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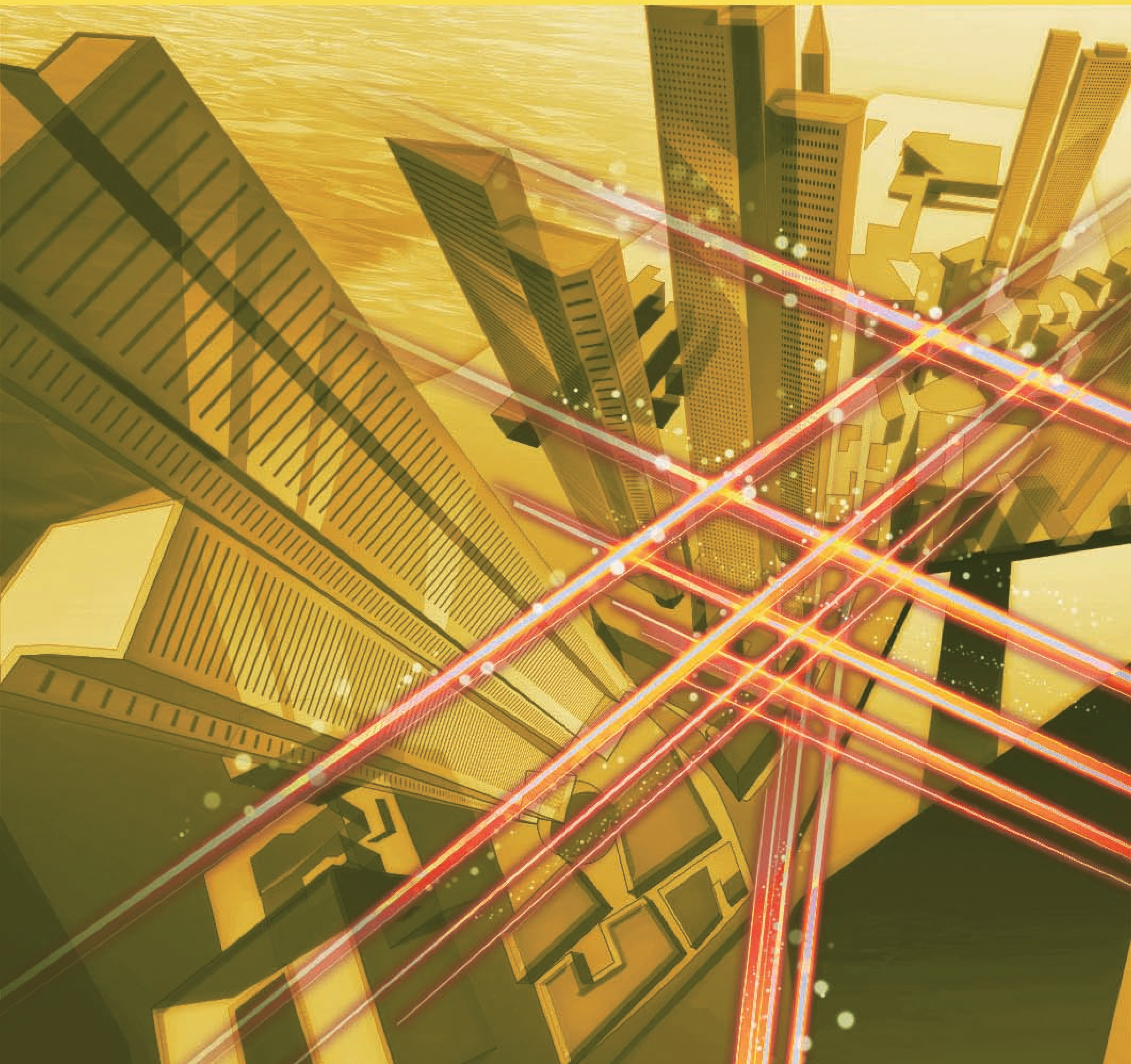

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Establishing the NTT Com Brand in Global Markets through a Fine Balance between Risk and Safety

Tetsuya Shoji
President & CEO, NTT Communications

Overview

NTT Communications has made a string of acquisitions in overseas IT (information technology) companies and has achieved its target of 278 billion yen in overseas sales of cloud services ahead of schedule. In the highly competitive ICT (information and communication technology) global market, what does the company have to do to grow into a true global brand? We asked Tetsuya Shoji, President & CEO of NTT Communications, to tell us about the company's vision and specific strategy for the future.

Keywords: ICT, cloud, orchestration

Global Cloud Vision: Constructing a rock-solid international infrastructure to become a global brand

—Mr. Shoji, congratulations on your appointment as President & CEO. Please tell us about your present outlook and aspirations for the future.

Since assuming this office in June, I have come across all sorts of things that I want to do. However, there isn't enough time to do everything, so I must manage my time carefully, but to begin with, I would like to establish several new directions toward the creation of our next medium-term vision. In addition, I feel the weight of the responsibility as the final decision maker.

Looking over the entire telecommunications industry, I would say that a revolution in information and communication technology (ICT) is taking place and that we are entering a very interesting era. For example, I believe that the cloud market in the United States is two to three years ahead of the market in Japan. From here on, if the Japanese market should grow with the same vitality as the U.S. market, a migration to the cloud should take off with an annual growth rate of more than just a few percentage points. This is an area with great potential!

At NTT Communications, which has expanded in the area of network and infrastructure services, we have been able to construct a cloud on our own network in parallel with advancements in cloud computing technologies. As you know, the main players in this field, for example, Google and Amazon, have been expanding their market share. They are OTT (over-the-top) players that offer services on the infrastructure and network that we provide. Yet we have also been providing networks and infrastructures to our customers. While fulfilling our mission of providing highly convenient, safe, and advanced solutions by transforming such networks and infrastructures into software and services, we are also preparing a platform for the global rollout of one-stop, all-encompassing solution services, including providing applications. Our rivals are a strong bunch, but we take pride in stepping with them into the "sumo ring" to compete for global business.

Our network services cover 196 countries, while our cloud services are provided from an infrastructure installed in 14 hubs in 11 countries and regions (as of the end of August 2015). In this regard, I also feel responsible for driving growth in overseas sales of the entire NTT Group through a business platform that provides these services to our customers. The idea is to combine the individual strengths of upper-layer service provider NTT DATA and global system integrator Dimension Data, and NTT Communications, which provides global support for the NTT Group.

—What is your strategy for developing global brand power in such a fiercely competitive ICT market?

In each overseas region where our Japanese corporate customers have set up bases, there exists a local telecommunications carrier that provides them with services equivalent to ours. Customers who are expanding their business both inside and outside Japan expect us to provide an ICT environment the same as that in Japan so that they can carry out their business in a stress-free manner.

In reality, however, I can't say that we have fully satisfied this need. To turn this situation around, we have announced a Global Cloud Vision to drive the growth of NTT Communications as a global brand. The name of this vision combines the new keywords "global" and "cloud."

With our Global Cloud Vision, we will address the problem of cyber security, for example, by protecting the customer's communication environment in a comprehensive, one-stop, and global manner from the network and cloud infrastructure right up to the customer's bases and terminals.

As typified by the words "Japanese quality," Japanese corporations and Japanese products have come to be known as highly reliable, safe, and secure. NTT Communications is also active in raising the level of quality. We regularly hold the Arcstar Carrier Forum in Japan to share our operations know-how with telecommunications carriers from around the world. This approach to quality is the reason why multinational customers have been choosing us over local telecommunications carriers. We also focus on reducing the amount of burdensome work that occurs outside of the customer's main line of business such as by providing operations services with multilingual support.

Our "Seamless ICT Solution" optimizes a corporation's ICT environment on a global basis when migrating to the cloud. We have a proven track record in introducing this solution by establishing basic patterns tailored to management problems in a variety of industries.

Due to our enthusiastic efforts in promoting to our customers our global rollout of wide-ranging services and solutions centered about cloud services, we have been able to achieve overseas sales of more than 278 billion yen.

—You have constructed a solid foundation. What further developments can we expect?

I am confident that our Seamless ICT Solution will facilitate our customers' management reforms. Going forward, I would like to further enhance our ICT operations and management that can be applied in a standardized way worldwide. Moreover, in addition to supporting Japanese companies in expanding their business, I am eager to offer our services to North American and European global enterprises listed in the Fortune 500.

With regard to a medium-term vision for 2016 and beyond that I mentioned earlier, I plan to announce key issues for building up our business including specific service plans at the NTT Communications Forum 2015 that we are holding in the fall. As a particularly exciting endeavor, I would like to pursue services that can achieve network functions on general-purpose servers using network function virtualization (NFV) technology.

At present, most network functions are provided as network appliances that are integrated with dedicated hardware, but NFV technology can achieve network functions on general-purpose servers without using dedicated hardware. I will also focus on *orchestration* services to achieve autonomic control, configuration, and management of complex computer systems consisting of hardware, middleware, applications, and services in those applications.

Work occupies more than half of a person's life: It must be enjoyed from a "know/like/enjoy" perspective

—It is said that speed is the key for winning in the ICT business. What is the best way to develop a sense of speed in the ICT industry?

I love amusement park rides, especially scary ones. In fact, I have ridden all of the scary and thrilling rides in Japanese amusement parks. I like to experience the force of gravity on my body. This is one way of developing a sense of speed. In work, a healthy balance is needed between risk and safety. Mario Andretti, the famous race car driver, said: "If everything seems under control, you're not going fast enough." In our work, this means that delivering reliable and maximum performance requires that we take ourselves to the limit and that we don't forget to take on challenges even if that means taking on some risk.

I also attach much importance to the words "know/like/enjoy" (pronounced "chikoraku" in Japanese) from the Analects of Confucius. In work, I believe we can apply these words as follows. When we are working on something, "knowledge" by itself can only take us to a certain level. However, if we come to "like" this work, we can move to a higher point and our performance will improve as a result. Then, if we come to truly "enjoy" it, work can take on added value above and beyond what we expected. Being optimistic in character, I have always thought it is important to make one's work enjoyable. A working member of society spends about 70 to 80% of his or her waking hours in work-related activities. In other words, we spend the majority of our active time in life involved in work, so work can hardly have value if we don't enjoy it. Certainly, "work should be fun!"

While keeping these ideas in mind, I would also like to mention something else I value in terms of mindset. That is striking a balance between "improvement" and "innovation" when pursuing something new. Improvement requires continuity, while innovation requires the ability to produce something new that others cannot follow. As a leader, I am committed to the concepts of improvement and innovation in order to move forward and take on challenges swiftly with all employees in a unified manner. For example, when explaining to a customer how using the cloud can change that company's business, it is necessary to stress that the cloud can be used not just to achieve a better system by introducing new technology but also to drive innovation in company management. My aim is to promote and enhance such proposal skills on a company-wide basis.

Of course, training and developing employees for leadership roles is important, but it is also important to improve the skills of all employees in the corporate sales sector from the bottom up. If the ability to mutually communicate, train each other, and share information can be instilled in all employees of an organization, each employee should be able to absorb knowledge on advanced technologies and services. The result would be bottom-up improvement throughout the organization.

Everyone has their own preferences and natural inclinations, so it is therefore important to put the right people in the right place for each mission. In addition to meeting directly with employees, those of us in management positions make an effort to implement optimum personnel assignment and training through objective indices and evaluations from others. It is also important that employees themselves be capable of self-evaluation. And most important of all is an employee's passion and motivation.

—Having passion and motivation is certainly a vital element. Based on your experience, what kind of outlook should one adopt in facing one's challenges?

From my involvement in a project toward the privatization of NTT, I learned the importance of seeing things from above, of taking a comprehensive view. At that time, Nippon Telegraph and Telephone Public Corporation was a public service corporation under the jurisdiction of government ministries and agencies. However, against a backdrop of technical innovations, we were being asked to take a more active and liberal approach to providing our telecommunications services to the market. This was when I was selected to be part of a team whose mission was to achieve this. At that time, having a global outlook was rare, but the key issues here were to determine what kind of format to provide services in and how to contribute to making services more convenient for the user. We were being entrusted with a great deal of responsibility and work. In facing such a major challenge, I learned the importance of taking a comprehensive, bird's-eye view instead of thinking only about the immediate future. I believe leaders in management positions should encourage the people below them to have such a comprehensive view.

As I mentioned, our industry—telecommunications—is progressing and expanding at high speed. If our focus is too local or too narrow, we lag behind many of our competitors. We need to take a good look at the world and our goals and reassess where we stand. It's necessary that we think about the kind of work that we should be doing from one or more viewpoints in addition to our current outlook. Performing this simulation on a daily basis should enable us to grow. I remember how one of my superiors asked me to adopt the following mindset at all times: "What should the Japanese telecommunications industry be like and what should be done to make it like that?" In this way, I learned the importance of comprehensive, comparative examination not only from the standpoint of operators but also from the standpoints of users, the government, employees, and others. It is imperative that we keep in mind the viewpoints of a wide range of stakeholders including our customers and partners and obtain an overall consensus in moving forward.

"Ichi-go Ichi-e"—Take on the challenges for the future and be comfortable with risk

—What would you say to those in charge of research and development (R&D)?

Artificial intelligence, or AI, has become a hot topic. This trend is not a transient thing; from here on, we can expect the fields driven by robotics and ICT to

expand. Take, for example, operations in a call center. It is not difficult to imagine how some exchanges with customers can be formalized and left to AI, thereby reducing the workload on human beings. As we move closer to the 2020 Tokyo Olympic and Paralympic Games, I would like to see even more progress in R&D and product development with a view to separating the work handled by people and human intelligence and that entrusted to AI and robotics, and creating an environment in which people and AI coexist. I think the full effectiveness of ICT can be demonstrated in this way. As I stated earlier, you cannot take on challenges without taking on some risk. Please get rid of any preconceived notions and feel free to apply your creativity and imagination to the max.

—Mr. Shoji, can you leave us with a few words of encouragement for all employees of NTT Communications?

I like the expression "Ichi-go Ichi-e," which means treasure every encounter, for it will never recur. Perhaps this is based on my experience in business, but I feel that encountering people who have skills and talents that I don't have is something very valuable in both my private and public life. In relation to what I talked about earlier, I would like everyone to have amazing and genuine encounters through work, which occupies more than half of our lives. Furthermore, an environment in which all employees enjoy the work that they are doing lays a foundation for providing our customers with secure, reliable, and high-quality services. It is of prime importance in my view that all employees of NTT Communications take pleasure in their work. I would like to see all of us enjoy our work to the fullest!

Interviewee profile

■ Career highlights

Tetsuya Shoji joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1977. He has served as Executive Manager of the Personnel Department of NTT WEST, Director of the General Affairs Department of NTT, and Senior Executive Vice President (in charge of sales) of NTT Communications. He has been in his present position since June 2015.

The NetroSphere Concept and Network Architecture

Ryuichi Sumi, Kimihide Matsumoto, Ichiro Inoue, and Yoshio Kajiyama

Abstract

The NetroSphere concept was devised by NTT laboratories to guide the development of communication network technology for the future. The aim is to provide customers and service providers with a network that provides the services they require at high speed, with high reliability, and at low cost by adopting an architecture in which a diverse range of functions can be used flexibly. This article outlines the aims of the NetroSphere concept and the network architecture that supports these aims.

Keywords: NetroSphere, future networks, B2B2X

1. Introduction

Overall, network services are affected by five main issues, which are as follows.

1.1 Flexibility to changes in demand and/or environment

Recently, the rise of OTT (over-the-top) content delivery has led to large changes in the communication environment, including carrier networks becoming *dumb pipe* networks and the transition of communication businesses and services from telephone-centric to data-centric models. It is getting harder to predict how things will change in the future. Currently, network infrastructures are configured from equipment dedicated to individual functions. Achieving high reliability and high capacity per equipment unit means that equipment tends to be expensive and large-scale. Also, services have been provided using a vertically integrated network model, referred to as a *silo-type* network. In a silo-type network, it is difficult to add or modify the network's functions or capacity to accommodate new services, and since some parts of the equipment cannot be used by other services even if they have a low usage rate, this can result in the overall network becoming inefficient when there are large changes in communication demand and the communication environment.

To address this situation, even carrier networks have recently been the subject of research and development (R&D) and standardization efforts relating to virtualization techniques such as network functions virtualization (NFV) and software-defined networking (SDN), and it is expected that advances will be made in the functional separation of network equipment. However, in a carrier network, the deployment of functions and the connection configuration are still designed for conventional dedicated equipment and are subject to the requirements of carrier networks such as high reliability and high scalability. As a result, even an advanced level of functional separation will not change the conventional silo-type configuration. This is perhaps why modularization has not yet advanced to the point where networks can be freely configured. Furthermore, since the network equipment that is currently used has a short end of life (EoL) cycle, there is a frequent need for EoL-related development, and the EoL of a single component becomes the EoL of the entire network infrastructure, resulting in increased network costs. In the future, there will be a need for flexible low-cost networks that can adapt to changes in demand and changes in the environment.

1.2 Service provision period

In preparing to launch a new network service, it can take months or even years to develop the new functions that are required. This makes it impossible to adapt immediately to the changing needs of service providers. This is also partly because the introduction of new functions is strongly tied in with the road map for dedicated products used by network functions. It is therefore hoped that a network can be implemented where it is possible to respond promptly to the diverse needs of service providers and reduce the service provision preparation period.

1.3 Diversification of user equipment

With the growing diversity of user equipment, including equipment installed at the customer's premises (CPE: customer premises equipment) and on-premises equipment, the increased number of firmware updates and other maintenance operations on this equipment is becoming a challenge. Furthermore, it is predicted that the development of the Internet of Things (IoT), where communication takes place between all sorts of objects, will result in growing diversity and scale of user equipment and the ways in which it is used. It is therefore necessary to develop a network architecture that can adapt to new modes of use such as IoT while minimizing the load on user equipment by providing on-premises type functions on the network side.

1.4 Operation

Even for the operation of communication services, there is a need for a mechanism that can be implemented with a small number of maintenance operators in order to reduce the operating expenditure (OPEX). To make fundamental changes to management operations so as to eliminate the need for human involvement, it will be necessary to implement measures such as mechanisms that do not require maintenance workers to be on call all night long, and to work towards a skill-less system where site work can be performed by anyone.

1.5 Security

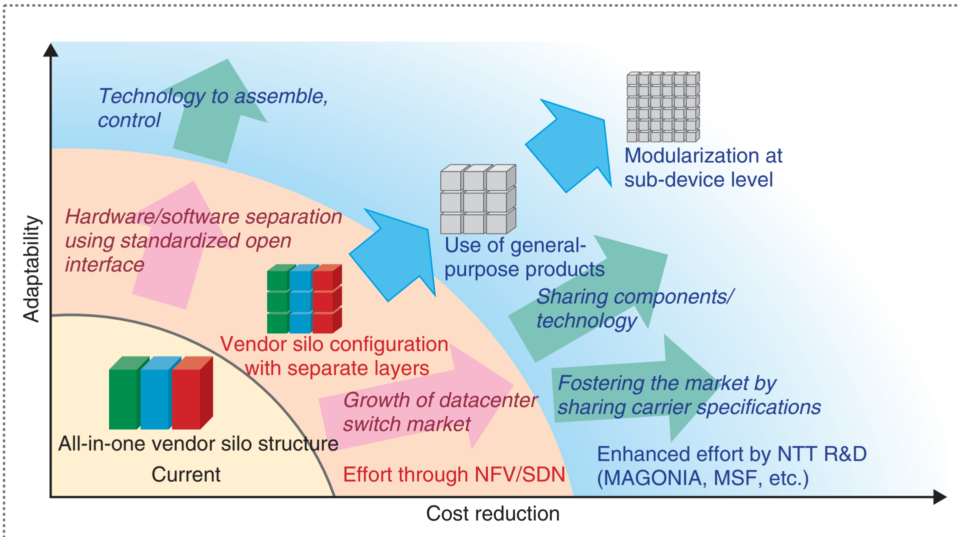
It is predicted that cyber security threats will continue to grow in the future. For example, it is said that it may be necessary to deal with large-scale cyber-terrorism affecting an entire network. In addition, for network structures that comprise a growing proportion of software, there is a need for new mechanisms and standards for reliability assurance, and for the efforts needed to support them.

2. The NetroSphere concept

At NTT laboratories, we are making progress in researching the construction of the future network infrastructure while continuing to make further progress in the abovementioned areas such as supporting diversity and providing flexibility to encourage joint creation. We also consider that it is necessary to take a fresh look at the status of networks and equipment and the role of communication providers that work with these networks. For this reason, we formulated the NetroSphere concept.

In future networks based on the NetroSphere concept, our aim is to create new value while protecting our customers from risk while synergistically adapting to changes in the outside environment above and beyond the traditional *connecting* role of networks. Network configuration functions are handled by splitting them into the smallest possible components and distributing each component to its optimal location. These network components can be freely combined to configure virtual equipment that provides the necessary functions and networks that are required by service providers. Furthermore, by having a shared resource pool of small network components that are only combined as and when they are needed, we can respond rapidly to the needs of customers and service providers and provide the necessary functions and capacity in a flexible way. Since each individual component has a simple function, this allows a wide variety of suppliers to enter the market, which is expected to lead to cost reductions. Moreover, it can drastically reduce the equipment costs by allowing redundancy and higher capacity to be achieved with high efficiency (**Fig. 1**).

Instead of a conventional silo-type structure, the network is split into hardware and software layers that are thoroughly separated into different functions, components, and modules to facilitate the entry of more players into the communication field, even from different industries. This will fundamentally reform the total cost structure of telecommunication services, reducing CAPEX (capital expenditure) and OPEX to less than one-tenth of their traditional levels, while providing a one-stop solution for operations that operate and maintain services. In this way, even for B2B2X (business-to-business-to-X) business models where various service partners and communication providers collaborate to provide services, we aim to achieve an order-of-magnitude improvement in the performance and speed of services by implementing a service development environment that can meet the



MSF: Multi-Service Fabric

Fig. 1. Approaches to achieving the NetroSphere concept.

needs of diverse service partners flexibly, promptly, and at low cost.

Specifically, by providing network and service functions as raw materials, the network structure is split into a software layer (virtual layer) and a hardware layer (real layer). In the real layer, commodity hardware (servers, switches, etc.) that is made jointly available to every service is clustered together to make the maximum possible use of light (wavelengths), and is efficiently arranged so as to minimize the use of photoelectric conversion (**Fig. 2**). The virtual layer allows the dynamic on-demand creation of building-block software components without being tied to any particular area, thereby enabling the implementation of *pick and mix* configurations by controlling and operating services according to a diverse range of requirements.

3. Network architecture and technical issues of NetroSphere concept

The network architecture of the NetroSphere concept and the technical issues associated with it are described below (**Fig. 3**).

3.1 Low-cost network resistant to changes in demand or the environment

The NetroSphere concept is based on a low-cost network architecture enabling services to be provided flexibly even if traffic levels suddenly increase tenfold or more or if there are changes in the way traffic circulates, and enabling services with low latency to be provided at low cost for the era of 5G communications and for the large number of communication terminals that will come into use with the expansion of IoT. Our aim is to reduce the cost of core networks that need to be expanded to handle more traffic by one-tenth, and to reduce the overall cost of networks including access and transmission equipment by one-third by 2020.

This will reduce costs by making network functions available as completely general-purpose raw materials, and by implementing network-wide resource pooling to adapt to fluctuations in demand so that the network utilization rate can be maximized. Specifically, the network is separated into service-specific functions and transmission and control functions that are shared by all services.

Depending on the demand and the needs of service providers, each function is implemented from architecture that can be freely combined (MSF: Multi-Service Fabric), or the network functions are separated from the hardware as software components so that by leasing server resources it is possible to provide a highly reliable system with efficient redundancy that is highly scalable and has low overhead. This results in a highly reliable server architecture (MAGONIA) [1]. Moreover, with the use of advanced visualization

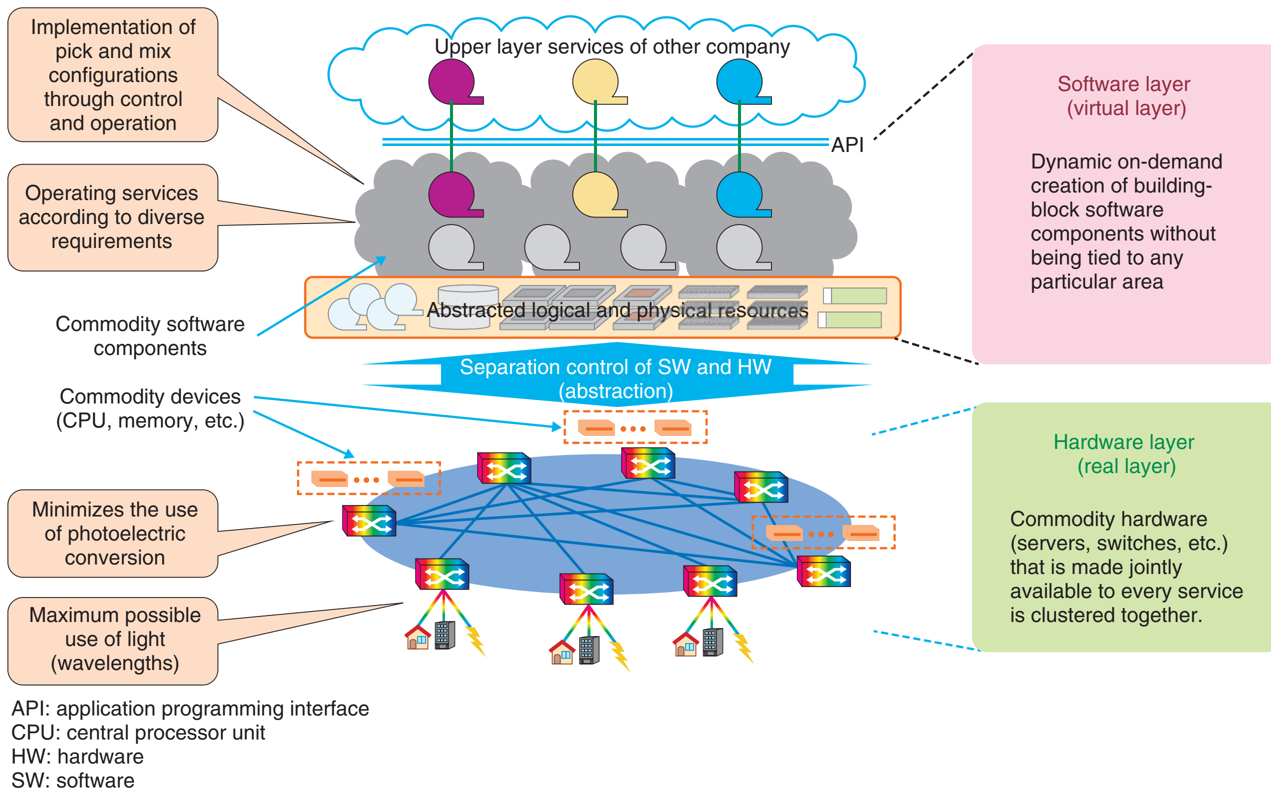


Fig. 2. Network vision based on the NetroSphere concept.

and analysis techniques such as the analysis of big data inside and outside of networks that are becoming increasingly complex, it is becoming possible to minimize the risk of equipment failure and traffic fluctuations by implementing control whereby resources are allocated proactively through resource optimization techniques, proactive traffic control technology, and network science.

3.2 Adapting to the needs of service providers and reducing the service development period

The NetroSphere concept aims to reduce the service development period and produce a network architecture that allows new services to be provided in a short period of time. To enable the provision of BTO (build to order) services that meet the needs and desires of service providers, we aim to adapt to the needs of service providers and develop services in a shorter time by preparing a mechanism for treating network service functions as building blocks for virtual functions that can be flexibly combined. We therefore propose service co-creation networking technology (**Fig. 4**) that can promptly and flexibly adapt to the needs of service providers by freely combining modularized network functions (functional blocks) depending on the service criteria and the state of network resources. This results in a network architecture in which the service provider uses virtualization technology to provide a logical slice of the same network environment as the physical network and is able to change, add, and modify in-service combinations of network resources while maintaining the SLA (service level agreement). For example, it makes it possible to deploy and configure network functions and bandwidth at optimal locations according to the attributes of the application that provides the service, depending on criteria such as the service's latency time and traffic exchange requirements.

3.3 Provision of user functions (on-premises, etc.) as network services

When functions are conventionally implemented using on-premises equipment or are deployed in a service provider's cloud, virtualization is used to provide these functions as network services, so that the latest functions are always available, resulting in a

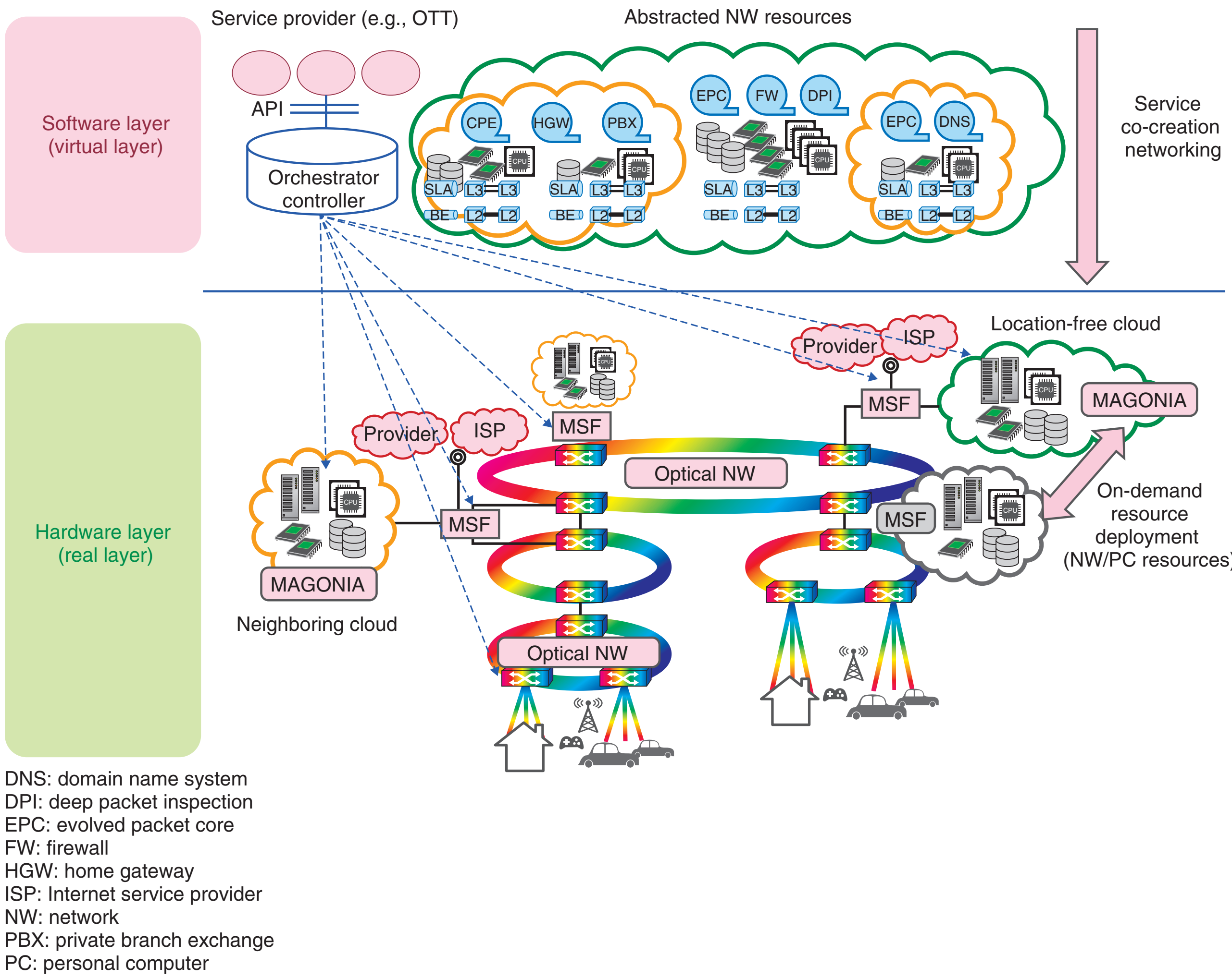


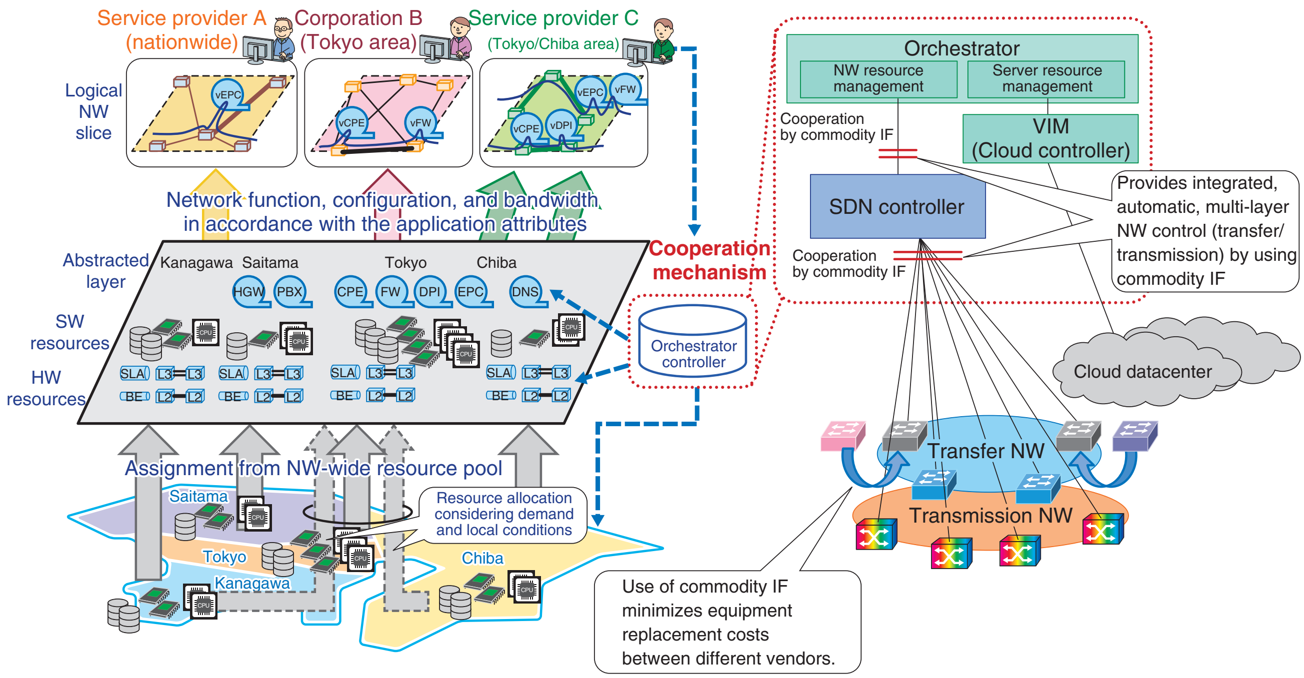
Fig. 3. Future network architecture based on the Netrosphere concept.

paradigm shift from ownership to use. This reduces the service cost and makes it more secure. For example, by deploying a user's on-premises CPE functions and the like on the network side, we aim to reduce the maintenance and operation work involved in tasks such as keeping the settings up to date. Moreover, by implementing a mechanism whereby raw material functions can be freely combined within the network, it is possible for diverse service providers, including newcomers to the field, to create new services (e.g., a service that combines vCPE with a firewall), and by adapting promptly and flexibly to diverse service demands in IoT, it is possible to create networks with new added value.

3.4 Streamlining and visualizing the effects of automated operations

In the NetroSphere concept, for operations related to network maintenance, we aim to provide an architecture that makes the utmost use of automation so it can be operated by a small number of personnel. We propose providing a network-wide resource pool so that operations can be automated to produce an operation architecture that facilitates efficient network operations with fewer personnel who do not need to be on 24-hour call (integrated control technology).

We also implement an environment in which the network usage situation can be visualized, and where service providers and the like can freely use the network. This can be implemented by automating the setting of related equipment associated with



IF: interface
VIM: virtualized infrastructure manager

Fig. 4. Service co-creation networking technology.

managing and augmenting the relationships between the functional elements that implement a service and the relationships between functions, allowing the service provider to visualize the network status (service quality, areas affected by equipment failure, etc.). When there is an equipment failure, prompt service recovery and equipment replacement at the affected location will become unnecessary through the use of a spare resource pool to automatically restore the network and reconfigure the network redundancy. By visualizing these network operation activities (navigation/annotation functions), we can also promote the visualization and improved efficiency of operations.

3.5 Providing a safe and secure communication environment

Our objective with the NetroSphere concept is to ensure overall security across the network against new, more sophisticated cyber threats in the future, and thus, we are aiming to achieve a mechanism that can respond quickly and flexibly even to new threats through cooperation between the network and cloud. We are also aiming for a mechanism whereby diverse people and things connected to a network (IoT, etc.) can use the network safely, and we are implementing a secure network environment that can respond to a diverse range of attacks, including concerted attacks where terminals are hijacked, and attacks on virtualized platforms.

We are promoting the establishment of reliable new design and evaluation techniques suited to diverse service providers and to the development of network virtualization technology (e.g., NFV, SDN). Furthermore, we are working to establish network technologies that are resistant to natural disasters and that can minimize their impact on services. For example, by adopting a design that minimizes the possibility of a network being cut off between hubs, we can mitigate the impact of large-scale disasters on communications, and we are establishing techniques for reconfiguring network resources according to the disaster location in order to minimize the impact when the disaster occurs.

To implement a network that is environmentally sustainable, we are implementing network architecture that uses low power to maintain a suitable level of performance during normal operation and that keeps connections alive while maintaining the minimum level of performance in the event of a disaster.

For further power savings and cost reductions, we are working on the introduction and growth of HVDC (high-voltage direct current) systems as a replacement for conventional 48 VDC (volts direct current) and AC (alternating current) power supplies.

4. Future prospects

To realize the NetroSphere concept, it will be necessary to proceed with reforms together with many of the players in the communications industry. In particular, to promote the spread of network functions based on general-purpose modular components, we are promoting initiatives such as the development of common specifications and international standards for carriers adhering to similar concepts.

Also, to accelerate the development of technology, we are establishing broad links with partners from various specialist fields such as domestic and overseas vendors and research organizations in order to develop technology through joint R&D efforts and verification trials.

Reference

[1] K. Ono, H. Yoshioka, M. Kaneko, S. Kondoh, M. Miyasaka, Y. Soejima, T. Moriya, K. Kanishima, A. Masuda, J. Koga, T. Tsuchiya, N. Yamashita, K. Tsuchikawa, and T. Yamada, "Implementing the NetroSphere Concept at NTT," NTT Technical Review, Vol. 13, No. 10, 2015.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201510fa2.html

Ryuichi Sumi

Vice President, General Manager, Planning Department, NTT Information Network Laboratory Group.

He received a B.E. in administration engineering from Keio University, Kanagawa, in 1988 and joined NTT Software Laboratories the same year. He studied software development support environment for CHILL (CCITT High Level Language for telephone switching systems) using a UNIX workstation and the Internet during 1988–1994. He moved to NTT Multimedia Business Department, where he developed a video on demand system over an optical fiber network with Microsoft. He also worked at NTT WEST and NTT Resonant (board members of Live Life Japan), and was actively involved in developing a local area information sharing portal, a video conference system over Internet protocol (IP) networks with document sharing function, web service products, and live entertainment ticket sales information portal services. After returning to NTT, he had led open source projects and produced committers in Tomcat, Java, and JBoss community. He has been in his present positon since 2012, and manages entire R&D activity about all network issue.

Kimihide Matsumoto

Executive Research Engineer, Executive Manager of Network Technology Project, NTT Network Technology Laboratories.

He received his B.S. and M.S. from Nagoya Institute of Technology in 1988 and 1990. He joined NTT in 1990 and conducted research on traffic engineering and quality management in telecommunications networks. From 1999 to 2005, he developed systems for IP-based services at NTT EAST. He is currently working on architecture of future telecommunications networks. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Ichiro Inoue

General Manager, Planning Department and General Manager, Network Systems Planning and Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in electronic and electrical engineering from the University of Tokyo in 1988 and 1990. He joined NTT Switching Systems Laboratories in 1990 and studied asynchronous transfer mode (ATM) adaptation layer and signaling protocols. During 1996–1997, he was a visiting scholar at Columbia University, New York, USA, doing research on xbind (SDN control architecture). He then spent time at NTT Network Service Systems Laboratories (NTT NS Labs) before moving to NTT Multimedia Business Department and then to NTT Phoenix Communications Inc., where he was involved in developing and operating a multimedia teleconferencing service network. After returning to NTT NS Labs, he conducted research and took part in ITU-T (Telecommunication Standardization Sector of International Telecommunication Union) and IETF (Internet Engineering Task Force) standardization efforts. He was also involved in joint studies with partners on GMPLS (generalized multi-protocol label switching), IP and optical technologies, and L1VPN. He is currently managing projects on future core network architectures and strategies for international standardization and R&D globalization. He received the Communications Society's Distinguished Contributions Award by serving as a committee secretariat of the network systems committee. He is a senior member of IEICE and a member of IEEE (Institute of Electrical and Electronics Engineers).

Yoshio Kajiyama

Senior Research Engineer, Supervisor of Research & Development Planning Department, NTT Access Network Service Systems Laboratories.

He received his B.S., M.S., and Ph.D. from Kyushu University, Fukuoka, in 1986, 1988, and 1998. He joined NTT Transmission Systems Laboratories in 1988 and had been engaged in research on broadband access network techniques such as ATM and PON (passive optical network). He was also involved in their international standardization in ITU-T SG13 and FSAN (Full Service Access Network) Group. He was with NTT Communications, where he developed a digital TV transmission network and VoIP (voice over IP) services from 1998 to 2006. He joined NTT Access Network Service Systems Laboratories in 2006 and developed Carrier Ethernet Service called BEW at NTT EAST and NTT WEST. He is a senior member of IEICE.

Implementing the NetroSphere Concept at NTT

Kanichiro Ono, Hirotaka Yoshioka, Masashi Kaneko, Satoshi Kondoh, Masahiro Miyasaka, Yuji Soejima, Takaaki Moriya, Ken Kanishima, Akeo Masuda, Junichi Koga, Toshiaki Tsuchiya, Nobuhiko Yamashita, Kimio Tsuchikawa, and Takashi Yamada

Abstract

NTT announced the NetroSphere concept in February 2015 as a new research and development (R&D) vision that aims to provide a variety of services in a prompt, low-cost, and reliable manner to customers and service providers who use the network. To implement the NetroSphere concept, NTT Information Network Laboratory Group is conducting R&D in diverse areas ranging from network architecture to virtualization, hardware, and operations. This article introduces these R&D activities.

Keywords: NetroSphere, network architecture, operations

1. MAGONIA server architecture

1.1 Configuration

NTT Network Service Systems Laboratories is developing a new server architecture called MAGONIA[*1] to enable the early creation of network services and greatly reduce system development and operating costs as part of the NetroSphere concept. The conventional approach to developing network systems is to use hardware and software optimized for each network function while meeting stringent requirements in reliability and performance that are demanded of a carrier. However, a system having such a separately optimized silo-type equipment configuration increases the quantity and types of necessary equipment while requiring operators to be located separately. This type of configuration consequently drives up operating costs and keeps maintenance and management costs over the entire system high, and as such, it has hindered the development and rollout of new services.

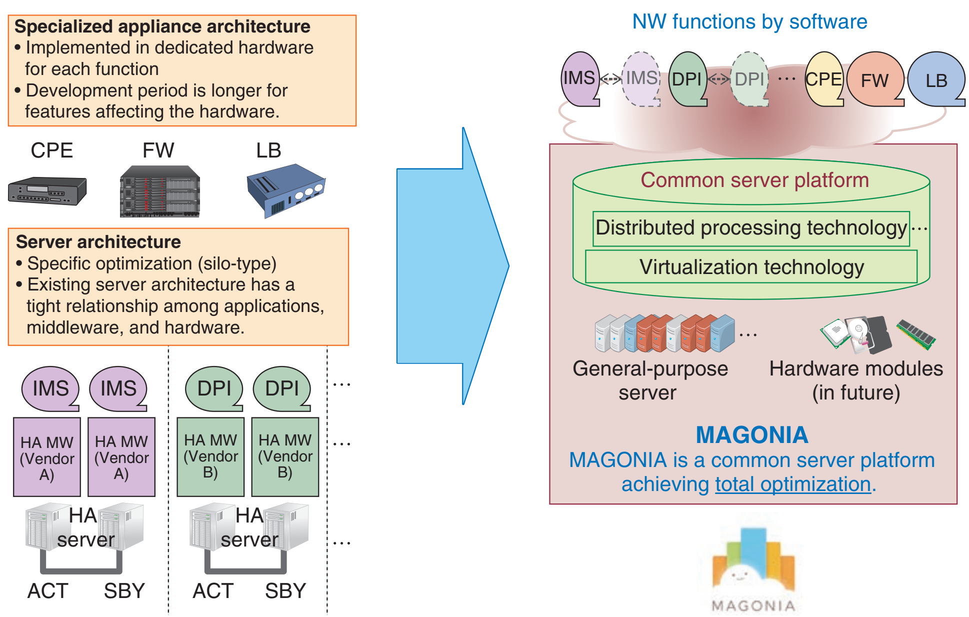
MAGONIA configures network functions as software separate from hardware and provides a common platform for efficient development of those functions as applications (**Fig. 1**). The development of network functions using MAGONIA makes it easy to ensure scalability and high reliability, which in the past could not be done without driving up development costs. In particular, using MAGONIA to achieve scalability enables small starts for services and facilitates the early creation of new services.

1.2 Platform functions

MAGONIA features two platform functions: a distributed processing base for achieving an n-active (N-ACT) server cluster and a virtualization base for achieving a resource pool (**Fig. 2**).

The distributed processing base enables the construction of an efficient N-ACT cluster in which all servers are up and running by having the active

*1 MAGONIA: *Magonia* is the name of a realm in the sky in French mythology. It is used here as the name of a platform that continues to evolve in harmony with the cloud, thereby resembling such a realm in the sky.



ACT: active
CPE: customer premises equipment
DPI: deep packet inspection
FW: firewall
HA: high availability
IMS: Internet protocol multimedia subsystem
LB: load balancer
MW: middleware
SBY: standby

Fig. 1. MAGONIA architecture.

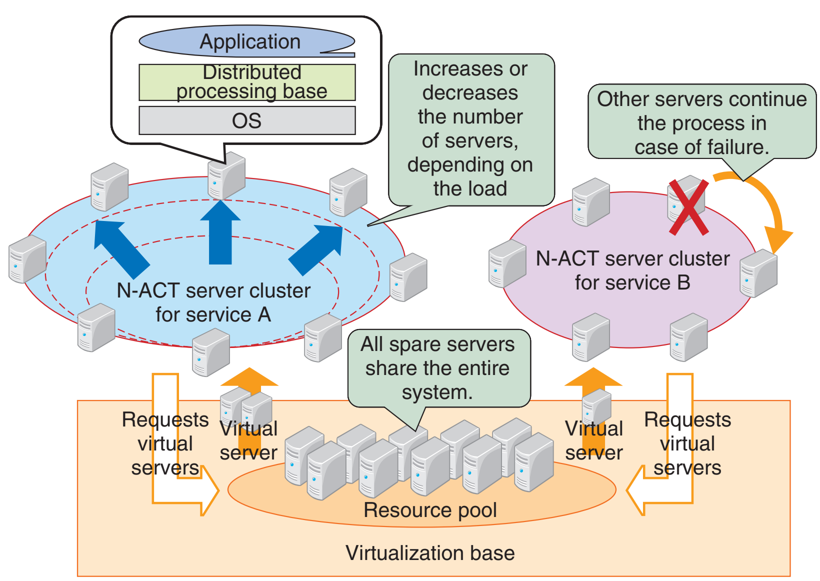


Fig. 2. MAGONIA's distributed processing base and virtualization base.

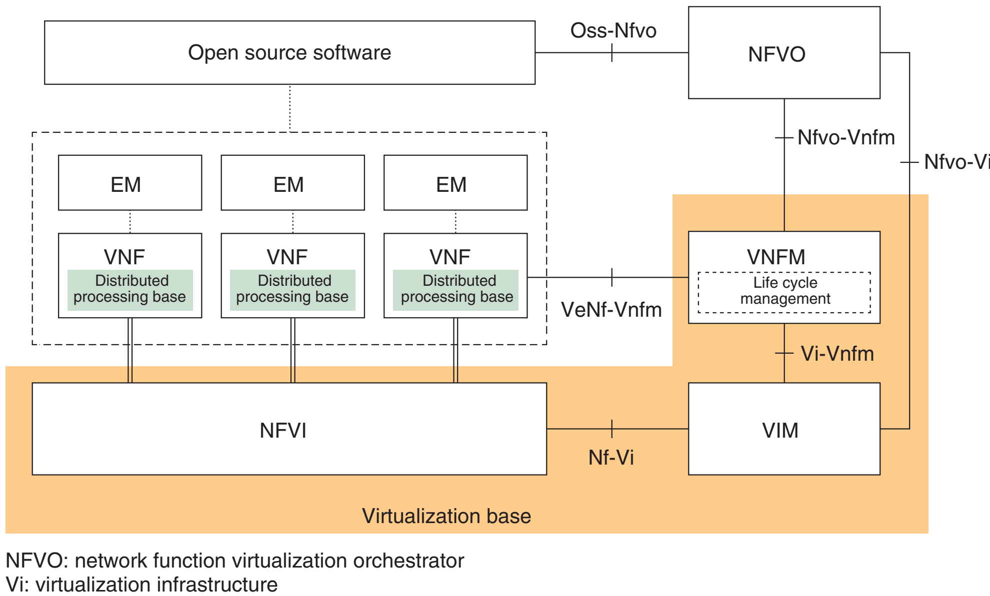


Fig. 3. Correspondence between NFV architecture and virtualization base.

system (in which processing is in progress) replicate the data of other servers, thereby doubling as a standby system. This negates the need for dedicated standby servers as in the active and standby (ACT-SBY) architecture used in conventional network systems. In an N-ACT cluster, servers are made to store replicated data based on a sorting algorithm called consistent hashing, which enables the number of servers making up a cluster to be increased or decreased on the fly without service downtime. In this way, system operation can always be achieved with the least number of servers needed to meet demand.

A resource pool, meanwhile, acts as a common source of resources (e.g., the processing power of central processing units (CPUs), the recording capacity of memory, and storage on physical servers) for multiple systems providing them. The resource pool in MAGONIA is achieved by the virtualization base, and it allocates resources in the form of virtual machines (VMs) according to requests issued by applications making up each system. This virtualization base conforms to the architecture framework of the European Telecommunications Standards Institute's Industry Specification Group on Network Functions Virtualization (ETSI NFV ISG)*2 and consists mainly of the network function virtualization infrastructure (NFVI) based on VMs and a virtual network function manager (VNFM) that provides a management mechanism for autonomous control of those VMs (**Fig. 3**).

A system applying MAGONIA using these platform functions can increase its facility usage efficiency by a significant amount compared to existing systems. Furthermore, in the event of a server failure, it can incorporate an alternate VM into its N-ACT cluster from the resource pool, thereby enabling autonomous recovery without having to dispatch maintenance personnel to the site where the failure occurred. A reduction in system operating costs can therefore be expected.

At NTT, we are promoting more open activities so that a variety of companies and enterprises can participate in the implementation of MAGONIA.

1.3 Release of API specifications

In this regard, we envision the distributed processing base to be provided as middleware. In February 2015, we released the specifications for the application programming interface (API) of the distributed processing base so that anyone will be able to design middleware and applications conforming to those specifications.

*2 ETSI NFV ISG: An organization established within the European Telecommunications Standards Institute to lead the formulation of specifications for network virtualization functions and the interfaces between them and the standardization of an overall architecture framework including the above.

As for the virtualization base, there has been rapid growth in cloud-related commercially available virtualization techniques in recent years, and at the same time, NFV-related products have been regularly launched on the market with the progress in standardization of NFV as virtualization architecture for network systems. We can expect competition in NFV-compliant products among a variety of vendors to intensify in the years to come. Our plan is to expand the use of the distributed processing base in combination with the virtualization base with the aim of implementing MAGONIA and achieving early implementation of the NetroSphere concept.

2. Proactive control and resource optimization technology

In the near future, the increase in 4K/8K high-definition video traffic and the introduction of co-creation services with customers through the wholesaling of fiber access are expected to make communications traffic all the more diverse and unpredictable. Moreover, as the modularization and combination of network functions based on the NetroSphere concept proceed, traffic flow will become increasingly complex, making it difficult to determine where traffic associated with particular services will actually flow in the network. NTT Network Technology Laboratories is addressing this complexity in the network and in traffic quality by conducting interdisciplinary research in the area of network science [1], making extensive use of technologies from different fields. We discuss here resource optimization technology using proactive control.

2.1 Optimized use of resources

The NetroSphere concept envisions a low-cost network made possible by combining common components. This will require technology for making effective use of pre-existing resources, which differs from the conventional approach to facility design and operation in which the service to be provided is known in advance and the facilities required for the service are deployed appropriately. Resource optimization technology aims to meet this need for using pre-existing resources by determining an optimal combination of software and hardware functions unevenly distributed in the network and implementing them on the physical network via integrated control functions (**Fig. 4**).

2.2 Key technologies

Specifically, the introduction of virtualization technology typified by software-defined networking (SDN) and NFV will enable the definition and construction of services on the logical network independent of the actual configuration of the physical network. The use of virtualization technology and the technologies summarized below will enable individual services to be mapped to the physical network in a flexible manner.

(1) Traffic prediction technology considering traffic-generation mechanisms

In addition to conventional techniques that uncover trends based on traffic observations, this technology will use human-flow analysis in physical space to reflect people—the source of traffic—and terminal mobility in traffic predictions to improve accuracy.

(2) Resource allocation technology considering availability in the face of future demand

This technology aims to appropriately allocate resources to meet present demand while taking into account the need to allocate resources to meet the demand for new services that may be launched in the future. Although it is impossible to predict future demand with perfect accuracy, we can enhance resource availability by setting aside a sufficient amount of allocable resources (bandwidth, CPU, memory, etc.) [2].

(3) Control technology considering prediction error

Traffic engineering aims to dynamically control traffic pathways according to traffic fluctuations, but the risk exists of a drop in communications quality due to excessive control caused by prediction error or to delay-time fluctuation caused by a change in path length. This technology is aimed at achieving robust control by minimizing the effects of prediction error through sequential and stepwise control based on model predictive control technology [3].

Each of the above technologies is substantially different from conventional control technologies that respond in a reactive manner when some kind of problem (congestion, quality degradation, etc.) occurs in the network. That is to say, each can be ranked as a proactive control technology that is intended to mitigate beforehand the risk of a problem occurring.

Resource optimization enables the low-cost provision of services through efficient use of software and hardware functions across the entire network. Proactive control, meanwhile, can improve network

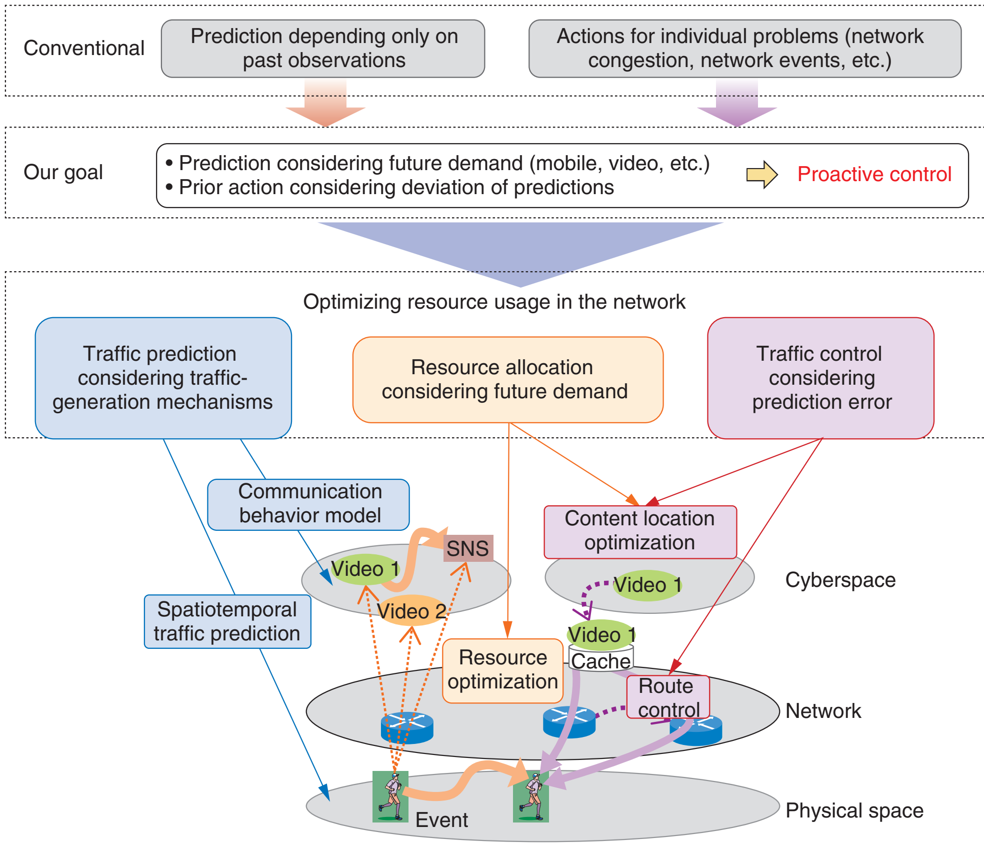


Fig. 4. Network resource optimization based on proactive control.

ease-of-use for customers by mitigating exposure to problems occurring in network functions. In addition, research conducted in areas throughout network science, including disaster avoidance and quality of experience (QoE), will drive the realization of the NetroSphere concept supporting customer and operator needs.

3. Multi-Service Fabric (MSF)

3.1 Flexible configuration

NTT Network Service Systems Laboratories is researching and developing Multi-Service Fabric (MSF). This technology divides the network into transport functions, service functions, and control functions (controller), in contrast to a conventional network configured with specialized equipment. It enables flexible network configuration through the formation of equipment clusters that combine general-purpose products.

The MSF contributes to the transport layer that routes communications and transfers data by optical means. MSF is technology that provides extensive and flexible functions, and its name is a reference to the many ways that fabric can be used according to how it is woven and cut.

3.2 Application to networks with special requirements

This technology can even be applied to carrier networks that have special high-reliability and high-scalability requirements. MSF aims for the deployment of new networks leading to flexible operations and drastic reductions in cost. In addition, by modeling the network configuration so that modularized server and switch pools can be managed as virtual resources and dynamically controlled, NTT can clarify the requirements for switches and other functional components. In this way, we aim to encourage the participation of many and diverse vendors and promote the commoditization of network equipment.

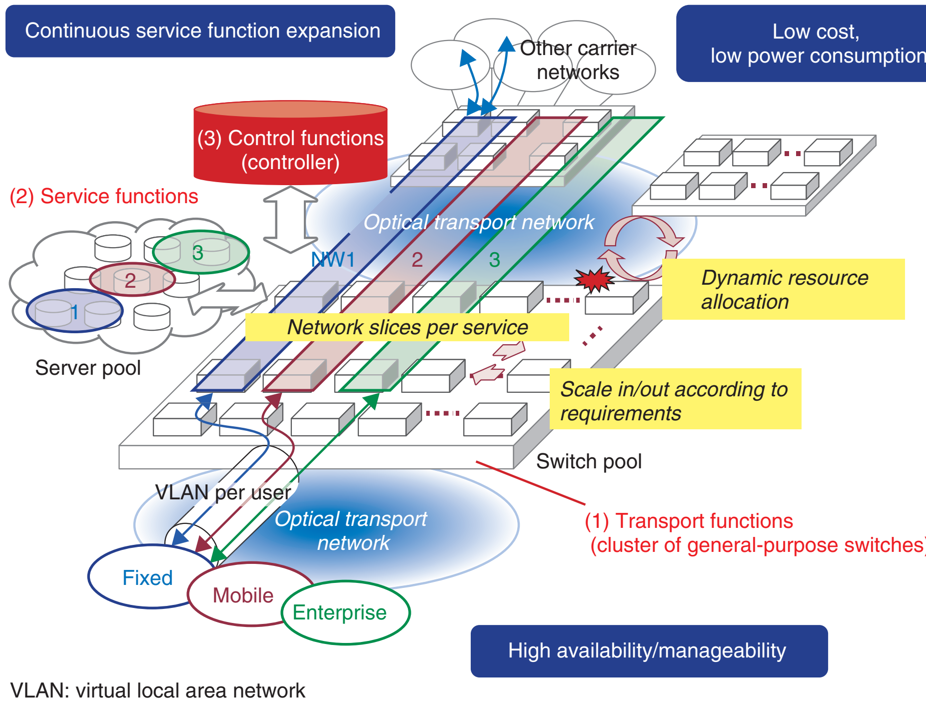


Fig. 5. MSF Architecture.

Conventional networks have been configured using specialized equipment developed on a function-by-function basis. There has consequently been a tendency to develop advanced and large-scale devices in which high reliability and large capacity is achieved in each piece of equipment.

In recent years, however, progress has been made in increasing the speed, capacity, and performance of general-purpose products with an emphasis on datacenter applications. In addition, advances have been made in researching and developing dynamic control technologies such as NFV and SDN and in standardizing interfaces between functions.

A conventional network that tends to consist of advanced and large-scale equipment as described above lacks flexibility in terms of adding or modifying functions or capacity according to business requirements. Such a network can also drive up costs since it is not possible for low-usage portions of certain equipment to be used by other equipment. Thus, to simultaneously achieve cost reductions and flexibility in network services, there is a need not only for higher levels of flexibility and efficiency, but also for a new type of high-function and high-reliability carrier network that can transfer and transport data in a network-wide manner without being limited to conventional router functions.

Meeting this need will require new network technology that can bring existing network technology at datacenters up to carrier grade and that can make maximum use of general-purpose products.

3.3 Separated functions

MSF architecture separates the network conventionally configured with specialized equipment into three sections: (1) transport functions, (2) service functions, and (3) control functions (MSF controller), as shown in **Fig. 5**. The transport functions section comprises simple general-purpose equipment (general-purpose switch cluster). The service functions section is achieved on the cloud separate from the transport functions section. Finally, the control functions section (MSF controller) controls the general-purpose switch cluster. The elemental technologies supporting MSF are configuration technology, which is aimed at making maximum use of general-purpose products in a low-cost L3SW (Layer-3 switch) cluster having a high degree of freedom, and control technology implemented in the controller.

3.4 Aim and effects of MSF

Our aim in using MSF is to ensure extendibility, improve maintainability and robustness, and promptly provide low-priced services. We seek the following effects by applying a network modeled on MSF technology.

(1) Simultaneous improvements in costs and flexibility

From a transport perspective, MSF is a means of providing essential carrier functions. It will enable the application of optical network technologies at all times and facilitate the low-cost configuration and flexible control of network elements.

(2) Maintenance flexibility through hardware commoditization

MSF will facilitate the commoditization of application technologies by simplifying hardware functions and by unifying specifications. It will enable faulty hardware to be replaced by equipment made by a different vendor, thereby adding flexibility to maintenance work.

(3) Flexible scalability with no boundaries

MSF will enable any type of network to be achieved using as much common architecture as possible. It can efficiently meet the specifications of individual networks and locations with flexible configurations ranging in size from small scale to large scale. At the same time, ongoing advances in general-purpose technologies will enable MSF to provide scalability with no boundaries or limits.

(4) Modularization of network equipment in the transport layer

By modularizing and simplifying equipment and using common architecture, MSF will transform large-scale *black-box* transport equipment into small-scale *white-box* equipment. With MSF, configuring a network with only simple hardware will make it easier to visualize operating conditions at the time of a system fault and reduce operation load by enabling multiple pieces of equipment to be abstracted and managed as a single unit.

The above effects mean that a network that applies MSF will be able to reduce facility costs and power consumption, improve maintainability and operability, and provide services in a prompt and uninterrupted manner.

3.5 Plans toward expanded use of MSF

Although still in the research stage, a prototype version of MSF was constructed in 2015. The plan is to use it in experiments conducted within the NTT Group to assess and improve the feasibility of this technology. The first step in these experiments will be to cluster general-purpose switches from multiple vendors with the aim of achieving a practical technology that can replace large-scale routers. The next step will be to establish network-wide, multi-layer coordination technology for transmission equipment and other peripheral devices.

In addition, NTT is engaging in joint studies with both domestic and overseas vendors in such fields as controllers, general-purpose switches, and virtualization technology, and is participating in technical discussions with overseas carriers, all to promote the development and spread of MSF-related technology.

There are also plans to hold proof of concept (POC) demonstrations with vendors in 2015 using open technologies (related to switch/controller products) to promote the spread of MSF as a viable technology. The effective use of such POC demonstrations should help spread MSF technology to vendors and carriers in other countries.

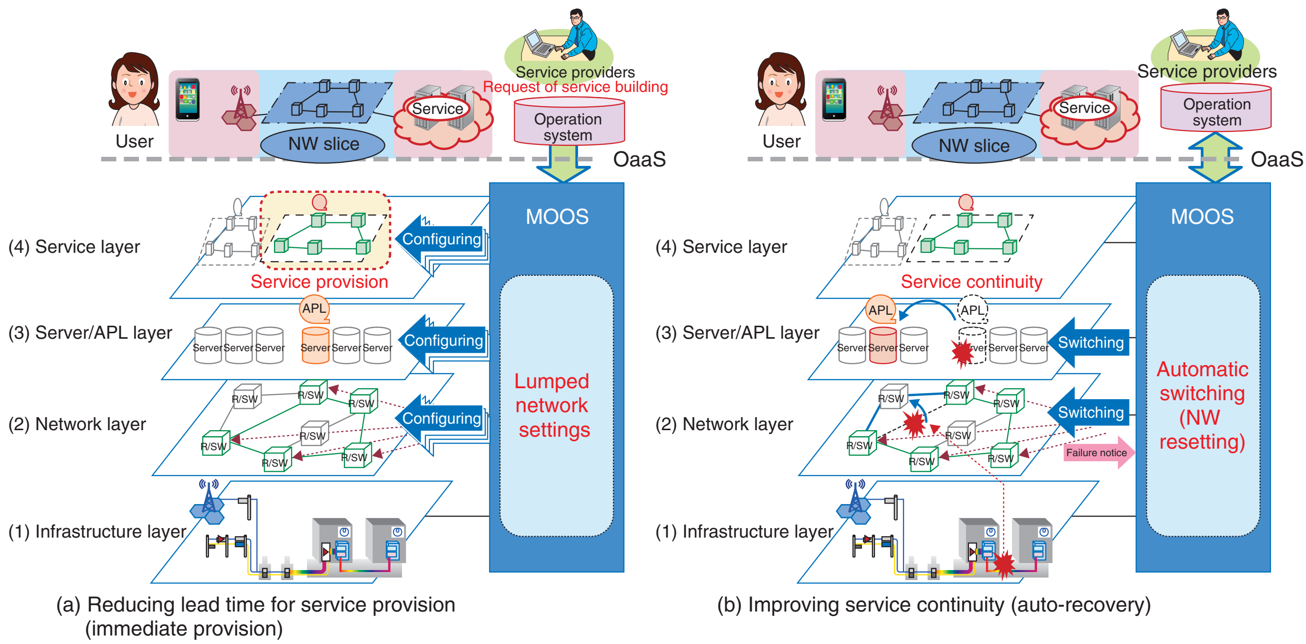
4. MOOS and OaaS

Operations cover a variety of tasks such as fulfillment, quality assurance, and billing. Under the NetroSphere concept, it is important that operations for managing and maintaining services be provided in a one-stop manner [4]. In this regard, NTT Network Service Systems Laboratories is researching and developing two key technologies.

(1) MOOS (management, orchestration, and operation system), which performs end-to-end management and control of the service components
(2) OaaS (Operations as a Service), which provides operation functions to service providers

Conventional network services are developed on a silo structure in which specialized equipment is tied to individual services/networks, and the operation systems of these services/networks automate related tasks. When an equipment failure occurs in such a structure, it may be clear how to switch over equipment and recover from the failure. However, the diversification of services in recent years has made network configurations and operations increasingly complicated. Therefore, finding ways of reducing capital expenditure (CAPEX) and operating expenditure (OPEX) has become a more critical issue than ever before.

In contrast, the NetroSphere concept is based on separate functions and equipment and separate resources and equipment in order to simplify the network, as described before. This kind of architecture and its operations are depicted in **Fig. 6**. This



APL: application

Fig. 6. Layered architecture applying MOOS and OaaS technology.

architecture is virtually composed of the network (2) and server (3) layers on top of the infrastructure (1) layer; the service (4) layer is configured at the very top. MOOS performs end-to-end collective management of layers (1) to (4). For example, MOOS makes all the necessary network settings and shortens the lead time to service provision (Fig. 6(a)). The automatic detection of equipment faults and autonomous resetting of the network and servers improve service continuity (Fig. 6(b)).

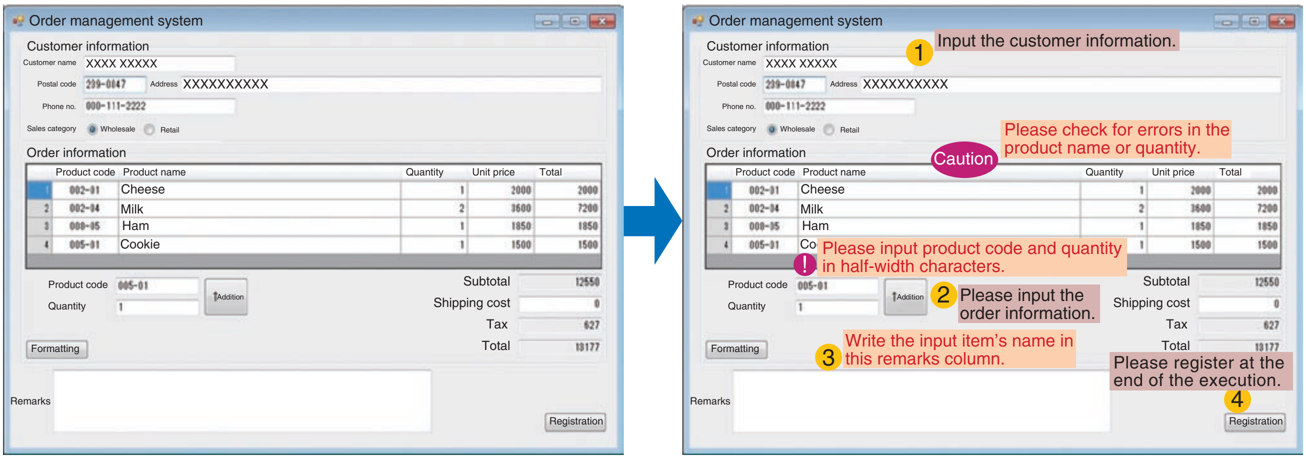
In studying MOOS, we assume the equipment configuration, quality requirements, and operational workflow. In designing MOOS in detail, we investigate some actual use cases. For example, when some equipment on the infrastructure layer has physically failed and the operator has been notified of an alarm occurring on the network layer, how can we determine what physical servers the applications are running on, and what services are being provided? In this case, we need to quickly figure out such complicated relations between the applications and servers, determine the area/users affected by that failure, identify failure factors, and initiate a recovery process. Our aim is to establish necessary technologies needed by MOOS as functions, taking the service level agreement of provided services into consideration.

The Management and Orchestration (MANO) Working Group in ETSI NFV ISG completed Phase 1 studies on high-level architecture and functional requirements in December 2014. They commenced Phase 2 studies in January 2015 [5]. At NTT, we are researching and developing MOOS while keeping in mind various factors such as NFV standardization trends.

Thus, with the aim of providing carrier services in a short time and reducing OPEX, we see MOOS as a means of constructing services quickly, adjusting the scale as needed, and controlling operations remotely. In addition to MOOS, we are researching/developing OaaS that would release those operation functions via an external interface to service providers. To promote the creation of new services, operation functions provided via an OaaS API assume the use of up-and-coming technologies in diverse fields such as the IoT (Internet of Things), cloud computing, virtualization technologies (NFV, SDN, etc.), and big data, as well as the ability to combine those technologies with services in a flexible and straightforward manner.

In this regard, the TeleManagement Forum (TM Forum)[*3] is studying an architecture that is based on

*3 TM Forum: A global industry association related to telecom operations. It aims to provide general-purpose solutions to problems in telecom operations and to study and standardize a framework for business processes and data/information.



(a) Before application of annotation technology

(b) After application of annotation technology

Fig. 7. Example of operation screen using annotation technology.

service requirements in a wholesale format [6]. In general, such an interface must be designed and evaluated from various viewpoints including usability, productivity, flexibility, and information granularity and must also be provided considering the needs of various types of service providers. For these reasons, our aim is not just to specify a common API but also to establish base technology that would allow for the combination of multiple APIs or the simplification of an API (e.g., removing certain options).

Thus, NTT aims to achieve unprecedented operations that can produce added values both quickly and at low-cost through our R&D of MOOS and OaaS.

5. Operation process navigation technology

Operational efficiency is a universal theme required in every business domain. In this section, we introduce our operation process navigation technology that supports terminal operations in office work, for example, by simplifying complicated operations or reducing the number of simple repetitive operations, and thus improves operational efficiency.

This technology is also required in the NetroSphere concept where various network services need to be provided accurately, quickly, and efficiently.

Companies use various operation support systems (OSSs) to improve operational efficiency and ultimately reduce OPEX. System operators work at system terminals by following operation processes defined in advance. The OSSs need to be modified in accordance with changes in operation processes caused by, for example, the launch of a new service or product. However, such modification typically involves a very high expense and considerable time, so it is therefore difficult to modify OSSs in a timely manner. Consequently, some companies may decide to abandon the idea of modifying the OSSs at all. In such cases, operators have to add extra operation processes that the OSSs cannot handle, resulting in complicated or lengthy processes. This causes heavy workloads and a lengthy operation time. Moreover, it frequently leads to human errors.

To address this issue, we are studying navigation technology that supports terminal operations without modifying existing OSSs. This technology consists of three essential technologies.

(1) Information-gathering technology that scrambles information from operators and OSSs
(2) Analysis technology that derives useful knowledge from the gathered information
(3) Instruction technology that provides operators with that knowledge

Annotation technology [7], which can display any information anywhere on a terminal screen without modifying the OSSs (**Fig. 7**), is one of the instruction technologies. This technology can be used, for example, to show correct operation instructions and helpful warnings/notes for the operators. In this way, the operators can carry out accurate and prompt operations without having to refer to manuals or seek support from expert personnel.

Apart from the annotation technology, we are also working on (i) log analysis technology for gathering

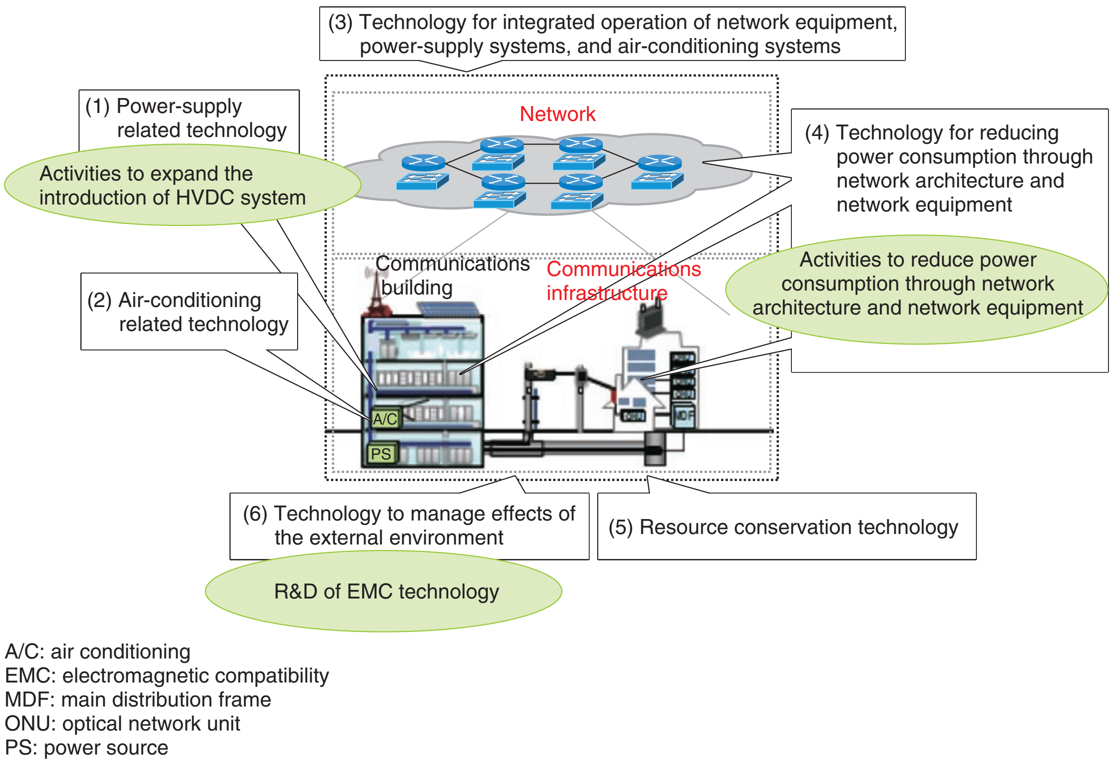


Fig. 8. Activities to reduce environmental load and put the NetroSphere concept into practice.

operation logs and extracting useful knowledge and (ii) system integration technology that simplifies complicated operation processes provided by the different OSSs.

The navigation technology is a general-purpose technology. It is therefore expected to contribute greatly to reducing OPEX in all business domains. Our next step is to enhance and extend the navigation technology as part of an ongoing effort to make operations more efficient.

6. Environmentally conscious technology (HVDC power supply system)

Implementing the NetroSphere concept requires a telecommunications infrastructure consisting of various facilities such as network equipment, air conditioning equipment, power supply equipment, and outdoor structures. Meanwhile, the environmental load across the entire telecommunications infrastructure must be reduced to achieve a sustainable society. For this reason, the NTT Information Network Laboratory Group has established a strategy coordination organization spanning all facility-managing research laboratories and NTT Group companies to research and develop elemental technologies for reducing the environmental load of information and communication technology (ICT) services (**Fig. 8**) [8]. These technologies fall into the following six areas.

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

At present, NTT is involved in ongoing efforts to reduce power consumption in network equipment, introduce high-voltage direct current (HVDC) power supply systems, and develop electromagnetic compatibility technologies.

Saving energy in network equipment is directly related to reducing electric power usage, that is, in reducing CO_2 emissions. In addition, transforming the systems that supply power to network equipment can further promote energy savings and cost reductions. Specifically, this means the introduction of HVDC power supply systems that supply power to network equipment at 380 VDC (volts direct current) instead of the conventional 48 VDC or 100/200 VAC (volts alternating current).

Introducing an HVDC power supply system provides specific advantages. In comparison with conventional 48 VDC, it can reduce costs by enabling the use of thinner cables and improving power conversion efficiency, and in comparison with 100/200 VAC, it can dramatically improve reliability and power conversion efficiency.

To facilitate the introduction of equipment with new specifications different from those in the past, NTT is developing new power supply systems as described above while also focusing on the standardization of HVDC specifications. Moreover, to expand the lineup of HVDC-compatible network equipment, NTT has formulated and released "Technical Requirements for High-voltage DC Power Feeding Interfaces of ICT Equipment," which specifies the technical requirements at the connection point between an HVDC power supply system and network equipment [9]. In addition, the NTT Group has declared its intention to formulate a strategy for introducing HVDC power supply systems and promoting their use. NTT aims to take the lead in promoting energy savings across the entire ICT field [10].

In the above ways, the NTT Information Network Laboratory Group is engaged in a variety of activities to reduce environmental load and put the NetroSphere concept into practice.

7. Collaborative system for implementing the NetroSphere concept

In the R&D of the NetroSphere concept, NTT favors an open collaborative system that progresses from an initial stage of concept study and technology development to joint efforts with many and varied players. That is to say, we have no desire to force our proposed NetroSphere concept on others; rather, we wish to work with others having the same sense of direction to improve our technical expertise and to brainstorm new ways of using the network. In this way, we aim to create an even better network that could not previously be imagined.

With its eye on the implementation of the NetroSphere concept, NTT will continue its efforts in not just technology development but also in expanding this collaborative approach.

References

[1] "Feature Articles: Network Science," NTT Technical Review, Vol. 13, No. 9, 2015.
https://www.ntt-review.jp/archive/2015/201509.html
[2] H. Honda, R. Matsumura, T. Tsuchiya, and A. Takahashi, "On Resource Allocation for Virtual Network Embedding," IEICE Tech. Rep., Vol. 115, No. 11, CQ2015-4, pp. 15–20, 2015 (in Japanese).
[3] Y. Takahashi, K. Ishibashi, N. Kamiyama, K. Shiomoto, T. Otoshi, Y. Ohsita, and M. Murata, "A Generating Method of Macroflow for Flow-based Routing," IEICE Tech. Rep., Vol. 113, No. 443, IA2013-84, pp. 31–36, 2014 (in Japanese).
[4] "Feature Articles: NTT Tsukuba Forum 2014 Workshop Lectures," NTT Technical Review, Vol. 13, No. 3, 2015.
https://www.ntt-review.jp/archive/2015/201503.html
[5] K. Takahashi and A. Terauchi, "An Overview of Standardization in ETSI NFV ISG MANO-WG," IEICE Tech. Rep., Vol. 114, No. 523, ICM2014-58, pp. 25–30, 2015 (in Japanese).
[6] Website of TM Forum, https://www.tmforum.org/open-digital-ecosystem-2/
[7] Y. Kawabata, T. Masuda, K. Tsuchikawa, H. Adachi, and A. Inoue, "Annotation Display/Editing Technique for Directly Displaying Business Know-how on Operation Screens," NTT Technical Journal, Vol. 27, No. 7, pp. 36–39, 2015 (in Japanese).
[8] "Feature Articles: Reducing the Environmental Burden of ICT Services," NTT Technical Review, Vol. 13, No. 3, 2015.
https://www.ntt-review.jp/archive/2015/201503.html
[9] NTT, "Technical Requirements for High-voltage DC Power Feeding Interfaces of ICT Equipment," 2015.
http://www.ntt.co.jp/ontime/e/img/pdf/TR176002ed1.1_20150401E.pdf
[10] NTT press release issued on August 4, 2014.
http://www.ntt.co.jp/news2014/1408e/140804a.html

Kanichiro Ono

Senior Research Engineer, Supervisor, Transport Network Innovation Project, NTT Network Service Systems Laboratories.

He received a B.E. from Keio University, Kanagawa, in 1994. He joined NTT in 1994. He is currently engaged in developing the Multi-Service Fabric (MSF).

Hirotaka Yoshioka

Senior Research Engineer, Supervisor, Transport Network Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in physics from Tokyo Metropolitan University in 1993 and 1995. He joined NTT Network Service Systems Laboratories in 1995, where he engaged in R&D of the legacy exchange system software, IP server, and edge and transport technologies. He is now involved in R&D of MSF.

Masashi Kaneko

Senior Research Engineer, Server Network Innovation Project, NTT Network Service Systems Laboratories.

He received an M.E. in information engineering from the University of Electro-Communications, Tokyo, in 2004. He joined NTT Network Service Systems Laboratories in 2004 and studied carrier-grade server platforms and service delivery platforms for NGN. He is currently studying the reliability and development efficiency of virtual network functions in NFV in the MAGONIA project.

Satoshi Kondoh

Engineer, Server Network Innovation Project, NTT Network Service Systems Laboratories*.

He received an M.E. in information science and engineering from Tokyo Institute of Technology in 2006. He joined NTT Network Service Systems Laboratories in 2006 and studied service delivery platforms and deep packet inspection. He is currently studying reliability and development efficiency of virtual network functions in NFV in the MAGONIA project.

*He is currently with NTT WEST.

Masahiro Miyasaka

Senior Research Engineer, Server Network Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in engineering science from Osaka University in 1996 and 1998. He joined NTT Network Service Systems Laboratories in 1998 and engaged in R&D of high-availability server systems for session control technologies. He is now researching server platform systems for service innovation. He is a member of the Institute of Electrical and Electronics Engineers (IEICE).

Yuji Soejima

Senior Research Engineer, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in engineering from Kyushu University, Fukuoka, in 2001 and 2003. He joined NTT Information Sharing Platform Laboratories in 2003. His research interests include network management systems and network security. He joined NTT Network Service Systems Laboratories in 2014. His research interests include future operation technologies. He is a member of IEICE.

Takaaki Moriya

Research Engineer, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E., M.S., and Ph.D. in engineering from the University of Tokyo in 2001, 2003, and 2011. He joined NTT Network Service Systems Laboratories in 2003. His research interests include ubiquitous/mobile networking, web-telco convergence, and future operation technologies. He also developed a Long-Term Evolution roaming service on IPX at NTT Communications for mobile/fixed telecommunications operators worldwide. He received the APSITT (Asia-Pacific Symposium on Information and Telecommunication Technologies) 2005 Best Paper Award, the Academic Encouragement Award 2009 from IEICE, and certificates of appreciation for his contribution to MIPv6/NEMO interoperability from ETSI in 2005 and from the IPv6 Promotion Council in 2013.

Ken Kanishima

Senior Research Engineer, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received a B.E. from the University of Tokyo in 1993 and an M.E. from Tokyo Institute of Technology in 1995. He joined NTT Information and Communication Systems Laboratories in 1995. His research interests include synergistic interoperations among networks and services. He is a member of IEICE.

Akeo Masuda

Senior Research Engineer, NTT Network Service Systems Laboratories.

He received a B.S. from the University of Tokyo in 1997 and an M.S. and Ph.D. from Waseda University, Tokyo, in 1999 and 2009. He joined NTT Network Service Systems Laboratories in 1997. His research interests include IP-QoS, optical networks, network virtualization, software defined networking, inter-domain routing, and wireless access protocols. He is a member of IEICE.

Junichi Koga

Senior Research Engineer, Network Systems Planning & Innovation Project, NTT Network Service Systems Laboratories.

He received his B.S. and M.S. in condensed matter physics from Kyushu University, Fukuoka, in 1997 and 1999. He joined NTT Network Service Systems Laboratories in 1999. His research interests include high-availability server systems and session control servers. He is a member of IEICE.

Kimio Tsuchikawa

Senior Research Engineer, Access Network Operation Project, NTT Access Network Service Systems Laboratories.

He received his B.E. and M.E. in applied physics from Nagoya University in 2000 and 2002. He joined NTT in 2002 and is currently engaged in developing operation support systems for access networks.

Toshiaki Tsuchiya

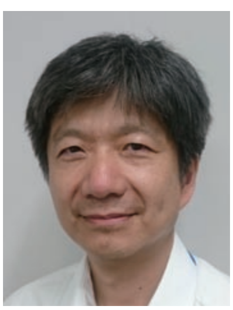
Senior Research Engineer, NTT Network Technology Laboratories.

He received his B.S. and M.S. in information science from Tokyo Institute of Technology in 1990 and 1992. He Joined NTT in 1992 and has been working in the area of provisioning and management of telecommunications networks. His current research interests are queueing theory, performance evaluation, and resource optimization of communication systems. He is a member of IEICE and the Operations Research Society of Japan (ORSJ).

Takashi Yamada

Manager, R&D Planning Department, NTT Information Network Laboratory Group.

He received his B.E., M.E., and Ph.D. in electrical engineering from Hokkaido University in 1997, 1999, and 2003. He joined NTT Access Network Systems Laboratories in 2003, where he researched energy efficient optical access network systems. He has been with the R&D Planning Department in the NTT Information Network Laboratory Group since 2013.



Nobuhiko Yamashita

Senior Research Engineer, Supervisor, Environmental Technology and Management Project, NTT Network Technology Laboratories.

He received a B.E. from Kyushu Institute of Technology, Fukuoka, in 1987. He joined NTT Electrical Communications Laboratories in 1987 and engaged in studies on high-speed power semiconductor devices and circuits for DC–DC converters. After working at ENNET Corporation and NTT FACILITIES, INC., he joined NTT Energy and Environment Systems Laboratories, where he developed power supply systems for telecommunication. He is currently working on the development of services and systems related to energy and the environment. He received the IEICE Academic Encouragement Award in 1995 and the IEICE Communications Society Distinguished Contributions Award in 2004. He is a member of the Institute of Electrical and Electronics Engineers (IEEE), IEICE, and the Institute of Electrical Engineers of Japan (IEEJ).

Transport Network Management Platform Technology for Achieving Common Operation among Multiple Network Elements

Yoshifumi Kato and Taku Kihara

Abstract

Research is underway at NTT Network Service Systems Laboratories on a unified element management system (EMS) platform that will achieve efficient network operation. Many types of network elements (NEs) are deployed on NTT networks. We need to operate various EMSs that are configured for a specific NE in order to manage the different types of NEs. Consequently, the use of multiple EMSs increases the operating cost and the operator workload.

We are working to solve this problem by studying a unified EMS, which we call transport network management (TM) platform technology, that can manage various kinds of network technologies. We present the concept and core technologies of TM platform technology in this article.

Keywords: element management, transport network element, transport network management platform technology

1. Introduction

NTT's networks consist of many types of network elements (NEs) and are therefore operated and managed using an element management system (EMS) and network management system (NMS). Network functions have recently become very complicated to adapt to the numerous services offered, and the functions of the optical NE have been segmented into smaller functions.

As a result, we need to operate multiple EMSs that are configured for specific NEs in order to manage the various types of NEs used. However, using different kinds of EMSs increases the operating cost as well as the workload of operators. This makes it difficult to achieve efficient network operation, for example, flow-through operation and centralized control, from an NMS.

At NTT Network Service Systems Laboratories, we are studying unified EMS platforms that can manage various network technologies such as synchronous digital hierarchy (SDH) and optical transport networks (OTNs) in order to achieve efficient network operation. One example of efficient operation is that provided by a unified human-machine interface (HMI). We can achieve such operation by applying transport network management (TM) platform technology to each EMS. This technology consists of an architecture that can be adapted to various kinds of NEs and unified interfaces, which enables operators to easily operate an NMS. Consequently, we can reduce the operating cost and easily operate large-scale networks using this technology (**Fig. 1**).

2. Features of TM platform technology

The TM platform technology has the following software architecture features.

1) An internal interface and a management model.

We apply TMF513 [1], a business agreement on

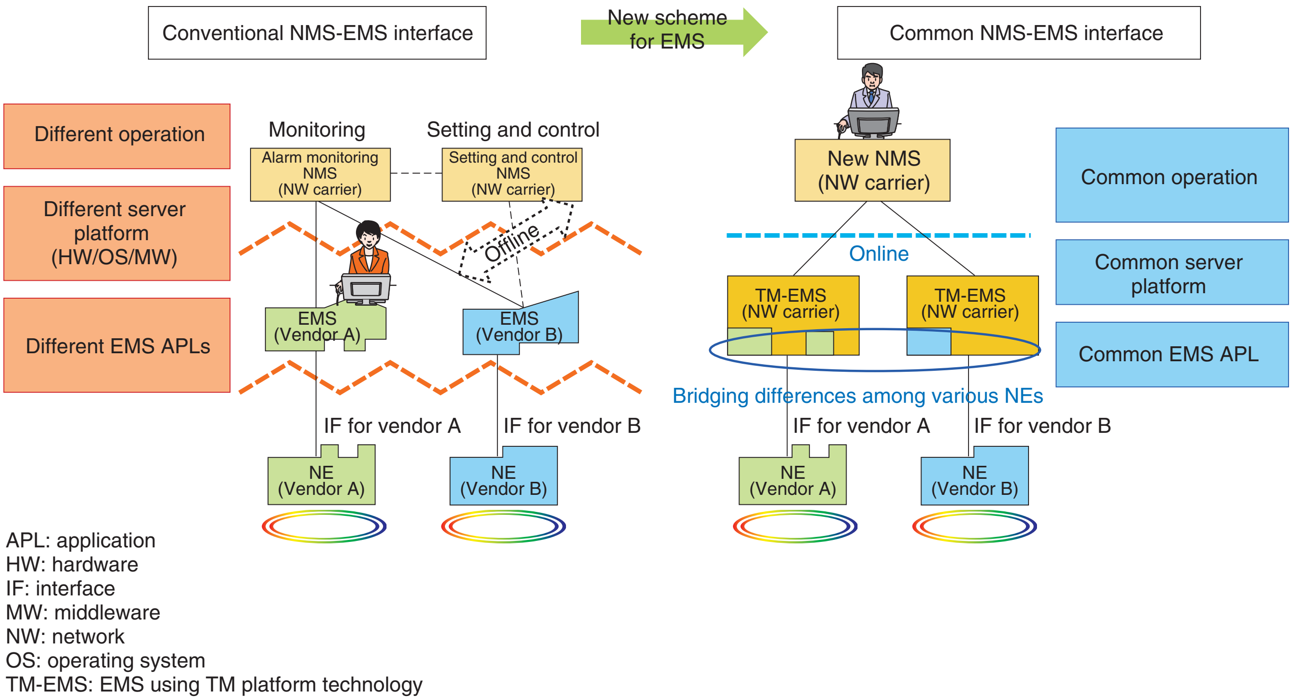


Fig. 1. Common NMS-EMS interface using TM platform technology.

multi-technology network management created by the TeleManagement Forum (TM Forum). The internal interface is customized using our EMS development know-how. For example, a business application platform that provides business logic can use a unified data model that can represent various NEs through the internal interface (**Fig. 2**). The international standard interface can provide unified monitoring but not an efficient NE configuration; therefore, we cannot achieve efficient operation such as flow-through operation. However, we can easily achieve flow-through operation by using the internal interface. To date, no other network carriers are currently applying TMF513 to large-scale network operation.

2) An internal architecture that can easily cooperate with NE vendors. The architecture is implemented through the EMS development know-how of NTT Network Service Systems Laboratories [2] (**Fig. 3**).

We explain these two features below in more detail.

2.1 Management model based on TMF513

A data model based on TMF513 is applied to the TM platform technology to form the management structure of NEs and paths. It is possible to represent various NEs by using a unified data model based on TMF513.

For example, an optical add/drop multiplexer (OADM) and 100-Gbit/s packet transport system (100G-PTS) are managed using the TM platform technology. An OADM is an NE that manages optical paths, which is based on an OTN. In contrast, a 100G-PTS can manage label switched paths (LSPs) and optical paths. The LSP is based on the Multiprotocol Label Switching-Transport Profile (MPLS-TP). Thus, paths managed by each NE are similar, but the features are different. However, it is possible to represent a path as a unified data model by applying TMF513 to an EMS. For instance, the model is represented by physical termination points, logical termination points, cross-connections between logical termination points, and routes (**Fig. 4**).

The TM platform technology can represent not only paths but also various NEs as a unified data model. Therefore, an EMS can bridge differences in specifications of the NE interface and manage various network resources such as NEs and paths.

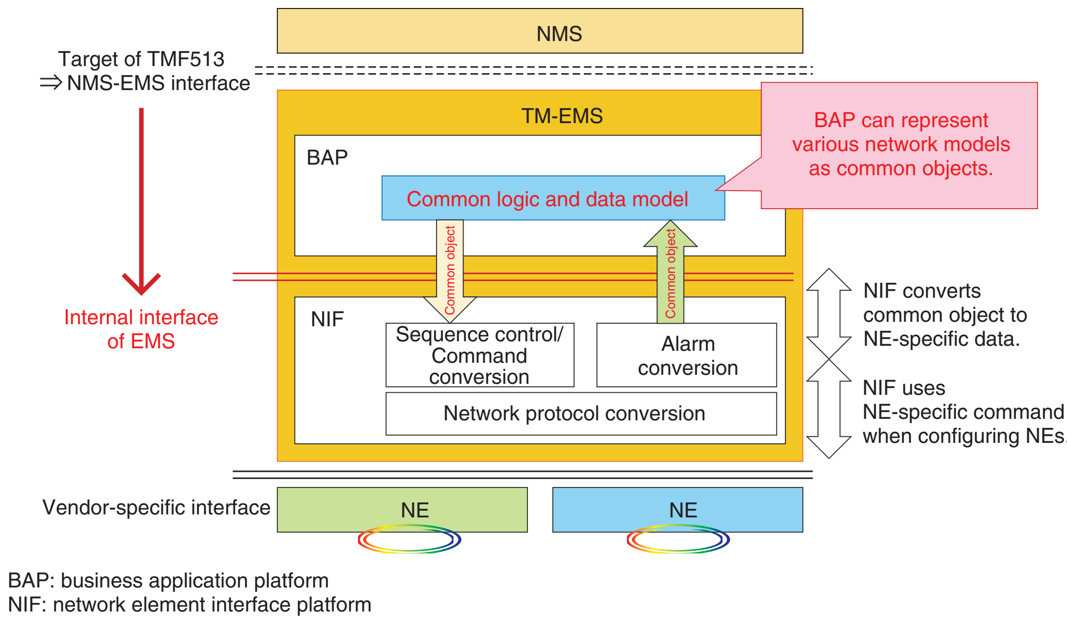


Fig. 2. Internal interface of EMS based on TMF513.

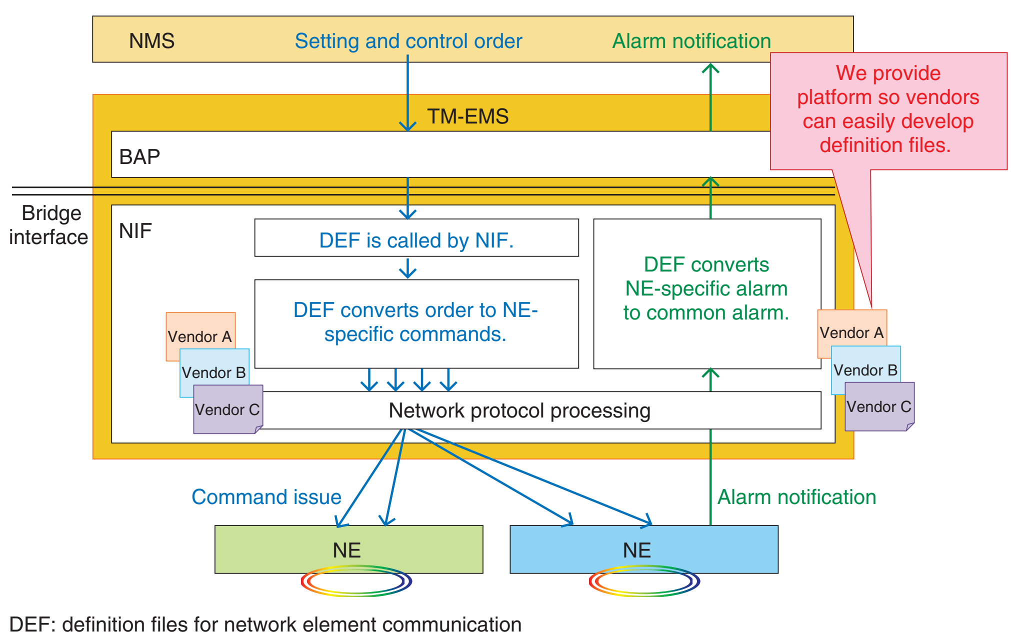


Fig. 3. Bridging differences in specifications of NE interface.

2.2 Definition files for NE communication

We explained that an EMS can represent various NEs as common data with a business application platform. However, when an EMS configures an NE, the EMS has to use an NE-specific command prompt. To achieve a suitable configuration for various NEs, we propose the use of definition files. These files can bridge differences in specifications of NE command sequences and NE command strings (Fig. 3).

The definition files are an expanded mechanism of

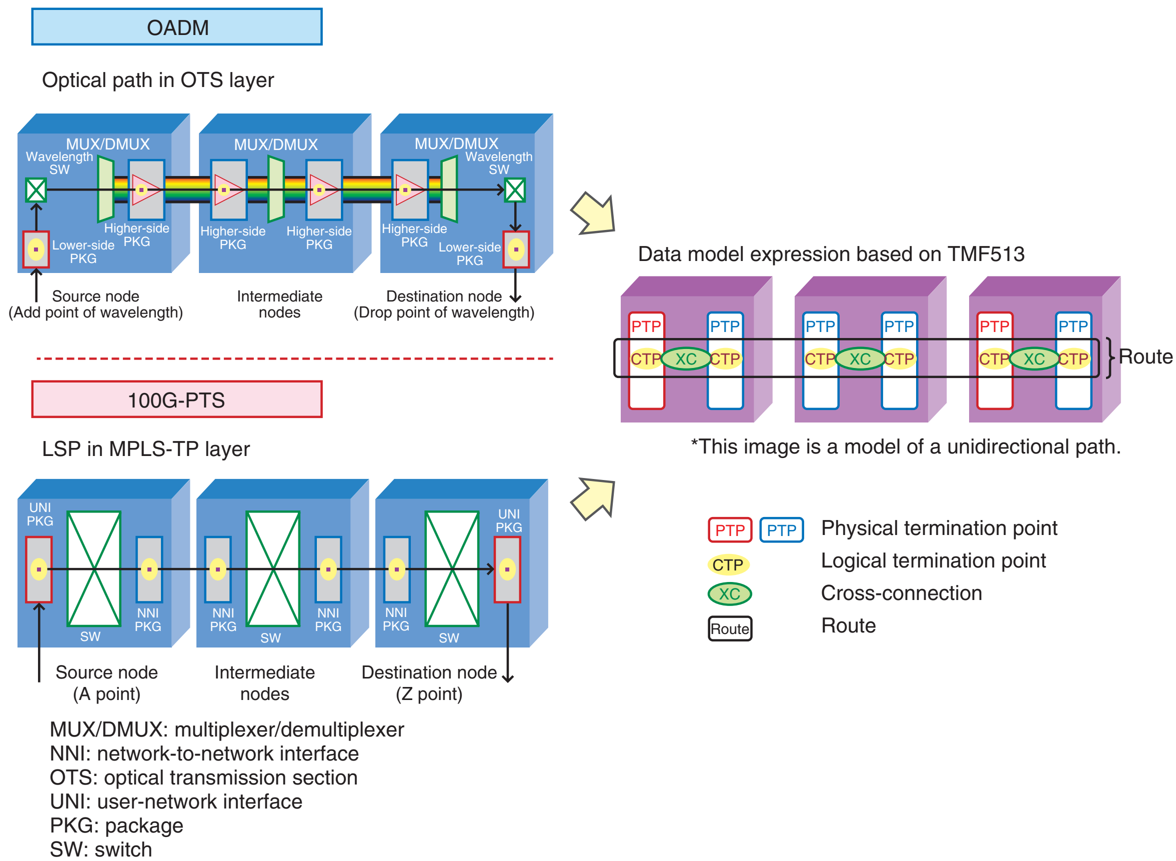


Fig. 4.   Data model expression between differences in transport layers (eg., path).

an EMS for a next-generation network (NGN). The EMS converts order requests of an NMS into command sets called a command scenario and configures a single NE using that command scenario. However, the EMS has to configure multiple NEs in a transport network. For example, when we set an optical path that passes through some NEs, the EMS configures all of these NEs, which consist of the source NE of the path, the destination NE of the path, and intermediate NEs along the path.

Therefore, we expanded the definition file function block to meet specific requirements of transport networks such as a multiple-NE configuration (**Fig. 5**). In particular, we implemented a new mechanism to this function block to determine the configuration sequence when an EMS configures multiple NEs. This mechanism has two types of order sequences for the NE configuration. The first one is a basic sequence. The basic sequence is used when the EMS sets a static configuration for some NEs. The second one is an extension sequence. When the EMS sets a path, the order sequence changes depending on the number of intermediate NEs. In this case, the extension sequence is used. The mechanism determines whether each order sequence is a basic or extension sequence, and we can set the appropriate order sequence when setting a path.

An EMS using TM platform technology (TM-EMS) achieves a flexible NE configuration by using the definition file function block. For example, even if the command line interface of an NE changes, a TM-EMS can manage the NE continuously simply by remaking some of the commands in the definition file function block. We can develop an EMS efficiently because the definition file function block is highly customizable.

3. Other features of TM platform technology

We describe here some other features of the TM platform technology.

One feature is that it uses componentized business

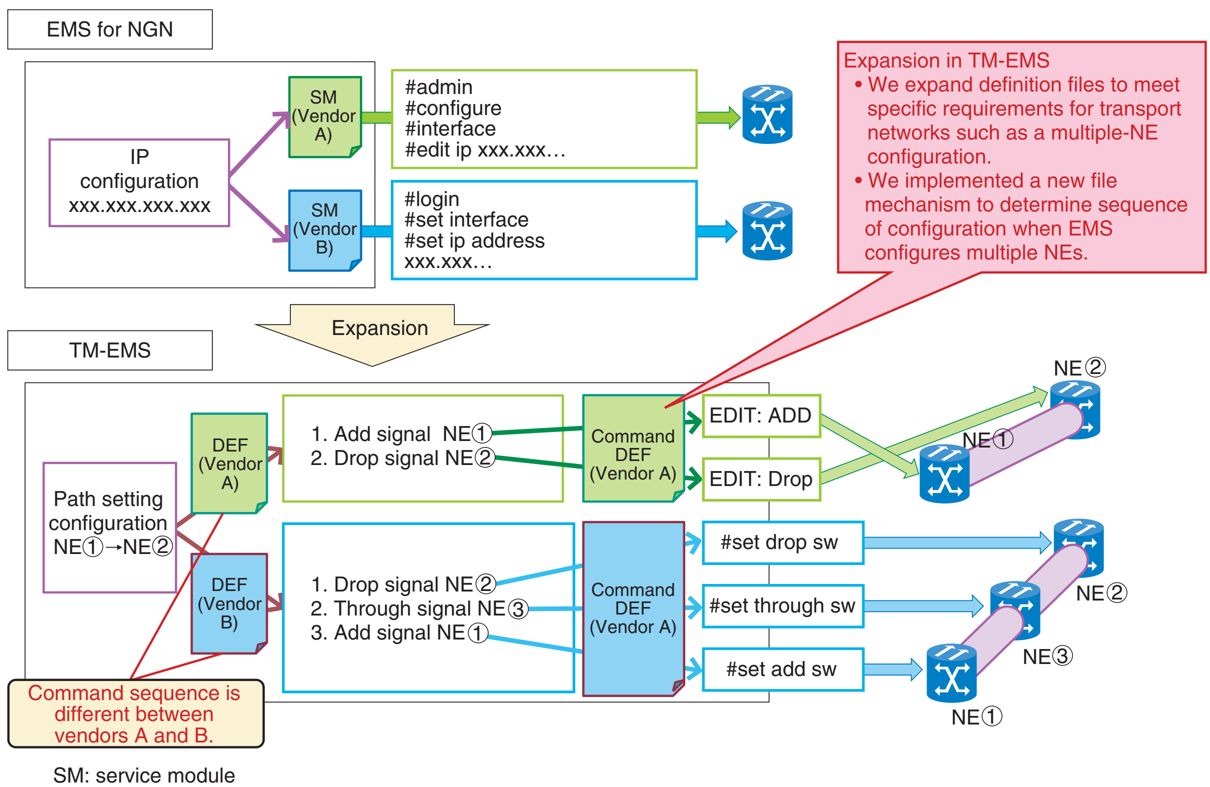


Fig. 5. Expansion of EMS concept for NGN.

scenarios. We can develop a TM-EMS efficiently by combining and adding components of a business scenario. We define three types of components based on the level of commonality. The first type is the EMS common component, which does not depend on the type of network or NE; one example is EMS server maintenance functions. The second type is the transport expansion component, which depends on the type of network but not on the specifications of an NE. For example, a function that manages path information is classified as this kind of component. The third type is the NE specification expansion component, which depends on the NE specifications such as proprietary functions of the vendor. This component provides high efficiency by easily customizing function blocks, for example, transport expansion or NE specification expansion, in the development of new networks or new EMSs.

Another feature is the protocol adopter, which selects the appropriate network protocol for establishing communication with NEs. There are many types of network protocols used between an EMS and NEs. In addition, an NE uses different protocols for different purposes such as alarm notification and NE configuration. For example, some NEs use the Transaction Language 1 (TL1) protocol both for alarm monitoring and NE configuration. Other NEs use the Simple Network Management Protocol (SNMP) for alarm notification and Telnet for NE configuration. Therefore, an EMS must select the appropriate network protocol when it communicates with an NE, and the protocol adapter has this function. With advances in TM platform technology, the protocol adopter can now select common network protocols such as TL1, Telnet, SNMPv1, and SNMPv2c.

4. Future prospects of TM platform technology

NTT Network Service Systems Laboratories began practical development of TM-EMS in 2011. We have developed platforms that are based on transport-network technologies such as SDH/OTN/MPLS-TP, and some products are already being used in commercial networks. The details of the EMSs we developed are discussed in the article “EMS Development and Deployment Using Transport Network Management

Platform Technology" [3] in this issue.

To manage various NEs, we are also developing the User Interface Assist Platform, which is a compact platform that meets operation simplification requirements. The development of this platform is discussed in the article "Development of User Interface Assist Platform Using Transport Network Management Platform Technology" [4].

In the future, we plan to improve the TM platform technology in cooperation with NTT Group companies such as NTT EAST and NTT WEST. The core technologies that are componentized network operation functions of the TM platform technology are intimately related to the NetroSphere concept that NTT laboratories are developing [5].

References

[1] TM Forum, "TMF513, Multi-Technology Network Management (MTNM) Business Agreement Release 3.5," 2007.

[2] S. Seto, K. Yamane, and S. Majima, "Service Activation System: IP Service Activator," NTT Technical Review, Vol. 3, No. 10, 2005.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200510051.pdf

[3] H. Ohyanagi, Y. Ishizuka, Y. Kato, and H. Minowa, "EMS Development and Deployment Using Transport Network Management Platform Technology," NTT Technical Review, Vol. 13, No. 10, 2015.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201510fa4.html

[4] H. Minowa, T. Furukawa, Y. Takeda, and S. Matsumoto, "Development of User Interface Assist Platform Using Transport Network Management Platform Technology," NTT Technical Review, Vol. 13, No. 10, 2015.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201510fa5.html

[5] R. Sumi, K. Matsumoto, I. Inoue, and Y. Kajiyama, "The NetroSphere Concept and Network Architecture," NTT Technical Review, Vol. 13, No. 10, 2015.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201510fa1.html

Yoshifumi Kato

Researcher, Transport Management Development Project, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in information and intelligent systems from Yokohama National University, Kanagawa, in 2007 and 2009. He joined NTT Network Service Systems Laboratories in 2009, where he has been engaged in research and development of transport network management technology.

Taku Kihara

Researcher, Transport Management Development Project, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in information and computer science from Keio University, Tokyo, in 2007 and 2009. He joined NTT Network Service Systems Laboratories in 2009, where he has been engaged in research on network fault detection systems. He is currently developing operation support systems.

EMS Development and Deployment Using Transport Network Management Platform Technology

Hiroyuki Ohyanagi, Yuichiro Ishizuka, Yoshifumi Kato, and Hironobu Minowa

Abstract

NTT Network Service Systems Laboratories is promoting practical development of element management systems (EMSs) for various network elements by focusing on transport network elements and taking advantage of the transport network management (TM) platform technology we developed.

We developed EMSs by using TM platform technology (TM-EMS) in order to integrate a human-machine interface for each network-element operation system, provide a unified interface for the network management system, and enable efficient flow-through operation. We introduce the EMSs we developed in this article.

Keywords: element management system, practical development, TMF513

1. Introduction

Development of element management systems (EMSs) for various network elements (NEs) has been underway at NTT Network Service Systems Laboratories since 2011, when we developed an EMS for optical add/drop multiplexers (OADMs). We introduce here the EMSs we developed using transport network management (TM) platform technology (TM-EMS), and we describe the NEs the EMSs manage.

2. TM-EMS for OADM

2.1 Background

An OADM is a transport network element that can multiplex optical signals and transport data to distant places. In NTT's transport network, three types of OADM NEs are in operation—reconfigurable OADM (R-OADM), broadband OADM (BOADM), and ROADM third generation (ROADM-3G)—and they are fabricated by several different vendors. Consequently, at one stage, we needed to operate five different kinds of OADM NEs.

This complex configuration motivated us to apply TM platform technology to develop an EMS for OADMs because the support for servers of the old network-element operation system (NE-OpS) for OADMs was scheduled to end. Our objective was to use a TM-EMS to integrate a human-machine interface (HMI) for each current NE-OpS for OADMs and provide a unified interface for a network management system (NMS) to enable flow-through operation (**Fig. 1**). The TM-EMS for OADMs (called an OT-EMS) has been in use at NTT EAST since April 2013 and NTT WEST since June 2013.

2.2 Technical features

To meet the requirements of a new EMS for OADMs, the OT-EMS should have two features that are similar to the old NE-OpS. One is the optical path management function and the other is the HMI operation for the OT-EMS.

We used the object model included in TMF513, the

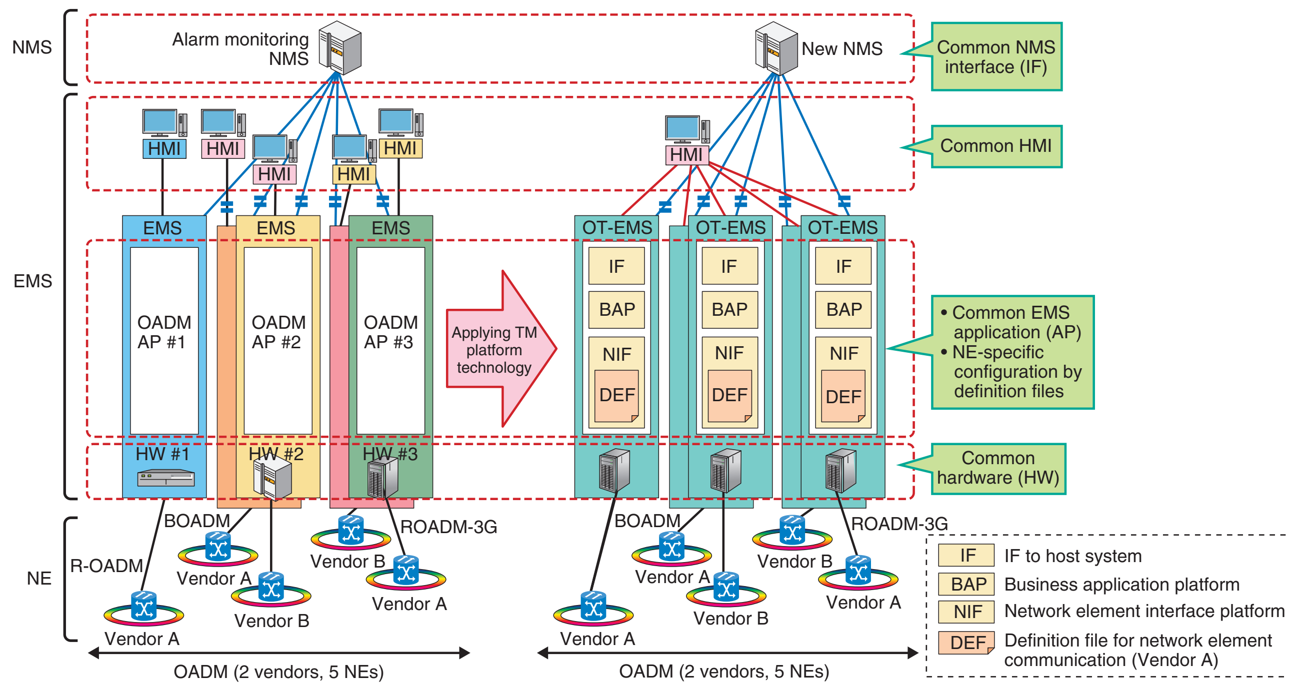


Fig. 1. Configuration of OT-EMS.

business agreement on multi-technology network management issued by the TeleManagement Forum [1], as the basis of the OT-EMS specifications. TMF513 specifies two types of objects: logical objects and physical objects. Logical objects represent information on path connections such as the termination point and cross-connection point of a signal. The termination point represents the input/output of the signal point, and the cross-connection point represents the connection between two termination points.

Physical objects represent information on components including hardware packages and optical modules. When an EMS configures an optical path, it requires physical package information on optical path routes. The EMS needs to link logical objects to physical objects. To set up an optical path to NEs, we defined these objects by understanding the details of each transport network element specification. In addition, we expanded the TMF513 object model by adding other objects, for example, *area* and *building*, which are necessary for NTT's network management. These objects are used by all of the TM-EMSs.

3. TM-EMS for 100G-PTS

3.1 Background

The 100-Gbit/s packet transport system (100G-PTS) is a new transport network element that enables the construction of more flexible and efficient networks. It has two function blocks. One is the optical transport function block, which supports 100-Gbit/s broadband optical paths, and the other is the packet transport function block, which supports the Multiprotocol Label Switching-Transport Profile (MPLS-TP). We developed a TM-EMS for 100G-PTSs (called PT-EMS) to manage both function blocks of 100G-PTSs. The network model of the PT-EMS is an expansion of the optical network model in the OT-EMS specification. The PT-EMS has been in use at NTT EAST since November 2014 and at NTT WEST since June 2015.

3.2 Technical features

We can represent the optical paths as a ring or linear topology in the OT-EMS because the OADM NEs can only set up to two transport routes. In contrast, the 100G-PTS NEs can construct more complex topologies because they can set as many as eight transport routes.

We can represent optical paths in the PT-EMS as a

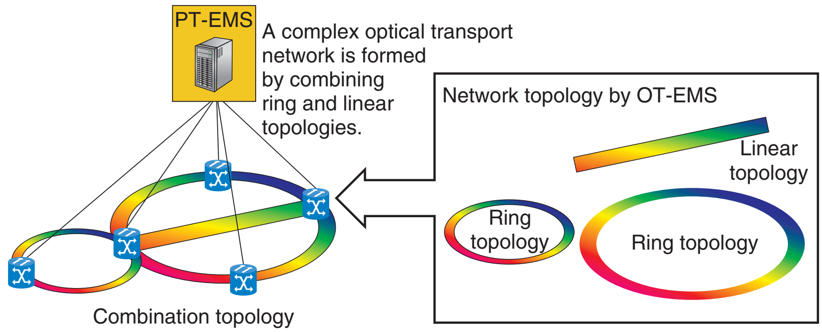


Fig. 2. New topology of PT-EMS.

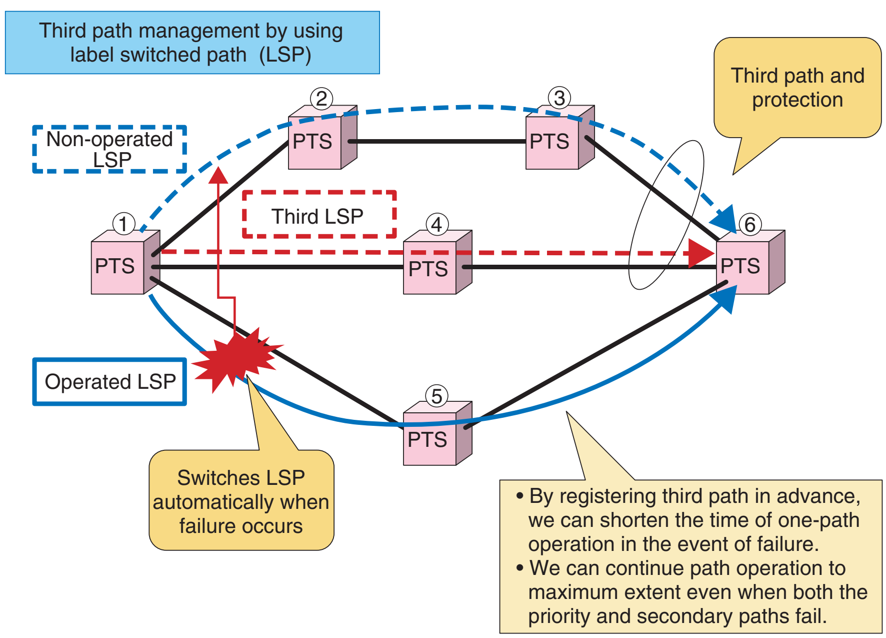


Fig. 3. Switch function to third path of PT-EMS.

ring, linear, or new topology, which is a combination of ring and linear topologies. Moreover, we can represent it not only as an OADM network but also as a more complex network that has more than three transport routes (**Fig. 2**).

In managing packet transport function blocks, we use objects in the TMF513 object model; this is similar to the use of NEs, packages, and path termination points in MPLS-TP path management. Therefore, we can provide an MPLS-TP path management flow that is similar to an optical path management flow by taking advantage of the OT-EMS specifications. In addition, the PT-EMS provides a switching function to the third path (**Fig. 3**). In path operation, the NEs can construct a network with redundancy by specifying priority and secondary paths in the event of path defects or failures. In addition, we can reserve the third path in the PT-EMS. If the priority or secondary path is defective, we can maintain redundancy with the third and non-defective paths. The PT-EMS provides a sequential screen transition for the switching function to the third path. Therefore, operators can quickly deal with defects and disasters without having to carry out a complicated procedure. This function is provided in the NEs in the PT-EMS but not in the 100G-PTS.

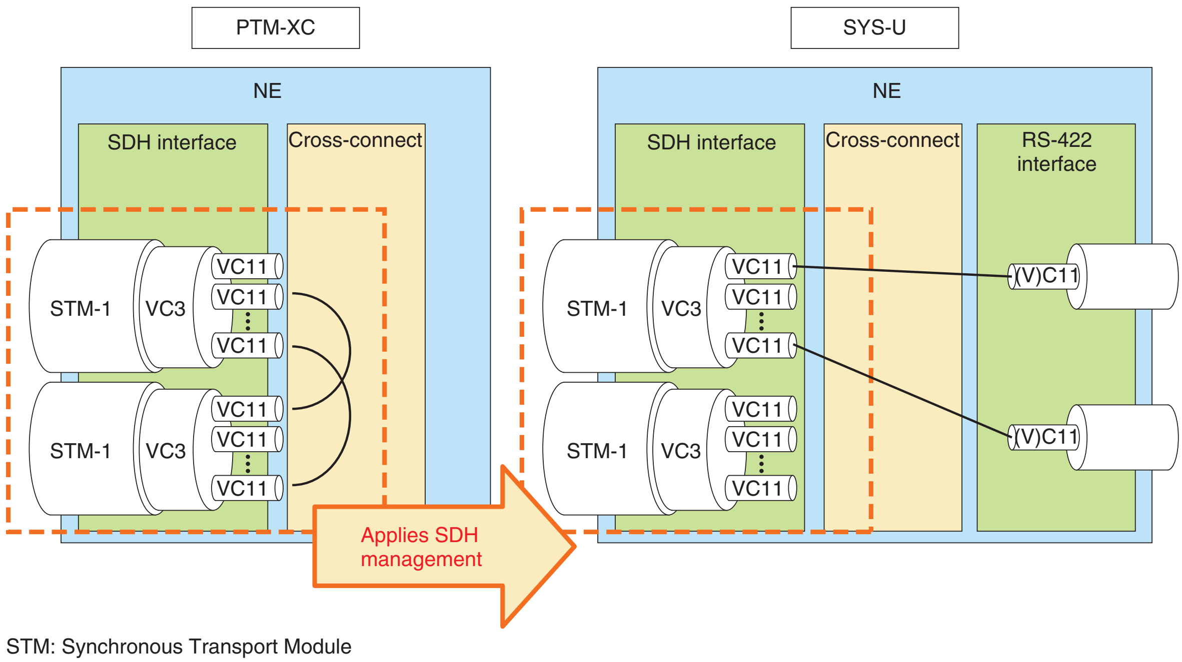


Fig. 4. Object model of PTM-XC and SYS-U.

4. TM-EMS for PTM-XC

4.1 Background

The NEs of the Packet Transport Multiplexer cross-connect (PTM-XC) are based on the PTM link system [2], and they have cross-connect functions that can connect lower-order paths (VC-11 and VC-2) by using packet transport technology based on the MPLS-TP on the synchronous digital hierarchy (SDH) network.

We can manage the NEs of the PTM-XC by configuring the SDH paths. Therefore, we developed a TM-EMS for PTM-XC (called PX-EMS) by applying TM platform technology to an optical path and MPLS-TP path management. The PX-EMS has been in use at NTT EAST and NTT WEST since September 2014.

4.2 Technical features

We added some new logical objects to the TM platform technology to manage the SDH NEs in the PX-EMS. To manage the SDH paths and the NEs of the PTM-XC, we can split and reassemble individual low-speed paths and can register and read test points. Therefore, we added the termination point object of VC-11, which is the SDH low-speed path, as an expansion of the object model in TMF513 in the PX-EMS.

5. TM-EMS for SYS-U

5.1 Background

To provide communication procedures on remote islands and in areas affected by natural disasters, NTT EAST and NTT WEST operate a satellite communication system with a satellite connection defined in Recommended Standard-422 (RS-422).

The communication devices used in the satellite communication system have become older, and therefore, NTT developed a high-efficiency satellite connection terminating element called SYS-U (system unit). This element assembles the SDH termination function, echo canceller function, and modem function. Using the SYS-U makes it possible to simplify the network and enables more efficient satellite connections. The SYS-U terminates the (V)C11* path as a satellite connection and communicates via the SDH optical signal. The SYS-U's units of communication, alarm, and cross-connection are the same as those of the NE of PTM-XC. Consequently, we decided to use the same object model as that specified in TMF513 (**Fig. 4**).

By taking advantage of the TM platform technology, we developed a TM-EMS for SYS-U (SAT-EMS).

* (V)C11: C11 path that stores the minimum overhead.

5.2 Technical features

We applied TM platform technology to optical paths, MPLS-TP and SDH paths, and we expanded the TMF513 object model. We achieved a highly efficient satellite connection terminating element by developing the SAT-EMS by using the object model in TMF513 in the (V)C11 and VC-11 paths. The SAT-EMS can configure lower-speed channels (64 kbit/s) than the VC-11 path (1.5 Mbit/s) in the PX-EMS.

6. Future prospects

We have expanded the TM platform technology with practical development of EMSs for various NEs. In the future, we plan to conduct research and development to promote more efficient development of EMSs by using our expanded TM platform technology. We will also work on improving this technology in order to apply it to EMSs and increase the common functionality of the TM-EMS.

References

[1] TeleManagement Forum, "TMF513, Multi-Technology Network Management (MTNM) Business Agreement Release 3.5," 2007.

[2] M. Ogawa, H. Iwashita, T. Takashima, T. Matsuda, K. Higuchi, and K. Koda, "Cross-connect System with Packet Transport Technology," NTT Technical Review, Vol. 13, No. 7, 2015. https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201507ra3.html

Hiroyuki Ohyanagi

Researcher, Transport Management Development Project, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in computer science, intelligent systems, and engineering from Osaka Prefecture University in 2009 and 2011. He joined NTT Network Service Systems Laboratories in 2011, where he researched and developed next-generation network service systems. He is currently developing operation support systems.

Yoshifumi Kato

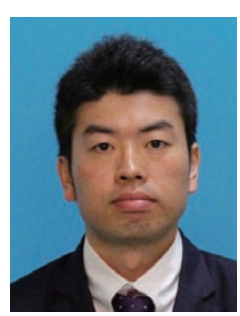
Researcher, Transport Management Development Project, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in information and intelligent systems from Yokohama National University, Kanagawa, in 2007 and 2009. He joined NTT Network Service Systems Laboratories in 2009, where he has been engaged in research and development of transport network management technology.

Yuichiro Ishizuka

Researcher, Transport Management Development Project, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received his B.E. and M.E. in information, mathematics, and physics from Kyoto University in 2009 and 2011. He joined NTT Network Service Systems Laboratories in 2011, where he has been engaged in research and development of transport network management technology.



Hironobu Minowa

Researcher, Environmental Technology Research Group, Research Laboratories, NTT DOCOMO, INC.

He received his M.E. in physics from Tokyo University of Science in 2008 and a Ph.D. in electrochemical engineering from Kanazawa University in 2014. He joined NTT Energy and Environment Systems Laboratories in 2008 and studied next-generation secondary batteries for backup power supplies. He moved to NTT Network Service Systems Laboratories in 2013 and developed operating systems for transmission equipment. He was transferred to NTT DOCOMO in 2015 and is currently studying a power feeding system for wireless base transceiver stations. He is a member of the Electrochemical Society of Japan.

Development of User Interface Assist Platform Using Transport Network Management Platform Technology

Hironobu Minowa, Tsuyoshi Furukawa, Yoshiharu Takeda, and Shinya Matsumoto

Abstract

We introduce here the User Interface Assist Platform, which enables the short-term and low-cost development of element management systems (EMSs). Such EMSs make it possible to achieve easy operation of network elements (NEs) when operation requirements are simple, such as when the network management operation requires simple commands or a single command for a single NE.

Keywords: compact EMS, User Interface Assist Platform, transport network management platform technology

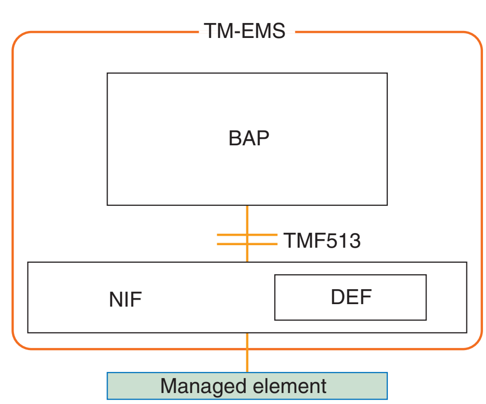
1. Introduction

NTT Network Service Systems Laboratories has developed transport network management (TM) platform technology. An element management system (EMS) developed using TM platform technology (TM-EMS) is characterized by two platform architectures: a business application platform that supports the network operator's operations, and a network element (NE) interface platform that translates an abstract resource requirement into a concrete element command.

The interface between the two platforms conforms to the operations for data models specified by the TeleManagement Forum in the TMF513 document, which provides data models for transport network management such as managed elements and equipment (**Fig. 1**).

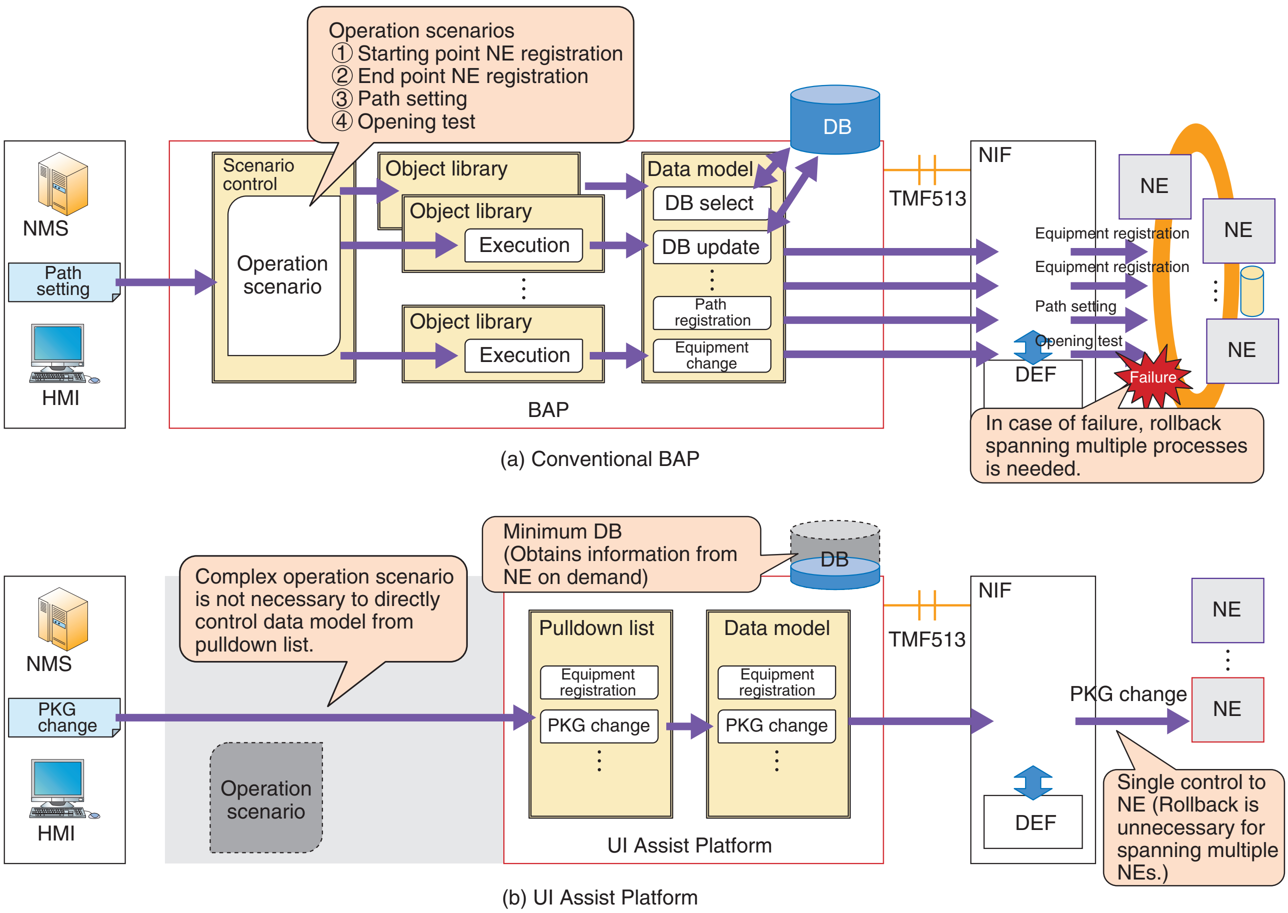
Transport network operations are sometimes very complicated, and to reduce an operator's workload, it is essential for the EMS to support functions such as providing a scenario of large-scale operations that consist of several different operations and a rollback function for recovering to a former state when the operation scenario fails. NTT Network Service Systems Laboratories has developed EMSs for several NEs in order to achieve a business application platform that can manage complicated operation scenarios.

However, it is not necessary for an EMS to support



BAP: business application platform
NIF: network element interface platform
DEF: definition file for network element communication

Fig. 1. Architecture of TM-EMS.



DB: database
HMI: human-machine interface
NMS: network management system
PKG: package

Fig. 2. Comparison of conventional business application platform and UI Assist Platform.

a complicated operation scenario and rollback function when operation requirements are simple such as when the operation is based on a single command for a single NE. Therefore, we simplified the structure of a conventional business application platform and developed the User Interface (UI) Assist Platform. This simplified platform does not have functions to provide operation scenarios or rollback, and it directly calls an NE interface platform through the TMF513-based interface (**Fig. 2**).

Our platform has a general-purpose function that is easier for operators to use than typing in commands and receiving status updates from an NE using the Telnet session layer protocol. Replacing the conventional business application platform with the UI Assist Platform enables the shorter-term and lower-cost development of EMSs for simple operations, while taking advantage of the TM-EMS function that manages the NEs of multiple vendors.

2. Design policy

It is important to emphasize generality in the design policy so that the UI Assist Platform can be developed to fit various NEs in the short term and at low cost. The features of the UI Assist Platform for several operation scenarios such as setting and control management, fault management, and configuration management are described in more detail in this section.

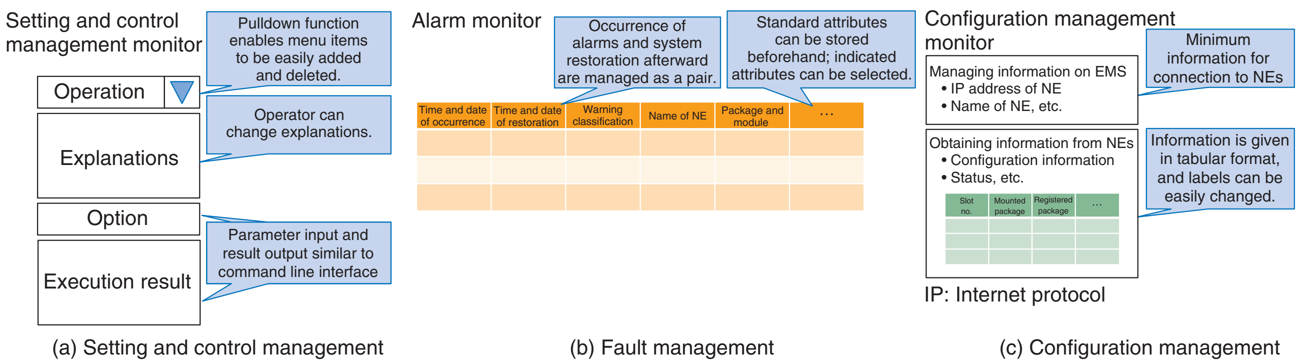


Fig. 3. Schematic view of design policy.

2.1 Setting and control management

To minimize the amount of development necessary when there are differences in specifications depending on the model or the vendor of an NE, we adopt a pulldown selection function to manage the settings of NEs. This function has a general-purpose human-machine interface (HMI) that supports parameter input and result output in a similar manner to the command line interface (**Fig. 3(a)**). The pulldown function of the operation menu enables further development such as addition and deletion of menu items. The operator can also change the indicated explanations of the operation menu item when it is selected.

2.2 Fault management

Alarms are stored in the database of the EMS and are paired into occurrence and restoration events as with the conventional business application platform because the NEs may not be able to provide current alarm information to the EMS (**Fig. 3(b)**). The UI Assist Platform includes the attributes of the data models of TMF513 such as alarm notification and TCA (threshold crossing alert) notification in column form in the EMS database in order to ensure generality. It is possible to choose columns displayed on the alarm monitor screen. Thus, we can minimize the necessary changes in the database definitions caused by differences in specifications of the alarm information of the NEs.

2.3 Configuration management

The database of the EMS manages the minimum amount of information for connection to NEs. The NE statuses can be obtained from the NEs at any time. Information is obtained from NEs in a tabular format in the HMI, and labels can be changed as needed to achieve generality (**Fig. 3(c)**). The generality enables the short-term and low-cost development of EMSs.

3. Achieving generality

We explain here the achievement of generality regarding setting and control management. The UI Assist Platform minimizes the effects of logic changes when adopting different NEs by providing a general-purpose setting screen in an HMI specialized to call definition files for NE communication. The general-purpose setting screen can call a single TMF513-based interface. Although the UI Assist Platform does not support a complicated rollback function using multiple TMF513-based interfaces, the rollback function can be implemented from the definition files in the case of a single call.

It is necessary to sufficiently confirm the conformability when adopting the UI Assist Platform for a complicated operation that requires highly specialized operator knowledge, for example, on operation scenarios and rollbacks. A simple operation requirement, in which an operation is based on a single command for a single NE, enables the short-term and low-cost development of EMSs by providing a general-purpose setting screen in the HMI.

The UI Assist Platform reads the information necessary for operation from the defined system generation (SG) files and calls the TMF513-based interface (**Fig. 4**). Category, operation, explanation, warning, and authority can be flexibly changed with the SG files. A concrete example of the SG files is shown in **Fig. 5**.

(1) Category SG is the setting for grouping several operation menus. The assortment of categories

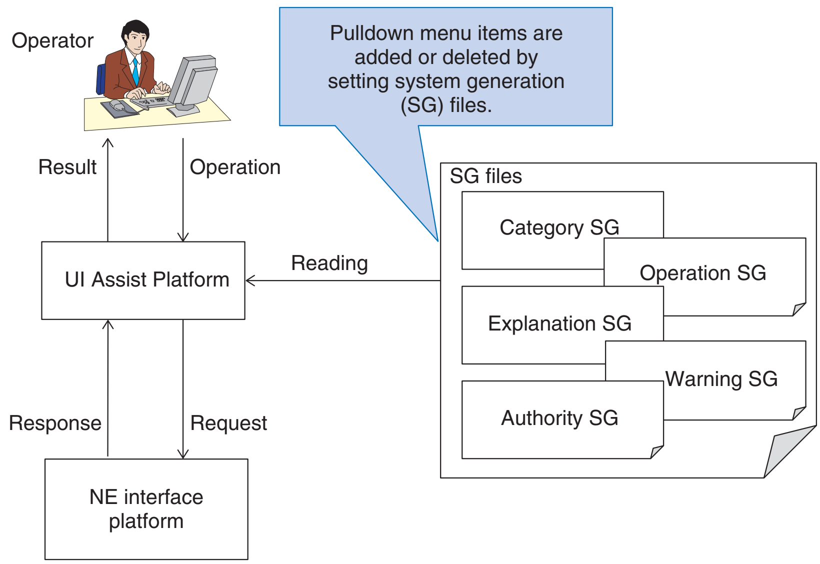


Fig. 4. System generation of UI Assist Platform.

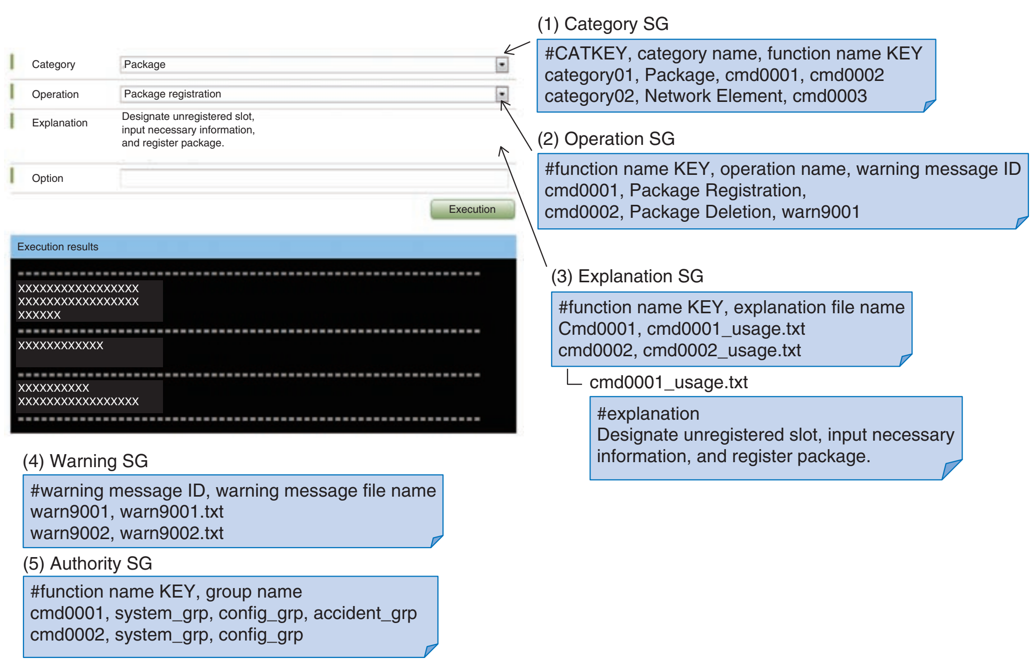


Fig. 5. Example of SG files.

is flexible. This setting will display the operation menu that is linked to a category when the category is selected.

(2) Operation SG is the setting for displaying the operation menu for an NE. The items in the pull-down list, which is the same as the operation menu, are associated with the TMF513-based interface. If an argument (i.e., a value) is necessary depending on the operation menu, the operator can input strings into the option field,

which is associated with the SG setting.

(3) Explanation SG is the setting for defining the explanation to display at the time of operation menu selection. By writing the potential arguments in advance, an operator can copy the values to the options field to support the input of the argument. Since an SG file can be changed even during operation, the operator can take advantage of the accumulated knowledge.

(4) Warning SG is the setting for displaying a warning message before execution according to the effect on the NEs.

(5) Authority SG is the setting for displaying items in a pulldown list. A pulldown list will appear according to the user level of the operator.

The UI Assist Platform achieves generality in which operation menus can be flexibly added by using an SG file.

4. Conclusion

We developed the UI Assist Platform, which enables efficient development of EMSs in the case of simple operation requirements using TM platform technology. We have already developed a TM-EMS using this platform. In the future, we plan to investigate applying this platform to NEs not only for transport networks, as middleware for developing compact EMSs.

Hironobu Minowa
Research Engineer, Environmental Technology Research Group, Research Laboratories, NTT DOCOMO, INC.
He received his M.E. in physics from Tokyo University of Science in 2008 and a Ph.D. in electrochemical engineering from Kanazawa University in 2014. He joined NTT Energy and Environment Systems Laboratories in 2008 and studied next-generation secondary batteries for backup power supplies. He moved to NTT Network Service Systems Laboratories in 2013 and developed operating systems for transmission equipment. He was transferred to NTT DOCOMO in 2015 and is currently studying a power feeding system for wireless base transceiver stations. He is a member of the Electrochemical Society of Japan.

Tsuyoshi Furukawa
Senior Research Engineer, Transport Management Development, Operation Innovation Project, NTT Network Service Systems Laboratories.
He received his B.E. and M.E. in electrical engineering from Waseda University, Tokyo, in 1993 and 1995, respectively. He joined NTT Optical Network Systems Laboratories in 1995 and studied network operation systems. He is currently engaged in research and development (R&D) of TM platform technology. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Yoshiharu Takeda
Senior Research Engineer, Transport Management Development, Operation Innovation Project, NTT Network Service Systems Laboratories.
He received his B.E. in electronics and electrical engineering from Nihon Kogakuin College, Tokyo, in 1990 and joined NTT the same year. He is currently involved in R&D of TM platform technology.

Shinya Matsumoto
Research Engineer, Transport Management Development, Operation Innovation Project, NTT Network Service Systems Laboratories.
He received his B.E. and M.E. in electronics and electrical engineering from Doshisha University, Kyoto, in 1987 and 1989, respectively. He joined NTT Communication Switching Laboratories in 1989 and studied intelligent networks. He is currently engaged in R&D of TM platform technology.

High-sensitivity Avalanche Photodiode and Receiver Optical Subassembly Technology for 100-Gbit/s Ethernet

Fumito Nakajima, Masahiro Nada, and Toshihide Yoshimatsu

Abstract

We have developed a 25-Gbit/s avalanche photodiode (APD) with an inverted p-down, triple mesa structure and a 100-Gbit/s (4 × 25-Gbit/s) APD receiver optical subassembly (APD-ROSA). The APD-ROSA includes a monolithic four-channel APD array and an ultrasmall planar-lightwave-circuit demultiplexer. In a performance evaluation, the APD achieved a record minimum receiver sensitivity of –20 dBm and 50-km error-free transmission without an optical amplifier.

Keywords: avalanche photodiode (APD), 100-Gbit/s Ethernet, receiver optical subassembly (ROSA)

1. Introduction

The rapid increase in the capacity of communication networks has led to many new services. To handle the growing amount of transmitted data, the Ethernet standard has been repeatedly extended [1], and faster and faster interface speeds are necessary in order to cope with this trend. In particular, datacenters will need to deal with ever-increasing amounts of data in limited areas, and at the same time, the capacity of optical components and reductions in their size and power consumption will be urgently required. In addition, the transmission distance of 100-Gbit/s Ethernet systems will also need to be extended in order to meet the requirements for future application areas. Extending the reach beyond 10 km is very important for telecom carriers because it will enable most inter-building networks to be covered.

The key to extending the distance is the optical receiver because the launch power of the laser diode in the transmitter is limited. A schematic image of a 100-Gbit/s Ethernet 10-km transmission system (100GBASE-LR4) that uses a transmission optical subassembly (TOSA) and receiver optical subassembly (ROSA) is shown in **Fig. 1(a)**. A typical ROSA includes a PIN photodiode to convert optical signals to electrical signals. The receiver sensitivity of a ROSA is limited in the system, and therefore, to extend the transmission distance, it is necessary to use an optical amplifier such as a semiconductor optical amplifier (SOA) in front of the ROSA, as shown in **Fig. 1(b)**. However, in this configuration, the receiver module size cannot be reduced enough to keep up with the expected size of packages such as that of a CFP4 transceiver. In addition, an SOA consumes as much as several watts of power and enlarges the footprint.

Thus, to provide a means of improving the sensitivity without increasing the package size, we proposed a novel high-speed avalanche photodiode (APD) [2], as shown in **Fig. 1(c)**. An APD has an internal gain that improves the sensitivity by several decibels compared to that of a PIN photodiode. Our APD, called an inverted p-down APD, has achieved a high multiplied

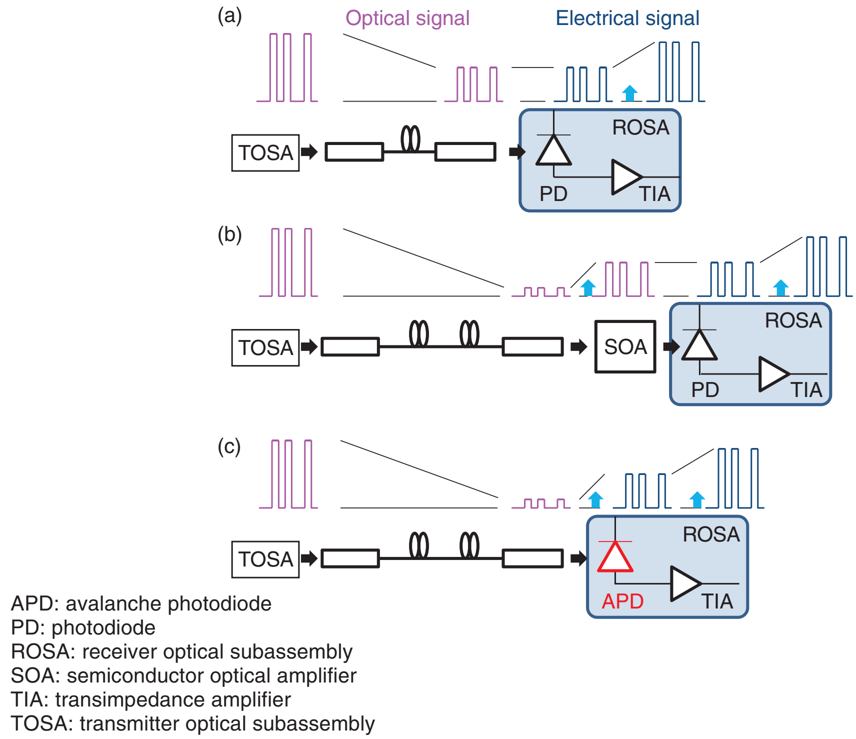


Fig. 1. 100-Gbit/s Ethernet transmission systems using TOSA and ROSA.

responsivity-bandwidth product of 18.5 × 9.1 = 168 A/W·GHz [3] and can operate with a bandwidth large enough for receiving 25-Gbit/s data. In this article, we describe the design and fabrication of the high-speed, stable APD and the results of applying it to a 100-Gbit/s four-channel APD-ROSA.

2. Inverted p-down APD

In addition to large bandwidth and high responsivity, the reliability and stability of an APD are the most important factors for its practical application, since a high applied voltage is necessary to obtain sufficient internal gain. We have devised a simple new APD structure, the inverted p-down APD, that is suitable for even higher speeds by scaling the structure down. The simple structure confines the electric field, which makes it possible to obtain good stability.

A schematic cross section of our APD is shown in **Fig. 2(a)**. The epitaxial layers were grown on a semi-insulating InP substrate by using MOCVD (metal organic chemical vapor deposition). The APD structure consists of a p-doped contact layer, p-doped and undoped InGaAs absorption layers, an InAlAs avalanche layer sandwiched between p- and n-doped field control layers, and an n-doped contact layer.

Although there is a trade-off between bandwidth and responsivity in an APD, we optimize the thickness relationship between the p-doped and undoped absorption layers to relax the trade-off, in accordance with the concept of MIC (maximized induced current) design [4]. This is necessary because the two types of photo-excited carriers, namely holes and electrons, are transported through the p-doped and undoped layers by different mechanisms. We show how the calculated responsivity and the calculated intrinsic 3-dB-down bandwidth for a multiplication factor (M) of 1 varies with the total thickness of the absorption layer in **Figs. 2(b)** and **2(c)**. The optimum intrinsic 3-dB-down bandwidth was achieved by tuning the proportion of the total absorption layer occupied by p-doped absorption. For a speed of 25 Gbit/s, a total thickness of 1.0 µm provides a sufficiently large bandwidth and a high responsivity of 0.9 A/W.

Furthermore, the gain-bandwidth product (GBP) is one of the most important factors to define the APD receiver sensitivity. Making the InAlAs avalanche layer thinner increases the GBP; however, it also increases the tunneling current density. Because a larger tunneling current degrades the optical receiver

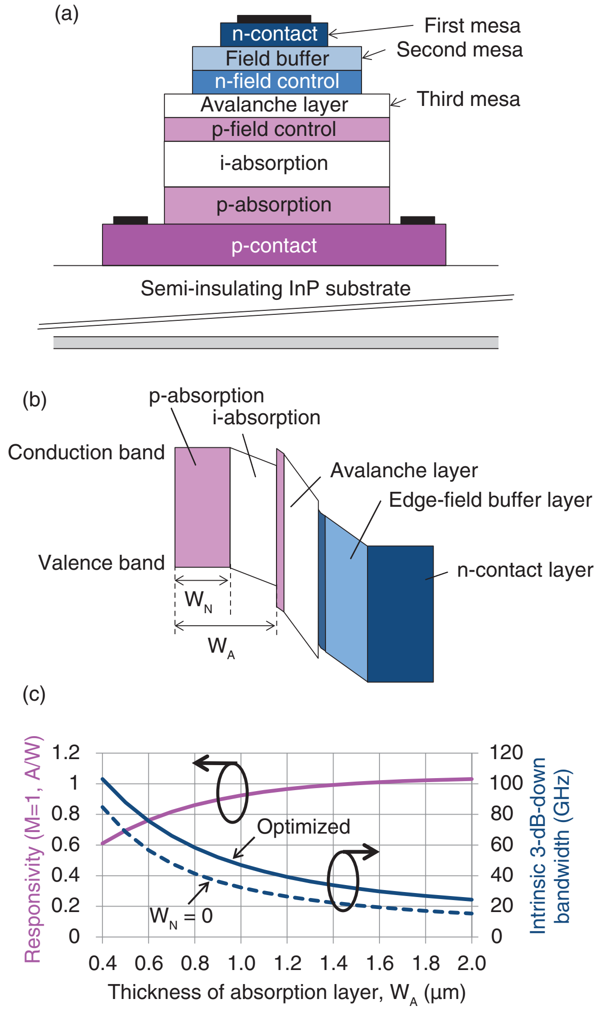


Fig. 2. (a) Schematic cross section of inverted p-down APD with triple mesa. (b) Parameters for calculation and (c) calculated responsivity (M = 1) and 3-dB-down bandwidth (M = 1), considered only in terms of intrinsic carrier transit time in absorption layer against total thickness of absorption layer.

sensitivity, we have to optimize the thickness of the avalanche layer to suit the application.

Thus, the thickness of the InAlAs avalanche layer is 0.1 µm, which enables us to obtain a large GBP of 235 GHz [3].

To obtain good stability and reliability, it is important to confine the electric field inside the avalanche layer vertically. To meet this requirement, we generally employ a SACM (separation of absorption, charge, and multiplication) structure [5]. The p-doped and n-doped field-control layers sandwiching the avalanche layer play an important role in confining the high electric field within the avalanche layer.

The electric field must also be laterally confined to prevent degradation of the semiconductor surface. The electric field affects not only the stability and reliability, but also the bandwidth determined by the CR (capacitance-resistance) time constant because the effective junction area is defined by the confinement of the electric field. Two techniques have been reported for achieving lateral confinement for 10-Gbit/s systems, namely, zinc diffusion [6] and ion implantation [7]. Although they obtained sufficient bandwidth and reliability for 10-Gbit/s operation, the APD structures built using these techniques require a complicated fabrication process. Our inverted p-down APD with triple-mesa structure is promising as a way to overcome this issue.

The triple-mesa structure shown in Fig. 2(a) reduces the intensity of the electric field in the peripheral region of the mesa [8]. All the mesas are formed by conventional wet etching techniques. This mesa structure results in reduced dark current at a mesa surface, which extends the life of the device.

Table 1. Dimensions of large-area diodes.

	Diode 1	Diode 2	Area ratio
Diameter 1 (1st mesa)	100 µm	200 µm	4.00
Diameter 2 (2nd mesa)	110 µm	210 µm	3.64
Diameter 3 (3rd mesa)	130 µm	230 µm	3.13

We evaluated the effect of the triple mesa by measuring the ratio of the capacitance-voltage (C-V) curves of two large-area diodes with different dimensions, as listed in **Table 1**. The area-size ratios between two diodes of the first, second, and third mesa were 3.13, 3.64, and 4.00, respectively. The C-V relationship can be expressed simply as

$$C(V) = \varepsilon(V)\, S(V) / d(V),$$

where ε, S, and d are the dielectric constant, effective area size, and depletion layer thickness, each of which depends on the bias voltage. By taking the ratio of the two C-V curves, the relationship is expressed as

$$C2(V) / C1(V) = S2(V) / S1(V).$$

The C-V curves of two diodes are shown in **Fig. 3(a)**. The capacitance ratio versus bias voltage calculated by two C-V curves is shown in **Fig. 3(b)**. The curve has three steps corresponding to the ratios of the three area sizes of the triple-mesa structure. Since the breakdown voltage of this sample is 27.4 V, these results show that the electric field is confined by

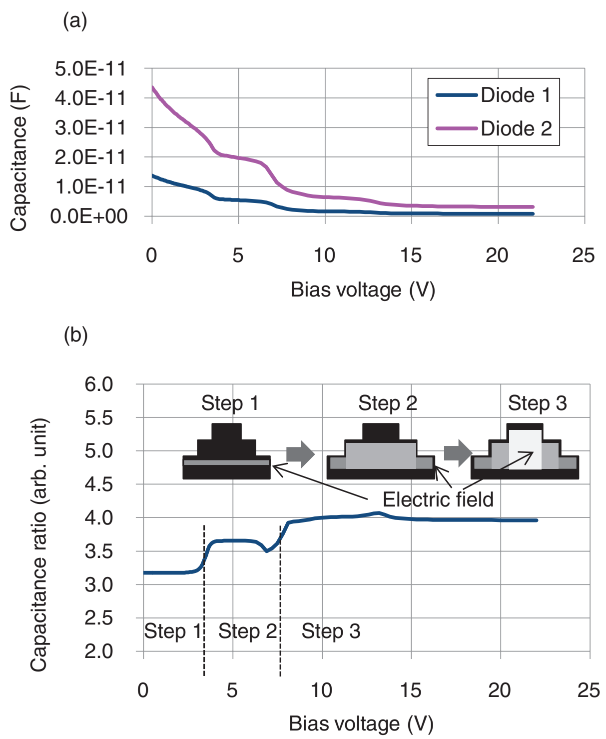


Fig. 3. (a) Capacitance vs. bias voltage curves of two diodes and (b) capacitance ratio vs. bias voltage.

the first mesa at the operating condition of M = 10.

The photocurrent distribution across the APD mesa at a bias condition providing an M value of 10 is shown in **Fig. 4**. Light was irradiated from the substrate side, and the optical power was set to –20 dBm. The photocurrent curve has a maximum level from –5 to 5 μm due to reflection from the mirror on the top of the first mesa and the high intensity of the electric field under the first mesa, as mentioned above. The 3-dB-down bandwidth was obtained by measuring the OE (opto-electronic) response at the corresponding point. The measured 3-dB-down bandwidth maintains almost the same value in the first mesa and falls off rapidly toward the outside. This indicates that the electric field is sufficiently high only under the first mesa. These results again demonstrate sufficient confinement of the electric field by the first mesa. The 3-dB-down bandwidth at the center reaches 18 GHz even for an M value of 10. This value is sufficient for 25-Gbit/s applications.

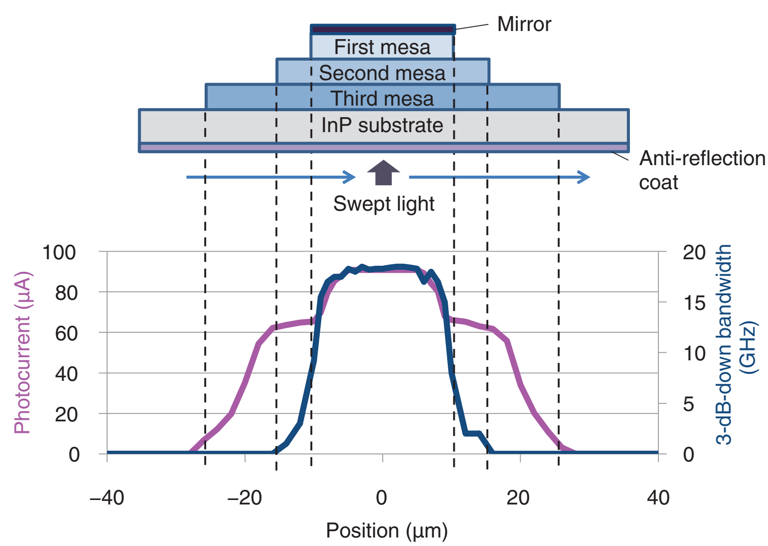
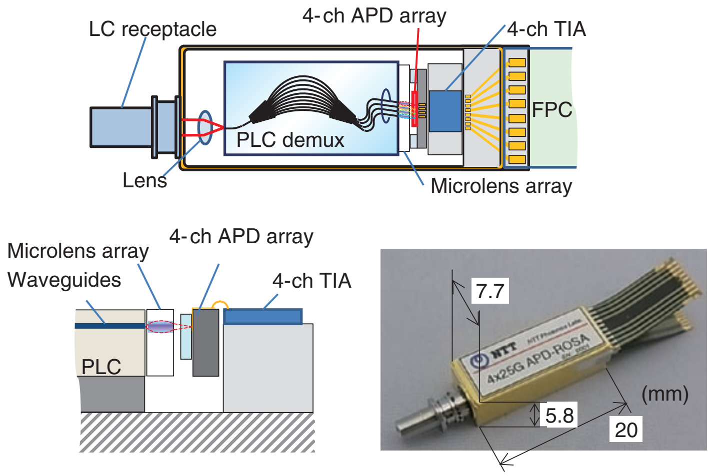


Fig. 4. Cross-sectional profile of photocurrent and 3-dB-down bandwidth against the position of irradiated light.



FPC: flexible-printed circuit
PLC: planar lightwave circuit

Fig. 5. Schematic view and photograph of 4-ch APD-ROSA.

3. APD-ROSA module for 100-Gbit/s Ethernet systems

Next, we applied our high-speed APD chip to the APD-ROSA. A photograph and schematic illustrations of our 4-ch APD-ROSA are shown in **Fig. 5**. The size of the package body, excluding the LC-type receptacle and FPCs (flexible-printed circuits), is 7.7 × 20 × 5.8 mm. The APD-ROSA includes a monolithic 4-ch APD array, a planar lightwave circuit demultiplexer (PLC demux), a microlens array, and a commercially available 4-ch transimpedance amplifier (TIA) [9, 10]. Our fabricated silica PLC demux has one single-mode input waveguide and four multimode output waveguides, which provide a flat-top spectrum [11]. The APD-array chip was flip-chip mounted on a subcarrier having signal lines for right-angle surface mounting. Since the glass microlens array and APD array on the subcarrier were attached to the output end of the PLC demux chip, the optical coupling distance between the PLC and APD was minimized to a few hundred micrometers.

We measured the back-to-back transmission and the transmission over a 50-km-long single-mode fiber (SMF). The experimental setup is shown in **Fig. 6**. Here, a 25.78-Gbit/s NRZ (non-return-to-zero) on-off keying optical signal consisting of a 2^{31}-1 PRBS (pseudo-random bit sequence) was generated using a tunable laser source and a $LiNbO_3$ Mach-Zehnder (LN) modulator. Wavelengths were set at 1295.56 (lane 0), 1300.05 (lane 1), 1304.58 (lane 2), and 1309.14 nm (lane 3).

Eye diagrams of the electrical output from the APD-ROSA for back-to-back transmission and after 50-km transmission are shown in **Fig. 7(a)**. We obtained clear eye openings for each lane and for both types of transmission. The BER (bit error rate) characteristics are shown in **Fig. 7(b)**, where the back-to-back receiver sensitivity levels were –20.0, –20.3, –20.1, and –20.0 dBm for lanes 0, 1, 2, and 3, respectively. After 50-km transmission, no significant transmission penalties were observed. Negative values of power penalties are explained by the relationship between the positive chirp parameter of the modulator and the normal chromatic dispersion of the 50-km SMF. These results show that our high-speed APD is applicable to APD-ROSAs for 100-Gbit/s systems, and they also indicate the possibility of extending the transmission distance without increasing the power consumption or package size of the receiver module. The APD-ROSA consumes as little as 0.7 W of power and needs no additional space for a preamp. This configuration opens up the possibility of mounting the ROSA in a CFP4 package and of using it in larger capacity Ethernet systems of the future, such as 400-Gbit/s and 1-Tbit/s Ethernet.

4. Conclusion

We developed an inverted p-down APD with high-speed and stable performance. High responsivity (0.9 A/W), large bandwidth (18 GHz at M = 10), and a

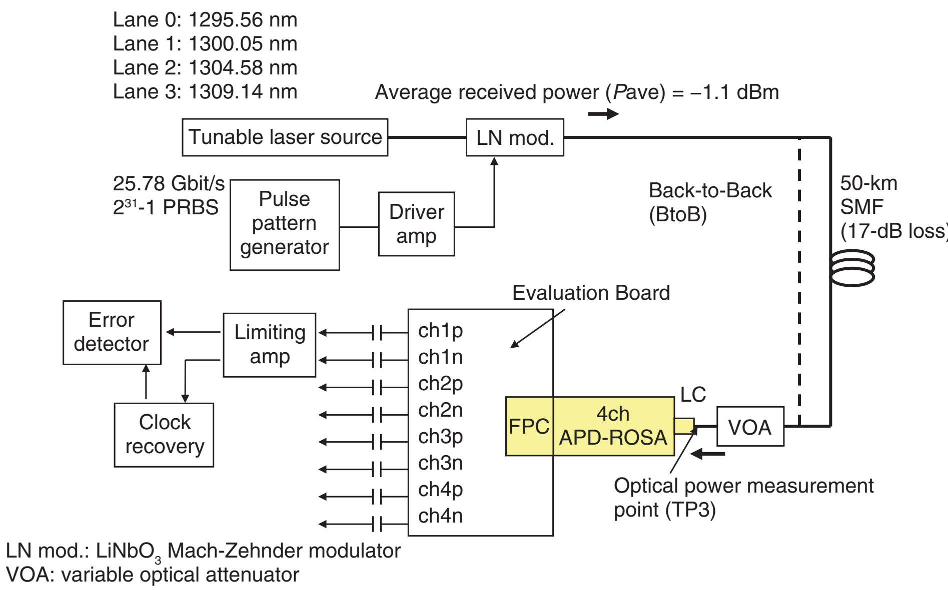


Fig. 6. Experimental setup.

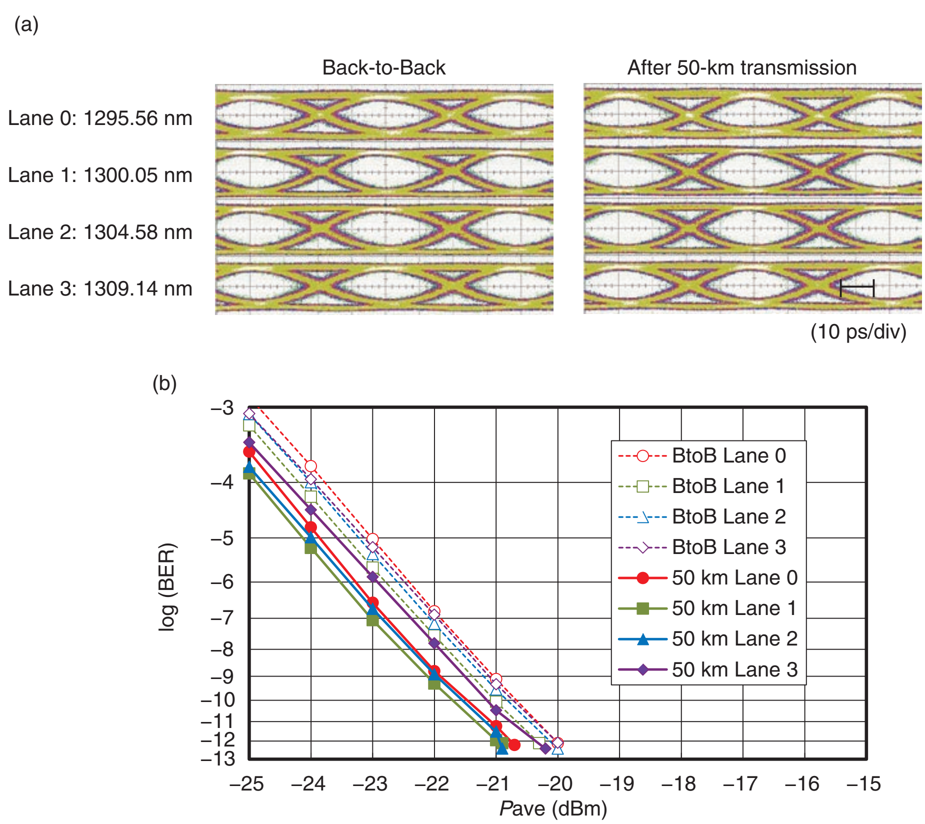


Fig. 7. (a) Electrical output waveforms and (b) BER curves for back-to-back and after 50-km transmission.

large GBP (235 GHz) were achieved by optimally designing the absorption layer (1.0 µm) and InAlAs avalanche layer (0.1 µm). The C-V characteristics and photocurrent profile indicate strong confinement of a high electric field in the avalanche layer, which is achieved with two field control layers and a triple-mesa structure.

A 100-Gbit/s (4 × 25-Gbit/s) ROSA using a monolithic four-channel APD array and an ultrasmall PLC demux exhibit minimum receiver sensitivities of –20 dBm and below for back-to-back transmission. We succeeded in achieving 50-km error-free transmission without an optical amplifier. These results indicate that our receiver module technology can contribute to reducing the size and power consumption of optical transceivers toward future 400-Gbit/s and 1-Tbit/s Ethernet multi-wavelength networks.

References

[1] IEEE P802.3bs 400 Gb/s Ethernet Task Force, http://www.ieee802.org/3/bs/

[2] M. Nada, Y. Muramoto, H. Yokoyama, N. Shigekawa, T. Ishibashi, and S. Kodama, “Inverted InAlAs/InGaAs Avalanche Photodiode with Low-high-low Electric Field Profile,” Jpn. J. Appl. Phys., Vol. 51, No. 2, p. 02BG03, 2012.

[3] M. Nada, Y. Muramoto, H. Yokoyama, T. Ishibashi, and S. Kodama, “InAlAs APD with High Multiplied Responsivity-bandwidth Product (MR-bandwidth product) of 168 A/W·GHz for 25 Gbit/s High-speed Operations,” Electron. Lett., Vol. 48, No. 7, pp. 397–399, 2012.

[4] Y. Muramoto and T. Ishibashi, “InP/InGaAs Pin Photodiode Structure Maximising Bandwidth and Efficiency,” Electron. Lett., Vol. 39, No. 24, pp. 1749–1750, 2003.

[5] J. C. Campbell, “Recent Advances in Telecommunications Avalanche Photodiodes,” J. Lightw. Technol., Vol. 25, No. 1, pp. 109–121, 2007.

[6] E. Yagyu, E. Ishimura, M. Nakaji, S. Ihara, Y. Mikami, H. Itamoto, T. Aoyagi, K. Yoshiara, and Y. Tokuda, “Design and Characteristics of Guardring-free Planar AlInAs Avalanche Photodiodes,” J. Lightw. Technol., Vol. 27, No. 8, pp. 1011–1017, 2009.

[7] Y. Hirota, Y. Muramoto, T. Takeshita, T. Ito, H. Ito, S. Ando, and T. Ishibashi, “Reliable non-Zn-diffused InP/InGaAs Avalanche Photodiode with Buried n-InP Layer Operated by Electron Injection Mode,” Electron. Lett., Vol. 40, No. 21, pp. 1378–1379, 2004.

[8] M. Nada, Y. Muramoto, H. Yokoyama, T. Ishibashi, and H. Matsuzaki, “Triple-mesa Avalanche Photodiode with Inverted P-Down Structure for Reliability and Stability,” J. Lightw. Technol., Vol. 32, No. 8, pp. 1543–1548, 2014.

[9] T. Yoshimatsu, M. Nada, M. Oguma, H. Yokoyama, T. Ohno, Y. Doi, I. Ogawa, and E. Yoshida, “Compact and High-sensitivity 100-Gb/s (4 × 25 Gb/s) APD-ROSA with a LAN-WDM PLC Demultiplexer,” Proc. of ECOC 2012 (38th European Conference and Exhibition on Optical Communication), Th.3.B.5, Amsterdam, The Netherlands, Sept. 2012.

[10] T. Yoshimatsu, M. Nada, M. Oguma, H. Yokoyama, T. Ohno, Y. Doi, I. Ogawa, H. Takahashi, and E. Yoshida, “Compact and High-sensitivity 100-Gb/s (4 × 25Gb/s) APD-ROSA with a LAN-WDM PLC Demultiplexer,” Opt. Express., Vol. 20, No. 26, pp. B393–B398, 2012.

[11] Y. Doi, M. Oguma, M. Ito, I. Ogawa, T. Yoshimatsu, T. Ohno, E. Yoshida, and H. Takahashi, “Compact ROSA for 100-Gb/s (4 × 25 Gb/s) Ethernet with a PLC-based AWG Demultiplexer,” Proc. of OFC (Optical Fiber Communication Conference) 2013, NW1J.5, Anaheim, CA, USA, Mar. 2013.

Fumito Nakajima

Senior Research Engineer, NTT Device Innovation Center.

He received his B.E., M.E., and Ph.D. from Hokkaido University in 1998, 2000, and 2003. In 2003, he joined NTT Photonics Laboratories. He has been involved in research and development of high-speed photodiodes and avalanche photodiodes for optical receivers. He is currently a senior research engineer with NTT Device Innovation Center. Dr. Nakajima is a member of the Institute of Electronics, Information, and Communication Engineers (IEICE).

Toshihide Yoshimatsu

Senior Research Engineer, NTT Device Innovation Center.

He received his B.E. and M.E. in applied physics from Tohoku University, Miyagi, in 1998 and 2000. He joined NTT Photonics Laboratories in 2000. He has been researching and developing ultrafast opto-electronic devices. He is currently a Senior Research Engineer with NTT Device Innovation Center. He received the SSDM Paper Award from the SSDM (Solid State Devices and Materials) Organizing Committee in 2004. He is a member of IEICE and JSAP.

Masahiro Nada

Researcher, NTT Device Technology Laboratories.

He received his B.E. and M.E. from the University of Electro-Communications, Tokyo, in 2007 and 2009. He joined NTT Photonics Laboratories in 2009. Since then, he has been involved in research on high-speed, high-sensitivity avalanche photodiodes. He is currently a researcher with NTT Device Technology Laboratories. Mr. Nada is a member of IEICE, the Japanese Society of Applied Physics (JSAP), and IEEE (Institute of Electrical and Electronics Engineers).

Development of World's Highest Density Ultra-high-count and High-density Optical Fiber Cable (2000 Cores)

Naoki Nakagawa, Shinya Hamaguchi, Yohei Endo, Yukihiko Shibata, Ryo Tanaka, Kazuki Nitta, Masanori Nogami, Kimiyoshi Nishimura, Tetsuya Iwadou, and Yoshitaka Enomoto

Abstract

With the diversification of network services, we can expect an increase in optical demand. To provide these services in a timely manner, we must utilize the limited number of available underground facilities both economically and effectively. We have developed the world's highest density ultra-high-count and high-density cables (2000 cores), an underground closure, and a water sensor module, which contribute to the effective use of underground facilities.

Keywords: optical fiber cable, rollable fiber ribbon, multiple cable installation

1. Introduction

Currently, more than 26 million fiber-to-the-home (FTTH) subscribers (48% of Japanese households) enjoy broadband services via optical fiber, which has now reached the mature stage. However, we expect a further increase in the demand for FTTH services because the Japanese government is promoting the *ICT Growth Strategy*, which includes creating new scenarios for information and communication technology (ICT) use, solving social problems, and improving and strengthening the common ICT infrastructure. This raises concerns about the shortage of conduits in underground facilities that will result from the increased installation of underground optical cables. Consequently, we must utilize the limited number of available underground facilities both economically and effectively. If we are to construct economical and efficient access networks, we need high-count and high-density cables that can make the best use of existing underground facilities.

To meet this requirement, we developed the world's highest density ultra-high-count and high-density optical fiber cable (2000 cores) that employs a novel optical fiber ribbon. We describe the cable and related components consisting of an underground closure and a water sensor module in the following sections.

2. New development concept

Conventionally, three 1000-core underground optical cables can be accommodated in a conduit by using a multiple cable installation technique, and thus, a maximum of 3000 fibers can be installed in one conduit [1]. If we are to use the multiple cable installation technique effectively, we need to design a new optical cable that has the same diameter as the current 1000-core optical cable (23 mm). The technique that is

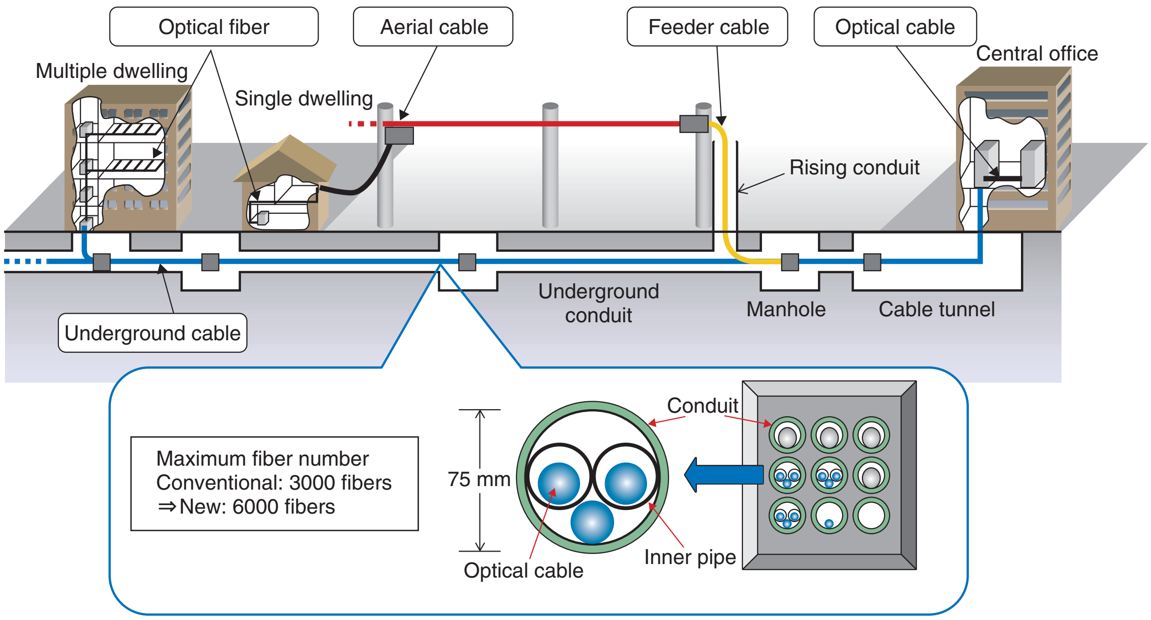


Fig. 1. Current multiple cable installation technique.

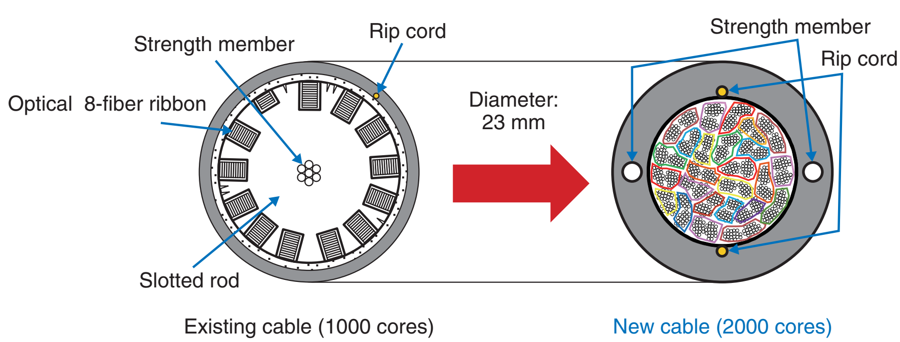


Fig. 2. Configurations of existing cable and newly developed 2000-core cable.

currently used for installing multiple cables in conduits is shown in **Fig. 1**. We have developed a new technique that enables us to install three 2000-core underground optical cables in a conduit, which means that a maximum of 6000 fibers can be accommodated per conduit. This technique makes it possible to reduce the cost of constructing underground facilities.

3. Ultra-high-count and high-density optical fiber cable (2000 cores)

3.1 Optical fiber cable structure

The configurations of the existing cable and the new ultra-high-count and high-density optical fiber cable (2000 cores) are shown in **Fig. 2**. The new cable is composed of 250 rollable fiber ribbons (each with 8 fibers), as well as strength members, rip cords, and a polyethylene sheath. The 250 ribbons are grouped into 25 units. Each unit contains 10 of the 8-fiber rollable fiber ribbons that are formed into strands. Two pieces of colored tape are crossed over each other and wound around each unit to enable them to be identified, and the intersections are glued together to improve the handling of each unit (described in more detail in the following subsections). The incorporated optical fiber is commercially available fiber specified in the ITU-T (Telecommunication Standardization

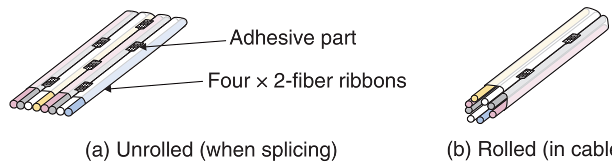


Fig. 3. Rollable optical 8-fiber ribbon with a new structure.

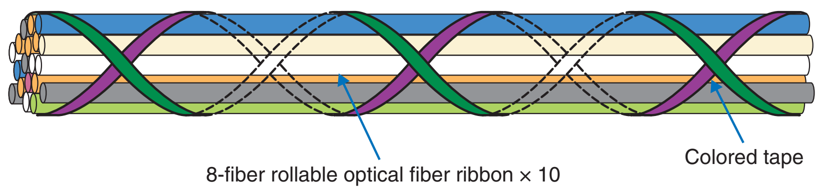


Fig. 4. Configuration of new unit.

Sector of the International Telecommunication Union) G.657.A1 standard. We succeeded in developing 2000-core optical fiber cable with an outer diameter of 23 mm by using these techniques and optimizing the cable structure, which included designing the appropriate thickness of the polyethylene sheath that protects the fibers.

3.2 Optical fiber ribbon structure

We use a ribbon that we call rollable fiber ribbon for this cable. The configuration of this novel fiber ribbon is shown unrolled in **Fig. 3(a)**. The ribbon is composed of four conventional optical 2-fiber ribbons that are arranged linearly, achieving a total of eight fibers. Each 2-fiber ribbon is composed of two coated optical fibers 250 μm in diameter. Two neighboring 2-fiber ribbons are fixed together periodically in the longitudinal direction. This structure enables the optical fiber ribbon to be rolled up easily, as shown in **Fig. 3(b)**, and accommodated very tightly in the cables. Mass splicing can be used to splice the fibers just as with conventional fiber ribbon.

3.3 New method of identifying and selecting the needed optical fiber

With this cable, we needed to consider a new method of identifying and selecting the type of optical fiber needed due to the change in the structure of the accommodated fibers. Conventionally, when we identify and select the optical fiber, we first use a slotted rod to identify the unit. Then, we choose the needed optical fiber based on the color combination of each fiber. Our newly developed cable does not have a slotted rod inside; therefore, we use two pieces of colored tape that cross over each other and wind around each unit to identify which type of optical fiber the unit contains (**Fig. 4**). Two lengths of colored tape are chosen from a selection of 10 different tape colors that are used for identifying current aerial cable units. In the new cable, we use a combination of two tape colors to identify the unit number, and then we choose the optical fiber that is needed just as with the existing cable. This new method of identifying and selecting the needed optical fiber facilitated our development of the ultra-high-count and high-density optical fiber cable (2000 cores).

4. Underground closure

We also developed the components needed to construct an underground closure for use as the connection points for the new cable. To minimize the development cost, we adopted the conventional closure chassis [2].

4.1 Large capacity fiber housing tray

This large capacity tray is specifically used when connecting new cables to each other. It can house 400 fibers, and we can install 15 trays in a conventional closure chassis. Therefore, we have successfully developed a closure that can house 3 new cables, or 6000 fibers (**Fig. 5**).

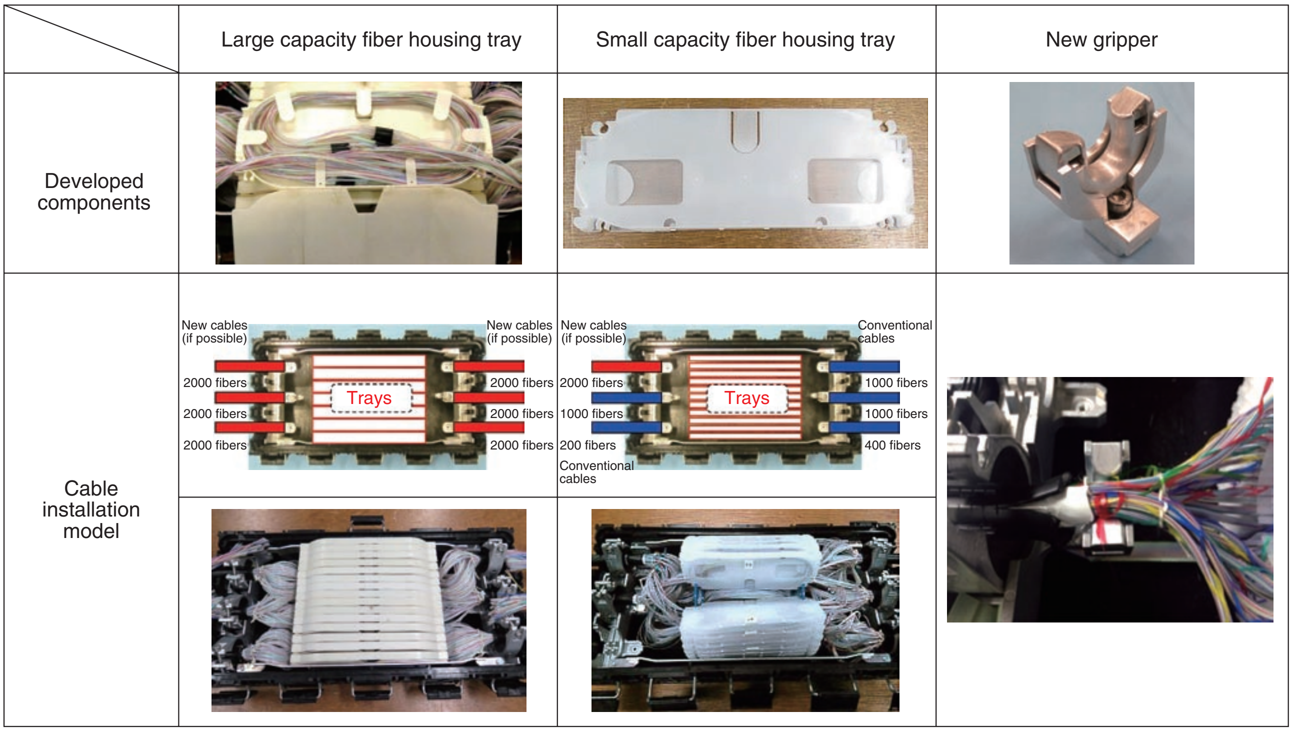


Fig. 5. Images of new components and their installation models.

4.2 Small capacity fiber housing tray

This tray is specifically used for connecting new cable and conventional low-count optical fiber cable when wiring certain existing routes. It can house 80 fibers. This number is twice that of the conventional tray with the same workability because we consider the workspace and optimize the number of trays that can be used in this closure. We can install 40 trays in a conventional closure chassis, so 3200 fibers can be housed in conventional closures (Fig. 5).

4.3 New gripper for strength member

A gripper is used to hold on to the strength member in order to limit the movement of the strength member. We improved the gripping of the strength member for the developed closure for the following reasons:

(1) Conventional cables have a slotted rod and a strength member in the center of the cable (Fig. 2). The conventional gripper used for the strength member inside the closures is the optimized configuration for cables having a slotted rod.

(2) The new cable configuration does not have a slotted rod, and it has two strength members outside the bundle of fibers (Fig. 2). Moreover, the diameter of the strength member and the sheath thickness of the new cable are larger than the conventional values. Therefore, the conventional gripper is unsatisfactory for handling the new cable.

We decided that the new cable needed a new gripper, and we determined the requirements for the new gripper by conducting an experimental investigation.

4.3.1 Experimental discussion

We conducted a heat cycle experiment to investigate the case in which the strength member is pulled or pushed from the cable sheath. In the experiment, the phenomenon in which the strength member is pulled and pushed from the cable by a heat cycle did not occur. Therefore, the new gripper must meet the following requirements. First, there must be no gripping force needed for the strength member. Also, the strength member needs to have conductivity.

4.3.2 Development of new gripper

We developed a new gripper based on the above result. We discuss here three important requirements: (1) conductivity must be achieved when the strength member and the gripper are in contact; (2) the new gripper must enable new cable to be installed

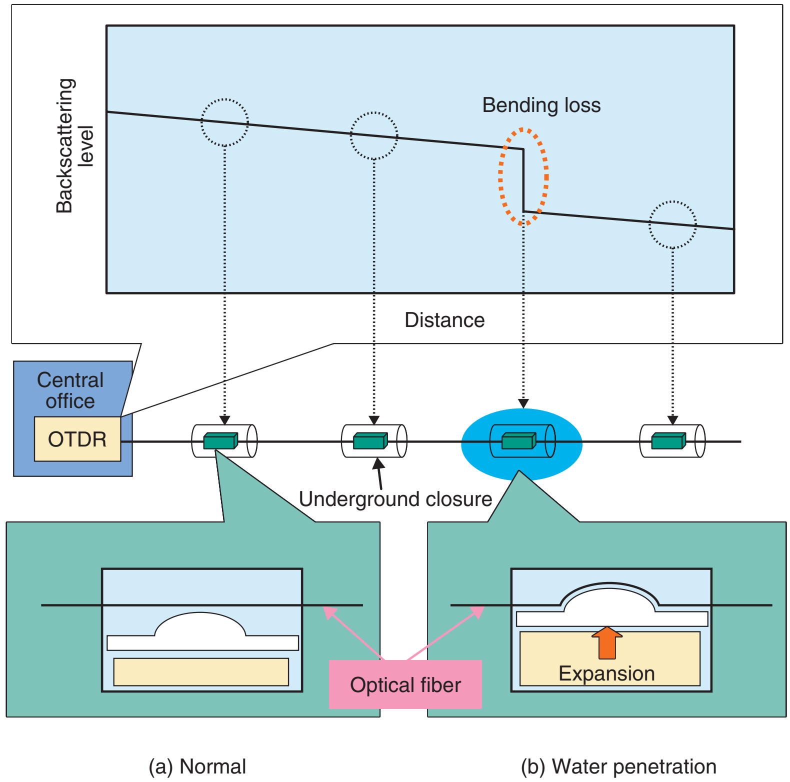


Fig. 6. Water sensor module.

regardless of the orientation of the installed cable; and (3) the gripper must not have an adverse effect on the fibers in the new cable. The new gripper is shown in Fig. 5. It consists of a continuity base and a continuity clasp.

We adopted a gripping technique that uses a spring, and we attached the spring to the insertion opening of the strength member, which meets requirement (1). We also adopted a configuration that allowed us to rotate the clasp. Therefore, the cable installation is independent of the strength member installation, and we meet requirement (2).

In regard to requirement (3), the configuration of the continuity clasp is semicircular, and the edge of the clasp is chamfered. Thus, the clasp has little effect on the fibers in a new cable when the new cable is installed in a closure.

5. Water sensor module

Water penetrating an underground closure over time can increase optical loss and degrade mechanical strength. For this reason, water sensor modules are attached to optical fibers for maintenance use in each underground closure. The water sensor module and the detection mechanism are shown in **Fig. 6**. If water penetrates the underground closure, the material encasing the water sensor module expands and applies a bending loss to the optical fiber. Water penetration in each underground closure can therefore be monitored by performing a periodic optical time domain reflectometer (OTDR) test [3, 4].

The proposed water sensor module is shown in **Fig. 7**. We applied the rollable fiber ribbon using bend-insensitive fibers to the optical fiber for maintenance use in the ultra-high-count and high-density optical fiber cable. We optimized the shape of the bending part of the water sensor module in order to apply a bending loss to the rollable fiber ribbon.

The experimental setup and the measured OTDR traces are shown in **Fig. 8**. The wavelength of the test light was 1650 nm, and the pulse width was 100 ns. From these OTDR traces, we were able to detect both water penetration locations.

6. Conclusion

We have developed an ultra-high-count and

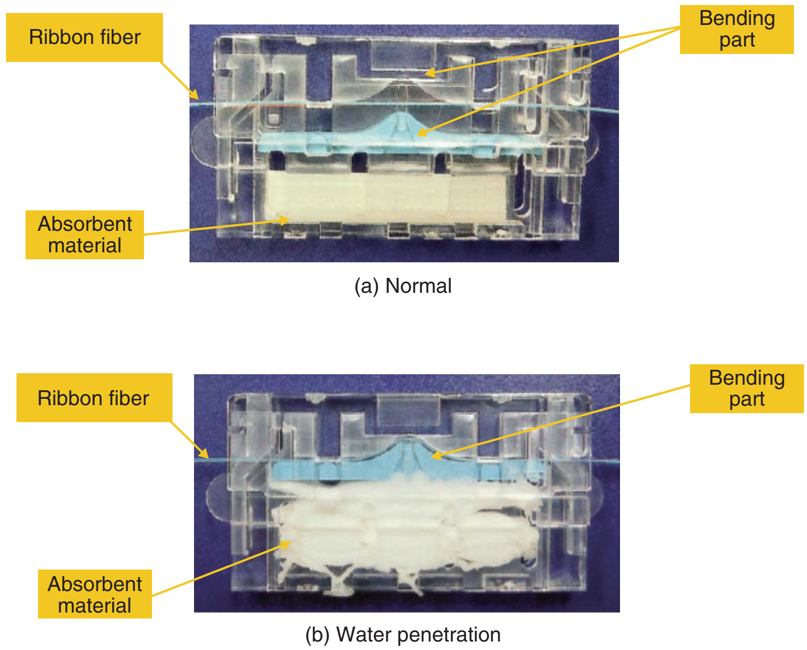


Fig. 7. Proposed water sensor module.

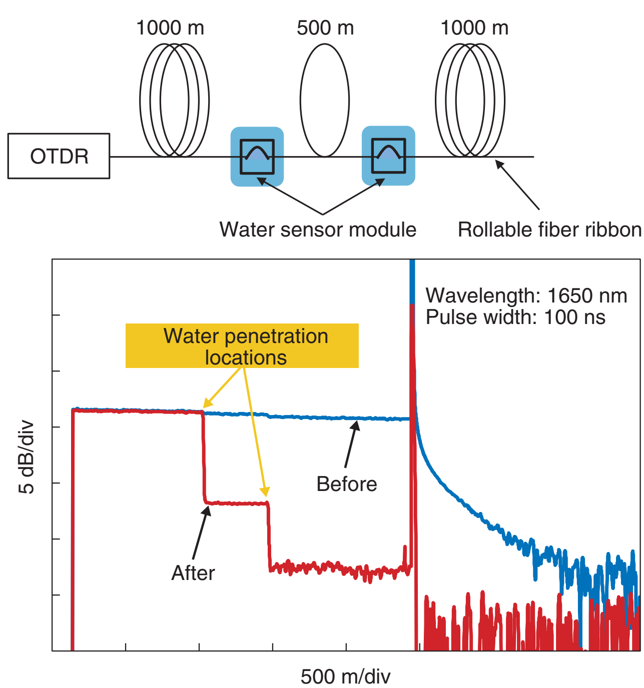


Fig. 8. Measured OTDR traces before and after water penetration.

high-density (2000-core) optical fiber cable as well as an underground closure and water sensor module. These components make it possible to increase the maximum fiber count in a conduit and make effective use of underground facilities. They will contribute to further large-scale deployment of FTTH services.

References

[1] K. Anzai, N. Toyota, T. Yamamoto, D. Kurematsu, S. Tetsutani, N. Ogawa, K. Shiraki, and K. Takamizawa, "Expansion of Applicability of Multiple Cabling Technology," NTT Technical Review, Vol. 7, No. 2, 2009.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200902le1.html

[2] K. Miyagishi, M. Harano, A. Hamaoka, T. Numata, and K. Takamizawa, "Development of Underground Optical Closure with Improved Assembly and Water-tightness," NTT Technical Review, Vol. 8, No. 3, 2010.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201003le2.html

[3] M. Arii, Y. Azuma, Y. Enomoto, K. Suzuki, N. Araki, S. Uruno, and T. Watanabe, "Optical Fiber Network Operation Technologies for Expanding Optical Access Network Services," NTT Technical Review, Vol. 5, No. 2, 2007.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200702032.pdf

[4] K. Nakazawa, T. Yamane, Y. Enomoto, and N. Araki, "Technologies for Checking Outside Optical Distribution Equipment," NTT Technical Review, Vol. 7, No. 11, 2009.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200911le2.html

Naoki Nakagawa
Research Engineer, NTT Access Network Service Systems Laboratories.
He joined NTT in 2009. He has recently been engaged in optical cable development.

Shinya Hamaguchi
NTT WEST.
He joined NTT in 2009 and has recently been engaged in the development of optical cable. He moved from NTT Access Network Service Systems Laboratories to NTT WEST in July 2015.

Yohei Endo
Research Engineer, NTT Access Network Service Systems Laboratories.
He joined NTT in 2011 and has recently been involved in the development of optical cable.

Yukihiko Shibata
Associate Manager, NTT EAST.
He joined NTT in 1998. He has recently been developing optical cable. He moved from NTT Access Network Service Systems Laboratories to NTT EAST in July 2015.

Ryo Tanaka
Assistant Manager, NTT WEST.
He joined NTT in 2005. He has recently been researching optical closure technology. He moved from NTT Access Network Service Systems Laboratories to NTT WEST in July 2015.

Kazuki Nitta
NTT WEST.
He joined NTT in 2007 and has recently been engaged in the research and development (R&D) of optical closure technology. He moved from NTT Access Network Service Systems Laboratories to NTT WEST in July 2015.

Masanori Nogami
NTT EAST.
He joined NTT in 2011. He has recently been engaged in the R&D of optical closure technology. He moved from NTT Access Network Service Systems Laboratories to NTT EAST in July 2015.

Kimiyoshi Nishimura
Associate Manager, NTT EAST.
He joined NTT in 1992. He has recently been involved in the R&D of optical closure technology. He moved from NTT Access Network Service Systems Laboratories to NTT EAST in July 2015.

Tetsuya Iwadou
Research Engineer, NTT Access Network Service Systems Laboratories.
He joined NTT in 2012. He has recently been engaged in developing an optical fiber line system.

Yoshitaka Enomoto
Senior Research Engineer, NTT Access Network Service Systems Laboratories.
He joined NTT in 1992. Since then, he has been engaged in R&D of an optical fiber line testing system and an optical fiber distribution system for central offices.

Image and Video Coding Related Standardization Activities of ISO/IEC JTC 1/SC 29

Seishi Takamura

Abstract

This article reviews recent standardization efforts related to image and video coding of the ISO (International Organization for Standardization)/IEC (International Electrotechnical Commission). We first review the aim of international standardization of media coding. Then we discuss the standardization process and explain some of the signature standards and their widespread ripple effects. Finally, we introduce recent trends and activities toward next-generation coding technologies that will possibly be standardized in the near future.

Keywords: ISO/IEC JTC 1/SC 29, JPEG, MPEG

1. Introduction

In the analog age, the medium used for audio signals was cassette tape, and the medium used for still and moving picture signals was silver halide film. Radio and television broadcasts and telephone transmissions were made possible with analog modulation technology. With the emergence of digital media, the fidelity of media signals has advanced significantly, in synchronization with the evolution of media coding (compression) technology.

2. Activities of SC 29

It is essential to conform to internationally coherent specifications and standards when interconnecting, securing, and deploying products and services using images and video. Subcommittee (SC)[*1] 29 (Coding of audio, picture, multimedia and hypermedia information) is one of the subcommittees of the international standardization body ISO/IEC JTC[*2] 1, and it has been the hub for standardization activities related to the coding of multimedia information technology [1]. To achieve wide acceptance and use of its standards in the market, SC 29 standardizes not only the coding technologies for audio-visual information but also streaming, searching, multiplexing, storing, and interfacing technologies.

As a result, SC 29 standards are widely utilized in home appliances such as digital cameras, camcorders and hard disk drive (HDD) recorders, audio-visual appliances such as hi-fi stereo systems, video players and personal computers (PCs), and mobile devices such as portable music players, smartphones, and tablets. These standards substantially contribute to today's visual, audio, multimedia, and information technology products and services. Needless to say, SC 29 plays an essential role in modern life and industry.

3. International and domestic bodies of SC 29

In 1986, ISO/IEC JTC 1/SC 2/Working Group

*1 SC: In JTC 1, most work on the development of standards is done by subcommittees, each of which deals with a particular field. JTC 1 currently has 20 SCs including SC 29 as well as study groups (SGs), special working groups (SWGs), and working groups (WGs).

*2 ISO/IEC JTC: International Organization for Standardization/International Electrotechnical Commission Joint Technical Committee.

(WG)[*3] 8 and its only subgroup, JPEG (Joint Photographic Experts Group) [2], were established. MPEG (Moving Picture Experts Group) [3], JBIG (Joint Bi-level Image Experts Group), and MHEG (Multimedia and Hypermedia Experts Group), were established in 1987, 1988, and 1990, respectively. In 1991, ISO/IEC JTC 1/SC 29 was established in order to standardize the functionality of end-user multimedia and hypermedia terminals. Dr. Hiroshi Yasuda (with NTT at the time) worked to establish SC 29 and was appointed its first Chair. Since then, a representative and organization from Japan has respectively served as the Chair and Secretariat. In 1998, Dr. Hiroshi Watanabe (with NTT at the time) succeeded as Chair, and Mr. Kohtaro Asai of Mitsubishi Electric took on the position in 2006. The International Secretariat is led by the Information Technology Standards Commission of Japan (ITSCJ), which is part of the Information Processing Society of Japan (IPSJ).

SC 29 holds a plenary meeting once a year. In July 2014, Japan hosted the 27th meeting in Sapporo for the second time, 23 years after the first meeting. At this meeting, the WG 1 Convener changed after 18 years. In June 2015, the 28th meeting was held in Warsaw, Poland, where Mr. Asai asked JTC 1 and the Technical Management Board for an extension of his term of office beyond the nine-year limit. His request was granted, allowing him to continue as Chair of SC 29 for an additional three-year term.

There are two WGs (WG 1 and WG 11) under the auspices of SC 29. WG 1 develops the standards for technologies such as still image coding, image retrieval, and high dynamic range extension. WG 11 develops the standards for technologies such as moving video and audio coding, systems, high efficiency coding, multiplexing, three-dimensional (3D) video coding, and video retrieval. Each WG holds three to four meetings a year in order to facilitate the standardization. Some of the major standards developed by SC 29 are listed in **Table 1**.

In Japan, a domestic SC 29 committee (SC 29 Japan National Body, chaired by Dr. Seishi Takamura of NTT) is responsible for carrying out SC 29 activities in Japan under the auspices of ITSCJ. It handles communications with the higher body and votes on standardization ballots. It also runs tutorial seminars to introduce its activities to the public. The SC 29 Japan National Body committee comprises five WG subcommittees: WG 1 (still image coding), WG 11/AUDIO (audio-visual coding, audio), WG 11/VIDEO (audio-visual coding, video), WG 11/SYSTEMS (audio-visual coding, systems), and WG 11/SYSTEMS/MPEG-7 SG. They work on gathering/consolidating domestic opinions, and they participate in and support the international WG activities.

4. Standards created by SC 29/WG 1

4.1 JPEG (1992)

JPEG was the first international standard for still image coding. It was quickly disseminated just after its publication. JPEG is still the prevailing standard and is used exclusively in almost all image-related standards such as those concerning smartphones, digital cameras, and web pictures. In 2010, the production of digital cameras culminated in 121.5 million shipments. Every day, at least 1.8 billion JPEG images are shared worldwide via social networking services (SNSs). JPEG has long been in an immovable position as the primary image storage format, which is quite unusual for the continually changing information technology field.

4.2 JBIG (1993)

JBIG is a lossless coding standard for binary (black and white) images. It provides a 20–80% higher compression ratio than the fax image coding method (about 1/20 compression). Its successor, JBIG-2, provides lossless coding and lossy coding and offers two to four times higher compression than JBIG.

4.3 JPEG-LS (1998)

JPEG-LS is a lossless and near-lossless coding standard for continuous-tone images. Although JPEG also has a lossless coding capability, JPEG-LS has a higher compression ratio. Additionally, its computational complexity is not very high, so it is suitable for hardware implementation.

4.4 JPEG 2000 (2000)

JPEG 2000 provides higher image quality than JPEG, particularly at low bit rates. It also provides a wide range of functionalities such as seamless lossy to lossless coding, progressive decoding, ROI (region of interest) coding, error resilience, and moving picture coding. JPEG 2000 is used in numerous fields including digital cinema, digital archiving, driver's license images, passport images, medical imaging, and satellite imaging.

*3 WG: A group of authorities formed by ISO/IEC to set standards for a particular field under the control of the parent SC.

Table 1. Major standards created by SC 29.

WG 1 related	ISO/IEC 10918 JPEG	Digital compression and coding of continuous-tone still images
	ISO/IEC 11544 JBIG	Progressive bi-level image compression
	ISO/IEC 14492 JBIG-2	Lossy/lossless coding of bi-level images
	ISO/IEC 14495 JPEG-LS	Lossless and near-lossless compression of continuous-tone still images
	ISO/IEC 15444 JPEG2000	JPEG 2000 image coding system
	ISO/IEC 18477 JPEG XT	Scalable compression and coding of continuous-tone still images
	ISO/IEC 29170 AIC	Advanced image coding and evaluation methodologies
	ISO/IEC 19566 JPEG Systems	JPEG Systems
	ISO/IEC NP 19710 JPEG AR	JPEG AR
	ISO/IEC 24800 JPSearch	JPSearch
	ISO/IEC 29199 JPEG XR	JPEG XR image coding system
WG 11 related	ISO/IEC 11172 MPEG-1	Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s
	ISO/IEC 13818 MPEG-2	Generic coding of moving pictures and associated audio information
	ISO/IEC 14496 MPEG-4	Coding of audio-visual objects
	ISO/IEC 15938 MPEG-7	Multimedia content description interface
	ISO/IEC 21000 MPEG-21	Multimedia framework
	ISO/IEC 23000 MPEG-A	Multimedia application format
	ISO/IEC 23001 MPEG-B	MPEG systems technologies
	ISO/IEC 23002 MPEG-C	MPEG video technologies
	ISO/IEC 23003 MPEG-D	MPEG audio technologies
	ISO/IEC 23004 MPEG-E	Multi-Media Middleware (M3W)
	ISO/IEC 23005 MPEG-V	Media context and control
	ISO/IEC 23006 MPEG-M	Multimedia service platform technologies
	ISO/IEC 23007 MPEG-U	Rich media user interfaces
	ISO/IEC 23008 MPEG-H	High efficiency coding and media delivery in heterogeneous environments
	ISO/IEC 23009 MPEG-DASH	Dynamic adaptive streaming over HTTP (DASH)

HTTP: Hypertext Transfer Protocol
NP: new work item proposal

5. Standards created by SC 29/WG 11

5.1 MPEG-1 (1993)

MPEG-1 aims at a video coding rate of 1.5 Mbit/s to be used in video CD (compact disc), PC, and web applications. MPEG-1 Audio Layer 3, known as MP3, is part of the MPEG-1 standard, which is widely used for audio players and Internet audio streaming.

5.2 MPEG-2 (1995)

MPEG-2 aims at a video coding rate of 4–10 Mbit/s for SDTV (standard definition television) and 15–30 Mbit/s for high definition TV (HDTV). Because MPEG-2 is effective for interlaced video and high-quality video materials (as required by broadcasting studios), it is widely used for storage media such as DVDs (digital versatile discs), terrestrial/satellite digital broadcasting, HDD recorders, and digital editing systems, which disseminate services via digital video transmission.

5.3 MPEG-4 (1998)

MPEG-4 is designed for a range of video coding rates from very low (10 kbit/s) to very high (40 Mbit/s) while providing higher compression than previous standards. Furthermore, it is the first video coding standard that has a VOP (video object plane) coding capability to handle several moving objects as well as the background. It is used in a cellular video phone service in Japan.

5.4 MPEG-4 Advanced Video Coding (AVC) (2003)

MPEG-4 AVC, with the ITU-T (International Telecommunication Union-Telecommunication Standardization Sector) designation of H.265, is designed for a very wide range of video coding rates from

10 kbit/s to 240 Mbit/s while achieving a compression ratio twice that of MPEG-2. It was widely accepted by the consumer market and has been adopted in many audio-visual appliances/services such as Blu-ray Discs, the 1seg mobile terrestrial digital audio/video and data broadcasting service in Japan, and HDTV broadcasting.

5.5 MPEG-H High Efficiency Video Coding (HEVC) (2013)

HEVC was standardized by the Joint Collaborative Team on Video Coding (JCT-VC) of WG 11 and ITU-T SG16, WP3 Q.6 (Working Party 3, Question 6), (also known as VCEG (Video Coding Experts Group)). It is also covered by the ITU-T designation H.265. It covers an extremely wide video coding rate range from 128 kbit/s to 800 Mbit/s. The balance of coding efficiency and computational complexity was carefully examined in the standardization process, and compression performance that was double that of MPEG-4 AVC was finally achieved. The compression performance of ultrahigh-definition TV (UHDTV) (over 4K video) is nearly three times better (64% bit rate reduction) than that of MPEG-4 AVC [4]. Since its publication in 2013, it has been adopted as the core video coding method of many services such as CS (communications satellite) 4K TV test broadcasting (Channel 4K), NTT Plala's first 4K commercial VOD (video on demand) service in Japan (Hikari TV 4K), and NTT DOCOMO's Docomo Anime Store. It will be used in the BS (broadcasting satellite) 8K test broadcasting system starting in 2016, and its use is expected to continue spreading and to lead to an expansion of the broadcast, home appliance, and communication market.

5.6 HEVC 2015 Edition

Right after the standardization of HEVC in 2013, its extensions were intensively studied and finalized as RExt (Range Extensions: 4:2:2/4:4:4 chroma format, high bit depth (up to 12 bits/sample)), MV-HEVC (Multi-view HEVC: 3D multi-view video coding), and SHVC (Scalable HEVC). A 3D-related extension was processed by JCT-3V, the Joint Collaborative Team on 3D Video Coding Extension of WG 11 and ITU-T SG16 WP3. These extensions were consolidated into the original HEVC and published as HEVC 2015 Edition with the ITU-T designation of H.265 (V2).

6. External evaluation of SC 29

SC 29 and its contributors have been highly evaluated worldwide because of the prominent industrial success they have achieved, and they have won some very prestigious awards including the First ISO Lawrence D. Eicher Award, the ISO150 Award, Emmy Awards (6 times), the Prime Minister of Japan Award, the Minister of Posts and Telecommunications Award, the Minister of Economy, Trade and Industry Awards (6 times), and the Industrial Science and Technology Policy and Environment Bureau Director-General's Awards (11 times).

7. Trends of SC 29/WG 1

Some of this group's working items (JPEG XT and JPSearch) have just been standardized or are about to be standardized. WG 1 is going to start working on the standardization of Advanced Image Coding (AIC), JPEG AR, JPEG Systems, JPEG Privacy, JPEG PLENO, and JPEG XS. These are explained in more detail below.

7.1 JPEG XT

Recent imaging devices can handle higher bit depths than 8 bits/sample. The prevailing JPEG format that is used exclusively as an image coding format is JPEG Baseline, which can only handle up to 8 bits/sample. New coding technology for high dynamic range (HDR) images is expected by allowing backward compatibility with JPEG Baseline. JPEG XT expresses an HDR image with a JPEG Baseline-compatible bitstream that contains residual information. The bitstream can be decoded by a legacy JPEG decoder (with low dynamic range) or by a JPEG XT decoder with high dynamic range. Part 1 of JPEG XT was standardized in 2012; currently, Parts 2 through 9, which support lossless coding and opacity features, are about to be standardized. Japan has made substantial contributions to this standardization effort.

7.2 JPSearch

JPSearch is aimed at efficiently retrieving images based on metadata. The data format, query format, application programming interface (API), and content description are provided.

7.3 JPEG XR

JPEG XR (extended range) aims to support high bit depth image coding while offering a lower complexity coding scheme than JPEG 2000. It is based on various other image coding schemes, primarily HD Photo, which was developed by Microsoft Corporation.

7.4 AIC

AIC is a next-generation image coding standard that achieves higher coding performance than JPEG 2000. Prior to actually providing the coding technology, AIC is developing the image quality evaluation technology.

7.5 JPEG AR

The aim of JPEG AR is to achieve the interoperability of AR (augmented reality)-assisted applications by standardizing associated frameworks and APIs. In October 2012, the Asian Forum on Smart Media and Augmented Reality was established, and its members have been working on standardizing JPEG AR in cooperation with WG 11. The market for AR-related services is expected to grow thanks to the emergence of new devices and applications.

7.6 JPEG Systems

JPEG Systems is a large-scale standard that synthesizes, analyzes, and integrates JPEG-family standards; its standardization was initiated in 2014. While it defines the common file format and code-stream syntax of conventional JPEG, JPEG Systems is also designed to cover future JPEG-family standards.

7.7 JPEG Privacy & Security

To assure privacy and security when sharing photos online through SNSs or (stock) photography databases, JPEG Privacy & Security will provide new functionality for JPEG encoded images such as ensuring privacy, maintaining data integrity, and protecting intellectual rights, while maintaining backward and forward compatibility to existing JPEG. A public workshop will be held in October 2015 during the JPEG meeting in Brussels, Belgium. This new working item was proposed by Japan.

7.8 JPEG PLENO

JPEG PLENO is targeting a standard framework for the representation and exchange of new imaging modalities such as light-field, point-cloud, and holographic imaging. Another target is to define new tools for improved compression while providing advanced functionality support for image manipulation, metadata, image access and interaction, privacy and security, and harmonization with the conventional JPEG format. A workshop was organized during the JPEG meeting in Warsaw in June 2015.

7.9 JPEG XS

Today's industrial applications often involve transport and storage of uncompressed images and video. This is the case, for instance, in video links, IP (Internet protocol) transport, Ethernet transport, proprietary transports, and memory buffers. In this context, the JPEG XS low-latency lightweight coding system is aimed at increasing the resolution and frame rate while ensuring good visual quality and keeping power use and bandwidth within a reasonable budget. A Call for Proposals is expected to be published at the 71st JPEG meeting in La Jolla, USA, in February 2016.

8. Trends of SC 29/WG 11

Further extensions are underway since the consolidation of HEVC 2015 Edition.

8.1 3D-HEVC

Different from the multiview video coding extension MV-HEVC, 3D-HEVC is aimed at depth-map-based 3D video coding and is being standardized by JCT-3V (JCT on 3D Video Coding Extensions). Coupling this coding technology with depth-image based rendering technology (outside the standardization scope) makes it possible to generate arbitrary viewpoint video in order to achieve a glassless 3D video system.

8.2 SCC

Conventional video coding standards are aimed at natural, camera-captured video coding. The Call for Proposal for SCC (screen content coding) is aimed at CG (computer graphics), game, and PC screen content coding. It was issued in January 2013, and JCT-VC has been working on its standardization. Its prospective applications include wireless displays, screen sharing, remote education, and electronic books.

8.3 HDR/WCG[*4]

The dynamic range of imaging devices and displays has been rapidly advancing. The maximum contrast a human eye can detect in one scene without adaptation is estimated to be 100 thousand to 1, and with unnoticeably slight adaptation, 1 million to 1 [5]. These ratios were taken into account in developing a new

*4 WCG: wide color gamut

coding scheme that allows HDR video with a pixel value of 16 bits/sample or floating point numbers. In February 2015, a Call for Evidence (CfE)*5 was issued, and at the WG 11 meeting in Warsaw in June 2015, the proposed technologies were evaluated in order to accelerate the standardization.

8.4 Future Video Coding

The Future Video Coding project is aimed at next-generation video coding that attains even higher coding performance than HEVC. Just as with HEVC standardization, it is a collaboration between WG 11 and ITU-T SG16 WP3 Q.6. At the WG 11 meeting in Strasbourg, France, in October 2014, the Brainstorming on Future Video Coding was organized, and its targets, applications, and timeline were discussed. A workshop on Future Video Coding is planned for the WG 11 meeting to be held in Geneva, Switzerland, in October 2015. Further improvement of compression is desired not only for UHDTV broadcasting but also for mobile streaming and video downloads. The market for these activities is expected to grow, and thus, these trends bear watching.

8.5 FTV

Super multiview video coding (FTV: Free-viewpoint Television) goes beyond the current stereo 3D and is now under consideration for standardization. A seminar and demonstrations were held at the WG 11 meeting in Sapporo in July 2014. The main contributors were from Japan and Europe. The CfE soliciting potential technologies that outperform HEVC for this type of video was issued in June 2015. The submitted proposals will be evaluated at the WG 11 meeting in October 2015.

9. Future exploration of SC 29

This article has overviewed the structure and activity of SC 29, which supports today's widespread multimedia technology, and introduced several image and video coding standards that were developed by SC 29. The standardization of HEVC extensions will converge by the end of 2015, and then many future-oriented exploration activities will gradually shift to the standardization phase, which will trigger another groundswell of activity.

Space limitations did not allow me to mention the deliverables of SC 29 other than image and video coding standards. These deliverables include a hybrid content service that spans broadcasting and telecommunication using MMT (MPEG Media Transport), network bandwidth- or terminal-adaptive video streaming using DASH (Dynamic Adaptive Streaming over HTTP), next-generation 3D audio coding, and a media format for 3D printers, which are becoming increasingly common. Such diverse elements have already been introduced in the market and will surely be standardized in the future. The importance of SC 29 will increase more than ever in synchronization with the evolution of networks, broadcasting, and digital appliances.

*5 CfE: Issued prior to the new work item proposal to publicly solicit evidence of the existence of technology that is superior to the current standard.

References

[1] Website of JTC 1/SC 29, https://www.itscj.ipsj.or.jp/sc29/
[2] Website of JPEG, http://www.jpeg.org
[3] Website of MPEG, http://mpeg.chiariglione.org
[4] T. K. Tan, M. Mrak, V. Baroncini, and N. Ramzan, "HEVC Verification Test Results," published in 17th JCT-VC meeting, document JCTVC-Q0204, Valencia, Spain, Mar./Apr. 2014.
[5] A. Luthra, E. Francois, and W. Husak, "N14510, Draft Requirements and Explorations for HDR/WCG Content Distribution and Storage," published in 108th MPEG meeting, Valencia, Spain, Mar./Apr. 2014.

Seishi Takamura

Distinguished Technical Member, Senior Research Engineer, Supervisor in the Video Coding Group of NTT Media Intelligence Laboratories.

He received his B.E., M.E., and Ph.D. from the Department of Electronic Engineering, Faculty of Engineering, the University of Tokyo in 1991, 1993, and 1996. His current research interests include efficient video coding and ultrahigh quality video coding. He has fulfilled various duties in the research and academic community in current and prior roles including Associate Editor of IEEE Transactions on Circuits and Systems for Video Technology (2006–2014), Executive Committee Member of the Institute of Electrical and Electronics Engineers (IEEE) Tokyo Section, the IEEE Japan Council, and the Institute of Electronics, Information and Communication Engineers (IEICE) Image Engineering SIG Secretary and Director—Technical Relations of the Institute of Image Information and Television Engineers (ITE). He has also served as Chair of ISO/IEC JTC 1/SC 29 Japan National Body, Japan Head of Delegates of ISO/IEC JTC 1/SC 29, and as an International Steering Committee Member of the Picture Coding Symposium. From 2005 to 2006, he was a visiting scientist at Stanford University, California, USA. He has received 33 academic awards including the ITE Niwa-Takayanagi Best Paper Award in 2002, the Information Processing Society of Japan (IPSJ) Nagao Special Researcher Award in 2006, PCSJ (Picture Coding Symposium of Japan) Frontier Awards in 2004 and 2008, the ITE Fujio Frontier Award in 2014, and TAF (Telecommunications Advancement Foundation) Telecom System Technology Awards in 2004, 2008, and 2015. He is a senior member of IEEE, IEICE, and IPSJ and a member of MENSA, the Institute of Image Electronics Engineers of Japan, and ITE.

A Case Study of a Problem that Occurred in Downstream Device of VoIP Gateway

Abstract

This article describes a problem that occurred in a VoIP (voice over Internet protocol) gateway and the actions taken to rectify it. This is the thirty-first article in a bimonthly series on practical field information on telecommunication technologies. This month's contribution is from the Network Interface Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: VoIP gateway, Hikari telephone, analog terminal

1. Introduction

A voice over Internet protocol (VoIP) gateway unit (GW) enables existing terminal facilities to use VoIP circuits without having to be upgraded after introducing optical facilities in the upstream access network. This approach enables VoIP service to be implemented at a relatively low cost and to be widely used by a large number of users, from general users to business/office users.

Such terminals have been used with the conventional telephone network (analog, ISDN*, etc.) without any problems. However, we have been consulted on communication problems that occurred when the upstream access network was upgraded to optical facilities. In this article, we refer to an actual case study to explain how such problems might occur.

2. Case study

In this case study, a terminal connected to the analog port of the GW was unable to make an outgoing call.

2.1 Event conditions

A customer who had undergone a change from an analog telephone system to an office-type VoIP telephone system (Hikari telephone system) reported events in which a terminal connected to the GW could not make an outgoing call. Specifically, if an outgoing call to a telephone number that included the numbers 1, 2, 3, or 6 was attempted on the push-button panel, a busy tone would be heard after a certain amount of time after dialing, and no connection would be made. The customer informed us that they had not had any problems with their terminals before changing to the Hikari telephone system.

An attempt was made to solve this problem by replacing GW A with equipment of the same model, but the problem persisted. However, when GW A was replaced with GW B, the problem went away. We therefore performed a series of tests to determine why calls could not be made with GW A but could be made with GW B (**Fig. 1**).

2.2 Overview of tests

After setting up facilities similar to those of the customer's in which the problem occurred, we performed the following tests.

(1) Replication test by connecting an analog terminal to analog port of GW A and GW B (test 1)

The method used here for originating a call from an

* ISDN: Integrated Services Digital Network

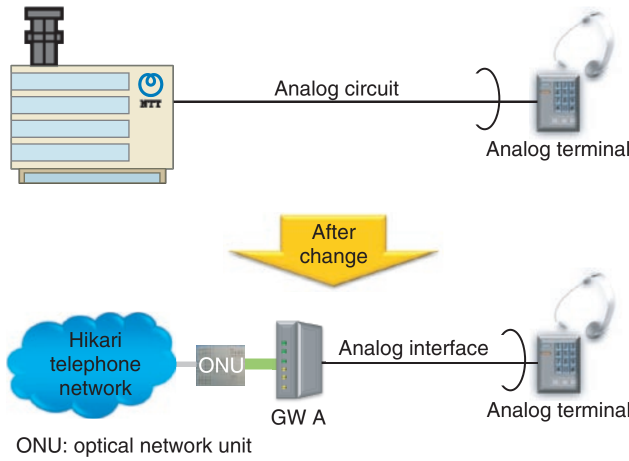


Fig. 1. Facility configuration.

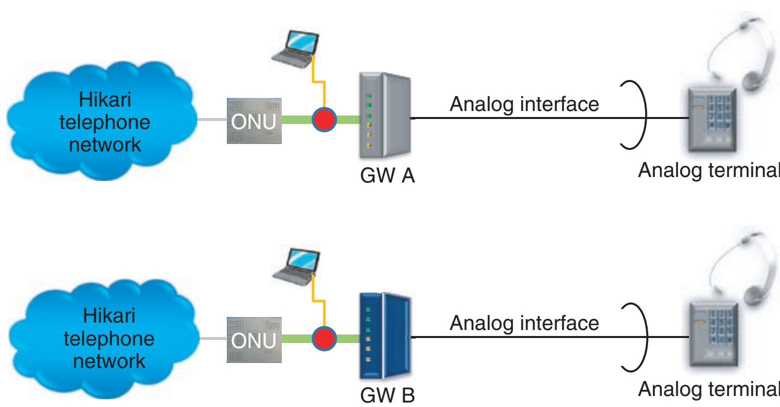


Fig. 2. Test configuration.

analog terminal was to press all push buttons 1–9 and 0 in an off-hook state. The telephone number that was recorded in the communication log of the GW was then compared to that obtained through packet capture in the upstream interval between the GW and the optical network unit.

(2) Terminal evaluation using terminal-equipment general tester (test 2)

The analog terminal was evaluated to determine whether it satisfied the technical standards set down by Japan's Ordinance Concerning Terminal Facilities (Ordinance of the Ministry of Posts and Telecommunications No. 31, 1985) as follows.

1) Requirements for push-button signals: Article 12, Item 2
2) DC (direct current) resistance value when closing DC circuit (electrical requirements of DC circuits etc.): Article 13, Item 1

(3) Event replication check when changing facilities upstream of the terminal to something other than GW A and GW B (test 3)

This test was done to check whether the same kind of event could be replicated when connecting the target analog terminal to a simulated analog circuit using a telephone circuit simulator.

2.3 Descriptions and results of tests

2.3.1 Test 1

(1) Description

We conducted a call-originating experiment connecting the analog terminal to GW A and GW B (**Fig. 2**) and performed the following actions.

```
01/01T00:01:32 01/01T00:01:27 00/00T00:00:00 01/01T00:01:32 A1 0 G=487 N 0

                 1457890
                        0     0     0     0       246     0     0     0     0       246
                        0     0     0     0                                 0         0
```

Fig. 3. Communication log.

Protocol	Length	Info
SIP/SDP	766	Request: INVITE tel:1457890
SIP	293	Status: 100 Trying |
SIP/SDP	645	Status: 183 Session Progress |

Fig. 4. Packet capture data.

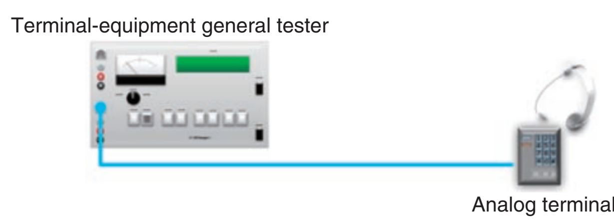


Fig. 5. Testing equipment used to conduct measurements based on Ordinance Concerning Terminal Facilities.

1) The communication logs (internal logs of GWs A and B) were collected and recorded during the experiment.
2) Information on the state of communication at the time of the experiment was collected through packet capture (red dot in figure denotes the capture point).

(2) Results

First, the logs and the capture data of connecting the analog terminal to GW B and pressing push buttons 1–9 and 0 revealed that all signals corresponding to those buttons were confirmed.

The results of connecting the analog terminal to GW A and pressing push buttons 1–9 and 0 are summarized below.

1) Push-button signals 2, 3, and 6 were not recorded in the communication log (**Fig. 3**).
2) Likewise, information on numbers 2, 3, and 6 were not recorded by packet capture (**Fig. 4**).

2.3.2 Test 2

(1) Description

In this test, we conducted measurements using a terminal-equipment general tester to determine whether the terminal satisfied the following technical standards specified by the Ordinance Concerning Terminal Facilities (**Fig. 5**).

1) Requirements for push-button signals (**Tables 1** and **2**)
2) Electrical requirements of DC circuits: When measuring the loop current in the range from 20 mA to 120 mA, "the DC resistance value of the DC circuit of the analog terminal with the DC circuit closed shall be in the range from 50 Ω to 300 Ω."

(2) Results

1) Results of measuring power for a current of 20 mA using the terminal-equipment general tester

The power difference between two frequencies—one at the low-frequency level and the other at the

Table 1. Frequencies of push-button signals.

High frequencies / Low frequencies	1209 Hz	1336 Hz	1477 Hz
697 Hz	1	2	3
770 Hz	4	5	6
852 Hz	7	8	9
941 Hz	*	0	#

Technical standards of Ordinance Concerning Terminal Facilities (excerpt)

Table 2. Requirements for push-button signals.

Item		Requirement
Allowed range of signal transmit power	Power difference between two frequencies	Within 5 dB, the power at a low frequency shall not exceed the power at the corresponding high frequency.

Item: Selected signal (PB)
State: Analog terminal
Current (C) 20mA

PB	Low.Freq (Hz)	(%)	High.Freq (Hz)	(%)	Low.L (dBm)	High.L (dBm)	Dif.L (dB)	Send (ms)	Pause (ms)	Cycle (ms)
1	699.1	+0.30	1215.8	+0.56	-10.8	-5.3	5.5	125	646	771
2	699.0	+0.29	1331.7	-0.32	-10.8	-4.7	6.1	142	486	628
3	699.3	+0.33	1471.8	-0.35	-10.8	-4.2	6.6	124	474	598
4	766.2	-0.49	1215.8	+0.56	-10.0	-5.3	4.7	115	272	387
5	766.2	-0.49	1331.7	-0.32	-10.1	-4.7	5.4	121	218	339
6	766.2	-0.49	1472.1	-0.33	-10.1	-4.2	5.9	99	271	370
7	847.4	-0.54	1215.8	+0.56	-9.4	-5.3	4.1	100	268	368
8	847.7	-0.51	1331.6	-0.33	-9.4	-4.7	4.7	101	198	299
9	847.5	-0.53	1472.0	-0.34	-9.5	-4.2	5.3	99	225	324
0	947.9	+0.73	1331.7	-0.32	-8.7	-4.7	4.0	99	179	278
*	948.0	+0.74	1215.8	+0.56	-8.7	-5.3	3.4	102	211	313
#	947.9	+0.73	1471.8	-0.35	-8.7	-4.3	4.4	99		
Max		+0.74		+0.56	-8.7	-4.2	6.6	142	646	771
Min		-0.54		-0.35	-10.8	-5.3	3.4	99	179	278

Fig. 6. Results of analog-terminal measurements.

high-frequency level of the analog terminal—was found to be greater than 5 dB when pushing the 1, 2, 3, 5, 6, and 9 push buttons, which did not satisfy the standard value (**Fig. 6**).

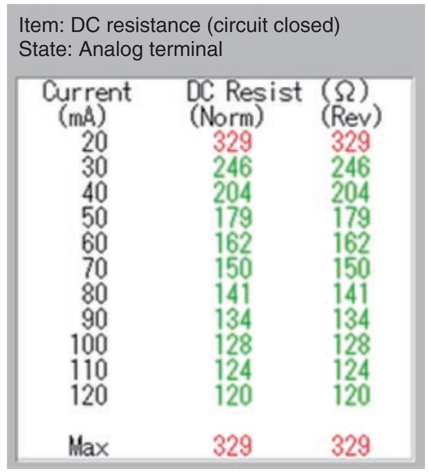
2) The DC resistance value for a loop current of 20 mA in the analog terminal was found to exceed 300 Ω, which did not satisfy requirements (**Fig. 7**).

2.3.3 Test 3

(1) Description

We changed the facilities connecting to the upstream of the analog terminal and performed a call-originating test using a telephone circuit simulator that simulated an analog circuit (**Fig. 8**).

Test method: Call the pseudo-number 123-5691 that combines the numbers 1, 2, 3, 5, 6, and 9 that were found to be outside the standard from the results



Item: DC resistance (circuit closed)
State: Analog terminal

Current (mA)	DC Resist (Ω) (Norm)	(Rev)
20	329	329
30	246	246
40	204	204
50	179	179
60	162	162
70	150	150
80	141	141
90	134	134
100	128	128
110	124	124
120	120	120
Max	329	329

Fig. 7. Results at time of closed loop (electrical requirements of DC circuits).

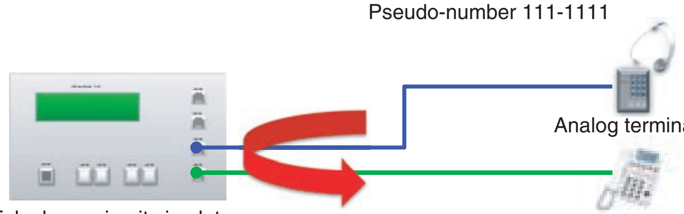


Fig. 8. Test configuration.

of test 2.

(2) Results

No events as in the case of GW A were observed when changing the facilities connecting to the upstream of the analog terminal and making a call in this test.

3. Findings

In this series of tests, certain numbers called from an analog terminal connected to GW A could not be recognized, and no connection could be made to the other party. We found that the power difference between certain low/high frequency combinations of the push-button signals was not within the 5-dBm standard and that the electrical requirements of DC circuits were not satisfied.

Another reason why connections could be made with GW B but not with GW A could be because specifications are different for the analog port. Specifically, power specifications for the low-/high-frequency level of push-button signals at the analog port were –9/–8 dBm for GW A and –13/–11 dBm for GW B.

The fact that one GW could connect the call and the other could not may also be due to product differences in the receiving sensitivity of the push-button signals.

4. Conclusion

We reported here a case study of a problem that occurred after a switchover to a VoIP circuit. When a problem occurs, an early solution can generally be reached and a prolonged problem can be prevented by collecting configuration information and device logs at an early stage and analyzing them. Moreover, IP-system analysis techniques such as packet capture are currently necessary. However, when attempting to solve problems related to VoIP GWs used in combination with IP and legacy interfaces, we cannot solve them without the use of troubleshooting methods and measurement devices that can deal with various types of interfaces. Finally, even a failure that seems to have been solved by replacing equipment should be governed by technical criteria (rules). It is not simply a compatibility issue as commonly concluded; there is always a specific reason for the failure.

External Awards

2014 IEICE Young Researchers' Award

Winner: Shinsuke Nakano, NTT Device Innovation Center
Date: March 11, 2015
Organization: Institute of Electronics, Information and Communication Engineers (IEICE)

For proposing a 6.7-mW 8.8-dB 60-GHz complementary metal oxide semiconductor (CMOS) amplifier and 2.5-mW/Gbps millimeter-wave transmitter using an OOK (on/off keying) pulse modulator based on CMOS inverters.
Published as: S. Nakano, H. Katsurai, and M. Nogawa, "A 6.7-mW 8.8-dB 60-GHz CMOS Amplifier," Proc. of the IEICE General Conference, C-12-22, Mar. 2014 (in Japanese) and S. Nakano, H. Katsurai, M. Togashi, H. Koizumi, and M. Nogawa, "20.1-mW 8-Gbps UWB-IR Millimeter-wave Transmitter Using an OOK Pulse Modulator Based on CMOS Inverters," Proc. of ISCAS 2014 (2014 IEEE International Symposium on Circuits and Systems), pp. 2696–2699, Melbourne, Australia, Jun. 2014.

2014 IEICE Young Researchers' Award

Winner: Yoshihiro Ogiso, NTT Device Innovation Center
Date: March 11, 2015
Organization: Institute of Electronics, Information and Communication Engineers (IEICE)

For proposing an InP(110) athermal IQ (in-phase quadrature) optical modulator with planar waveguide structure.
Published as: Y. Ogiso, Y. Nakanishi, S. Kanazawa, E. Yamada, H. Tanobe, M. Arai, Y. Shibata, and M. Kohtoku, "Planar n-SI-n Heterostructure Athermal InP (110) Optical Modulator," Optics Express, Vol. 22, No. 21, pp. 25776–25781, Oct. 2014.

The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, the Prize for Science and Technology (Research Category)

Winner: Hiroshi Takahashi, Sophia University; Yasuyuki Inoue, NTT Electronics Corporation; and Senichi Suzuki, NTT Device Innovation Center
Date: April 15, 2015
Organization: Ministry of Education, Culture, Sports, Science and Technology

For development of wavelength multi/demultiplexer based on arrayed-waveguide grating.
Published as: H. Takahashi, K. Oda, H. Toba, and Y. Inoue, "Transmission Characteristics of Arrayed Waveguide N×N Wavelength Multiplexer," J. Lightwave Technol., Vol. 13, No. 3, pp. 447–455, Mar. 1995.

Research Encouragement Award

Winner: Yoji Yamato, NTT Software Innovation Center
Date: June 4, 2015
Organization: Steering Committee on Network Software of IEICE Communications Society

For "Automatic Verification Technology of Software Patches for User Virtual Machines on IaaS Cloud."
Published as: Y. Yamato, "Automatic Verification Technology of Software Patches for User Virtual Machines on IaaS Cloud," NWS2014-5-02, Tokyo, Japan, Oct. 2014.

TTC Distinguished Service Award

Winner: Satoru Furukawa, NTT Network Service Systems Laboratories
Date: June 22, 2015
Organization: Telecommunication Technology Committee (TTC)

For his contribution to the promotion of standardization of PSTN (Public Switched Telephone Network) migration.

COMPSAC 2015 Honorary Award

Winner: Michiharu Takemoto and Susumu Takeuchi, NTT Network Innovation Laboratories
Date: July 1, 2015
Organization: IEEE COMPSAC 2015 (39th Annual International Computers, Software & Applications Conference)

For Agent-based Service Platform (ASPF).
At the exhibition, NTT proposed modeling elements (a device, process, or concept) both in the real world and cyberspace, and abstracting each element as an agent (independent program). A service is formed as a series of agents.

Technical Committee on Communication Quality Encouragement Award

Winner: Kimiko Kawashima, NTT Network Technology Laboratories; Hiroaki Mori, Kyushu University; Hitoshi Aoki, NTT Network Technology Laboratories; and Takanori Hayashi, NTT Network Technology Laboratories
Date: July 6, 2015
Organization: Technical Committee on Communication Quality of IEICE Communications Society

For "Subjective Quality Assessment Characteristics of Sense of Presence for 4K Coded Video."
Published as: K. Kawashima, H. Mori, H. Aoki, and T. Hayashi, "Subjective Quality Assessment Characteristics of Sense of Presence for 4K Coded Video," IEICE Tech. Rep., Vol. 114, No. 488, CQ2014-112, pp. 1–6, Mar. 2015.

Young Researcher Award

Winner: Shunsuke Kurumatani, NTT Software Innovation Center
Date: July 10, 2015
Organization: Executive Committee of DICOMO (Multimedia, Distributed, Cooperative, and Mobile) 2015 Symposium

For "Evaluation of Application Performance on a Software-based Fault Tolerance."
Published as: S. Kurumatani, Y. Kasae, Y. Tsuruoka, S. Morishita, H. Akama, and H. Takahashi, "Evaluation of Application Performance on a Software-based Fault Tolerance," Proc. of DICOMO 2015, 7D-4, pp. 1502–1508, Tokyo, Japan, Jul. 2015 (in Japanese).

EMS Award

Winner: Ryo Nakao, NTT Nanophotonics Center, NTT Device Technology Laboratories
Date: July 17, 2015
Organization: Electronic Materials Symposium (EMS) Steering Committee

For “Dislocation Reduction in MOVPE-grown InGaAs/GaAs MQWs with GaAs/Ge Buffer Layers on Si Substrates by Thermal Cycle Annealing.”
Published as: R. Nakao, M. Arai, T. Yamamoto, and S. Matsuo, “Dislocation Reduction in MOVPE-grown InGaAs/GaAs MQWs with GaAs/Ge Buffer Layers on Si Substrates by Thermal Cycle Annealing,” Proc. of the 34th Electronic Materials Symposium, Th2-3, Shiga, Japan, Jul. 2015 (in Japanese).

NETs2015 Distinguished Paper Award

Winner: Yoji Yamato, NTT Software Innovation Center
Date: July 18, 2015
Organization: International Conference on Internet Studies 2015 (NETs2015)

For “Server Structure Proposal and Automatic Verification Technology on IaaS Cloud of Plural Type Servers.”

We propose a server proposal and automatic performance verification technology on IaaS (Infrastructure as a Service) cloud with bare metals, containers and virtual machines. Firstly we measured the performance of each type of server. Based on the performance results, our systems propose the appropriate type of server to satisfy user requirements.
Published as: Y. Yamato, “Server Structure Proposal and Automatic Verification Technology on IaaS Cloud of Plural Type Servers,” Proc. of NETs2015, Tokyo, Japan, Jul. 2015.

Papers Published in Technical Journals and Conference Proceedings

What Happens in a Small Transistor with Single-electron Resolution?

K. Nishiguchi

Proc. of EM-NANO 2015 (the 5th International Symposium on Organic and Inorganic Electronic Materials and Related Nanotechnologies), p. 36, Niigata, Japan, June 2015.

Downscaling of silicon transistors using state-of-the-art technology has already reached the 20–16-nm generation and enabled massive production of high-performance electrical circuits for various applications. Such downscaling also provides transistors with new functionalities: single-electron transfer and room-temperature detection. These two functions allow new applications utilizing single electrons.

Second-order Configuration of Local Features for Geometrically Stable Image Matching and Retrieval

X. Wu and K. Kashino

IEEE Transactions on Circuits and Systems for Video Technology, Vol. 25, No. 8, pp. 1395–1408, August 2015.

Local features offer high repeatability, which supports efficient matching between images, but they do not provide sufficient discriminative power. Imposing a geometric coherence constraint on local features improves the discriminative power but makes the matching sensitive to anisotropic transformations. We propose a novel feature representation approach to solve the latter problem. Each image is abstracted by a set of tuples of local features. We revisit affine shape adaptation and extend its conclusion to characterize the geometrically stable feature of each tuple. The representation thus provides higher repeatability with anisotropic scaling and shearing than found in previous research. We develop a simple matching model by voting in the geometrically stable feature space, where votes arise from tuple correspondences. To make the required index space linear as regards the number of features, we propose a second approach called a centrality-sensitive pyramid to select potentially meaningful tuples of local features on the basis of their spatial neighborhood information. It achieves faster neighborhood association and has greater robustness to errors in interest point detection and description. We comprehensively evaluated our approach using Flickr Logos 32, Holiday, Oxford Buildings, and Flickr 100 K benchmarks. The results of extensive experiments and comparisons with advanced approaches demonstrate the superiority of our approach in image retrieval tasks.

Effect of Load-balancing against Disaster Congestion with Actual Subscriber Extension Telephone Numbers

D. Satoh, H. Kawano, and Y. Chiba

IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. E98-A, No. 8, pp. 1637–1646, August 2015.

We demonstrated that load balancing using actual subscriber extension numbers was practical and effective against traffic congestion after a disaster based on actual data. We investigated the ratios of the same subscriber extension numbers in each prefecture and found that most of them were located almost evenly all over the country without being concentrated in a particular area. The ratio of every number except for the fourth-last digit in the last group of four numbers in a telephone number was used almost equally and located almost evenly all over the country. Tolerance against overload in the last, second-, and third-last single digits stays close to that in the ideal situation if we assume that each session initiation protocol server has a capacity in accordance with the ratio of each number on every single digit in the last group of four numbers in Japan.

Observing the Semiconducting Band-gap Alignment of MoS_2 Layers of Different Atomic Thicknesses Using a $MoS_2/SiO_2/Si$ Heterojunction Tunnel Diode

K. Nishiguchi, A. Castellanos-Gomez, H. Yamaguchi, A. Fujiwara, H. S. J. van der Zant, and G. A. Steele

Applied Physics Letters, Vol. 107, p. 053101, August 2015.

We demonstrate a tunnel diode composed of a vertical $MoS_2/SiO_2/$ Si heterostructure. A MoS_2 flake consisting of four areas of different thicknesses functions as a gate terminal of a silicon field-effect transistor. A thin gate oxide allows tunneling current to flow between the n-type MoS_2 layers and p-type Si channel. The tunneling-current characteristics show multiple negative differential resistance features, which we interpret as an indication of different conduction-band alignments of the MoS_2 layers of different thicknesses. The presented tunnel device can also be used as a hybrid-heterostructure device combining the advantages of two-dimensional materials with those of silicon transistors.

Maintenance of Communication Carrier Networks against Large-scale Earthquakes

Y. Takahashi and D. Satoh

IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. E98-A, No. 8, pp. 1602–1609, August 2015.

The network operations center of a communication carrier plays an important and critical role in the early stage of disaster response because its function is to maintain communication services, which includes traffic control and restoration of services. This paper describes traffic control and restoration of services affected by the Great East Japan Earthquake and discusses challenges on traffic congestion and restoration for future large-scale disasters.

Topological Graph Layouts into a Triangular Prism

M. Miyauchi

Proc. of the 28th Workshop on Circuits and Systems, pp. 49–54, Awaji, Hyogo, Japan, August 2015.

This paper newly defines a (topological) graph layout into a triangular prism. A *graph layout into a triangular prism* is a graph layout into a triangular prism that carries the vertices along the three crests between two triangles of the prism and the edges in the three rectangular surfaces such that no two edges cross in the interior of the surfaces. Also, a *topological* graph layout into a triangular prism is defined as edges that are allowed to cross the crests. This paper constructs topological complete bipartite graph layouts into a triangular prism with fewer crest-crossings than previous results.

On the Computational Power of Constant-depth Exact Quantum Circuits

Y. Takahashi

Proc. of ICIAM 2015 (the 8th International Congress on Industrial and Applied Mathematics), Beijing, China, August 2015.

We show that there exists a constant-depth polynomial-size quantum circuit for the quantum OR operation. We also show that under a plausible assumption, there exists a classically hard problem that is solvable by using a constant-depth quantum circuit with gates for the quantum Fourier transform.

Experience Simulator for the Digital Museum

Y. Ikei, S. Shimabukuro, S. Kato, K. Komase, K. Hirota, T. Amemiya, and M. Kitazaki

Proc. of HCI International 2015 (the 17th International Conference on Human-Computer Interaction), pp. 436–446, Los Angeles, USA, August 2015.

An experience transfer method is discussed to introduce a physical reliving of the previous person's body motion. The evaluation showed that the vestibular stimulation markedly enhanced the sensation of walking, and that the self-body with a first person view produced the highest rating.

Interest Point Selection by Topology Coherence for Multi-query Image Retrieval

X. Wu and K. Kashino

Multimedia Tools and Applications, Vol. 74, No. 17, pp. 7147–7180, September 2015.

Although the bag-of-visual-words model in computer vision has been demonstrated successfully for the retrieval of particular objects, it suffers from limited accuracy when images of the same object are very different in terms of viewpoint or scale. Naively leveraging multiple views of the same object to query the database naturally alleviates this problem to some extent. However, the bottleneck appears to be the presence of background clutter, which causes significant confusion with images of different objects. To address this issue, we explore the structural organization of interest points within multiple query images and select those that derive from the tentative region of interest to significantly reduce the negative contributions of confusing images. The approach is discriminative in distinguishing clutter from interest points, and at the same time, is highly robust as regards variation in viewpoint and scale as well as errors in interest point detection and description.
