conformance and interoperability testing, and Interop events have become important activities, as can be seen from the many references made to them in the news media. As we have seen, the CIT results will be reflected in the existing Recommendations, and participating companies can list products confirmed to be compliant with the Recommendations in the CIT database on the ITU-T website. Companies that want to purchase IPTV products compliant with ITU-T Recommendations can go to the database and easily find suitable vendors.

In 2011, several countries, including Brazil and the United Arab Emirates, expressed interest in hosting Interop events. ITU-T is also planning to promote LIME (H.762) and other application platforms by hosting an Application Contest Event, along with an Interop event, during this year's ITU Telecom.

NTT R&D will not only actively participate in those events, but also proactively lead their management, thereby promoting international standards based on contributions based on NTT technologies.

Masahito Kawamori
Senior Research Engineer, NTT Cyber Solutions Laboratories.

He joined NTT Laboratories in 1989. He has worked in research areas such as artificial intelligence, language processing, and interactive agents using speech recognition. His current research area is metadata and rights language, media delivery for broadcasting and broadband communications with special emphasis on IPTV, and the convergence of fixed and mobile communications services. Since 2000, he has been the leader of the Metadata Task Group of the Association of Radio Industries and Businesses (ARIB) Working Group for Broadcasting Systems based on a Home Server. He is involved in IPTV standardization work in ITU-T and is the Rapporteur of Q13/16 and the IPTV-GSI TSR Coordinator.

External Awards

Best Presentation Award
Winners: Kevin Duh and Ching-man Au Yeung, NTT Communication Science Laboratories
Date: Feb. 25, 2011
Organization: 12th International Conference on Intelligent Text Processing and Computational Linguistics

For "Providing Cross-Lingual Editing Assistance to Wikipedia Editors".

The 26th TELECOM System Technology Award
Winners: Hiroyuki Funakoshi and Tatsuya Matsukawa, NTT Service Integration Laboratories
Date: Mar. 22, 2011
Organization: The Telecommunications Advancement Foundation

For "A Failure Rate Estimation Considering the Change in the Number of Equipment".
Published in: IEICE Trans. on Commun., Vol. J93-B, No. 4, pp. 681–692, Apr. 2010.

For "A Simple Estimation Method of Network Reliability with Failure Scale".
Published in: IEICE Trans. on Commun., Vol. J88-B, No. 8, pp. 1444–1453, Aug. 2005.

For "Analyzing Failure Frequency and Severity in Communication Networks".
Published in: Proc. of the 56th Annual Reliability and Maintainability Symposium (RAMS 2010), Jan. 2010.

For "Unavailability Evaluation Method for Communication Network Management".
Published in: Proc. of the 55th Annual Reliability and Maintainability Symposium (RAMS 2009), Jan. 2009.

Papers Published in Technical Journals and Conference Proceedings

Simultaneous Enlargement of SRAM Read/Write Noise Margin by Controlling Virtual Ground Lines
H. Makino, T. Kusumoto, S. Nakata, S. Mutoh, M. Miyama, T. Yoshimura, S. Iwade, and Y. Matsuda

Proc. of NEWCAS 2010, the 8th IEEE International Conference, p. 73, Montreal, Quebec, Canada.

The SRAM operating margin in 65-nm technology is analyzed. The peak characteristic in the read margin versus supply voltage was found to be caused by the channel length modulation effect. Controlling the memory cell virtual ground line proved to be effective in enlarging the operating margin simultaneously in the read and write operations. A simple optimum circuit that does not require any dynamic voltage control and achieves an operating margin comparable to conventional circuits that do require dynamic voltage control is proposed.

Efficient Data Selection for Spoken Document Retrieval Based on Prior Confidence Estimation Using Speech and Context Independent Models
S. Kobashikawa, T. Asami, Y. Yamaguchi, H. Masataki, and S. Takahashi

Proc. of Spoken Language Technology Workshop (SLT), 2010, IEEE, pp. 200–205, Berkeley, CA, USA.

This paper proposes an efficient speech sample selection technique that can identify those samples that will be well recognized. Conventional confidence measures can identify well-recognized speech samples, but they require speech recognition to estimate confidence scores. Low-confidence speech samples should not undergo recognition since they yield speech documents that will eventually be rejected. The proposed technique can select the samples that will justify the application of speech recognition. It is based on rapid prior confidence estimation by using speech and context independent models to calculate acoustic likelihood values on a frame-by-frame basis. Tests show that the proposed confidence estimation technique is over 50 times faster than the conventional posterior confidence measure while maintaining equivalent data selection performance for speech recognition and spoken document retrieval.

Fault Recovery Performance Analysis of Functionally Distributed Transport Networking System
K. Ogawa, K. Higuchi, and S. Chaki

Intelligent Networking, Collaborative Systems and Applications (INCOSA), Springer, Vol. 329, pp. 281–295, 2011.

We propose a fault recovery method in functionally distributed transport networking that separates the control-plane processing part (control element (CE)) from the forwarding-plane processing part

(forwarding element (FE)) of the router. In this architecture, one path-control process in the CE consolidates and processes the path computations and the path settings for multiple FEs. This leads to a reduction in path-control complexity and efficient operation of large-scale networks. On the other hand, it is absolutely critical to ensure the high reliability of the CE. We analyze the performance of the proposed fault recovery method by using a software implementation.