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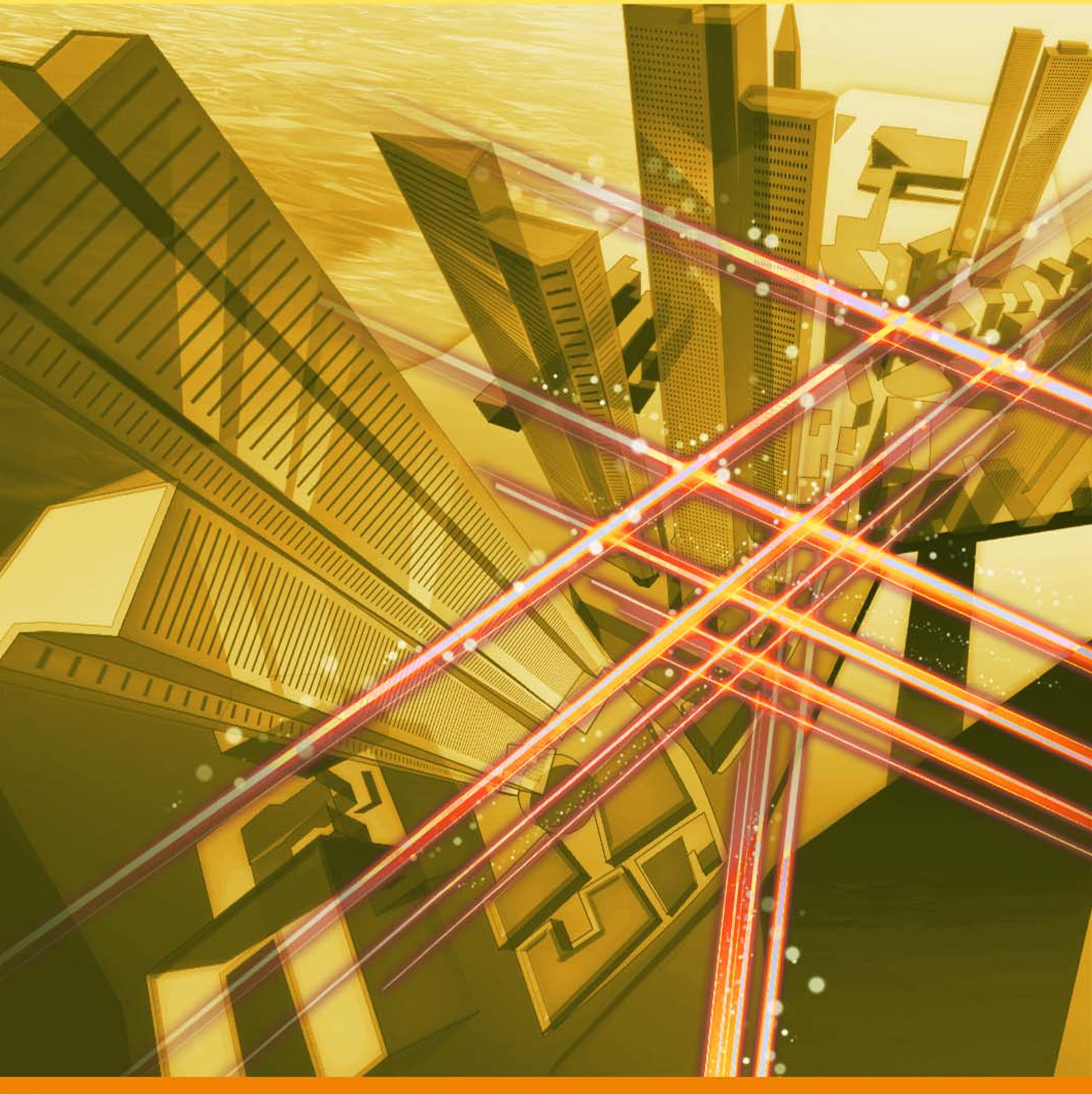

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- everis and the Next Generation of Digital

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Transforming the Business Structure to Expand Service Business

Motoyuki Ii
Senior Executive Vice President,
Senior Executive Manager of Corporate Sales Promotion Headquarters, NTT EAST

Overview

NTT EAST is boldly shifting its management resources to expand its scope of business based on a locally focused organizational system. The number of contracts for the optical access service involving the Hikari Collaboration Model topped 4 million in August 2016, and NTT EAST is aggressively pursuing initiatives for revitalizing regional economies under the banner of *new business creation*. We asked Senior Executive Vice President Motoyuki Ii to tell us about this major change in the corporate mindset and the actual efforts underway to make this change a reality.

Keywords: optical access service, business user, transformation

Achieving a major change in corporate mindset toward profit-oriented management

—Mr. Ii, can you first tell us about the current state of activities at NTT EAST?

Our operating income for fiscal year 2015 totaled 161.8 billion yen, marking record earnings for two consecutive fiscal years. Actually, this figure represents profit from cost cutting. True growth, however, comes from raising revenue. It is therefore vitally important that we broaden our scope of business. Last fiscal year, we announced a major shift in our business structure toward profit-oriented management in the company's medium-term management strategy.

The three main goals of this transformation are to *strengthen the business user market, promote the Hikari Collaboration Model*, and *improve management efficiency and productivity*. To put it simply, sales costs up to now have focused on the proliferation of optical access services for individual consumers, but with the number of subscribers now exceeding the 10-million mark, this growth trend is slowing. Considering that the deployment of optical access services to this market has largely been achieved, we are steering the company in a new direction toward the effective use of optical access services and information and communication technology (ICT), not only in business but also in local governments and institutions such as schools and hospitals. Furthermore, in addition to introducing and implementing optical access services and ICT, we have begun to propose *solutions*, that is, ways of using these technologies for the benefit of our customers.

—Up to now, it appears that the management process was running smoothly. How did this radical change in the corporate mindset come about?

The company culture and way of thinking, whether in the time of Nippon Telegraph and Telephone Public Corporation or in the early phase of deploying optical access services, was always "It will work out somehow as long as we do our best." However, times have changed—we can no longer survive solely by selling technology. It has become vitally important that we provide technology and services together. In doing so, however, we have noticed that we cannot provide all of the services that our customers need by ourselves.

One way of making proposals that satisfy our customers would be to look for partners that can provide needed services and to present our customers with our offers together. However, to be honest, working together with other enterprises as partners has never been our strong point. A simple reason for this is that we have not worked in such a collaborative manner in the past. Yet, if we don't make an effort to create such a system, it will be difficult to change direction. In short, it is imperative that we take specific measures to reform our mindset from a company based on the principle of direct management to one based on collaboration.

Currently, President Masayuki Yamamura and all directors are using the word "transformation" when talking to employees and on-site staff about the need to change the way we have been doing things and revise our corporate mindset and behavior. A key to achieve transformation is to change our mindset. Although it's important to present a specific action plan, true transformation will not necessarily follow. This is because simply doing what one is told is not normally accompanied by thought and mind. In contrast, an action plan that is accompanied by a sense of agreement as in "Yes, this is how we can change!" will naturally lead to changes in behavior.

When we look at the market environment, we can see that the effects of Abenomics (economic policies promoted by Prime Minister Shinzo Abe) have not yet reached the small- and medium-sized businesses that make up part of our customer base. I feel that these customers have not yet benefited from those policies. That's all the more reason we need to collaborate with partners. I believe that collaboration will mutually enhance both our value and our partners' value and stimulate the entire market. To this end, I urge those in the planning department to refrain from just managing from a desk and go out into the field. In this way, they can work together with our customers and see firsthand what the problems are. In fact, these two types of behavior—pursuing collaboration and getting out into the field—have led to building strong connections with our customers.

To give a specific example, positive effects have been achieved by changing the way we hold seminars. In the past, we would present our services and technologies as a whole in Tokyo much like a trade show. Now, however, instead of holding one large

seminar in this way, we are holding multiple seminars in various prefectures, each of which targets customers of particular industries or scales of business and adopts practical themes. Furthermore, as we cannot invite a large number of customers ourselves, we hold these seminars together with our regional partners, exchange business cards, and engage in face-to-face communication. After such seminars, customers with whom we have formed a relationship can access our website, which creates the potential for digital marketing and an opportunity to meet their needs in the form of a beneficial cycle. Of course, holding a number of seminars annually is a lot of work, but our staff is up to the challenge.

Work philosophy: Putting the attitude of a leader into words

—When did you begin to feel the importance of transformation? Is there anything that you have done on your own accord toward transformation?

That would be about eight years ago during my time as manager of the Niigata branch office. I felt that there was a need for reform in the way we performed our daily duties, and I conveyed this sentiment to my subordinates as my work philosophy. Doing so was actually a big change for me as well. I wrote up this work philosophy with the intention of conveying what I was thinking in my own words to unify the direction of the entire organization. I think the style of "watch me and follow me without saying anything" is an old style of management that doesn't work today.

There are five points in my work philosophy. Let me introduce a couple of them here. The first is that the most important thing in work is reforming the current state of things, and the driving force behind this reform is a change in behavior. In order to change behavior, a change in mindset is necessary. Achieving a change in mindset requires work that throws out everything from the past. This means throwing out experiences of both successes and failures. That is, while success may be possible now despite failing sometime in the past, the inverse is also true. However, I stated that conviction and will cannot be thrown out or forgotten regardless of the result.

Another point is that the mission of a leader is not simply to set the direction but also to change the mindset and behavior of the organization's members and to foster the development of their abilities. At present, about 11,000 employees belong to the Corporate Sales Promotion Headquarters that I am in charge of, which means that I am leading about one-third of the company's human resources. Making a mistake in the way that I lead here can naturally result in major damage to the company. I, of course, feel the pressure from such a role, but I cannot present an anxious face as a leader. Instead, I try to lift and stimulate the spirit of my staff with words like "You can do it!" and "Everything's OK!"

Transformation comes with risk. There is, of course, a mental resistance to throwing everything out if conditions have so far been favorable and successes have been achieved. However, the market can change rapidly while one is resting on one's laurels. I am privileged to take on that responsibility in times of transformation and to fulfill my mission.

—In what specific ways are you taking up this challenge?

Let me use a freight train as an example. The president at the very front of the train is the first to negotiate a curve on the tracks. There is therefore a time lag before everyone else on the train down to the very last car reaches that curve. We are now waiting for that last car to round the curve. The person at the very front must be patient with this time lag. However, the mission of a manager is to cope promptly with issues, so taking a big swing with great force like a pendulum is required to produce enough energy to move the entire organization. A path with such a large curve is actually unfolding right now.

For example, I feel that our mindset with regard to the business user market has undergone a great change this last year. Up till recently, we have endeavored to propose service upgrades to existing customers and to maintain contracts. Since last year, however, we have been pursuing walk-in sales. This is a marketing strategy in which the 400 personnel in charge of sales to small- and medium-sized businesses make visits as "ICT concierges" to ask them what they might need or what problems they might have.

Incidentally, these staff members visited about 60,000 companies in one year, and they visited some companies a number of times. I told them that these visits—whether successful or not—would provide them with a lot of experience while improving their sales skills and building up their know-how. The results after one year of this challenge were orders from 2500 companies, or about 4% of the companies visited. These may not seem like very impressive figures, but such a demanding experience itself relates to transformation. Currently, most of our new employees pass through this program.

Furthermore, we have traditionally used a made-to-order technique for medium-sized firms, local governments, and institutions such as schools and hospitals in which we propose and provide solutions tailored to their needs. However, we have now switched to a completely opposite ready-made technique in which we prepare patterns of proven proposals to which minor adjustments can be made. In the past, fitting a proposal to an individual customer's needs from scratch was time consuming and labor intensive, which placed a burden on the customer as well. Now, however, we visit every last one of our potential customers for which this ready-made technique might hold true, taking with us a hospital pattern if the customer happens to be a hospital and a school pattern if a school. I believe that such experiences and results will become the foundation of our transformation.

Set a goal, find a role model, and create your own style

—Mr. Ii, what would you say to all NTT EAST employees?

First, please do not give up easily. I first learned to fish during my time as manager of the Niigata branch office. There are certain things about fishing that relate to business. If you change your fishing spot because you are not catching any fish, you may not be able to time that move with the occurrence of rip currents where fishing is good, and the time taken by moving might be longer than the actual fishing time. However, if you set a clear goal and proceed with conviction, there will definitely come a time when your target and movement coincide! In addition, you cannot forget that large fish are more prevalent in deeper waters than shallow, but moving to deeper fishing grounds to catch bigger fish requires some means of getting out to sea. This requires the use of a boat, but a fishing boat requires a license. In this way, pursuing even one thing to the end results in acquiring detailed knowledge of that subject. In the same way, please take up your work in a determined and persistent manner. As I mentioned earlier, sales may be successful only 4% of the time no matter how many times you meet personally with customers, but continuing on without giving up will eventually reveal something new and useful. Facing a challenge repeatedly can be viewed as good practice. For example, you can think of yourself as an actor on stage when visiting a client. At that time, you should use a senior colleague as a role model with a good technique to imitate, and then rehearse that technique over and over again. After that, you should then create your own style of working.

—Finally, what kind of attitude would you like our researchers to adopt in their work?

To put it bluntly, I would like them to create earth-shattering things. Being the sales unit of the company, we introduce and propose the results of research to our customers as needed. However, presenting groundbreaking results is all the more impressive. Actually, our customers greatly enjoy demonstrations of our latest technologies and services when we show them around NTT laboratories. Such activities generate conversation and can lead to new business. I would like to delight and impress our customers with our research results even more. At present, there is increasing interest in artificial intelligence. It is becoming known that our technologies and services, which are already being commended in the real world, as in the meeting minutes of the Diet's Lower House, are many and varied and have the potential to be a driving force in the world. There are therefore high expectations of NTT. Against this background, I would like to ask our researchers to produce even more amazing results going forward.

Interviewee profile

■ Career highlights

Motoyuki Ii joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1983. After becoming Manager of NTT EAST Niigata branch office in July 2007, he became NTT EAST Senior Vice President and concurrent Executive Manager of the Plant Department and Strategy Planning Department, Network Business Headquarters, in June 2011. He then became Executive Vice President and Senior Executive Manager of Corporate Sales Promotion Headquarters in June 2015, and took up his present position in June 2016.

Accelerating the Demonstration and Adoption of NetroSphere

Tadashi Ito

Abstract

The NTT Group aims to accelerate the transformation to a business-to-business-to-X (B2B2X) business model in response to changes in the telecommunication market. NetroSphere is the concept of a flexible and robust network that can cope with diverse and uncertain demand in the B2B2X model. The Feature Articles in this issue introduce the development of the network architecture and network systems technology that advance the materialization of the NetroSphere concept. It also touches on NetroSpherePIT and the global rollout to carriers and vendors as a collaborative program for accelerating the implementation of this concept.

Keywords: NetroSphere, network architecture, global collaboration

1. Introduction

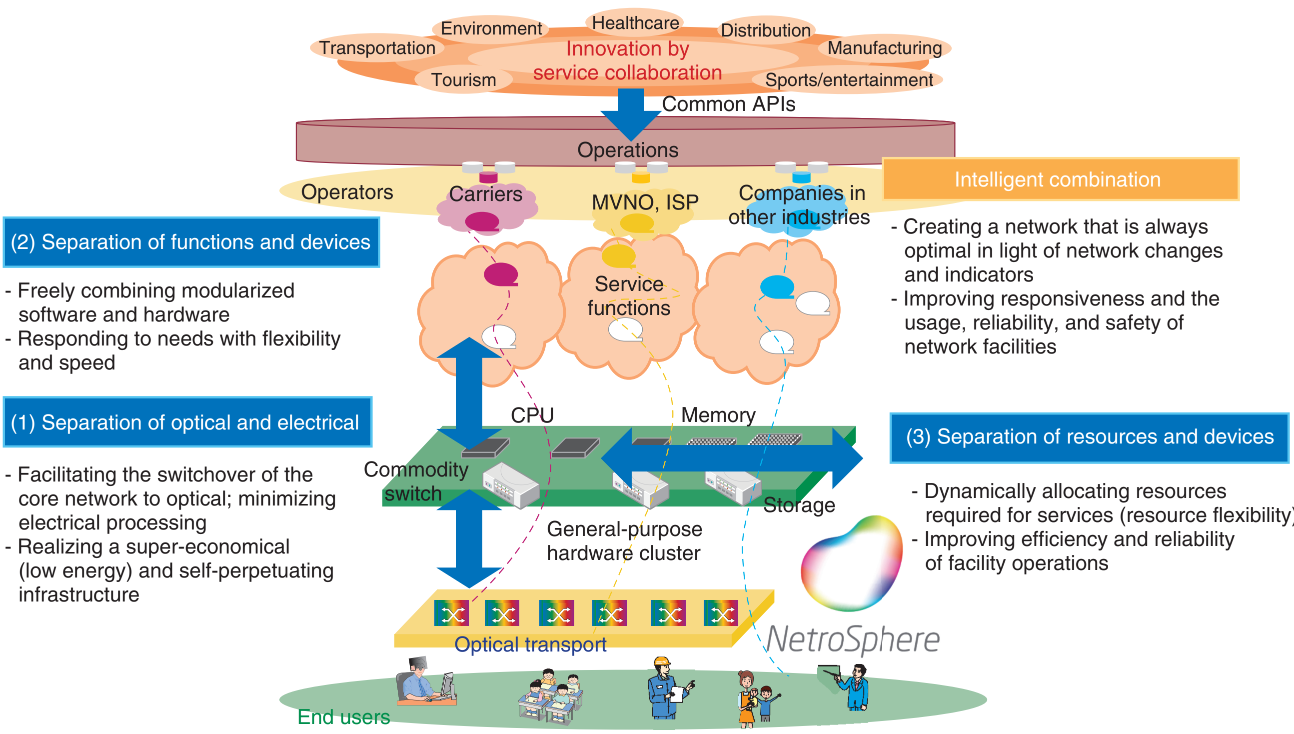
The telecommunication market is rapidly changing into an environment that surpasses the traditional value of connectivity and produces new value revolving around mobile and cloud services geared to OTT (over-the-top) players. In light of this environmental change, the NTT Group announced *Towards the Next Stage 2.0* as a medium-term management strategy and is now aiming to accelerate the evolution towards a form of business such as the Hikari Collaboration Model (wholesaling of fiber access service) by NTT EAST and NTT WEST. We are also working to achieve business in which networks are bundled with services such as MVNO (mobile virtual network operator) services, and the transformation to a business-to-business-to-X (B2B2X) business model through collaboration with partners in diverse fields. In addition, we are in a transformative period that involves the development of the Internet of Things (IoT) and machine-to-machine (M2M) services that are moving from traditional services focused on people to sensors and connected cars, while network requirements and the surrounding environment are undergoing major innovations.

NTT formulated and announced the NetroSphere concept in February 2015 as a new network research and development (R&D) concept in order to address various future changes such as the full-scale implementation of the B2B2X model and IoT/M2M services, as well as the introduction of fifth-generation (5G) mobile communication technology. NetroSphere fulfills a variety of customer requirements through the free combination of modularized network functions, and its ubiquitous presence protects against risks and the changing environment [1] (**Fig. 1**).

Since announcing the NetroSphere concept, NTT has been striving to advance the penetration of this concept. To do this, we held dialogs with global carriers and vendors and pursued active interoperation and use of cloud technologies such as OpenStack. This enabled NTT to develop plans for a future network that will lead the world and to promote the R&D of elemental technologies that will constitute this network (**Fig. 2**).

2. Materialization of the NetroSphere concept

The initial work on the NetroSphere concept focused on facilitating the development of a new architecture centered on a core network and server systems, including a new network architecture called Multi-Service Fabric (MSF) [2]; a new server



API: application programming interface
CPU: central processing unit
ISP: Internet service provider

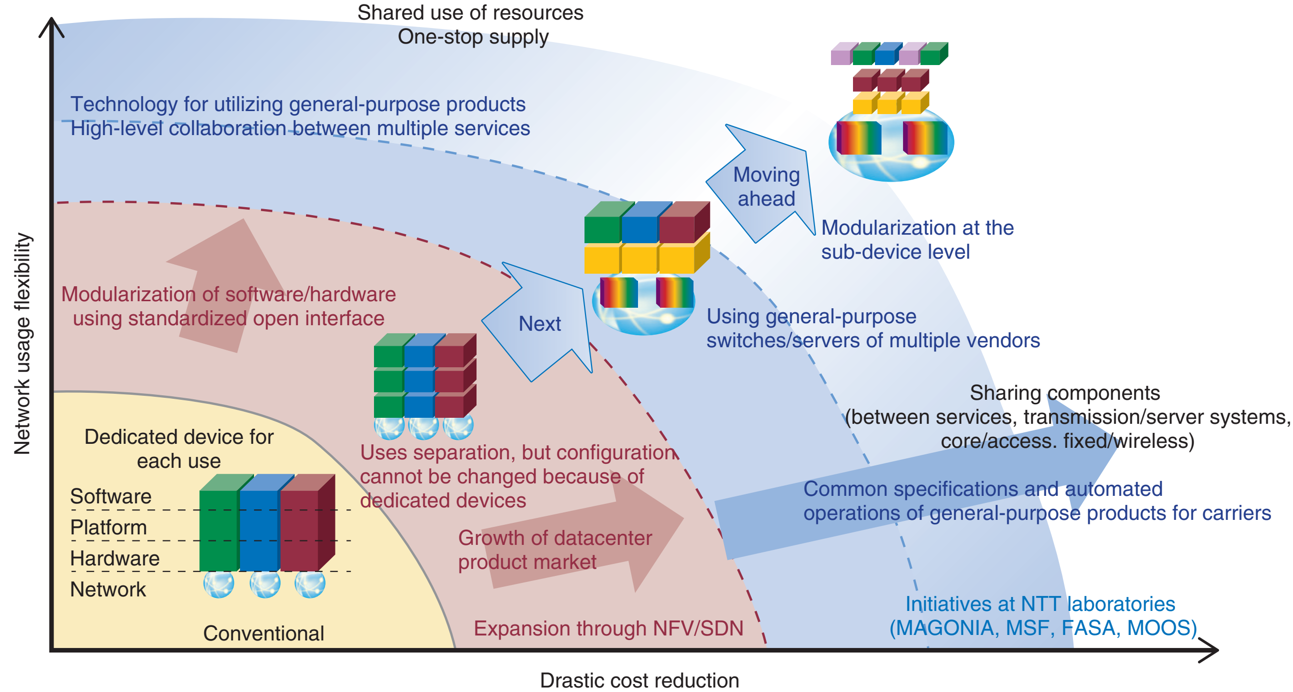
Fig. 1. Concept for implementing NetroSphere.

architecture called MAGONIA; and a management and orchestration operation system (MOOS), which exercises flexible control over MSF and MAGONIA. In technology development, we are pursuing open and global sharing of the concept and are actively promoting collaborative development with approved vendors. Announcements of the intent to cooperate in developing technology for the NetroSphere concept have come from multiple global vendors [3], while productization by individual companies in line with the NetroSphere concept is gaining momentum [4].

We investigated applications of MAGONIA not only to communication systems, but also to non-stop traffic congestion prediction and signal control systems by leveraging the benefits of a highly reliable, real-time distributed processing base technology, and we verified the effectiveness of these applications through demonstration tests [5, 6]. These examples show the application potential of NetroSphere architecture for a broad range of information and communication technology (ICT) systems. In addition, we are collaborating with Intel Corporation to develop SPP (Soft Patch Panel) technology that achieves ultra-high-speed interconnection over a diversity of services [7].

In February 2016, we expanded the NetroSphere concept to the access system domain and proposed Flexible Access System Architecture (FASA) as a new architecture for access systems [8]. FASA can be flexibly and economically constructed in response to service requirements by thoroughly modularizing the functions that constitute access device and freely combining these components. This conceptual proposal concerning device modularization that ventures into the field of access device implementation is a world first. Now, as we approach the era of 5G and IoT, we consider FASA to be an architecture that enables low cost and flexible combination of wired and wireless devices as well as flexible response even when computing resources must be deployed near the user, such as edge computing and ultra-low latency services.

After the concept was announced in February, NTT began recruiting global partners for the widespread



NFV: network functions virtualization
SDN: software-defined networking

Fig. 2. Efforts underway to realize NetroSphere.

adoption of the FASA concept. In May, NTT released a FASA white paper, which is a detailed description of the FASA concept, together with a draft of the inter-component interface (API: application programming interface). Radical changes are taking place in the way access devices are handled, and such devices are undergoing a conversion to general-purpose and more economical ones. In addition, initiatives are increasing towards new uses of access systems for a wide range of partners [9].

While NTT laboratories are advancing the development of elemental technologies that realize the NetroSphere concept, they have also started building and operating a NetroSphere demonstration test environment that materializes the NetroSphere concept. This environment, named NetroSpherePIT, is not only used for visualizing the concept, and for establishing and verifying its technology; it is also used for developing concrete examples of ideas in real, physical form together with NTT operating companies and various partners to create new usage scenarios, services, and functions [10, 11].

Through these initiatives, the phase of permeating the NetroSphere concept has been completed, and we have entered the demonstration phase with an eye on commercialization, while the development of technology and products by various worldwide vendors is moving forward.

3. Future network architecture and NetroSphere technology usage sought by NTT R&D

In this section, we describe what we want to achieve in the future with NetroSphere.

3.1 Approach and direction of future network architecture

Our objective is to achieve the appropriate and timely provision of a network in response to uncertain future demands from service providers (partners in the B2B2X model), and therefore, we will construct a network that freely combines various functions and components according to requirements. This will be achieved by adopting a network architecture utilizing virtualization technologies (network functions virtualization: NFV, and software-defined networking: SDN) and employing the three-separation

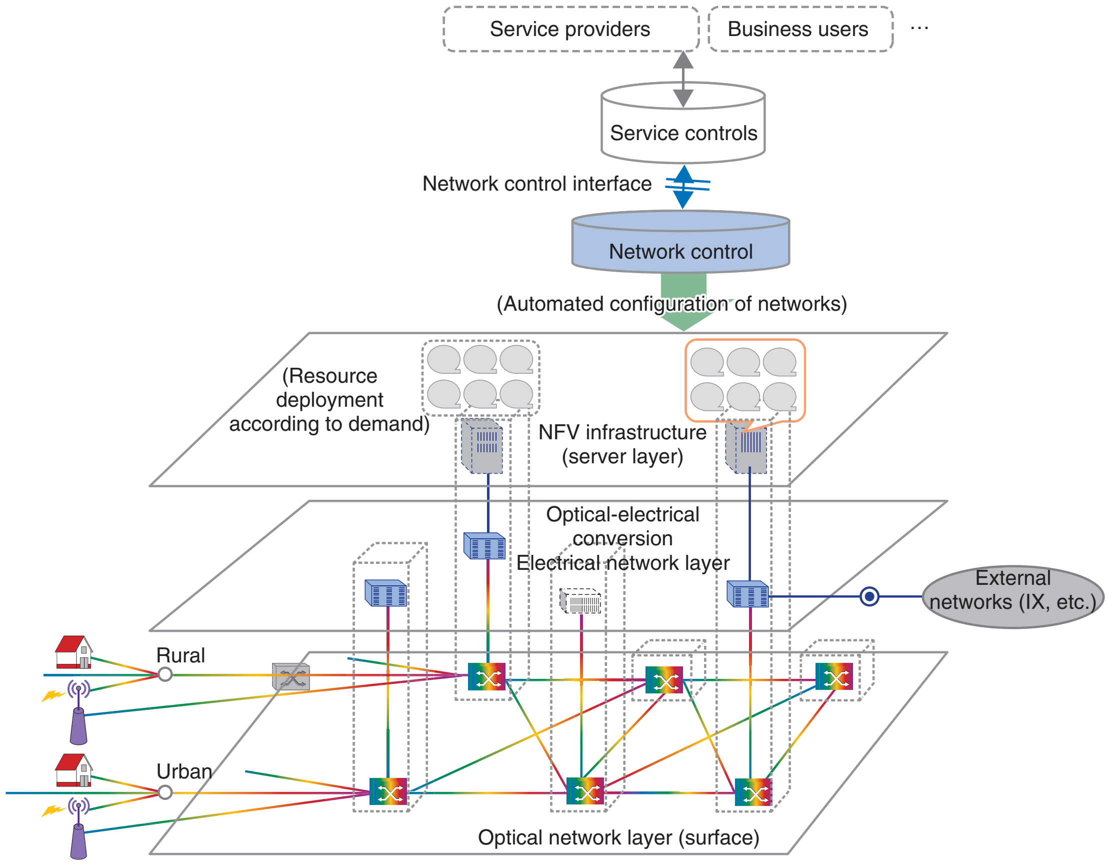


Fig. 3. Future network architecture based on the NetroSphere concept.

approach (optical vs. electrical, function vs. device, and resource vs. device) in the NetroSphere concept.

In the future, network functions designed under the assumption of frequent short-term changes will be implemented with software, and software additions and revisions will be implemented and allocated appropriately within the network (on server equipment). Together with this, rapid provision of network functions through reconfiguration of software and the network (controlled by SDN) will become possible.

In contrast, for networks that must be expanded over a wide area, the goal is to achieve long-term economical operations that are free from the effects of service-dependent changes. This will be accomplished by using a simple network architecture consisting of general-purpose devices, where optical transmission is performed as much as possible, and functions that depend on individual services are implemented in software and separated (**Fig. 3**).

3.2 Transport network architecture

The major changes in transport networks are presumed to be increased traffic volume and the introduction of new technology. To deal with the increased traffic volume, the plan is to expand network capacity by raising transmission speeds and expanding the electrical conversion interfaces at optical nodes. Also, maintaining an optical-electrical separation will minimize the effects on optical transmission that undergoes surface expansion over a wide area.

In areas and facilities where the traffic volume is smaller than interface capacity, improving usage efficiency through traffic layering by electrical operations (such as a layer-2 switch) is thought to be an option. However, in consideration of changes in traffic volume and characteristics over the long term, a method with cost-effective operation and resource allocation, for example, of wavelength, will be selected. In addition, the optical-electrical separation makes it possible to implement a network in which the respective advances in optical and electrical technology can be independently accepted.

3.3 Server network architecture

The major changes in server networks are presumed to be the introduction of new services such as the IoT and M2M. IoT/M2M traffic has various characteristics. Like a telemeter, it has no movement and very little traffic; like a connected car, it has a broad range of movement and a small amount of traffic; and like a drive recorder, it has a lot of movement and a lot of traffic. For existing silo-type facilities* optimized for individual services, efficient accommodation of IoT and M2M terminals, for which vast numbers are anticipated, will be difficult. This is because the signal processing capacity of the existing silo-type facilities will be insufficient even if there is spare capacity in transmission, and facility expansion will be necessary due to the lack of certain network resources. By maintaining a resource-device separation in order to have flexible allocation of required resources for signal processing and packet transmission functions, optimal network provisioning can be implemented efficiently through an appropriate balance suited not just to IoT and M2M but also to individual traffic characteristics.

3.4 Network control architecture

The major changes resulting from the adoption of the B2B2X model are presumed to be a short-term reconfiguration of the optical transmission/transport network and the server network by service providers who supply services for end users. To achieve these short-term changes by service providers, a network control interface will be set up, and automatic network configuration will be provided. Prompt and economical network provisioning can be achieved by automatically conducting network settings and operations in order to satisfy the diverse requirements from service providers (from broad network requirements to more detailed ones) [12].

4. Global expansion of the NetroSphere concept

Since the announcement of the NetroSphere concept in February 2015, in order to facilitate specific implementations of the concept, the NTT laboratories have moved forward with the global expansion of the concept with the goal of achieving widespread adoption of technologies and products based on this concept.

Until now, we have been delivering our vision of future networks through international conferences and other events, while also examining use cases and the applicability of new technologies towards concrete collaboration with global carriers and vendors. As discussed above, the NetroSphere concept will bring about substantial innovation in the network architecture of telecommunication carriers. We have been gaining the approval of many global carriers and vendors and have been starting collaboration with partners outside Japan.

One of the base technologies of NetroSphere is virtualization. Since its introduction, virtualization has been advancing as server technology for datacenters, and the technology has been developed and adopted through open solutions centered on software implementation. Both NFV and SDN apply virtualization technology to telecommunication carriers' infrastructure. Major innovation in infrastructure technology development and standardization is considered necessary so that carriers can use these technologies. Therefore, it is necessary to facilitate technology development and expanded adoption by using open source software and the like, based not only on existing de jure standardization but also on open collaboration. Consequently, to implement this type of effective approach in the development of NetroSphere, NTT has opened the door to associated global carrier and vendor partners, and is proceeding with technology development and expanded adoption of the technology through combined use of diverse methods that go beyond existing frameworks.

In its collaboration with global carriers, NTT is studying the use cases and applicability of technology through joint efforts with Asia-Pacific (APAC) carriers, in addition to its existing activities with European and American carriers through standardization organizations. In the APAC region, the growth potential of telecommunication markets is comparatively high, and investment in the new technologies and services of the telecommunication infrastructure is expected. The region is composed of countries with diverse local characteristics. Therefore, new services based on diverse customer requirements can be expected to be introduced in the telecommunication market and ICT industry.

We believe that the network flexibility resulting from NetroSphere will be adopted not only in the Japanese market but also in the markets of the APAC region with their great diversity. NTT thus aims to

* Silo-type facilities: Telecommunication facilities that are optimally configured for signal processing and packet transmission capacity using dedicated systems for designated services.

bring innovation to the entire global sector to contribute to the expansion of these markets.

With respect to global vendors, NTT intends to share the concept for future networks and move ahead with the joint implementation of technology discussions and examination of specifications. We are carrying out joint examination of use cases, network configuration methods, and technology specifications employing the primary technologies of NetroSphere—MSF, MAGONIA, FASA, and MOOS—with several vendors who are active worldwide. Furthermore, preparations are being made for jointly conducting PoC (proof of concept) demonstrations to verify the feasibility of new technology.

As a specific example in server technology, starting in February 2014, a joint study project was initiated by Nokia Corporation (formerly Alcatel-Lucent), Fujitsu Limited, and NTT towards the establishment of distributed server technology as the basic functional section of the communication network together with a new server architecture [13]. In February 2016, Ericsson and NTT began collaborating on technology concerning a next generation cloud server [3]. Technology for separating server hardware, and management and control technology are positioned as important elemental technologies that need to be established to achieve the NetroSphere concept that will provide new services in a shorter time. NTT is facilitating open collaboration with these global partners to achieve the NetroSphere concept in the future.

5. Future development

NetroSphere has gone beyond the concept stage and is entering the verification phase with an eye on commercialization. Towards full-scale implementation of IoT and 5G, we aim to develop NetroSphere as a network infrastructure that supports the B2B2X collaboration business of the NTT Group as we look ahead beyond the year 2020. With the NetroSphere architecture, it is also possible to have a small start that responds flexibly to service requirements in the form of add-ons to the existing network. We aim for concrete application in the global market in time for the big event in 2020, so we are taking the initiative to achieve the rapid commercialization of the technology.

Furthermore, we will make maximum use of the benefits of the NetroSphere architecture by combining it with *Network-AI*, NTT's artificial intelligence (AI) technology, that enables dramatic improvements in network security and diverse network log information usage (big data analysis), and will thereby improve the value of networks that are easy for partners (service providers) to use with safety and security.

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Director, NTT Information Network Laboratory Group.
He received a B.E. and M.E. from Keio University, Kanagawa, in 1985 and 1987. Since joining NTT in 1987, he has conducted research on asynchronous transfer mode based multimedia switching architecture and hardware/software implementation. He has also been involved in design and planning of NTT's commercial networks, management of laboratory research and development, and human resource strategy planning.

NetroSpherePIT: Demonstrations to Accelerate the Adoption of NetroSphere

Takenori Okutani, Akio Kawabata, Tadashi Kotani, Takashi Yamada, and Masato Maruyama

Abstract

We constructed a demonstration experiment environment called NetroSpherePIT in order to materialize and visualize the NetroSphere concept, and we commenced demonstration experiments with various technologies required for its implementation. In this article, we explain one of the NetroSpherePIT demonstration experiments and the technical issues that were revealed in the experiment.

Keywords: NetroSphere, demonstration experiment, collaboration

1. Introduction

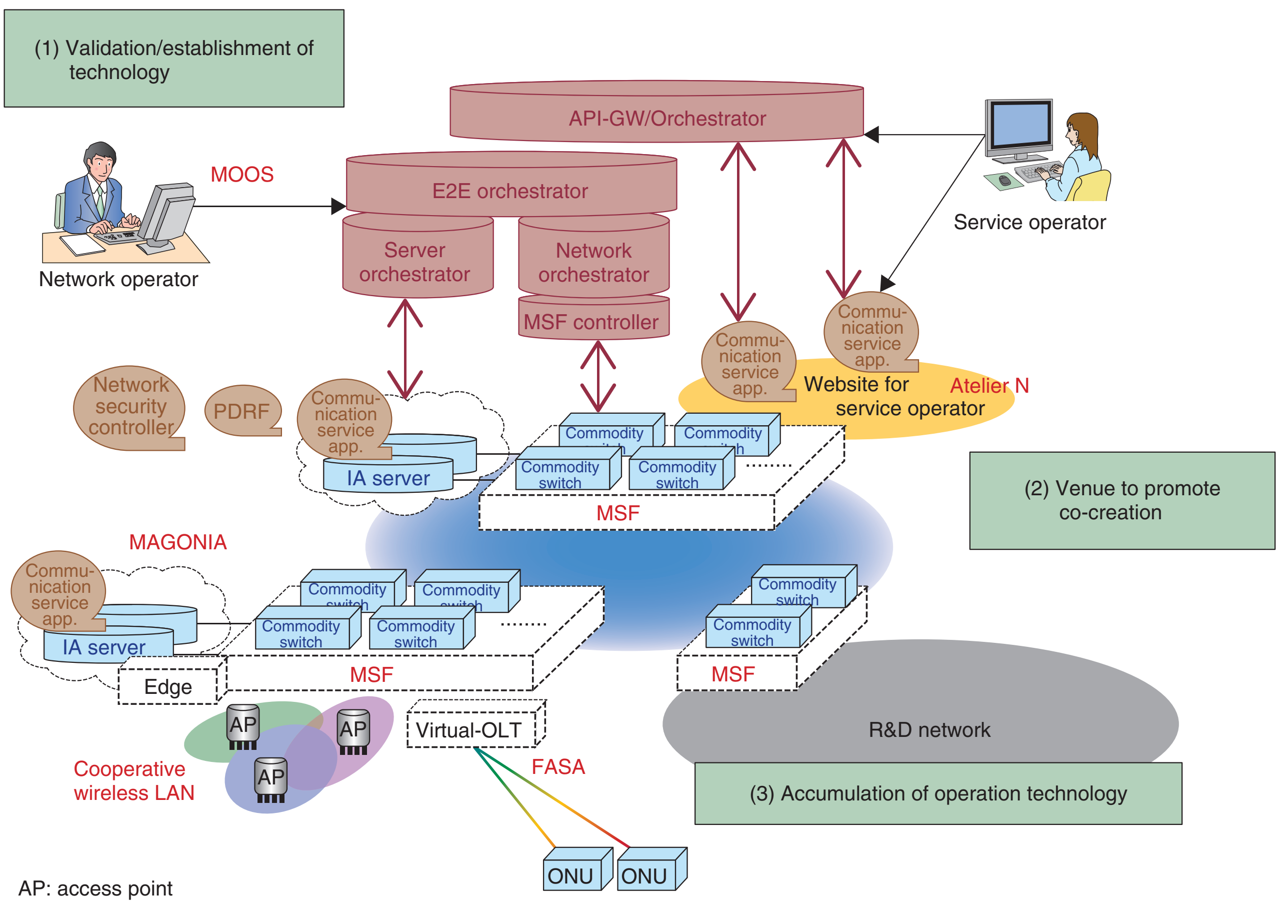
NTT Network Service Systems Laboratories built a demonstration environment called NetroSpherePIT (hereinafter referred to as PIT) to realize the NetroSphere concept and commenced experiments [1, 2]. The name PIT was selected as a starting point for releasing new technologies and services into the field. This will be done by NTT in collaboration with a broad range of partners such as vendors, carriers, and academics both domestically and internationally who participate in the demonstration experiments. In PIT, products will not only be tested as a single item but will also be verified from the viewpoint of total service using a series of products. PIT will also function as a venue for collaboration among partner companies. Our objectives are to visualize the NetroSphere concept and to create an environment in which network operators and partner companies can experience the usability of NetroSphere. PIT will also be applied as infrastructure for research and development (R&D) and will be used actively as a venue to accumulate technology.

In this article, we introduce PIT and the use scenarios for verifying the NetroSphere concept, which was exhibited at the NTT R&D Forum held in February 2016.

2. Summary of NetroSpherePIT

PIT consists of key components that realize the NetroSphere concept. These include Multi-Service Fabric (MSF), Flexible Access System Architecture (FASA), MAGONIA, Integrated Control, operator cooperative functions, network security, and Atelier N. The overall structure of PIT is shown in **Fig. 1**. With PIT, all communication applications are achieved using software and mounted on MAGONIA, which is the application platform. The MSF transfer/switching platform, which is shared by various services, connects network functions in different locations. Furthermore, the access network is made from a virtual optical line terminal (OLT), which conforms to the FASA concept in which the access system function is implemented by software on general-purpose hardware. PIT is thus realized by using general-purpose hardware and a uniform architecture and platform.

Each communication application and MSF, MAGONIA, and the virtual OLT can be uniformly managed and operated by a MOOS (management, orchestration, and operation system), which has an orchestrator



AP: access point
API: application programming interface
GW: gateway
E2E: end-to-end
IA: Internet appliance
LAN: local area network
PDRF: product development request form

Fig. 1. Structure diagram of NetroSpherePIT.

function. The function deployment model is shown in **Fig. 2**. This model uses the NFV (network functions virtualization) architecture as the base and is configured so as to achieve efficient management of networks and server resources. Also, the application programming interface (API) for collaborating operators is extended. We plan to further develop this model taking into consideration the implementation of products available on the market.

To confirm the validity and feasibility of the NetroSphere concept, we checked the following four operations, which are the basic network functions of each component:

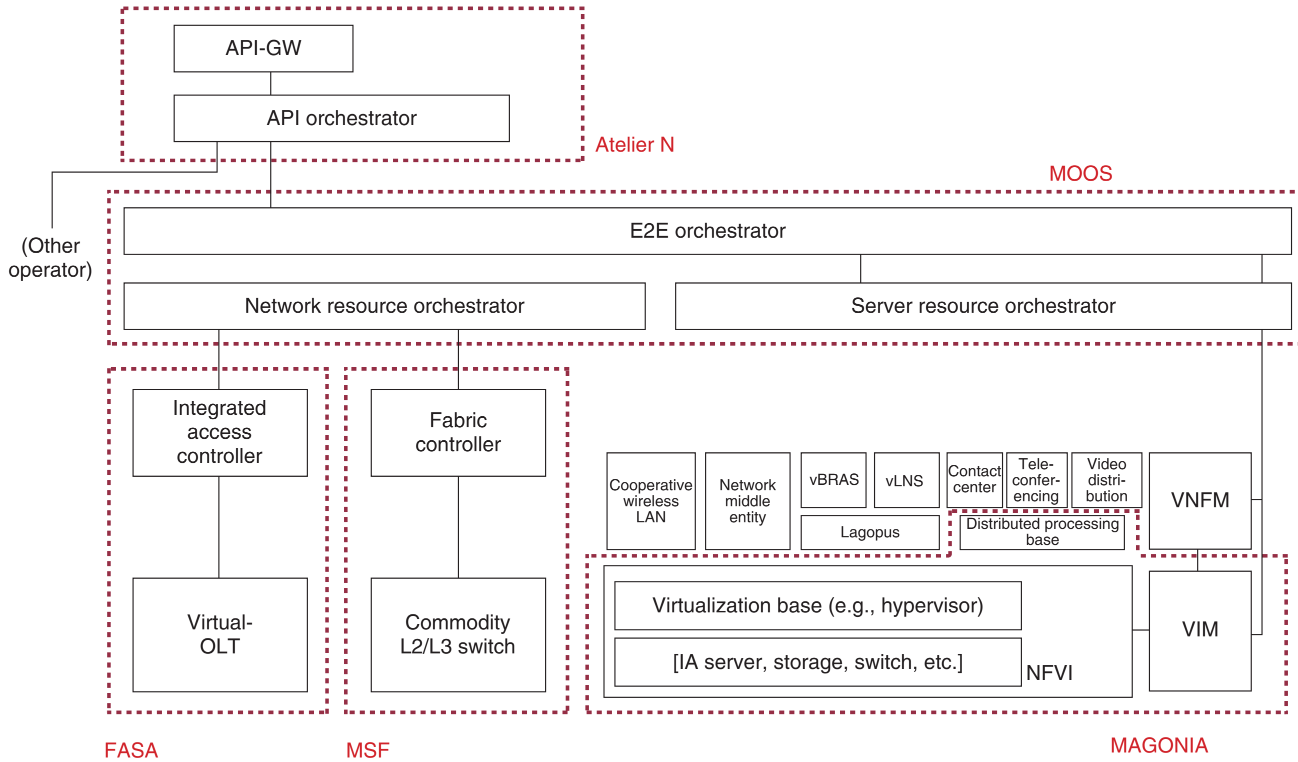
(1) Network slice function to provide multiple network services on an identical infrastructure network

(2) Technology enabling the use of various network functions on the general-purpose server via software

(3) Technology that controls the network slice and network functions in a consolidated manner on general-purpose servers

(4) API function that enables collaborating operators to control various network functions

In addition, we extracted the following three high level requirements to verify the effectiveness of visualization on the NetroSphere concept. From these we created a scenario, where NetroSphere operates as one system, and then verified its performance.



L2/L3: layer 2/layer 3
NFVI: network functions virtualization infrastructure
vBRAS: virtual broadband remote server
VIM: virtualized infrastructure manager
VNFM: virtual network functions manager

Fig. 2. Function deployment model.

2.1 Hardware that is general-purpose and modularized, works regardless of location, and can be pooled

Various communication services (e.g., EPC (evolved packet core), Internet service provider (ISP) access, virtual private network (VPN) service) provided by the NTT Group are delivered on identical infrastructures. A backup resource can be shared and will operate regardless of location. The specific details are as follows:

(1) Each service function will be provided on identical hardware on MSF and MAGONIA.

(2) Various supplier devices will be used and can therefore be automatically embedded into the network, regardless of who performs the maintenance or of the use of other devices.

(3) A backup resource located in a broad area for a limited period/limited area can be used.

2.2 Delivering one-stop service from service operator

Various network functions are provided by an integrated interface, which enables one-stop service.

(1) The service from the access network to the VPN and to the cloud is controlled on the GUI (graphical user interface) of the service operator using an interface defined by common specifications within the group.

(2) A solution service is provided by linking applications provided by the system integrator and network functions (from the API).

Network functions for various operational tasks will be controlled in an integrated manner and will be automated.

(3) Total network security is provided through the collection/analysis of attacks, determination of countermeasures, and control of each network function.

(4) When devices are added or are damaged, the

setting/control of related devices is autonomously controlled, and the standard architecture is always autonomously maintained.

2.3 New increase in network value for future network services

With NetroSphere, we will expand NTT's business coverage by providing network functions that meet new network requirements for the Internet of Things (IoT) and the 5G (fifth-generation) mobile communication network.

(1) Virtual network functions such as a low delay application, vCPE (virtual customer premises equipment), and virtual base band unit (BBU)*1 will be provided.

(2) A network middle entity that provides new added value to machine-to-machine (M2M) and IoT will be provided.

3. Items validated for NetroSpherePIT

We created three scenarios and evaluated the system operation in each scenario in order to meet the high level requirements mentioned in subsections 2.1–2.3. We explain the scenarios here.

3.1 Achieving common architecture for communication carriers

This use scenario is for communication device vendors and communication carriers where the NTT Group provides communication services on an identical infrastructure, which is intended to improve the efficiency of various operations. For this scenario, we loaded a tunnel function that is accessed by ISPs, as a communication application operating on a general-purpose server. This enables the application functions to be regenerated across locations when a failure occurs, and to be controlled together with the changes in network paths. We can thus provide a highly reliable service efficiently. To deal with sudden increases in demand, we created a communication application remotely on a general-purpose server deployed as backup. By embedding such schemes, we can handle the situation in a flexible manner without a large capital investment, even if there are unclear demands such as IoT/M2M or various service requirements.

Going through these use scenarios clarified that we needed to implement different functions according to each network function and in order to automatically embed functions in the network without affecting maintenance personnel or other connected devices. We will study efficient ways of achieving this and will also investigate the fully automated maintenance and operation.

3.2 Providing one-stop operation

This use scenario is for middle B operators (the second B in the B2B2X (business-to-business-to-X) business model). With this scenario, middle B operators use the API provided by the network realized by NetroSphere and link/interlock NTT networks to operator services to achieve one-stop operation. It is also intended to achieve monitoring/control in a similar way to that of the network built by the operator itself. When middle B operators deliver application services on the cloud, or their own network service together with NTT's VPN as a package, the middle B operators create VPN functions by using TMF (TeleManagement Forum)'s standard API, thus enabling real-time monitoring of network status such as failures. Embedding such a scheme in the network makes it possible to achieve efficient operation among operators. We can expect to see an expansion of middle B business and a further expansion of network usage resulting from this.

In this use scenario, the service identification (ID) that is managed by the network orchestrator and the server orchestrator, both of which provide a service catalogue*2, as well as the ID that is allocated to the network function, which is a component of those orchestrators (such as the VLAN (virtual LAN)-ID of the switch), are currently assigned in a fixed format and are locally managed. We found that it is necessary to investigate the management format of the ID (local/distributed) and the allocation format to ensure the reliability of the whole system and to improve operational efficiency. The challenge will be to implement/promote this format to orchestration vendors.

3.3 Creating service together with service operators

This is a use scenario for service operators that is aimed at simplifying the development of new services by combining the communication service provided by the network and the application provided by the service operator. In this scenario, we created a developer portal that enables functions and applications provided by NetroSphere to be seen in a unified

*1 BBU: Digital signal processing section that is part of the wireless base station.

*2 Service catalogue: Devices and configuration to provide network service in the orchestrator.

manner. We also developed a trial application using APIs for service operators, which has been released via Atelier N.

We will use all of these use scenarios to extract issues in order to improve usability when service operators make use of various network functions, and we will create collaborative services with the service operators.

4. Future development

We constructed PIT using key components that materialize the NetroSphere concept such as MSF, FASA, MAGONIA, Integrated Control, operator cooperative functions, network security, and Atelier N. In the future, we will conduct experiments on PIT for new services and functions with operating companies of NTT as well as service operators, and we will make use of PIT as a venue to clarify the effects and issues of NetroSphere toward its commercialization. We will work out the specifications of individual products together with the Asia Pacific (APAC) carriers and work to spread the use of the products. To achieve this, we plan to actively use PIT to conduct experiments together with APAC carriers.

At the same time, we will actively connect the network with each NTT operating company and research institution, and use this as an R&D network. By continuing these endeavors in the PIT environment, we hope to deliver technology that is useful for NTT business and that contributes to the development of the industry.

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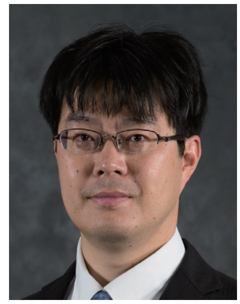

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New Access System Architecture (FASA)—Enabling Provision of Services Flexibly and Promptly

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Abstract

Flexible Access System Architecture (FASA) is a new access system architecture that satisfies various requirements from service providers and end users and enables prompt provision of services. NTT Access Network Service Systems Laboratories materialized this architecture, created a list of functions to be modularized, and investigated common API (application programming interface) specifications using use cases and dynamic bandwidth assignment as an example. A white paper was created as a reference. This article introduces some of the main elements of the white paper.

Keywords: FASA, access network element, modularization

1. Introduction

As the diversification of telecommunications usage, in addition to the B2C (business-to-consumer) telecommunications services that are directly provided to end users by telecommunications carriers, B2B2C (business-to-business-to-consumer) telecommunications services are on the increase, where telecommunications services are provided to the end user via various service providers. NTT announced the Hikari Collaboration Model in 2014 [1]. Since then, we have been providing new services through co-creation with various business players. Access network systems must be capable of quickly coping with such changes in these situations. However, conventional access network elements have been developed so that they are specific to each service, which has made it difficult to quickly satisfy requirements that are becoming more and more diverse due to changes in the business models of telecommunications services. Because of this, it was necessary to redevelop the entire access network element.

NTT proposed the NetroSphere concept [2] in order to satisfy the increase in diverse requirements and provide services promptly. To implement this concept, we are currently carrying out research and development (R&D) of technology that enables us to modularize the functions of the access network elements and also enables these functions to be combined. On February 8, 2016, we announced our new access system architecture called Flexible Access System Architecture (FASA), which is based on the NetroSphere concept [3]. In addition to announcing the concept of FASA, we also explained that a draft plan for common application programming interfaces (APIs) for implementing FASA would be released, and we stated our intention to call for partners to collaborate in defining the FASA specifications. Since this press release, NTT Access Network Service Systems Laboratories has been investigating the FASA concept, a list of functions to be modularized, use cases, and common API specifications using dynamic bandwidth assignment (DBA)*1 as an example. On May 31, 2016, we unveiled the white paper as a

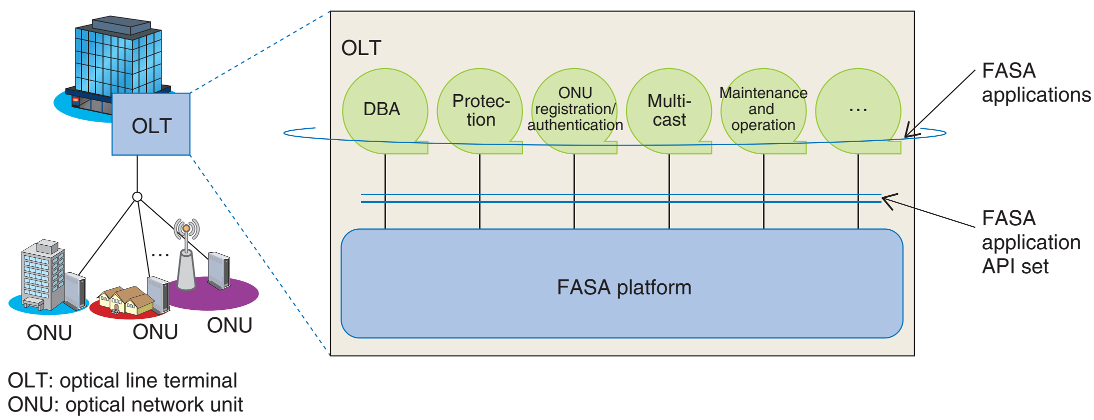

Fig. 1. Concept and component of modularization by FASA.

reference and also called for collaborative partners to work on the FASA specifications [4].

2. Summary of white paper

Here, we briefly describe the main sections of the white paper.

2.1 Concept of FASA

Conventional access network elements are developed specifically for individual services. Therefore, when functions are added or replaced, it is necessary to redevelop the entire access network elements. In addition, spare equipment and maintenance skills specific to each access network element are required for maintenance and operation. For that reason, access network elements need to be more flexible and expandable in order to be able to promptly satisfy requirements from various telecommunications carriers and services.

In consideration of these requirements, we are positioning FASA as a new access system architecture and concept with the following characteristics:

(1) Functions in access network elements are modularized, thus avoiding the development of equipment specific to a service or a service provider.

(2) The functions that differ from service to service and/or among service providers are realized by software modules[*2] with common interfaces.

(3) The dependency among software modules is minimized, and the replaceable software modules run on a platform.

By achieving the above items, we can provide functions quickly and economically that are tailored to the service, while still maintaining service quality.

2.2 Structure of access network element based on FASA and target of investigation

The concept of FASA modularization and its components are illustrated in **Fig. 1**. As the diagram shows, the access network element based on FASA consists of FASA applications[*3] and a FASA platform[*4].

The FASA applications abstract the functions, which vary according to the services or service providers, and are implemented as a software module using common input/output interfaces (FASA application APIs[*5]). Because the input/output interfaces are commonalized, it is easy to add or replace functions and enables quick provision of various services.

The FASA platform is a basic component of the access network element, which provides FASA application APIs to the FASA applications and also provides functions that do not need to be changed for each service because those functions are standardized.

*1 DBA: A function that dynamically assigns the upstream bandwidth of PON.

*2 Software module: A module that forms necessary functions as software in a replaceable unit.

*3 FASA application: A replaceable software module that is implemented using FASA application APIs.

*4 FASA platform: A basic component of an access network element that provides FASA application APIs to the FASA applications, while providing functions that do not depend on requirements from particular services or service providers because of standardization.

*5 FASA application API: An API that connects the FASA applications and the FASA platform.

The white paper lists the FASA application APIs, which are common interfaces that link the FASA applications and the FASA platform. These FASA application APIs can be commonly used and do not depend on the access transmission system, for example, P2P (point-to-point) or passive optical network (PON), or on standards such as Ethernet PON or NG-PON2 (Next Generation PON2).

2.3 Functions to be implemented by FASA applications

In the white paper, we organized the main functions of the access network element and extracted the functions to be implemented by the FASA applications (**Table 1**). Of the functions indicated in the table, we classified those that should be implemented by the FASA applications that need to be replaced or extended to satisfy requirements unique to the service or service provider. Some functions that do not need to be replaced or extended because they are specified in the standardization are classified as functions to be implemented on the FASA platform.

For example, a function to satisfy service requirements in DBA is a function that should be part of the FASA applications. An example of a requirement that differs with each service or service provider is a policy that indicates which communication quality (low delay or high bandwidth efficiency) is to be given preference. The policy for bandwidth assignment differs according to the service or service provider; hence, this should be implemented as a FASA application. DBA is a process to adaptively assign bandwidth (the time slot in which the data signal can be transmitted) in the upstream direction from optical network units (ONUs) to an optical line terminal (OLT) to each ONU. This can be classified into status reporting (SR)-DBA, which assigns bandwidth based on reports from the ONUs, and non-status reporting (NSR)-DBA, which assigns bandwidth without the reports. With SR-DBA, it is possible to assign bandwidth with high bandwidth efficiency based on ONU reporting; hence, it is often used for fiber-to-the-home (FTTH). However, the round trip for control signals traveling between the ONU and the OLT takes time. Hence, when low delay is preferred, such as in mobile fronthaul (MFH), another method is chosen.

A function for DBA frame processing conforming to the given standards in the DBA function should be implemented on the FASA platform. To achieve an access network element of the 40-Gbit/s class, which conforms to the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) G.989 series, basic processing functions such as frame processing need to be implemented according to the standard. Such basic functions are common, regardless of the service or service provider, and should therefore be implemented on the FASA platform.

2.4 Example of FASA application API: DBA

In the white paper, we listed possible FASA use cases by using DBA as an example application. We organized APIs and the functional blocks to obtain necessary functions to realize each use case and then compiled the common API set so that they could cover all of the use cases.

The assumption in the white paper is that use cases such as multi-service (e.g., MFH, FTTH) are provided by PON. For example, the maximum delay tolerance specified for the data signals of MFH is stricter than for FTTH. With FASA, even if the access network element was developed for FTTH aiming for high bandwidth efficiency, by replacing FASA applications of DBA, it is possible to satisfy the strict delay specifications of MFH. To add and replace FASA applications according to the requirements from the service or service provider, it is necessary to have an API set that covers all the assumed use cases of the services and service providers.

For the DBA to meet MFH requirements, we can use optical-mobile cooperative DBA [5] that assigns bandwidth by obtaining necessary information for bandwidth assignment from external equipment, or NSR-DBA that assigns bandwidth based on statistical traffic data and traffic patterns.

The APIs and functional blocks of DBA in these use cases are shown in **Fig. 2**. The functional blocks consist of policy determination, assignment calculation, cooperative control, traffic monitoring, report processing, and grant processing.

In the SR-DBA for FTTH, the whole DBA will be implemented as a FASA application (fully software). In addition, we also assume an implementation where part of the DBA (policy determination) is to be implemented as a FASA application (partially software), which has a similar structure to the conventional PON.

To handle these use cases, we stipulated FASA application APIs for traffic information, request information, assigned amount, transmission start time, parameters for assignment calculation, parameters for policy determination, and cooperative information.

Table 1. Main functions of access network element and classifications of implementation.

Functional group	Function	FASA application or FASA platform
PON data signal processing function	Basic function	Platform
PON access control function	ONU registration/authentication	Application
	DBA	Platform
		Application
	DWA	Platform
		Application
	DoS attack prevention	Application
L2 data signal processing function	SNI port	Platform
	Bridge function	Platform
	Traffic monitor	Platform
	Aggregation	Platform
		Application
	Precedence control	Platform
		Application
	VLAN management	Application
Maintenance and operation function	Maintenance and operation frame processing	Platform
	Maintenance and operation port/monitoring control port	Platform
	SBI	Application
	Settings	Platform
		Application
	Management	Application
	Maintenance and operation	Platform
		Application
	Test	Application
PON multicast function	IP multicast	Platform
	Filter settings	Application
	Multicast proxy	Application
Power-saving control function	ONU power saving	Platform
		Application
	OLT power saving	Platform
		Application
Frequency/time-of-day synchronization function	Means of synchronization	Platform
		Application
Protection function	Protection	Platform
		Application

DoS: denial of service
DWA: dynamic wavelength assignment
IP: Internet protocol
L2: layer 2
SBI: south bound interface
SNI: service node interface
VLAN: virtual local area network

3. Future development

On May 31, 2016, we released the white paper on the FASA home page, and we posted the white paper and called for partners in the TOPICS section on the NTT Group website. We released the English version of the white paper on June 29, 2016 [6].

In the future, we will collaborate with partners to clarify specifications for access network elements such as the architecture, carrier requirements, use cases, and APIs. We plan to demonstrate a proof of concept and complete the API set by February 2017 (**Fig. 3**).

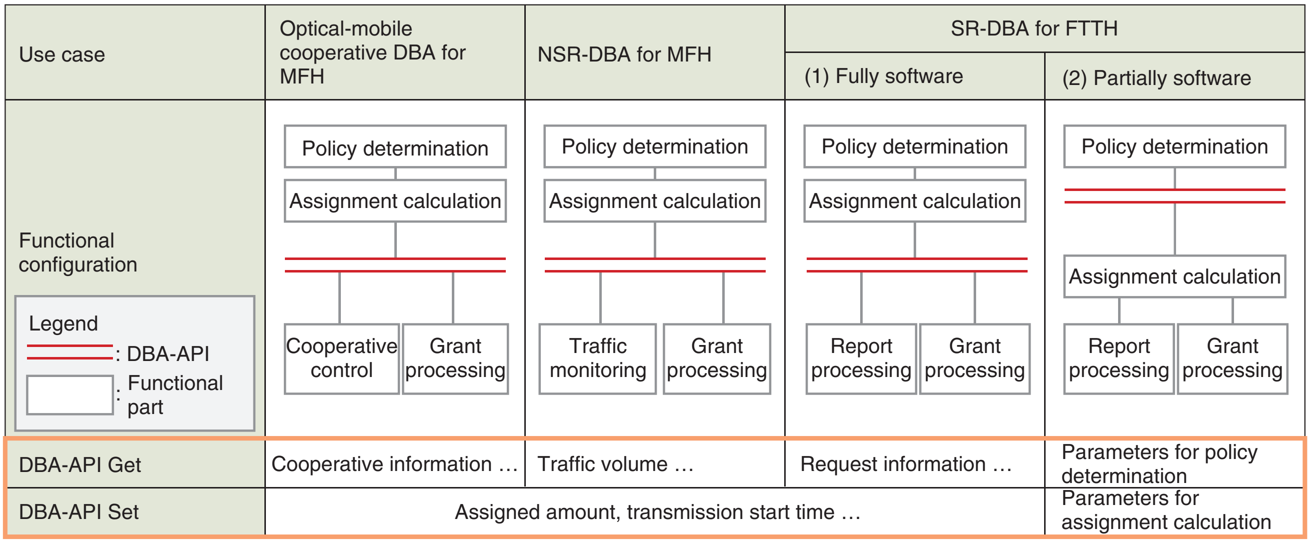

Fig. 2. API and functional blocks of DBA in each use case.

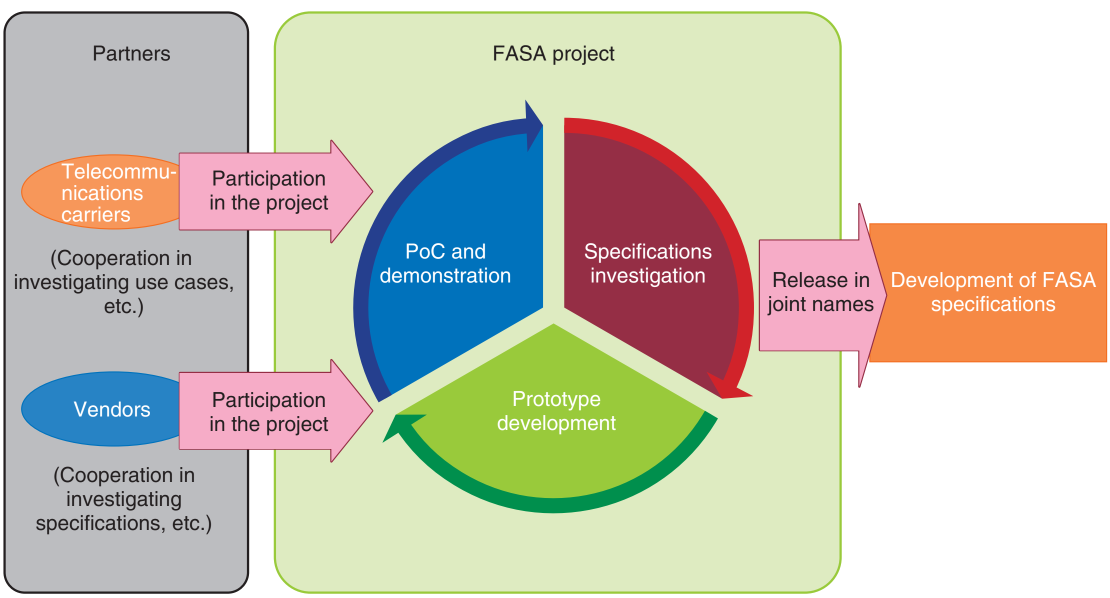

Fig. 3. Cooperation activities in FASA project.

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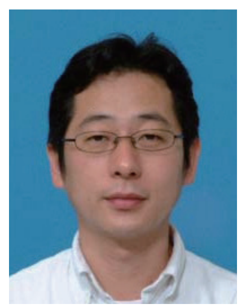

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Network Control Technology to Realize the NetroSphere Concept

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Abstract

NTT has announced its NetroSphere concept, which was developed with the objective of promptly, reliably, and economically supplying services required by network users and middle B operators (the second B in the B2B2X (business-to-business-to-X) business model). NTT Network Technology Laboratories is conducting research on network control technologies to respond to the needs of diverse middle B operators flexibly and efficiently and to provide high-quality services with the aim of achieving the NetroSphere concept. This article examines the progress of these initiatives.

Keywords: network configuration and control, resource optimization, security

1. Introduction

NTT has announced its NetroSphere concept [1], which is being developed in order to promptly, reliably, and economically supply services required by network users and middle B operators (service operators). In this article, we introduce three network control technologies that enable us to respond flexibly and efficiently with high-quality service to the needs of various middle B operators. These technologies consist of *network abstraction* to implement network design and configuration, *network resource optimal control* to enable responses to temporary changes in demand, and *cyber-attack suppression control* that achieves stable service during cyber-attacks.

2. Key changes affecting the networks

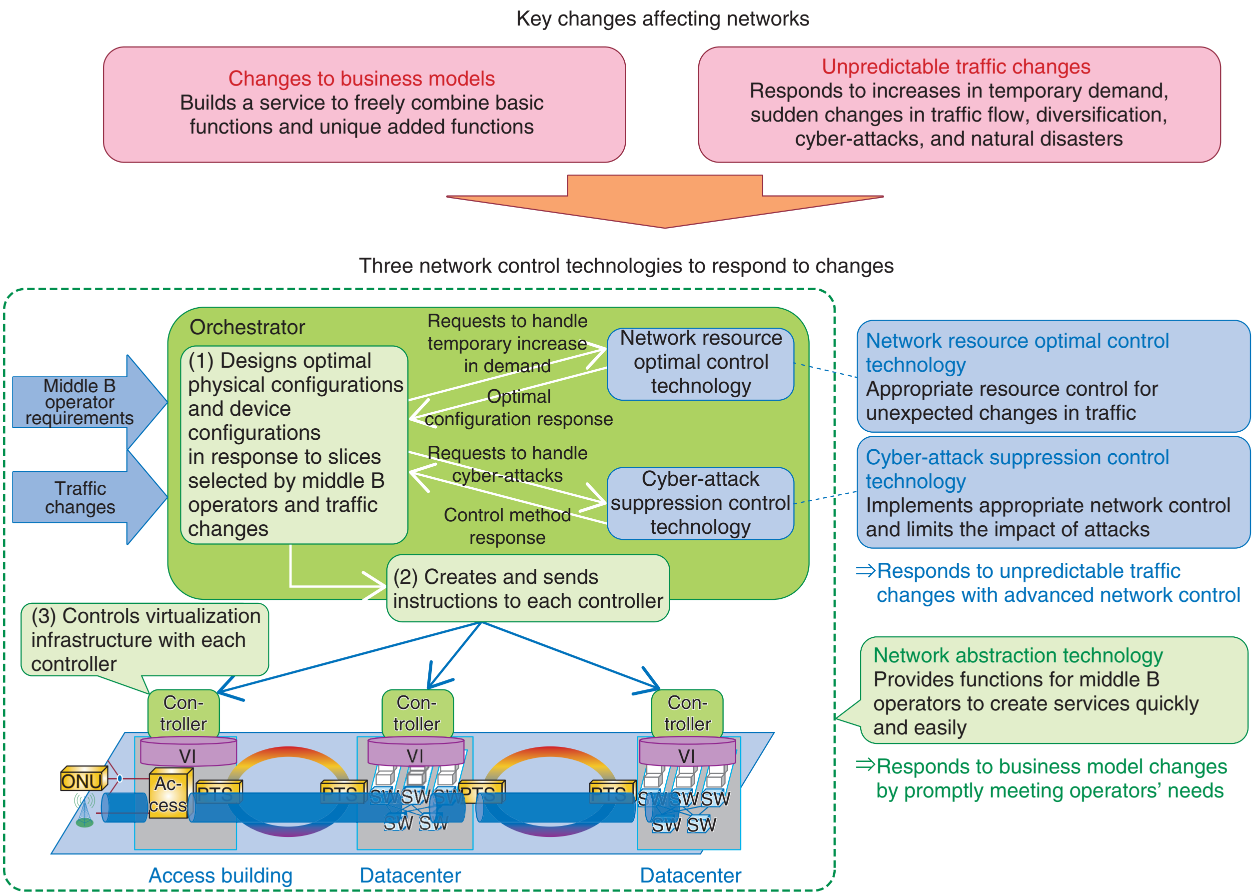
First, the positioning and relevance of the technologies mentioned above are explained (**Fig. 1**). To realize the NetroSphere concept, it is necessary to respond to two kinds of changes: business models and traffic that is difficult to predict.

2.1 Changes to business models

Changes to business models means shifting from a standardized supply service model where carriers provide services through individual networks such as NGN (Next Generation Network), to a B2B2X (business-to-business-to-X) business model where middle B operators can build businesses and services according to their needs by freely incorporating original value-added functions to the base functions supplied by the carriers. Accommodating these changes requires networks that can respond flexibly to various middle B operator needs and that can promptly offer services. The technology to achieve this is network abstraction technology.

2.2 Unpredictable traffic changes

Network traffic up to now has been uniform and predictable, as service traffic has been dominated by services provided by carriers, for example, phone, Internet, and video services. However, in the NetroSphere era, we envisage an increase in the unpredictability of traffic changes. This may be caused by various elements such as rapid changes to traffic flow due to the start of new services from middle B operators with the previously mentioned business model



ONU: optical network unit
PTS: packet transport system
SW: switch
VI: virtualized infrastructure

Fig. 1. Three network control technologies to respond to changes.

changes; diversification of traffic characteristics due to the spread of numerous services, especially IoT (Internet of Things) services; temporary increases in demand due to large-scale events; and rapid responses to major disasters and cyber-attacks. For the unpredictable traffic changes above, network resource optimal control technology makes it possible to respond to temporary changes in demand, and cyber-attack suppression control technology can achieve stable service quality during a cyber-attack. These two kinds of technology are used as network configuration algorithms within the network abstraction technologies, and are capable of handling unpredictable traffic changes.

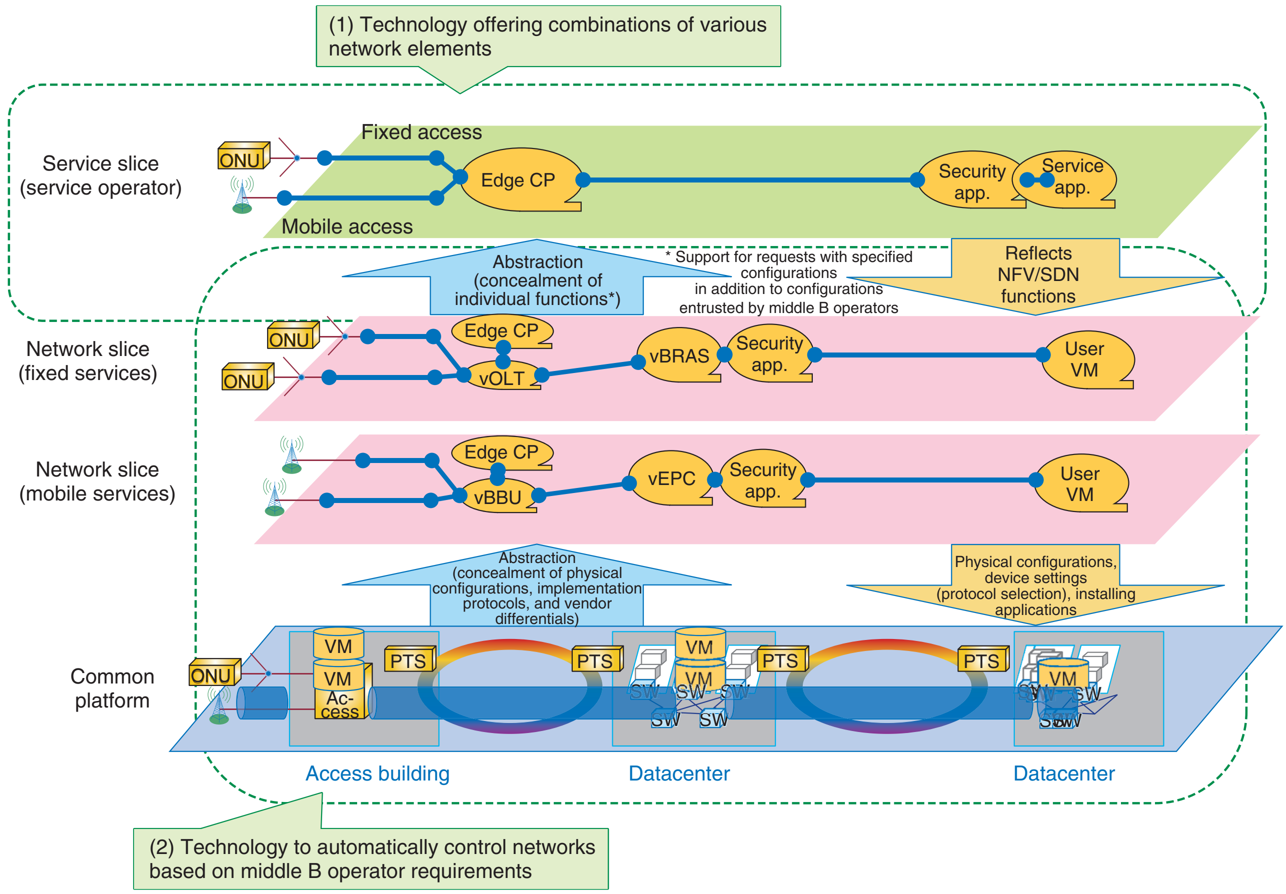
3. Network abstraction technologies

With network abstraction technologies, the network copes with business model changes using two network technologies. One offers combinations of various network elements, and the other automatically controls networks based on middle B operator requirements (**Fig. 2**).

3.1 Technology offering combinations of various network elements

With these technologies, we can define virtual networks that combine network elements for middle B operators as *service slices* and enable abstraction and customization of service slices according to middle B operators' use cases.

Service slices support patterns in which network

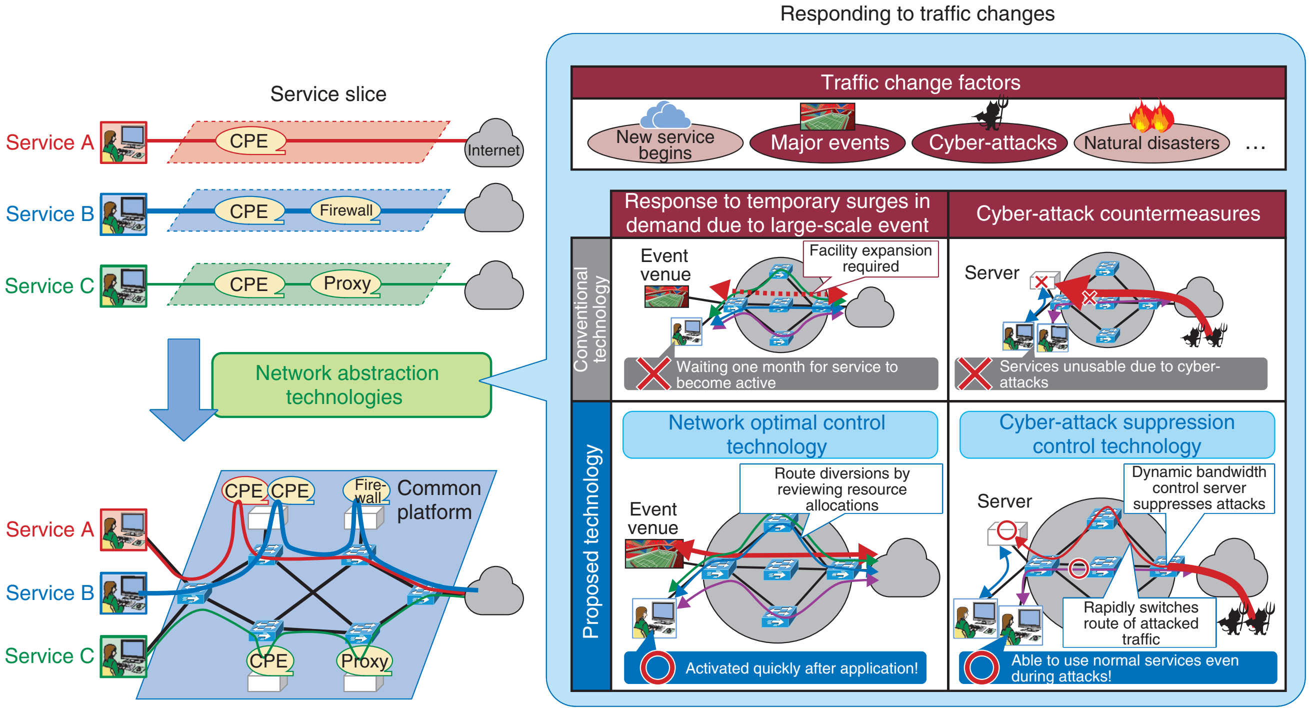


App: application
BBU: base band unit
BRAS: broadband remote access server
CP: computing
EPC: evolved packet core
NFV: network functions virtualization [3]
OLT: optical line terminal
SDN: software-defined network
VM: virtual machine

Fig. 2. Network abstraction technologies.

functions and the physical configuration are concealed and middle B operators entrust the specific configuration to us, as well as patterns in which middle B operators specify the physical configuration themselves. An example of the former would be holding a videoconference for a maximum of 10 bases within an end-to-end delay of not more than 500 ms, where the specific physical configuration is entrusted to us. An example of the latter could be placing a videoconferencing control server in a Tokyo datacenter, with the physical configuration specified.

With the entrusting pattern based on middle B operator requirements, the deployment and inter-functional path of the required network and application functions are automatically determined according to the resource usage situation and service requirements. As a result, even operators (such as those from other industries participating in the Hikari Collaboration Model) who could not previously develop network-using services due to a lack of detailed knowledge about the network can now easily initiate services. With the specified physical configuration pattern, we can support some middle B operators such as existing carriers and Internet service providers (ISPs) who require the maintenance and operation model where they understand the network's



CPE: customer premises equipment

Fig. 3. Network resource optimal control and cyber-attack suppression control technologies.

specific physical configuration and can request to change the configuration as needed according to service usage conditions. We have succeeded in providing services responding to the needs of diverse middle B operators by supporting both of these patterns.

3.2 Technology to automatically control networks based on middle B operator requirements

This technology can automate at a stroke the processes from the determination of the network configuration through to the configuration of physical equipment based on middle B operators' requirements. With this technology, automated processing takes place with a series of virtual network function installations and equipment settings based on catalogues (service slice templates whose contents were previously determined) selected by middle B operators to match the service requirements. Prompt, easy service provision is achieved by providing functions for automating a series of network configuration processes to middle B operators as service slices.

In this way, by combining the two network abstraction technologies described above, network-using middle B operators can simply and promptly provide more diverse services than were previously available.

4. Network resource optimal control technology

With virtualized networks such as NetroSphere, we provide services by assigning physical network resources to service slices created based on middle B operator requirements [2]. These resource allocations enable free and flexible operation, but the allocation has an impact on facility use efficiency, service quality, and reliability. We aim to control resources appropriately in response to various traffic changes, so here, we introduce network optimal control technologies applied to respond to temporary increases in demand (**Fig. 3**).

When hosting new services with physical networks that already accommodate numerous services, capacity may be lacking due to insufficient usable resources, and new services may not be accommodated. In such cases, we can accommodate the relevant service capacity by reviewing the overall network resource allocation. For example, we can assume there will be large-scale demand for fixed periods such as during the Olympics and the World Cup. With conventional technology, problems with insufficient resources can be solved by expanding the facilities in advance. For the carrier, however, the equipment remains idle after the event is over and becomes a case of over-investment. Moreover, customers have to wait for the service to launch during the period of facility expansion, so the application must be completed long before the actual usage period.

Accordingly, network resource optimal control technology does not involve expanding the facilities but instead accommodates new demand by redeploying existing services to alternative routes. This technology uses features of virtual networks capable of flexibly changing service slices and physical resource mapping. In this case, however, numerous restrictions must be considered. From the standpoint of operational costs, it is preferable to limit the number of resource-redeployed services as much as possible. From a service quality standpoint, it is necessary to preserve quality conditions required at different levels for each service, including bandwidth, delay, and packet loss ratios. Moreover, from a facility cost standpoint, it is desirable to expand surplus resources as much as possible after resource redeployment. The number of combinations of services for which resource redeployment is possible and that enable alternative routes is huge. Thus, it is very difficult to calculate the optimal solution to meet the above-mentioned restrictions from among all combinations. However, solutions can be discovered quickly using heuristic solutions*1.

With this network resource optimal control technology, it is possible for carriers to effectively exploit existing facilities and for customers to use services promptly.

5. Cyber-attack suppression control technology

We have been conducting research on cyber-attack suppression control technology in order to prevent cyber-attacks such as harmful distributed denial of service (DDoS) attacks*2 (Fig. 3). DDoS attacks not only impede services supplied from targeted servers but also have an impact (e.g., congestion) on the network path links that cyber-attack traffic flows through. This becomes a problem for both middle B operators and carriers. Furthermore, with conventional means to prevent cyber-attacks that install security products on networks, it is necessary to forward all cyber-attack traffic to the security products. At such times, the security products may not function very well due to issues such as the previously mentioned route congestion.

Accordingly, in addition to security products, cyber-attack suppression control technology limits the impact of cyber-attacks by controlling whole network paths and bandwidths. Examples of specific techniques include diversion route high-speed recalculation to accelerate route switching by searching for local diversion routes in the event of network congestion caused by DDoS attacks. This is deemed applicable for large networks such as ISP networks. Another technique is dynamic bandwidth control to limit the impact of cyber-attacks by dynamically controlling bandwidth so that the volume of traffic flowing to the target is distributed evenly at multiple gateways at the network endpoint nodes, and service is maintained. By using these technologies, we can provide customers with stable service quality even during cyber-attacks.

6. Future development

Any of the three technologies introduced in this article can be considered important factors in the need to realize robust networks that can respond to changes in the NetroSphere concept. In the future, in order to accelerate the implementation of these technologies, we will undertake wide-ranging collaborations both in Japan and abroad with vendors and research institutes, open source groups, and others specializing in various fields and will push forward with establishing technologies through joint research development and verification tests.

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*1 Heuristics solution: The heuristics solution uses experiential principles that may be effective to solve problems to derive executable solutions. It enables solutions to be calculated more quickly than an optimal solution, with some loss of accuracy.

*2 DDoS attack: DDoS attacks render services inoperable at targeted servers either by consuming a large amount of bandwidth by sending out packets in large volumes or exploiting loads generated by, for example, session formations and the consumption of server resources such as CPU (central processing unit) and memory. DDoS attacks can be scaled up and become more difficult to defend in the case of multiple attackers or where attackers use multiple terminals simultaneously to attack the target.

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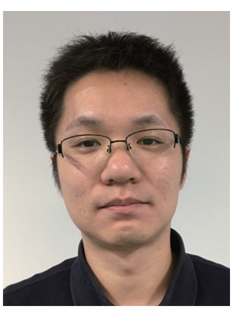

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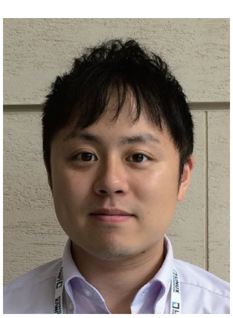

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One-stop Operation Technology

Yuji Soejima, Motomu Nakajima, and Kensuke Takahashi

Abstract

We introduce our one-stop operation technology that enables unified operation and maintenance of multiple operator networks and associated services (cloud and applications) for middle B operators in the B2B2X (business-to-business-to-X) business model.

Keywords: OaaS, B2B2X, service cooperation

1. Introduction

In business-to-business-to-X (B2B2X) business models, middle B operators (service operators) provide services for end users by freely and flexibly combining a wide variety of services such as infrastructure services and associated applications supplied by first B operators (network and cloud operators). Although first B operator services are not limited to wholesale services, in this article we refer to them as wholesale services in order to distinguish them from middle B operator services.

In order for first B operators to get middle B operators to use the wholesale services, operations concerning service orders, setting changes, and information notification when failures occur have come to be offered not through manual operations but through the use of application programming interfaces (APIs) as operation functions. Providing these operation functions as a service is called operation as a service (OaaS) [1]. Using OaaS APIs supplied by first B operators, middle B operators can apply for network and cloud services and achieve information sharing on malfunctions faster and easier than before.

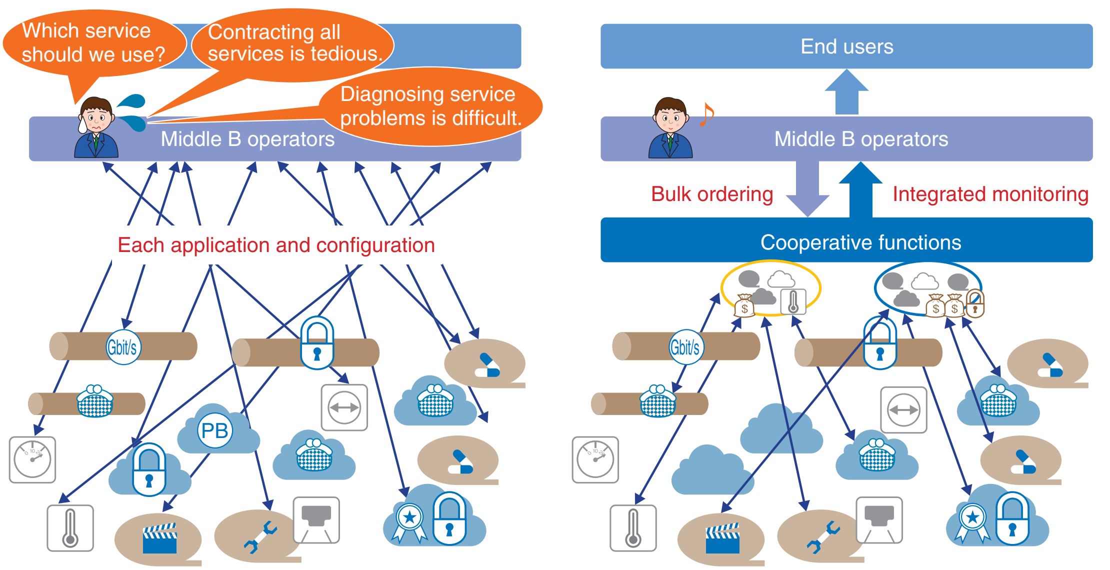
However, in the B2B2X model, middle B operators need to determine the wholesale services (such as network and cloud services) they want to combine from multiple wholesale services, apply for the wholesale services after ensuring inter-service consistency, and diagnose failures over the entire wholesale service. This means that the operation becomes very complex (**Fig. 1(a)**). Accordingly, if first B operators can consolidate multiple wholesale services and supply them as unified operation and maintenance mechanisms to middle B operators, middle B operators' operation costs can be reduced, and the prospect arises of further expanding the B2B2X model and creating more services (**Fig. 1(b)**). The mechanism that enables unified operation and maintenance is our one-stop operation technology.

The core technologies of one-stop operations are: 1) fulfillment technologies for service catalogues that abstract and federate each wholesale service supplied by first B operators, and 2) cooperative functions that enable unified operation and maintenance using each wholesale service's OaaS APIs.

2. Configuration technologies for service catalogues

Unifying the service order eases the complexity of middle B operator operations, but greater efficiencies can be achieved by preparing combinations of often-used wholesale services and basic scenarios as service catalogues and providing consolidated services. Naturally, it is necessary to customize them for middle B operators since the basic scenario alone does not fully meet the middle B operators' needs. However, using the service catalogue as a template is more effective than investigating desired wholesale services from scratch.

Simply determining combinations of wholesale services will not bring down the operational costs of elements such as orders. They must be supplied with a specific order flow including the order procedure for multiple wholesale services, the means of obtaining parameters when there are dependent relationships among services, and the method of reflecting



(a) When rolling out B2B2X models

(b) Mechanisms to enable unified operation and maintenance

Fig. 1. One-stop operation.

these parameters in the services. In order to offer a prefixed scenario of a wholesale service, the order flow specialized for that wholesale service should be created using OaaS APIs supplied by the first B operators. However, preparing all of the combined scenarios is impractical and, as mentioned previously, in real business situations, individual customizations may be necessary, and some wholesale services may need to be replaced with other wholesale services in the same category. Accordingly, it is important to have functions that link well among wholesale services and that unify operations based on the circumstances.

3. Cooperative functions

Cooperative functions maintain general-purpose service catalogues and operation flows, and they manage services by combining these catalogues and flows with individual parameters designated with each order by middle B operators. When middle B operators order services, first B operators replace the dedicated wholesale service part within the operation flow with the actual wholesale service in response to the designated parameters and use that wholesale service's OaaS APIs for application processing. Once all the wholesale service orders and construction work have been completed, the cooperative functions notify the middle B operators of the completion of the service order. The status of the order can be obtained from the cooperative functions, or individual notification requests can be made using the order options.

It is also necessary to respond to failures, reports from end users, and other matters after the start of services. Middle B operators check the health of wholesale services in parallel with the health of their own in-house facilities. While it is possible to use the OaaS APIs of the targeted wholesale service directly in order to obtain failure information, it is also possible to use OaaS APIs supplied by cooperative functions. Cooperative functions automatically gather failure information by using the OaaS APIs of the targeted wholesale service because the cooperative functions have information on the wholesale services and their interrelationships. Moreover, if cooperative functions not only consolidate the gathered failure information but also inform middle B operators of suspected failure areas, middle B operators can support end users in a timely manner.

4. Future development

At the NetroSpherePIT event [2] in 2016, we demonstrated functions that build services that overarch networks and clouds among multiple operators as use cases that provide VoD (video on demand) services from middle B operators using networks supplied by multiple first B operators, and clouds supplied by other first B operators. In this demo, networks supplied by multiple first B operators are combined with cooperative functions to construct redundant networks. Moreover, we demonstrated operational functions triggered by the detection of video degradation to estimate suspected failure areas and automatically switched networks to restore services. In the future, we aim to expand the targeted operational domain based on issues extracted from verification results, formulate general-purpose service catalogues and operation flow specifications, proceed with verifications in a commercial environment, and enhance the technologies for cooperative functions.

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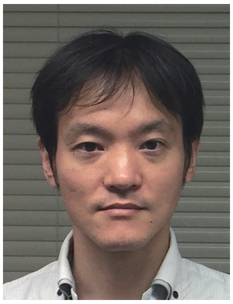

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Promoting the MSF Architecture for Flexible Networks

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Abstract

NTT Network Service Systems Laboratories is promoting Multi-Service Fabric (MSF), a network architecture that was announced in February 2015. This article describes some of the functional models that feature controllers and switches used in MSF. The research and development progress and the future outlook are also briefly explained.

Keywords: Multi-Service Fabric, commodity switch, SDN (software-defined networking) controller

1. Introduction

The objective in developing the Multi-Service Fabric (MSF) is to break away from complex network designs and complex operations that depend on the operation and performance characteristics of different vendor devices based on conventional high-cost and multifunction routers. Maximizing the use of low-cost and simple commodity devices streamlines network functions and absorbs differences between vendor devices to create a system that is easy to run. As a result, we can create an environment in which network operators and a large number of network users can easily implement and operate the networks, and a wide range of services can be provided quickly, thus contributing to the expansion of the communication network market. The progress of MSF research is summarized in **Table 1**.

2. The MSF challenge

The MSF architecture achieves the required transport capacity scale for networks of any size—from small-scale to large-scale—by combining low-cost commodity switches, which are provided by multiple vendors and are rapidly becoming popular. In addition, MSF makes it easy to build an independent and versatile logical network (hereinafter referred to as an *overlay network*) on a physical network, which will contribute to providing services securely and timely. Other carriers and OTT (over-the-top) service providers around the world are also aggressively integrating general-purpose products and open technologies into networks. NTT is progressing in a similar direction and aims to develop the world's first uniform network architecture using commodity switches that realize new networks—from small networks inside a building to wide area networks between buildings—and enables delivery of a quality of service that even carriers can use.

3. Key advantages of MSF architecture

MSF architecture has the following advantages.

(1) It flexibly provides an optimally scaled network suitable for a variety of use cases.

(2) It enables use of multiple kinds of vendor devices without requiring awareness of the characteristic differences.

(3) Use of simple devices and network topology, and automation of network control through controllers eliminate the need for advanced operating skills.

(4) It enables the use of ideal commodity devices in step with technical progress to minimize purchasing and operating costs.

Table 1. Progress of MSF research.

July 2014	Architecture is named Multi-Service Fabric (MSF).
August 2014	Proof of concept (PoC) studies begin with two global vendors.
February 2015	Press release is issued on the NetroSphere concept.
	First conceptual demonstration is held at NTT R&D Forum 2015.
May 2015	The head of NTT Network Service Systems Laboratories delivers the keynote address at Network Virtualization SDN World conference held in London, UK.
August 2015	First successful PoC is achieved at global vendor venue.
October 2015	Lecture is given on SDN & OpenFlow World Congress held in Düsseldorf, Germany.
February 2016	Completion and successful demonstration of first prototype at NTT R&D Forum 2016
June 2016	Keynote address is delivered at Network Virtualization & SDN Europe held in Madrid, Spain.

SDN: software-defined networking

4. Architecture overview

The architecture is based on the policies outlined below. The concept of the architecture is shown in **Fig. 1**.

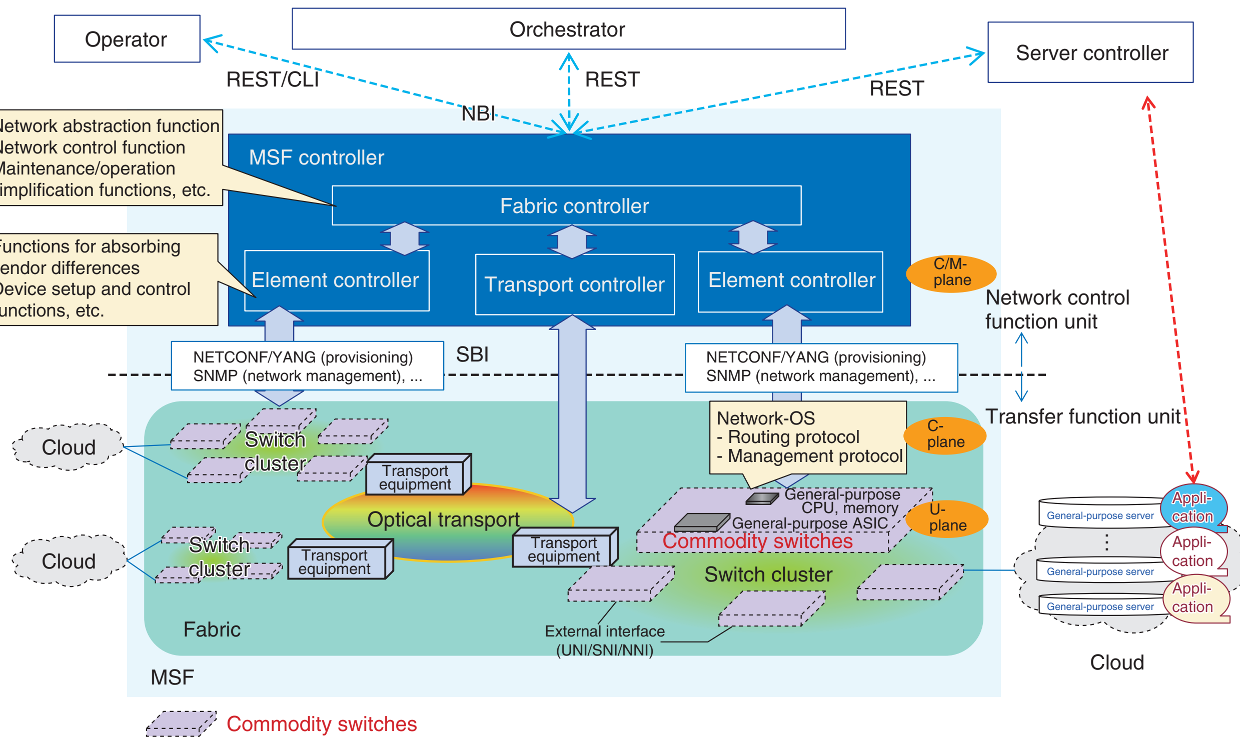
- The architecture is comprised of commodity switches that are effective for high-speed transmission, controllers that combine these switches and carry out control as a switch cluster, and servers featuring advanced functions, all of which enable independent extension.
- The network provides service-independent transfer functions. Service-dependent functions are implemented in the cloud server.
- As for basic transport functions, the autonomous distribution function (especially layer 3 (L3) function (IP/MPLS: Internet protocol/multiprotocol label switching)) in the network operating system (Network-OS) that runs on the network device ensures network scale and stability that are required for a carrier quality of service. The controller controls the configuration of the overlay network (a hybrid model consisting of autonomous and external control).
- The provided network can be connected to the existing network and user devices, and it supports the general protocols on the existing network, enabling quick installation.
- Commodity hardware, open software, and open interfaces will be used to the greatest possible extent.
- The functions and performance of commodity switches with limited functionality will be expanded by the controller using switch cluster configuration technology and control technology.
- To support a wide range of applications, the controller provides maintenance personnel, orchestrators, and server cloud controllers with a northbound interface (NBI) of general representational state transfer (REST). In addition, maintenance is simplified thanks to functionality that visualizes the architecture as an abstract network to the upper orchestration system.
- The MSF controllers are composed of fabric controllers with network control functions and a function to abstract networks, as well as element controllers with a function to absorb the differences between vendors of individual clusters and a function to control settings, which improves the scalability of future systems.
- The same architecture is applied for various networks such as datacenter networks inside buildings and wide area networks used by carriers. The architecture also makes it possible to control the linkage with transmission systems used in connections between offices.

5. Key functions implemented by controllers

The controllers that manage MSF consist of an application function unit that implements network control and operation functions, and a platform unit that provides the necessary platform to run these functions.

5.1 Application function unit

The application function unit provides the underlay network control function that achieves the automated configuration of the cluster network and frees operators from having to carry out time-consuming device-dependent configuration tasks and device model-dependent



ASIC: application-specific integrated circuit
CLI: command line interface
CPU: central processing unit
NNI: network-to-network interface
SBI: southbound interface
SNI: application server network interface (also known as ANI or application network interface)
SNMP: Simple Network Management Protocol
UNI: user network interface

Fig. 1. MSF architecture overview.

Network-OS upgrades. It also provides the overlay network control function that complements the capacity limitation of switches by providing elements such as an overlay network and route aggregation, and the maintenance/operation simplification function that can easily manage switches as a cluster and obtain information on traffic exchanges in the cluster.

5.2 Platform unit

The platform unit controls and manages individual device components and makes the greatest possible use of open software and open interfaces. The following interfaces can be used:

- NBI: REST, CLI (command line interface)
- SBI (southbound interface): SNMP (Simple Network Management Protocol) Trap/MIB (management information base), NETCONF (Network Configuration Protocol)/YANG (Yet Another Next Generation), Telnet (CLI), LLDP (Link Layer Discovery Protocol)

To quickly achieve control of the device settings of multi-vendor network devices, SBI has a mechanism capable of absorbing the differences between vendor devices (driver functions) and the APIs (application programing interfaces) that enable device vendors to prepare drivers. In addition, a basic redundancy functionality required for commercial operation is also provided.

6. Functions provided by the network

The following protocols and functions are provided for external networks and connected devices (CE: customer edge) by the switch cluster.

- Service (overlay network) functions: L2 virtual private network (VPN), L3VPN (IPv4/IPv6)
- Ports provided for CE: VLAN (virtual local area network)-Tag (IEEE802.1q) enable/disable, link

aggregation (IEEE802.3ad) enable/disable in combination
- Connection mode for CE in L3VPN: Direct (connected/VRRP (Virtual Router Redundancy Protocol)) connection, a static connection, OSPF (Open Shortest Path First) connection, BGP (Border Gateway Protocol) connection

7. Future development

By the beginning of 2017, we will have integrated a switch cluster and controller in a field-trial-ready product. Initially, we are targeting a single cluster in buildings and aim to commercialize a product that links the cluster to a server cloud by 2017. We welcome partners who will collaborate with us on the MSF project for global roll-out. We are promoting this project to assist suppliers of MSF-compatible devices and controllers and integrators that build MSF systems for customers.

NTT is considering making public the MSF specifications and the know-how involved in verification procedures, and if required, the controller source code also, to make it easier for a large number of partners to participate in the MSF project.

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MAGONIA (DPB: Distributed Processing Base) Applied to a Traffic Congestion Prediction and Signal Control System

Hiroaki Kobayashi, Takehiro Kitano, Mitsuhiro Okamoto, and Takeshi Fukumoto

Abstract

High computational capacity and high fault tolerance are required in advanced social infrastructures such as future intelligent transportation systems and smart grids that collect and analyze large amounts of data in real time and then provide feedback. This article introduces application examples of the distributed processing technology of MAGONIA, a new server architecture (part of NetroSphere), in a traffic congestion prediction and signal control system, one of the social infrastructures currently under development at NTT DATA.

Keywords: MAGONIA, distributed processing, intelligent transport system (ITS)

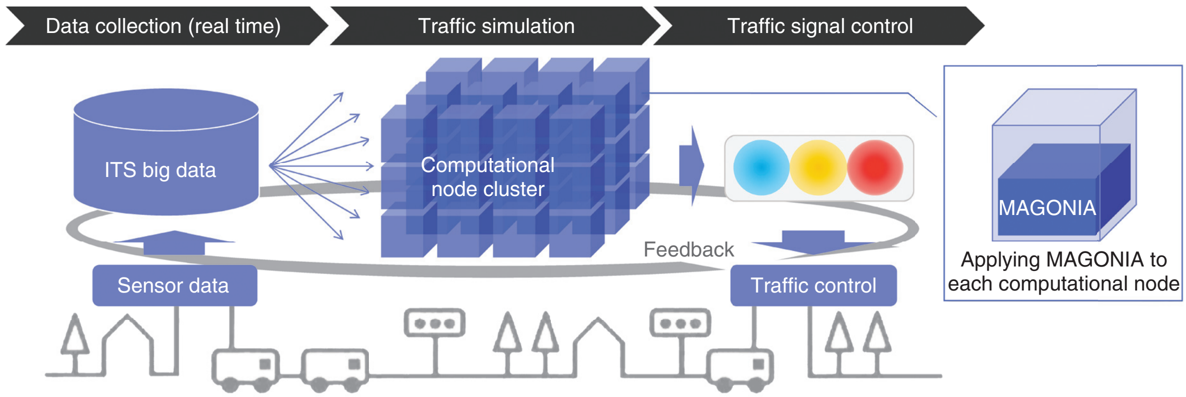
1. Introduction

NTT Network Service Systems Laboratories is currently carrying out research and development on MAGONIA, a new server architecture and part of the NetroSphere concept, to quickly create new services and drastically reduce CAPEX/OPEX (capital expenditures and operating expenses) [1, 2]. The distributed processing base (DPB), the core technology of MAGONIA, provides the high fault tolerance, scalability, and short response time that telecom systems need. Since these functions are required in systems other than telecom systems, we aim to create new services and reduce development time by increasing the application range of MAGONIA. To this end, we have been collaborating with NTT DATA in experiments [3] since September 2015 to assess its applicability to a traffic congestion prediction and signal control system [4].

2. Overview of joint experiments

The traffic congestion prediction and signal control system analyzes vehicle behavior in a target area from a large amount of sensor data obtained in real time (referred to below as *traffic simulation*) in order to control traffic signals based on the results (**Fig. 1**). The system requires high fault tolerance for commercialization. Since the computational power required by the traffic simulation changes with the traffic volume, the system must be scalable to flexibly cope with increases and decreases in load. In addition, a short response time is necessary to feed back the analysis results to traffic signals within the time limit.

These issues must be solved to enable commercialization of the traffic congestion and signal control system. Therefore, the existing traffic simulation logic was ported to the MAGONIA DPB, and the resulting system was tested to assess its feasibility in terms of fault tolerance, scalability, and response time.



Traffic congestion prediction and signal control system: Large amounts of sensor data are collected in real time. The system uses the data to analyze traffic tendencies in a target area (traffic simulation) and control traffic signals based on the analysis results to reduce congestion. Applying the MAGONIA DPB to computational nodes performing traffic simulation improves the fault tolerance and scalability.

ITS: intelligent transportation system

Fig. 1. Traffic congestion prediction and signal control system overview.

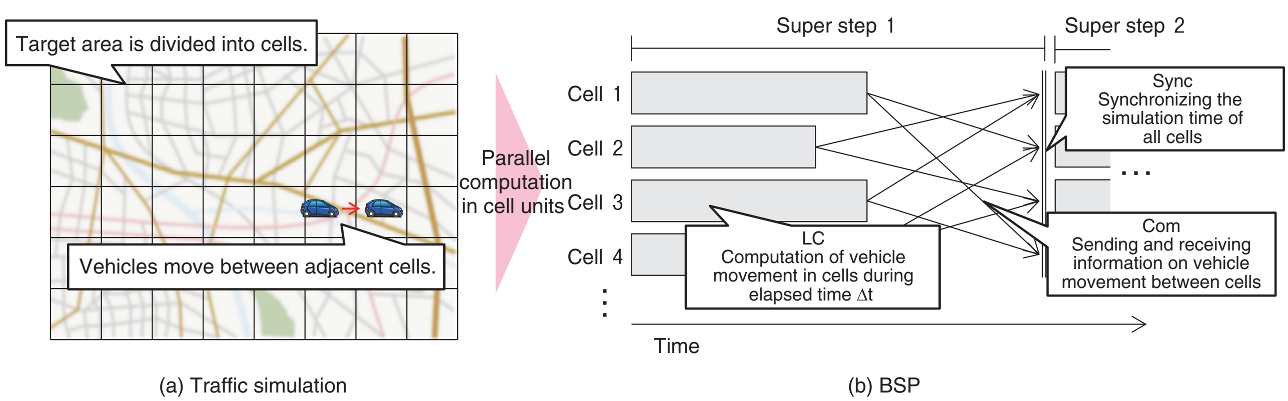


Fig. 2. Model for processing traffic simulation.

3. Computational model for traffic simulation

In traffic simulation, processing must be completed within the feedback cycle required for the traffic signal control. To satisfy this requirement, target areas for simulation are divided into small areas (referred to as *cells*), and multiple computational nodes are used to perform parallel processing of cells. Since vehicles are likely to move between cells in the meantime, computations in each cell are not completely independent and require cooperative operation between cells.

A model called bulk synchronous parallel (BSP) [5] is used to enable effective processing. BSP consists of repeated processing in a series of *super step* units that involve the three phases of local computation (LC), communication (Com), and synchronization (Sync). The processing in each phase of traffic simulation is summarized in **Fig. 2**.

4. Applying MAGONIA DPB

The effectiveness of the MAGONIA DPB has been demonstrated in telecom services. In such services, load is distributed in session units (example: call units). Because sessions are independent and stay

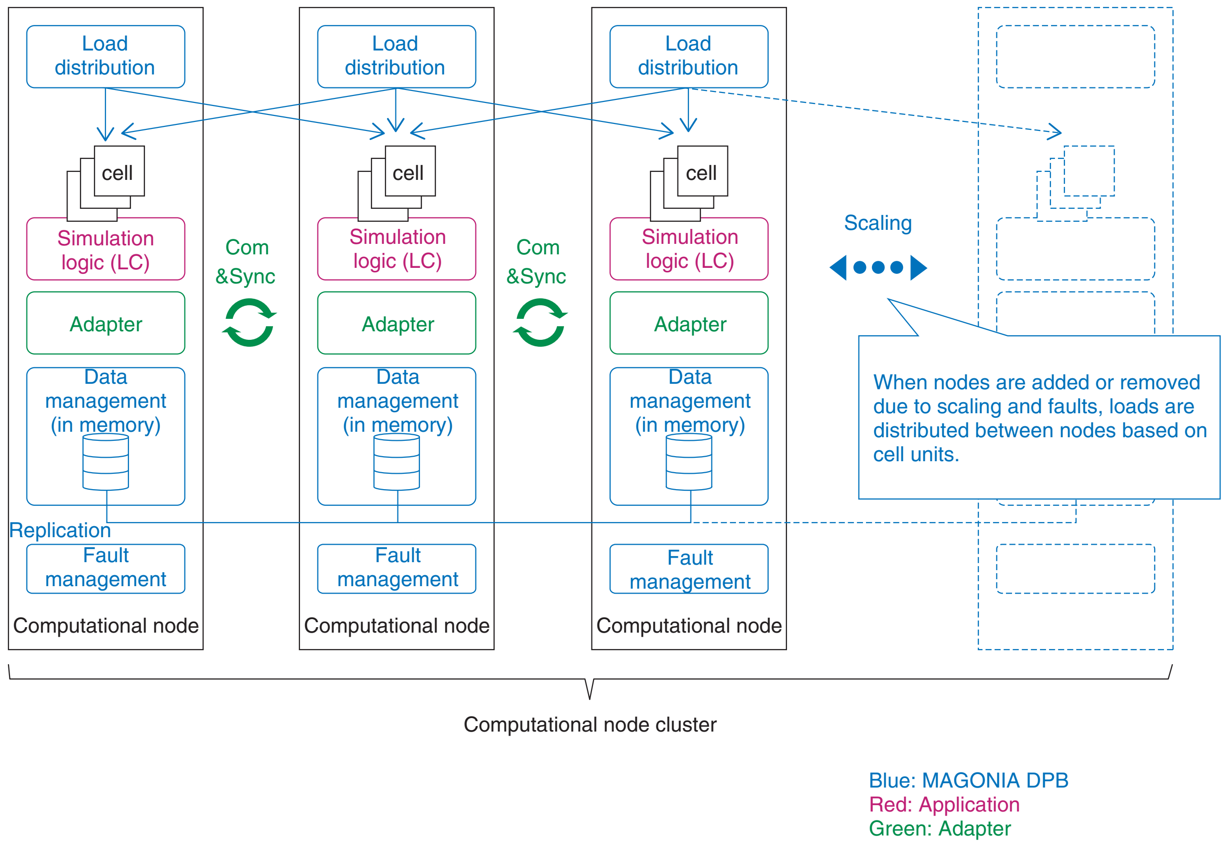


Fig. 3. Traffic congestion prediction and signal control system on the DPB.

independent in distributed processing, the operation characteristics differ considerably from the previously mentioned BSP model. To bridge this gap, new adapters supporting Com and Sync were added to the system (**Fig. 3**). With this approach, we have successfully implemented the traffic simulation on top of the DPB while minimizing the modification of the existing traffic simulation logic.

4.1 System overview

The traffic system implemented on top of the DPB (Fig. 3) performs the following procedure. Firstly, the system distributes processing in the computational node clusters based on cell units. Each computational node then executes LC for each cell it is assigned to, and upon completing LC, it continues to the Com phase and sends the data to adjacent cells. When the Com phase is completed, it continues to the Sync phase, after which it starts the next super step.

4.2 Improved fault tolerance

To guarantee fault tolerance, the DPB supports checkpointing. The checkpoint of each cell is replicated to multiple computational nodes, and should a node fail, another node with a respective replicated cell unit will automatically fail over (take over processing). In this way, by replicating checkpoint and distributing failover on a cell-by-cell basis, the system can lessen the increase in the load.

In this experiment, it was verified that instant failover made it possible to complete simulation within the feedback cycle, even when a computational node failure occurred during traffic simulation. The capability to minimize the impact of faults to this high degree is a major characteristic of the MAGONIA DPB. Because checkpointing and failover are completed in the computational node cluster, fault tolerance can be achieved without relying on external data storage.

4.3 Improved scalability

The DPB supports the addition and removal of computational nodes without interrupting the simulation. To cope with load fluctuations due to changes in traffic volume, the number of computational nodes and the mapping of cells and computational nodes change dynamically to ensure there is a sufficient amount of resources. Through experiments, it was verified that it is possible to dynamically add and remove computational nodes without interrupting traffic simulation.

4.4 Reduced response time

Placing data in the memory of a computational node that executes LC reduces network and disk input/output. Additionally, overlapping LC and Com by assigning different threads to LC and Com minimizes time overheads. We were able to verify in experiments that the high speed of the new infrastructure made it possible to complete the traffic simulation within the feedback cycle to traffic signals.

5. Future outlook

In the future, we will use actual sensing data to assess the system. In addition to the telecom systems and ITS (intelligent transport systems) described here, MAGONIA will also be extended to a wide variety of services that demand fault tolerance and scalability.

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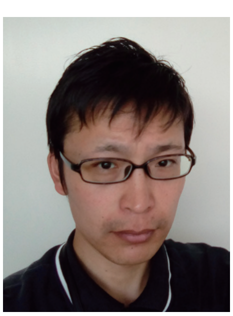

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MAGONIA (Soft Patch Panel): High-speed Inter-function Technique

Tetsuro Nakamura, Yasufumi Ogawa, Naoki Takada, and Hiroyuki Nakamura

Abstract

NTT Network Service Systems Laboratories is aiming to create a wide range of services by building a transport cloud enabling a combination of transport service functions to be provided. This requires that there be no function degradation between service functions. This article presents Soft Patch Panel (SPP), a high-speed inter-function technique developed in collaboration with Intel Corporation. SPP reduces communication delays between functions and makes it possible to combine a variety of service functions.

Keywords: high-speed communications, virtualization, server

1. Introduction

NTT aims to become a catalyst to provide services to a variety of players, changing from the conventional B2C (business-to-consumer) business model based on communication lines. A business-to-business-to-X (B2B2X) business model represents this change of course. The *middle B* (in B2B2X) will be able to freely interconnect transport service functions such as carrier routers or firewalls and make it possible to create a variety of services, as shown in **Fig. 1**.

2. Functions provision and virtualization technology

Transport service functions in a carrier network were formerly provided using dedicated hardware developed for each function. In this type of configuration, functions and hardware were integrated. Thus, a resource seldom used for one function computation could not be made available to another function. This created a surplus of resources, leading to inefficiencies.

Virtualization technology provides a virtualization layer between the hardware and each function in order to conceal the functions from the hardware. Separating the functions from hardware through the use of virtualization technology makes it possible to assign the required amount of computational resources when needed to a function without having to consider the hardware, thus achieving flexible and efficient networks.

For example, in a virtualized network where functions are separated from the hardware, there is no need for dedicated hardware per function, and a single general-purpose server can run multiple virtual machines (VMs) and provide functions for each VM. However, conspicuous degradation of performance is a problem with virtualization. In the following section, we introduce a case of inter-function routing in a virtualized network.

3. Problem with inter-function technique

In conventional networks that are not virtualized, hardware switches are used to connect equipment in order to interconnect multiple functions. In a virtualized network, multiple VMs run on a single general-purpose server. For this reason, it is necessary to create switches to connect VMs on the general-purpose server to interconnect multiple functions. As an example, in OpenStack[*1], an integrated virtualization

*1 OpenStack: Software developed as open source for building a cloud environment.

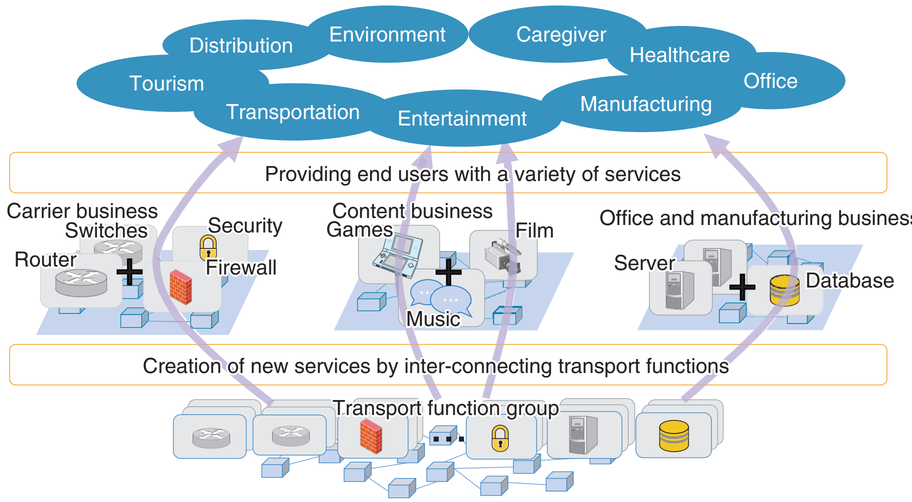

Fig. 1. The B2B2X model NTT aims to achieve.

environment, the Open vSwitch (OvS)*2 software switch has become standard for connecting VMs. However, OvS does not provide adequate performance because the software is used to perform processing that was previously performed by hardware switches. As a result, network processing to pass packets from a physical network interface card (NIC) to a VM, or from one VM to another VM, tends to create a bottleneck for the entire system.

Some commercialized technologies avoid this bottleneck by completely ignoring software switching in virtualization and by directly showing the physical NIC to the VM (pass-through technology). For example, single root input/output virtualization (SR-IOV)*3, one example of a pass-through technology, directly shows the physical NIC to the VM and achieves software switch processing using the hardware functions in the physical NIC. However, increasing the number of VMs without adding physical NICs creates bottlenecks in the hardware, and connection switching cannot be performed dynamically. This makes the separation of functions and hardware incomplete, which greatly reduces the advantages of virtualization.

4. Soft Patch Panel

Soft Patch Panel (SPP) is a new technique that enables high-speed and flexible inter-functions to resolve the problems described in the previous section [1]. SPP speeds up processing in a way that differs from the pass-through technology of SR-IOV that directly shows the physical NIC to the VM. In this case, shared memory is provided between VMs, and because each VM can directly reference the same memory area, the copying of packets that creates a bottleneck in a conventional virtualization layer is eliminated (**Fig. 2**). Moreover, a high-speed technology called the Intel Data Plane Development Kit (Intel DPDK)*4 is used to exchange packets between the physical NIC and shared memory.

Use of this configuration enables SPP to perform as well as or better than SR-IOV. As stated above, when the number of VMs increases and SR-IOV is used, the physical NIC hardware function performs the packet distribution, which means that a physical NIC must be added to obtain sufficient processing performance. In contrast, SPP provides high speed functionality in a configuration where functions are separated from hardware. High performance can thus be obtained without adding a physical NIC, as shown in **Fig. 3**.

In this type of configuration, input and output destinations of packets can be changed by controlling each referenced VM memory area via software. This means that SPP implements dynamic exchanges between VMs and between a VM and physical NIC. Thus, network operators do not need to be aware of complex configurations such as memory space, and

*2 OvS: A virtualization switch developed as open source.
*3 SR-IOV: A pass-through technology that improves I/O performance in a virtualized environment.
*4 Intel DPDK: High-speed technology that omits packet processing in the operating system kernel. Intel is a trademark of Intel Corporation or its subsidiaries in the U.S. and/or other countries.

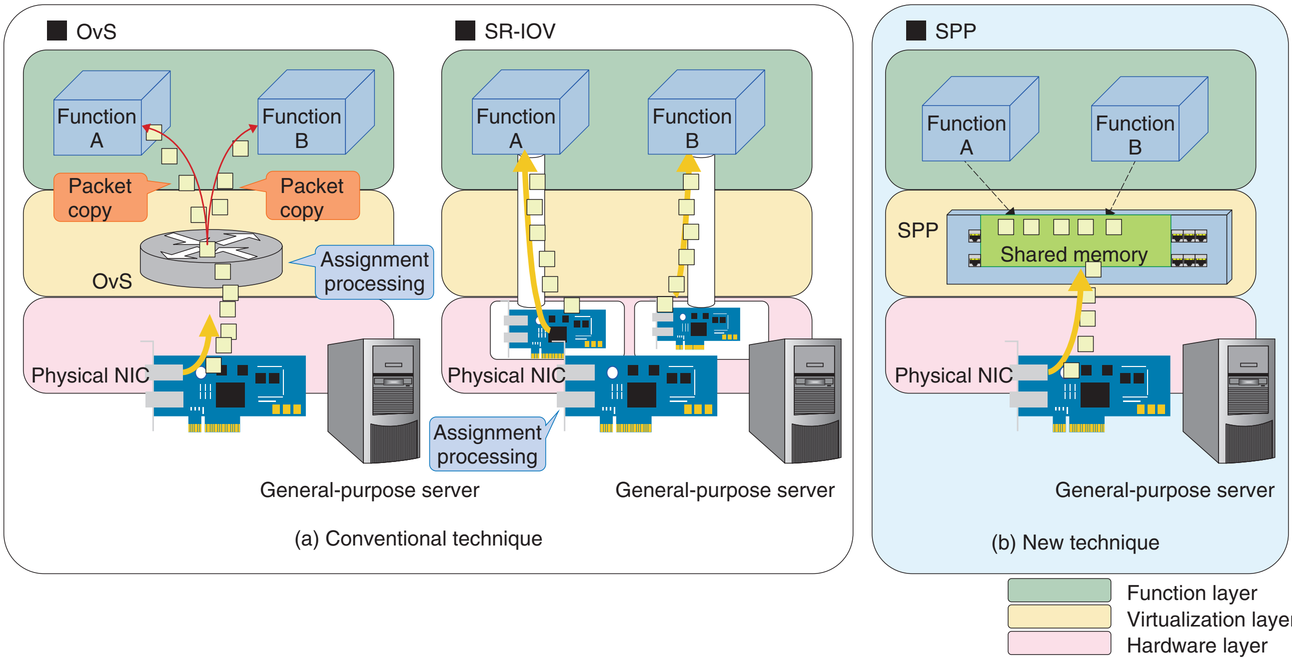

Fig. 2. Configuration image of SPP and conventional technique.

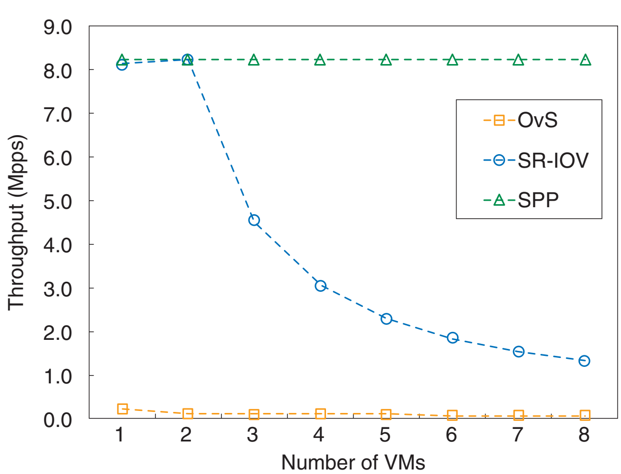

Fig. 3. Results of SPP performance assessments.

simple terminal operations are sufficient to make connection changes in real time. This type of connection switching used to be performed by patch panels. SPP now makes available a patch panel in a virtualized network, enabling network control via software.

Use of SPP as basic technology in the infrastructure allows network operators and the *middle B* to flexibly combine transport service functions in a carrier network without degrading performance.

5. Future outlook

SPP is being developed in a collaborative research project with Intel Corporation. NTT and Intel share objectives and directions and discuss product requirements. Then Intel produces a product based on these discussions, and NTT assesses it. The implemented SPP has been made available on the Internet as open source software. Commercialization requires continued comprehensive efforts such as improving security and adding maintenance management functions.

Going forward, we will further improve SPP by utilizing it in various use scenarios and making it even easier to use so that it will contribute to the creation of new services, bring added value, and help to realize the NetroSphere concept.

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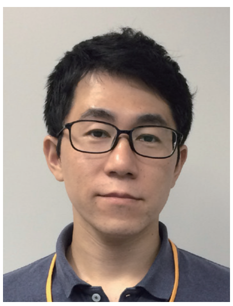

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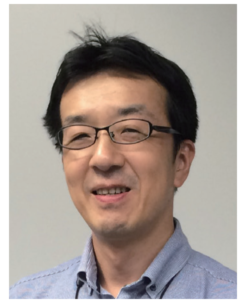

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Spatial and Planar Optical Circuit (SPOC) Technology and Its Application to Photonic Network Devices

Yuzo Ishii, Yuichiro Ikuma, Kota Shikama, and Kenya Suzuki

Abstract

Because photonic networks have evolved from point-to-point systems to ring or mesh networks, higher scalability is required in the devices used in optical nodes. Hybridization of waveguide and free-space optics or spatial and planar optical circuits (SPOCs) may provide the necessary solutions to meet this requirement. A SPOC platform is attractive because it can take advantage of both waveguide technology and free-space optics. Waveguide technology provides a high degree of integration of optical functionality for such devices as splitters and non-wavelength selective switches, while free-space optics supplies a high degree of parallelism with two-dimensional spatial light modulators such as liquid crystal on silicon (LCOS) devices. In this article, we summarize the basics of SPOC technology and review its application to reconfigurable optical add/drop multiplexing (ROADM) devices. The key element of a waveguide on a SPOC platform is the spatial beam transformer, which has the same circuit structure as an arrayed waveguide grating but functions as a microlens array and provides attractive features such as dense integration of switches. An LCOS device has numerous phase modulating pixels, enabling flexible manipulation of lightwaves. We used a SPOC platform to construct and demonstrate several types of wavelength selective switches for ROADM applications.

Keywords: spatial and planar optical circuit (SPOC), wavelength selective switch, free-space optics

1. Introduction

As photonic networks have evolved from point-to-point systems to ring or mesh networks, reconfigurable optical add/drop multiplexing (ROADM) systems have been deployed, which are required to have colorless, directionless, and contentionless (CDC) capabilities [1]. Optical switching devices such as wavelength selective switches (WSSs) and multicast switches (MCSs) are important components in CDC-ROADM systems. Although waveguide-based WSSs were first proposed in early ROADM networks [2, 3], free-space optics based configurations have mainly been deployed in the actual systems only since the end of the last decade. The free-space optics based approach enables us to provide not only a sharp wavelength filter due to a high spatial resolution but also port scalability due to a high degree of parallelism. The MCS, on the other hand, is constructed based on waveguide technology [4] since it does not provide any wavelength-selective operation, which usually requires a bulk grating component located in the free space.

Combining waveguide technology with free-space optics can provide a solution that is not achievable using either method individually. The use of an arrayed waveguide grating (AWG) in combination with a MEMS (microelectromechanical systems)

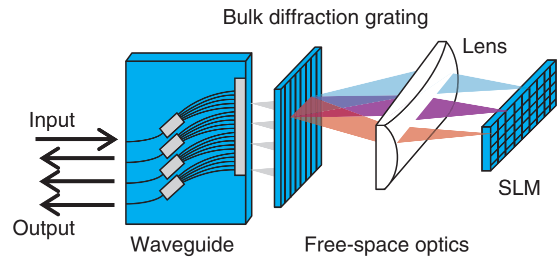


Fig. 1. SPOC concept; a waveguide device with highly controlled multiple beam emission is used as an I/O interface between fiber optics and free-space optics, and traditional bulk optics including a grating, lenses, and SLM are used in the latter part.

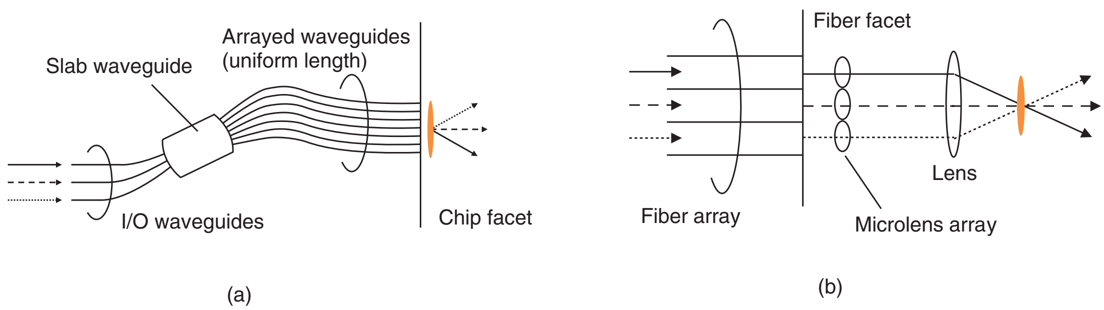


Fig. 2. Optical frontend configurations: (a) SBT circuit for launching three beams with different angles from the same position at the chip facet. (b) Equivalent optical design based on conventional discrete lenses.

mirror was first proposed in 2001 [5], and since then, several ideas including the use of a wavelength blocker [6, 7], tunable optical dispersion filter [8–13], and WSS [14–17] have been reported.

In this article, we describe our study, which is focused primarily on WSSs, and explain our concept of a spatial and planar optical circuit (SPOC) that combines the waveguide and free-space optics to get the best of both technologies.

2. SPOC [18]

An example of the SPOC concept is illustrated in **Fig. 1**. The waveguide frontend is used as an input/output (I/O) component for interfacing with the fiber optics and free-space optics, and traditional bulk optics including a grating, lenses, and spatial light modulator (SLM) are used in the free space to complete the design. The diffraction grating needed to implement the WSS is located with its dispersion axis aligned normal to the waveguide.

One unique and essential circuit element in the waveguide is a spatial beam transformer (SBT) [19], as shown in **Fig. 2(a)**. The SBT consists of multiple I/O waveguides, a slab waveguide, and arrayed waveguides. The SBT has a similar layout to that of a conventional AWG, but the path length difference of the arrayed waveguides is set to zero. It functions as follows. A lightwave input from the center input waveguide (indicated by the dashed arrow in Fig. 2(a)) spreads in the slab waveguide, couples to the arrayed waveguides, and exits from the chip facet to free space. Arrayed waveguides with a uniform path length difference maintain the wavefront of the lightwave so that a plane wave is output from the facet. Changing the input to another waveguide (indicated by a solid or dotted arrow) tilts the wavefront, so the output wavefront is also tilted.

Furthermore, it is also possible to bend the wavefront by controlling the path length among the arrayed waveguides so that one can launch not only a collimated beam but also a converging (or diverging) beam. The design flexibility in the SBT enables us to remove the discrete microlenses in the front of the fiber array. The equivalent optical design using conventional optics is shown in **Fig. 2(b)** for comparison.

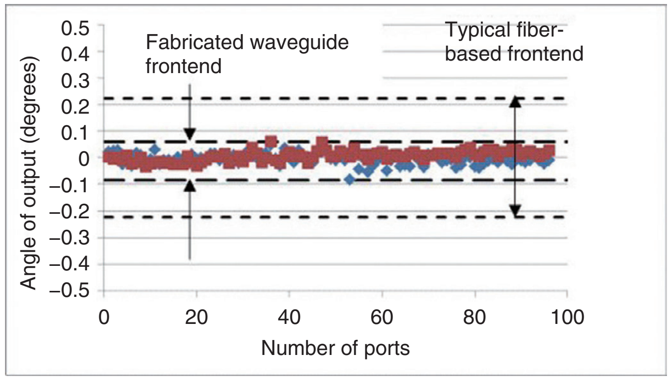
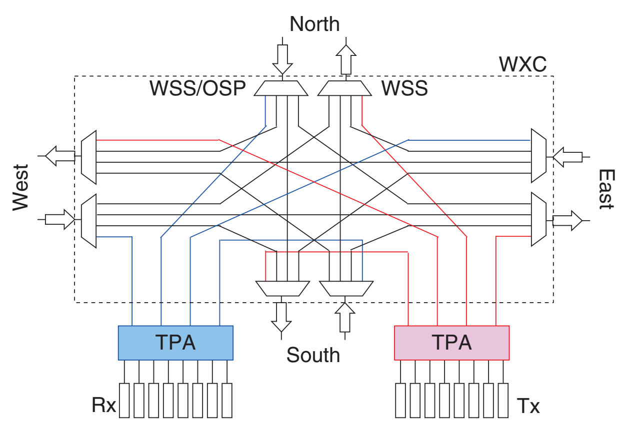


Fig. 3. Pointing accuracy measured for 96-SBT array. Red and blue dots respectively indicate TE (transverse-electric) and TM (transverse-magnetic) polarization.



OSP: optical splitter
Rx: receiver
Tx: transmitter
WXC: wavelength cross-connect

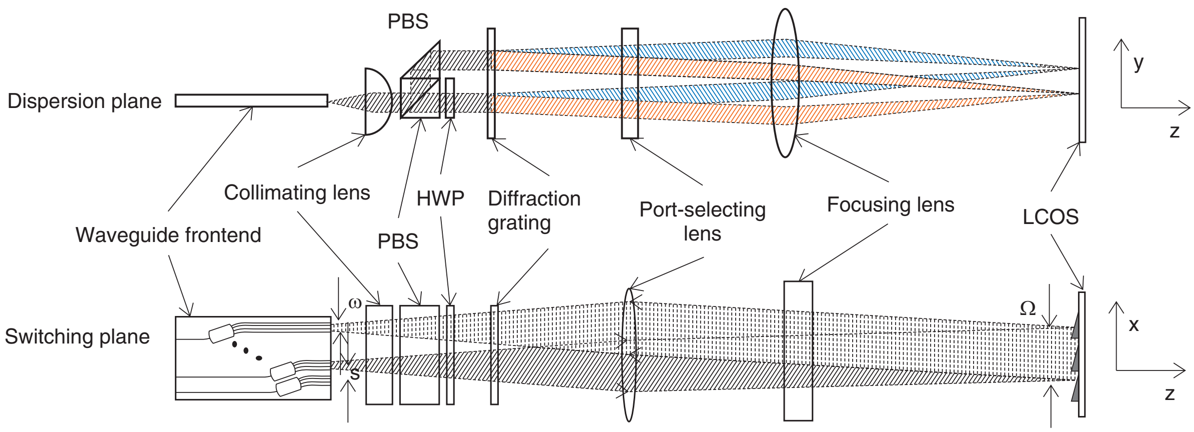
Fig. 4. Schematic configuration of typical CDC-ROADM.

The integration of (micro)lenses means that the SBT is suitable for packaging the ports densely. Moreover, the beams are expected to be positioned well because there is no misalignment with the microlenses. The uniformity of the launched beam angle over 96 SBT circuits fabricated using the standard silica-based planar lightwave circuit (PLC) process is shown in **Fig. 3**. Excellent pointing accuracy less than +/-0.1 degrees was obtained for both polarizations, which is three times smaller than in the typical fiber-array-based frontend. The launch angle is translated into the transmission wavelength of a conventional AWG. Adjustment of the transmission wavelength in an AWG is well established, so the launch angle in the SBT can also be controlled well.

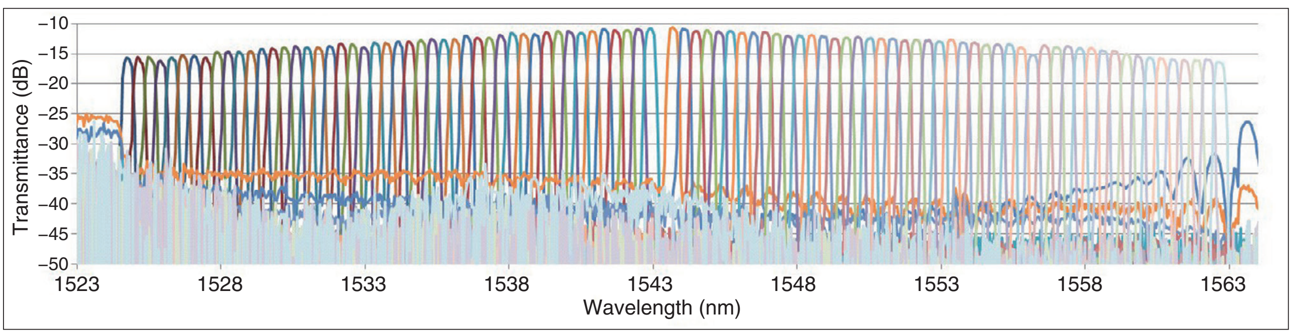
Some applications using SPOC are described in the following section.

3. Applications of SPOC

A typical node configuration for a CDC-ROADM network is shown in **Fig. 4**. The building blocks of each node consist of a WSS, a transponder aggregator (TPA), and optical amplifiers. Some of the wavelength division multiplexing (WDM) signals arriving at a node are routed by the WSS in different



(a)



(b)

Fig. 5. (a) Optical system schematics of a 1 × 95 WSS in two orthogonal projections. (b) Superimposed transmission spectra of 95 curves that were taken at the different ports.

directions. The remaining signals are dropped and added at the node. They are directed from/to the TPA to/from the WSS.

3.1 Ultra-high port count WSS [20]

Port scalability is important for WSSs used in CDC-ROADM nodes because each node has to deal with a large number of WDM channels. For example, for an 8-degree node with 88 wavelength channels, the total number of WDM channels is 704. If 8 × 8 MCSs are used as the TPA, a WSS with 95 output ports (88 for the TPA; 7 for the other directions) is needed to achieve a drop rate of 100%.

The 1 × 95 WSS optical design using the SPOC technology is shown in **Fig. 5(a)**. This ultra-high port count WSS consists of a waveguide frontend, a collimating lens, polarization diversity optics (polarization beam splitter (PBS) and half-wave plate (HWP)), a diffraction grating, port-selecting and focusing cylindrical lenses, and an LCOS-based SLM.

The WDM signal input to the waveguide frontend is radiated into free space. The signal is collimated with a collimating lens in a direction normal to the waveguide substrate (y-axis). Because the LCOS is a polarization-sensitive device [21], we implemented polarization diversity optics in which the signal is split into two orthogonal linear polarizations along the y-axis. One of them is rotated 90 degrees with the HWP so that the linearly polarized signal is incident to the LCOS. The signal then passes through a diffraction grating of which the dispersion direction is along the y-axis. Next, the signal is collimated in the x-axis direction by the port-selecting lens and focused along the y-axis by the focusing lens. The SLM reflects the signal back along the same route to the frontend in the y-axis while it steers the signal so that

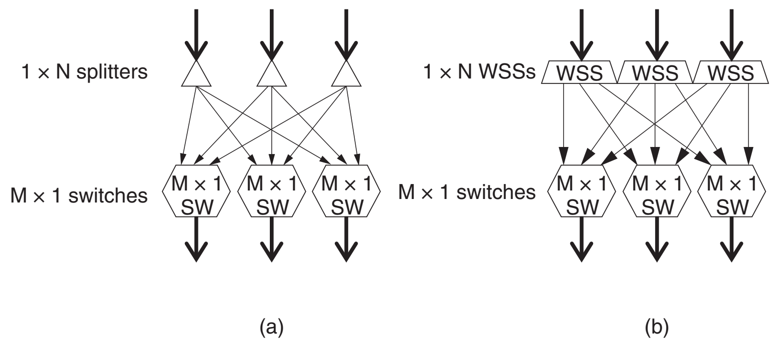


Fig. 6. Functional diagram of M × N TPAs: (a) MCS and (b) proposed low-loss TPA.

it hits a different position on the frontend in the x-axis. Hereafter, we call the x- and y-axes the switching and dispersion axis, respectively.

The SBT circuit was designed to have a beam radius of 26 µm at the chip facet with a port-to-port separation of 117 µm; therefore, the total effective aperture and physical chip size in the x-axis are only 11.2 and 17.5 mm, respectively. With the help of the high-dispersion grating, the respective focal lengths of the port-selecting and focusing lenses are 150 and 100 mm. The transmission spectra of the 1 × 95 WSS, in which each of the 95 WDM channels was routed to different output ports, is shown in **Fig. 5(b)**.

3.2 Low-loss TPA [22]

Another key device for constructing a CDC-ROADM node is a TPA; to date, a PLC-based MCS has been the only commercial solution. A block diagram of the MCS is shown in **Fig. 6(a)**. Incoming WDM signals are first broadcast by N, which is the number of transponders connected to the MCS. M units of the 1 × N splitters are integrated in one chip, where M is the number of degrees in the ROADM node. N units of M × 1 switches are also integrated to select one route of M degrees to send to a transponder.

Although the silica-based PLC has been matured and has proved to have high reliability, the MCS suffers from a principle loss of splitting. Therefore, it is becoming impractical with the scaling up in the number of transponders.

Another approach to implement the M × N TPA is shown in **Fig. 6(b)**. Here, M units of 1 × N WSSs and N units of M × 1 switches are connected. Unlike the MCS, each output port is connected to only one input port at a time; this is a necessary and sufficient functionality for a TPA because each transponder handles a single wavelength channel at a time. Since it has no splitters inside and therefore no intrinsic loss, this WSS-based TPA is preferable for a large scale TPA with large N compared to a conventional MCS-based TPA.

Using the SPOC platform enables the frontend of the M units of 1 × N WSSs and N units of 1 × M switches to be integrated in one chip, as shown in **Fig. 7(a)**. The M × 1 switch can be made with Mach-Zehnder interferometers in a tree arrangement with TO (thermo-optics) phase shifters, as shown in **Fig. 7(b)**. The diagram in Fig. 7(a) illustrates the case for M = 4 and N = 4. WDM signals from four different directions are input from the ports labeled *M fiber direction* and multiplexed in the angular domain by SBTs. They hit different areas on the LCOS, and each one supports a different WSS. This means that multiple WSSs can be angularly multiplexed.

The measured spectra of the fabricated 8 × 24 TPA are shown in **Fig. 8**, where 24 WDM signals of the 50-GHz-grid channel spacing in the C-band were independently routed to 24 output ports. The 24 graphs correspond to the output ports, and each plot has eight curves representing the input ports.

We can see directionless and contentionless switching from the set of graphs for output ports 1, 5, 9, and 13, where the same wavelengths from different input ports were routed to different output ports. Wavelength selective switching is clearly evident in the set of graphs for output ports 2, 6, 10, and 14, where four different channels from input port 3 were routed to different output ports. Flexible-grid operation is also clearly evident in the set of graphs for output ports 4, 8, 12, and 16, showing respectively that 50-, 100-, 150-, and 200-GHz transmission bands were obtained. The minimum insertion loss was 10.7 dB, which is lower than the theoretical loss of 13.8 dB of an MCS with the same port count.

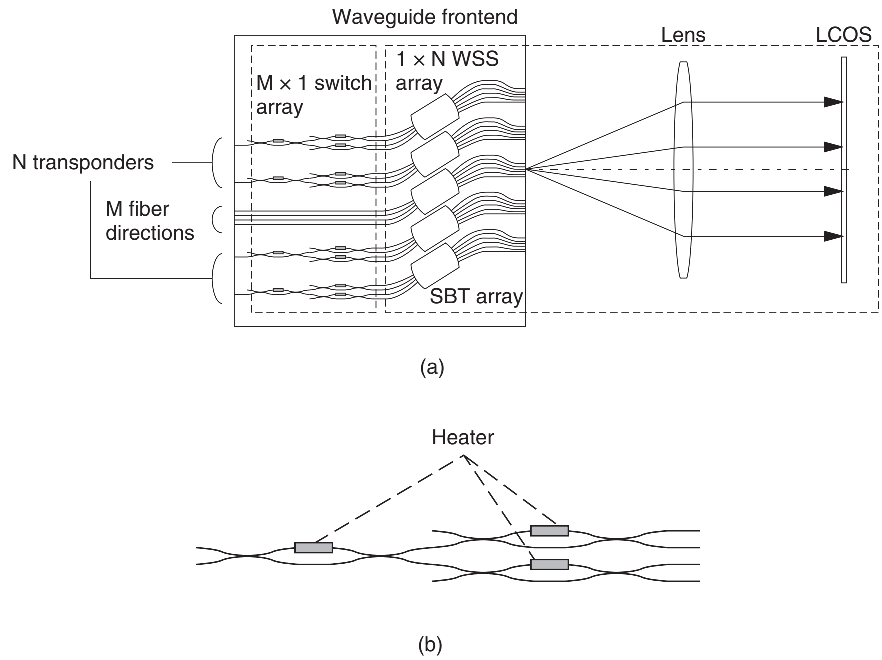


Fig. 7. (a) Optics schematic diagram of M × N TPA using SPOC and (b) schematic of non-wavelength selective M × 1 switch.

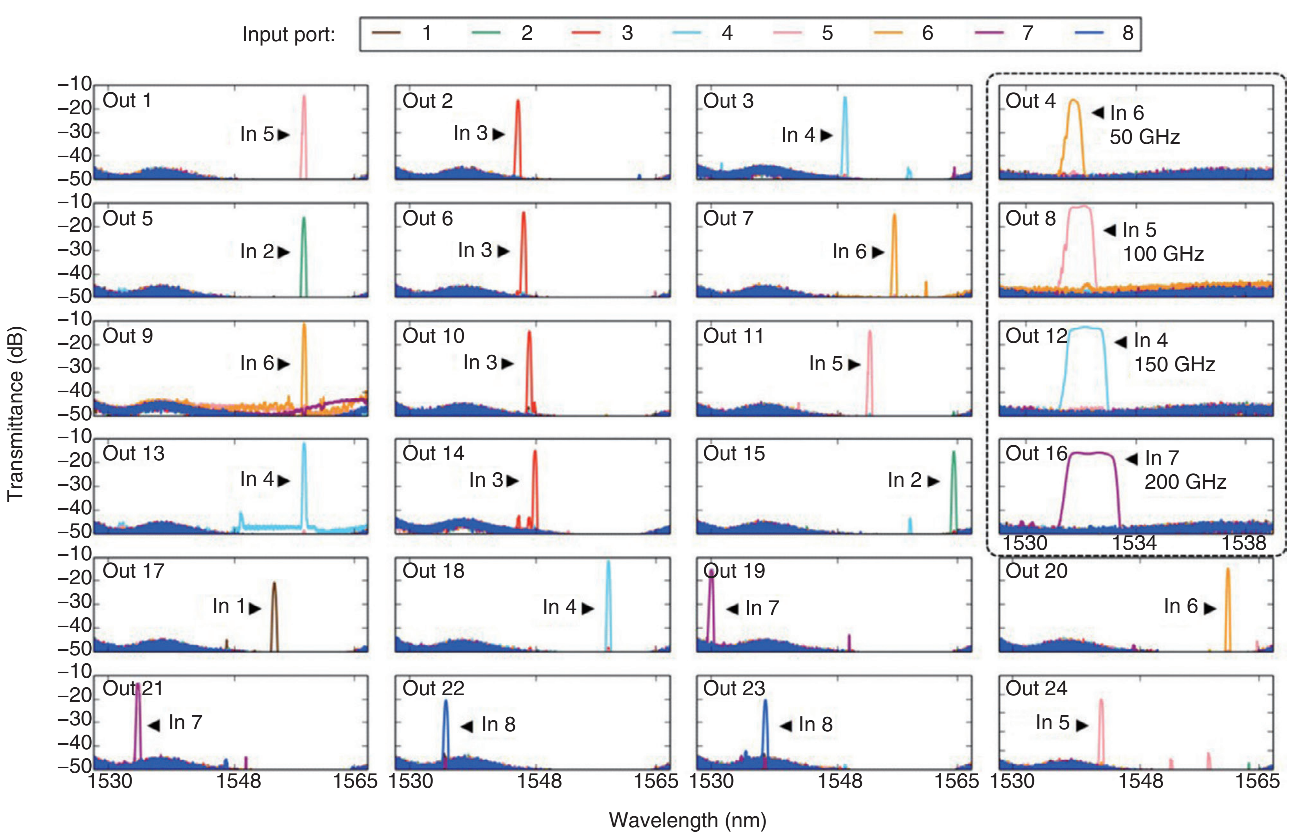


Fig. 8. Transmission spectra for 24 output ports of TPA (single polarization). A narrow wavelength range is shown for Out 4, 8, 12, and 16 to show the flexible-grid operation (dashed box).

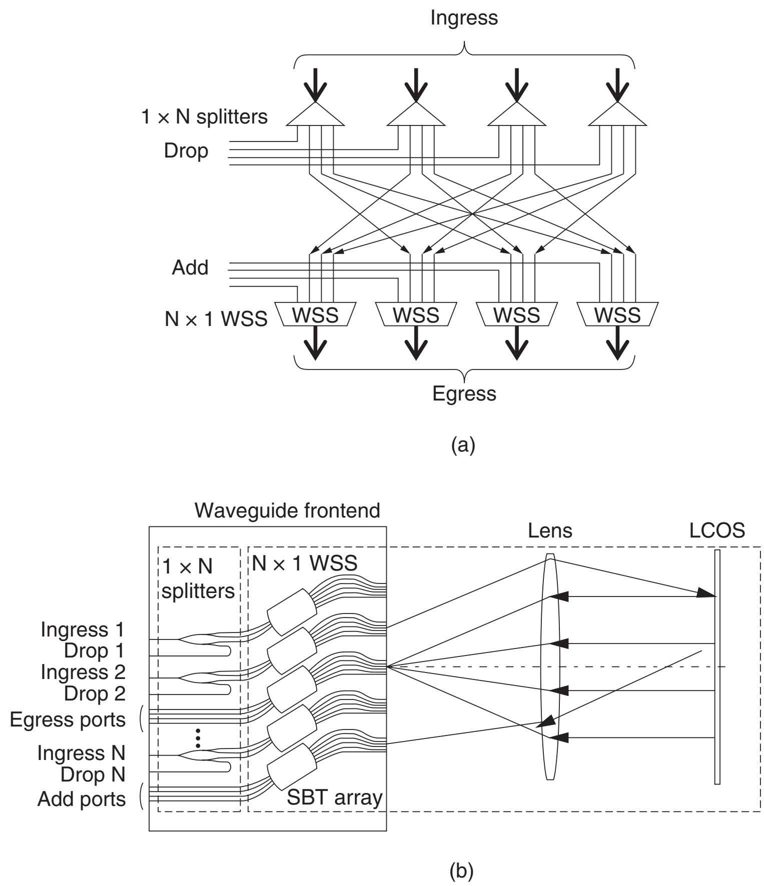


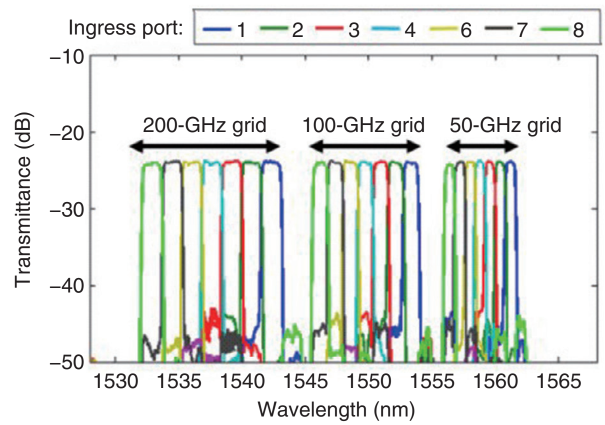
Fig. 9. N × N WXC: (a) functional diagram and (b) optics schematic diagram.

3.3 Integrated wavelength cross-connect with add/drop functionality

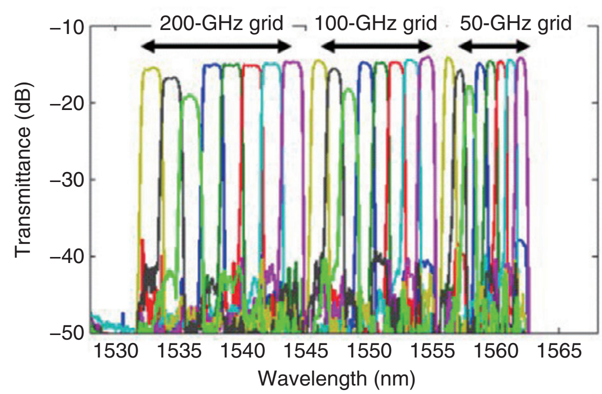
If we look again at Fig. 4, we can see many WSSs in the wavelength cross-connect (WXC) area, which is indicated by the dashed lines. WSS multiplexing is also useful for constructing a WXC.

Schematic diagrams of the functional block and optics system for the integrated WXC we constructed are shown in **Fig. 9** [23]. We used a broadcast-and-select type WXC configuration in which 1 × N splitters broadcast WDM signals from the ingress ports, and each N × 1 WSS selects one of them. The drop and add ports are used to access the TPAs. Because it is illogical to return a signal in the direction from which it originated, the splitter and the WSS for the same direction are not connected. The output ports of the splitters and the input ports of the WSSs that are not connected are used as drop and add ports. As shown in Fig. 9(b), N units of 1 × N splitters can be integrated into the waveguide frontend, and one of the split ports of each splitter is looped back to serve as a drop port. An SBT is integrated at the bottom of the waveguide frontend for use in adding ports.

The functionality of the constructed WXC was experimentally tested for channel bandwidths of 100, 150, and 200 GHz to evaluate the flexible-grid operation. Routing to Egress 5 as an example connection between the Ingress and Egress ports is shown in **Fig. 10(a)**. The plot shows that every input port was routed to every output port except for the ports with the same port number in each bandwidth. The connections for the Add and Egress ports are shown in **Fig. 10(b)**. Each Add port was routed to the corresponding Egress port without a splitter, so the insertion losses of the Add ports were lower than those of the Ingress ports. The losses from the Ingress to the Egress ports included an intrinsic splitting loss of 9 dB, which is inevitable due to the broadcast-and-select configuration.



(a)



(b)

Fig. 10. Transmission spectra of 8 × 8 WXC: (a) all Ingress ports are configured to route to Egress port 5. (b) All Add ports are configured to route to the Egress port, where several-dB attenuations are provided to some ports. Better loss is seen due to the lack of 1 × 8 splitters (9-dB intrinsic loss).

4. Conclusion

We have described platform technology that combines two-dimensional planar waveguide photonics and three-dimensional free-space optics, which we call a spatial and planar optical circuit, or SPOC. The planar waveguide technology provides a high degree of integration of optical functionality for such devices as microlenses, splitters, and simple switches, while free-space optics supplies a high degree of parallelism with two-dimensional spatial light modulators such as LCOS devices.

With the unique advantages of SPOC, we demonstrated three applications for ROADM devices in a photonic network. These include the ultra-high port count 1 × 95 WSS, the low-loss 8 × 24 TPA, and the single module 8 × 8 WXC.

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Ethernet Private Line System with World's Highest Quality (Bandwidth Guarantee, High Availability, and Low Delay)

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Abstract

Virtual private networks and broadband Ethernet are increasingly being used as corporate wide area networks. Consequently, demand is growing for higher availability and lower delay in addition to the bandwidth guarantee and carrier-grade maintainability and operability of conventional digital private line systems. We describe here an Ethernet private line system that achieves the world's highest level of quality to meet that demand.

Keywords: Ethernet private line service, transport network, hitless switching

1. Introduction

The use of Ethernet for constructing local area networks has increased recently, and along with this, virtual private networks (VPNs) and broadband Ethernet, which can provide high-speed lines at reasonable cost, are being increasingly deployed as corporate wide area networks. However, there is strong demand for higher availability and lower delay in addition to the existing demand for the bandwidth guarantee and carrier-grade operation, administration, and maintenance (OAM) of conventional digital private line systems. This demand is particularly high for service-critical lines and emergency lines. In the transfer of video data to be used for broadcasting or other important purposes, for example, even the loss of a single key frame may cause a few seconds of traffic interruption in video streaming, so there is a need for redundancy technology that prevents interruption of communication due to hardware failures. A delay in file transfer by TCP/IP (Transmission Control Protocol/Internet protocol) greatly affects throughput. Lower delay is also required for e-commerce and other use scenarios that are sensitive to delay. Furthermore, it is also necessary to ensure stable communication, even under peak traffic conditions such as during disasters and other emergencies, and the system should enable line quality to be maintained at the same level as conventional digital private line systems.

In conventional digital private line systems, synchronous digital hierarchy (SDH) technologies based on time-division multiplexing have been adopted to provide high-quality service at the full fixed-line bandwidth contracted by the user. With SDH, carrier-grade functions for line and path management, maintenance and operation, and redundancy have been implemented.

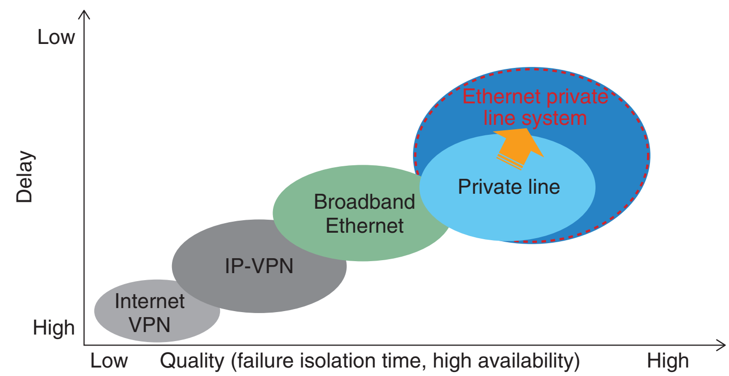


Fig. 1. Positioning of private line systems.

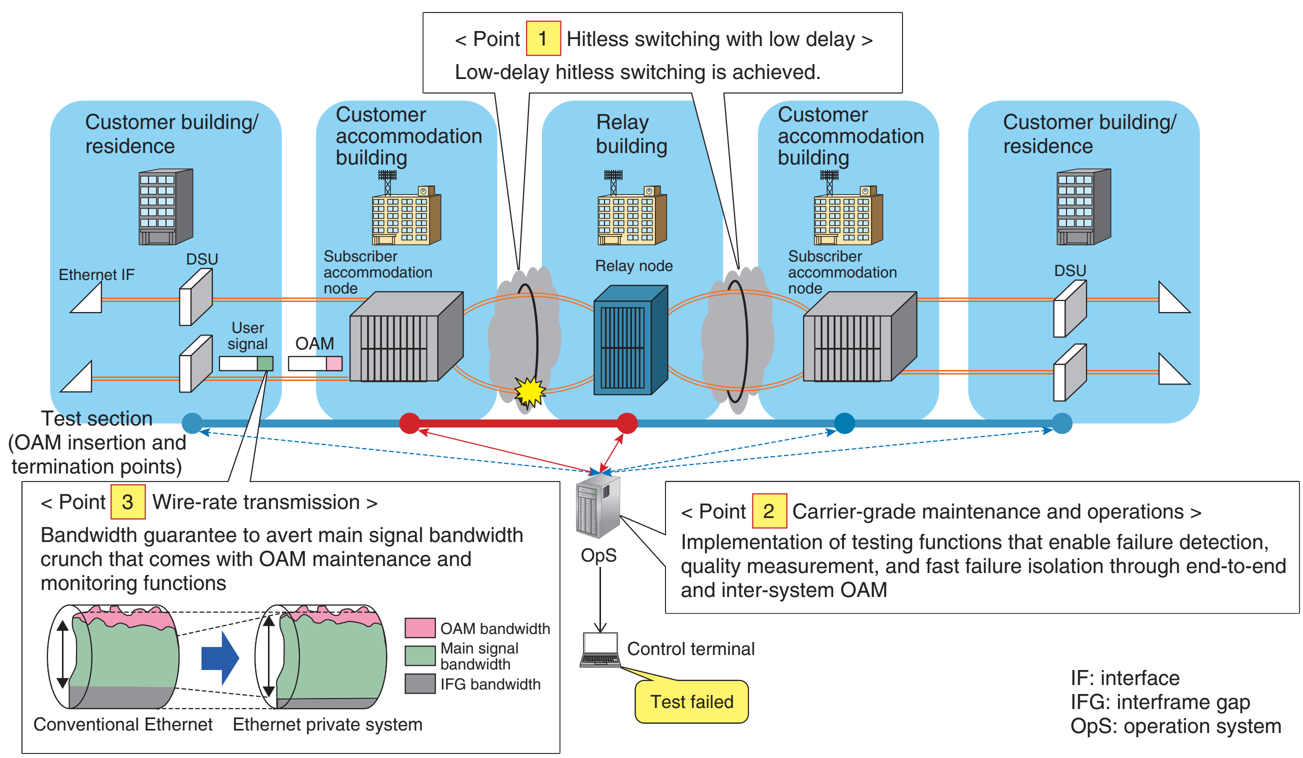


Fig. 2. Overview of Ethernet private line system and key technical points.

NTT Network Service Systems Laboratories has developed an Ethernet private line system that can provide broadband services with high availability and low delay while maintaining bandwidth guarantee and carrier-grade maintenance and operation functions by applying packet transport technology (**Fig. 1**). This system implements low-delay hitless switching, an end-to-end maintenance monitoring function, and wire-rate transmission to achieve an Ethernet system with a quality level that exceeds that of conventional digital private line systems (**Fig. 2**). The Ethernet private line system comprises a relay node, subscriber accommodation nodes, digital service units (DSUs), and an operation system. We describe here the main technical features of the Ethernet private line system.

2. Technical issues for achieving high quality in an Ethernet system

There are three additional technical requirements for achieving the high quality level of conventional digital private line systems using Ethernet (Fig. 2).

2.1 High availability (hitless switching) and low delay

In systems using statistical multiplexing such as Ethernet, the delay tends to be longer compared to fixed-rate transmission systems since all of the frames need to be momentarily buffered for processing in the node before transmission.

Also, hitless switching technology can be applied to achieve high availability in conventional SDH-based digital private line systems. Hitless switching uses a redundancy approach in which the same frame is copied onto two redundant paths. Frames are checked at the receiving side, and the valid frame is selected and transmitted so that there is no disconnection even in the event of a failure on a transmission path. This kind of hitless switching is different from packet transmission in that the signal is continuously transmitted with fixed time slots, so the frames in short paths are buffered to prevent disconnection due to differences in path length (variation in delay) caused by path switching. The frames remain in the buffer until the arrival of the long-path frame, and control is performed so that the selection is made after the long-path frame arrives. Accordingly, it is not possible to achieve both high availability and low delay at the same time because the output signal is always delayed by the amount of delay in the long path. Thus, implementation of redundancy that provides both high availability and low delay is a problem that needs to be solved in order to achieve high quality in an Ethernet private line system.

2.2 Carrier-grade maintenance and operation functions

Ethernet did not originally provide maintenance and operation functions, but such functions have been specified as Ethernet has come into use in carrier networks. However, these functions were inadequate for such high-quality networks because maintenance of high-quality networks requires testing functions that are capable of failure detection, quality measurement, and rapid isolation of failures in node sections, including end-to-end. Specifically, fine-grained monitoring and determination of failure locations between DSUs and in each node section by OAM are needed to quickly identify degraded points/locations. In particular, in-service loopback testing at various points on a path is an essential function for failure isolation. A quality measurement function is also necessary for maintaining quality with respect to bandwidth and delay.

2.3 Wire-rate transmission

Although it is now possible to use OAM functions to implement maintenance and monitoring functions such as failure detection, testing, and quality measurement, the monitoring is constant, so periodic circulation of OAM frames on the main signal path is necessary. That is accompanied by bandwidth constraints on the main signal, making it difficult to guarantee the equivalent of the physical line bandwidth (wire rate). It will be necessary to achieve wire-rate transmission, which is the upper limit of the physical interface, and reliably provide the contracted bandwidth, while ensuring carrier-grade maintenance and operation by OAM.

3. Three features of Ethernet private line systems

Here, we describe three technical features of Ethernet private line systems.

3.1 Low-delay hitless switching technology

Ethernet is unaffected by variations due to differences in path length because it uses frames instead of a continuous signal. We applied this feature to address the problem of reducing delay in conventional SDH-based hitless switching and to achieve both high availability and low delay in this system.

In the low-delay hitless switching applied in our Ethernet private line system shown in **Fig. 3**, frames are sent over two paths, and the first to arrive is selected. At that time, the frame is transmitted without waiting for the other frame to arrive over the long path, so a large decrease in delay relative to the SDH hitless switching mechanism is possible. This decrease is on the order of milliseconds and corresponds to the difference in the long path delay.

In this system, the packet sequence may end up being reversed when a packet is lost on the short path. In view of the possible packet loss during the transmission, the system performs sequence control of packets in order to prevent a reversal in the packet sequence.

The priority processing for first-arriving frames used in this system greatly reduces the delay. Moreover,

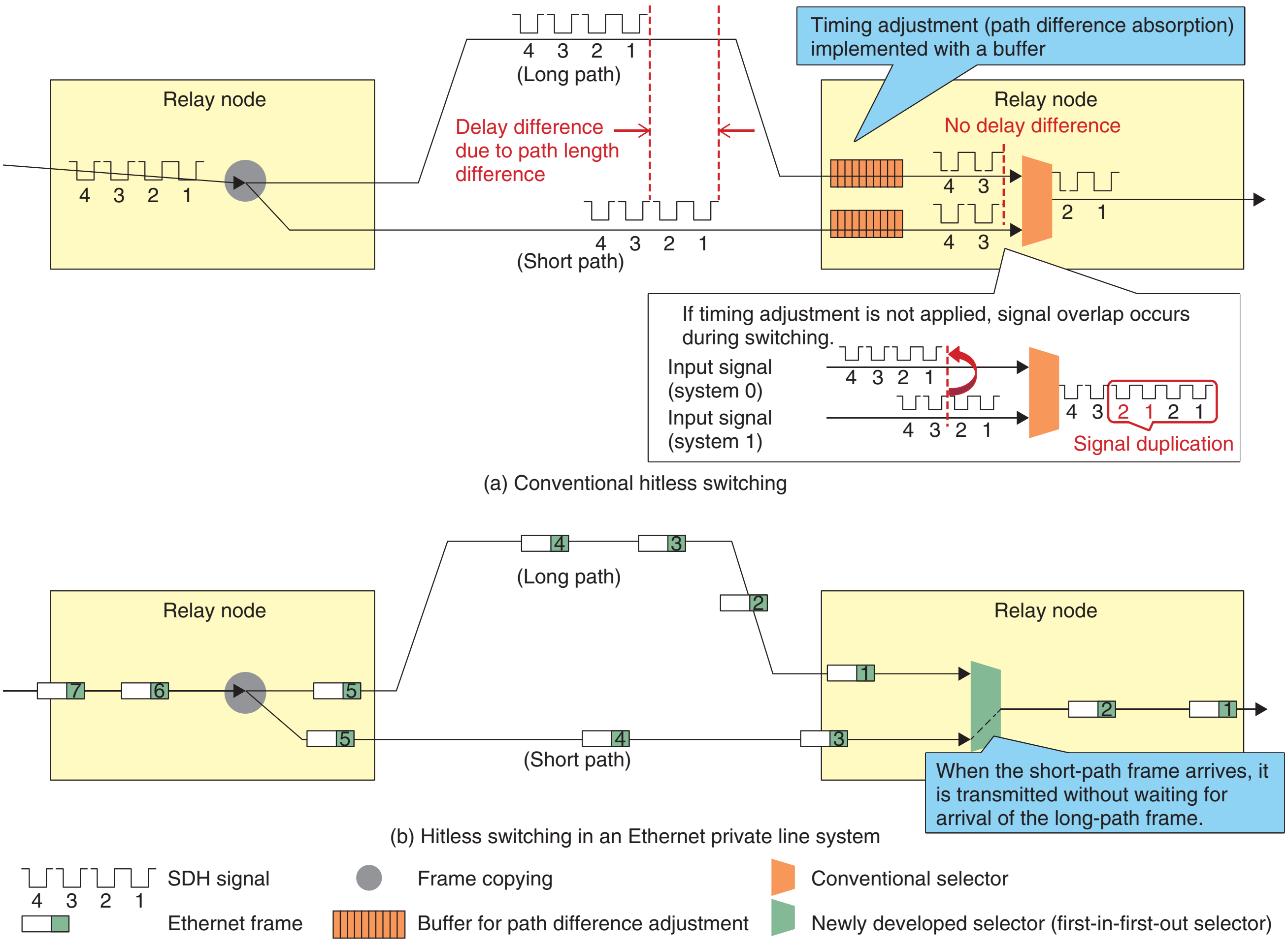


Fig. 3. Low-delay hitless switching.

we implemented the world's first hitless switching technology, which can be applied during planned maintenance and failures.

3.2 Carrier-grade maintenance and operation functions

(1) Measuring end-to-end quality

All of the nodes in the system, including the DSUs, are equipped with OAM functions for determining the locations of degraded quality in each node section, including measurement of end-to-end quality. These functions enable failure detection via continuity checks in all segments within the network and in all node sections. Also, the amount of delay can be periodically recorded as traffic data by conducting proactive delay measurement tests.

(2) Rapid failure isolation

To ensure the continuity of sequence numbers when OAM frames and the main signal frames are mixed by using a low-delay hitless switching mechanism, it is necessary to perform OAM loopback tests (**Fig. 4**). However, when looping back at nodes other than path termination points, jumps in the sequence numbers are misinterpreted as lost packets by the hitless switching processing unit.

To deal with this problem, the system implements a test that is equivalent to a loopback at any point by combining loopback tests between node units and carrying out monitoring within the node units. In this way, maintenance personnel can simply use the operation system to select lines for testing without having to be aware of each section test, thus implementing virtual path testing in which points of failure can be automatically identified by tests run on monitored sections. Furthermore, providing testing functions by OAM both enables in-service testing regardless of user bandwidth use conditions and provides an operating system function for visual display of

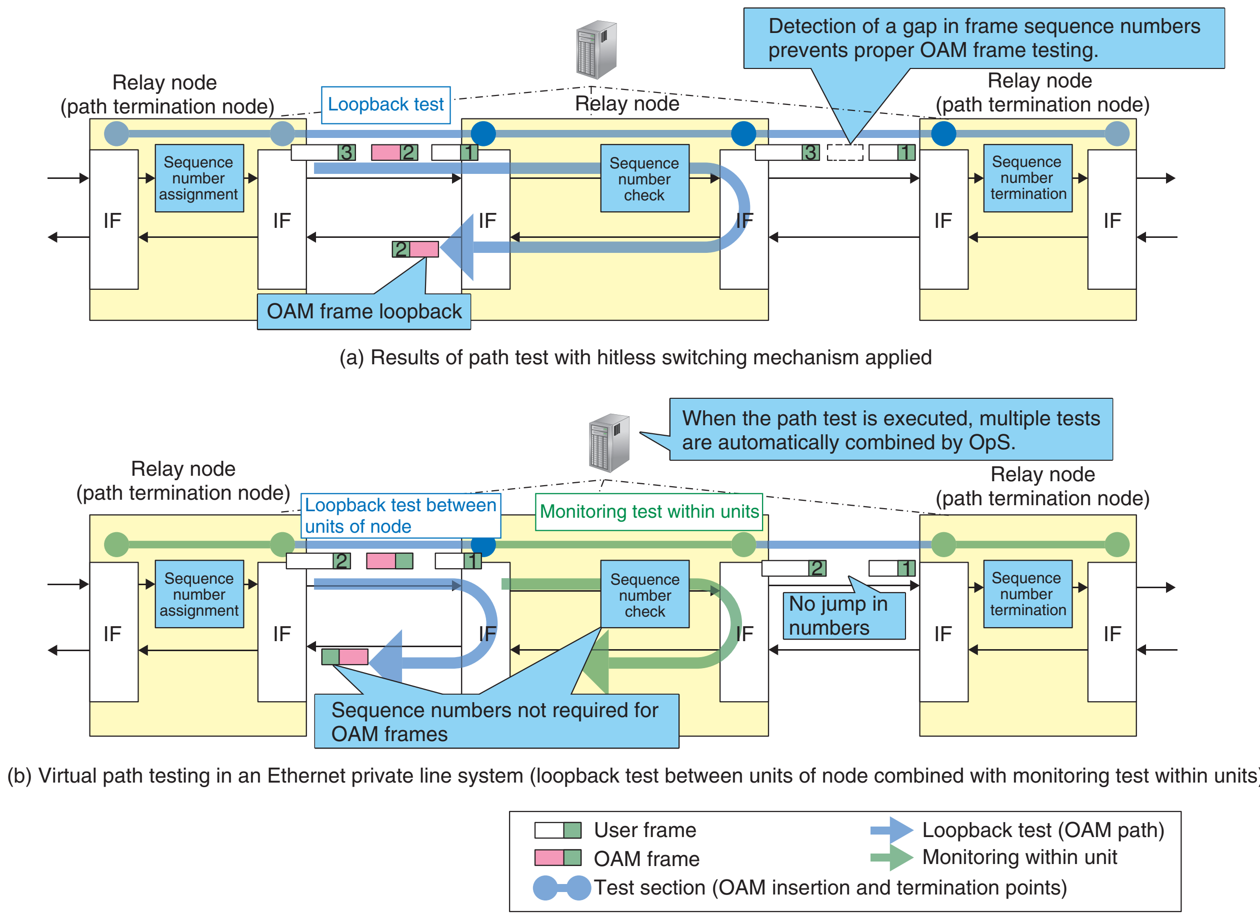


Fig. 4. Virtual path testing.

locations where alarms were issued by nodes, thus supporting smooth communication with on-site maintenance personnel.

3.3 Wire-rate transmission technology

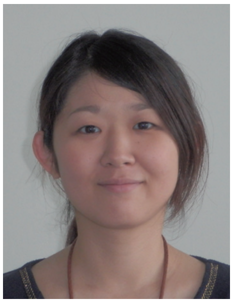
The Ethernet private line system applies synchronous Ethernet technology and wire-rate transmission technology that uses interframe gap (IFG) reduction for a bandwidth guarantee in order to implement carrier-grade maintenance and operation functions such as end-to-end OAM failure detection and delay measurement. Because Ethernet is an asynchronous protocol, deviations in clock synchronization between node units are absorbed by IFG reduction. In this system, however, we solve that problem with synchronous Ethernet (also referred as Sync-E), which transmits a clock signal between nodes via the Ethernet physical layer as specified by the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) Recommendation G.8261 [1]. Doing so enables use of the available bandwidth by not using IFG reduction for transmitting OAM frames or downloading firmware. Compression of IFG according to bandwidth enables end-to-end failure detection and delay measurement, and it also enables remote in-service firmware updating to a DSU isolated from user traffic.

4. Future development

We have described an Ethernet private line system that was developed by NTT Network Service Systems Laboratories. In the future, we will continue to work on meeting customer needs for even higher bandwidth and service quality.

Reference

[1] ITU-T Recommendation G.8261, https://www.itu.int/rec/T-REC-G.8261



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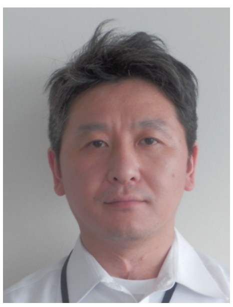

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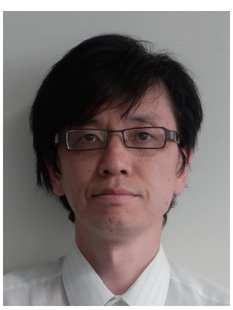

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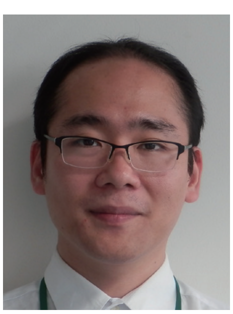

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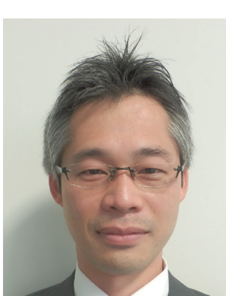

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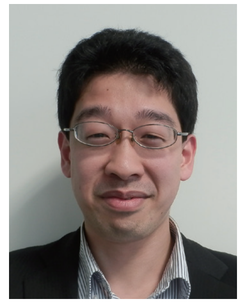

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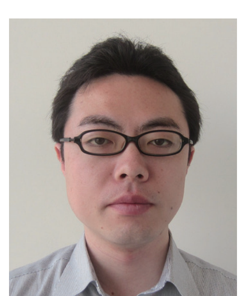

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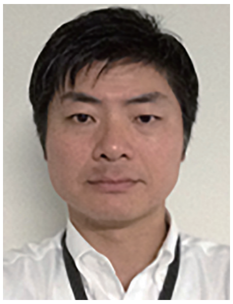

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Activities of the Asia-Pacific Telecommunity/Telecommunication Technology Committee BSG (Bridging the Standardization Gap) Working Group

Hideyuki Iwata

Abstract

This article introduces the activities underway by the Telecommunication Technology Committee of Japan and the Asia-Pacific Telecommunity to promote solutions that use information and communication technology to resolve social issues in rural areas of Southeast Asian countries.

Keywords: ICT solution, rural area, M2M

1. Introduction

In 2007, the Telecommunication Technology Committee (TTC) established the Promotion Committee to conduct case studies on solutions that use information and communication technology (ICT) to resolve social issues in Southeast Asia, and compiled a handbook to facilitate dissemination of the case study results in the region. In 2012, these activities were transferred to the Bridging the Standardization Gap (BSG) Working Group in TTC. In addition, a case study team was established in the Expert Group on Bridging the Standardization Gap (EG-BSG) of the Asia-Pacific Telecommunity Standardization Program (ASTAP) to promote solutions that use ICT to resolve social issues in rural areas of Asia.

2. Case studies

Since 2007, TTC has been embarking on the following five pilot projects with the support of the J2 (Human Resource Development Program for Exchange of ICT Researchers and Engineers) and J3 (Construction of ICT telecenter) programs of the Asia-Pacific Telecommunity (APT) EBC-J (Extra-Budgetary Contribution from the Government of Japan).

(1) A medical solution in Tanah Datar Regency, West Sumatra Province, Indonesia. This solution involves the construction of a wireless network to link medical institutions and the creation of a medical information database.

(2) An environmental solution in Palangkaraya, Central Kalimantan Province, Indonesia. This is designed to suppress peat fires, which occur during the dry season, by using a machine-to-machine (M2M) network (**Fig. 1**). This study was carried out in cooperation with the University of Palangka Raya.

(3) Optical fiber network construction and educational and medical solution in Bario village, Borneo, Malaysia. This study was carried out in cooperation with the University of Malaysia Sarawak.

(4) Agricultural and fishery solution in Palakpakin Lake in San Pablo City, the Philippines. This solution involves the construction of an M2M network to improve yields from tilapia

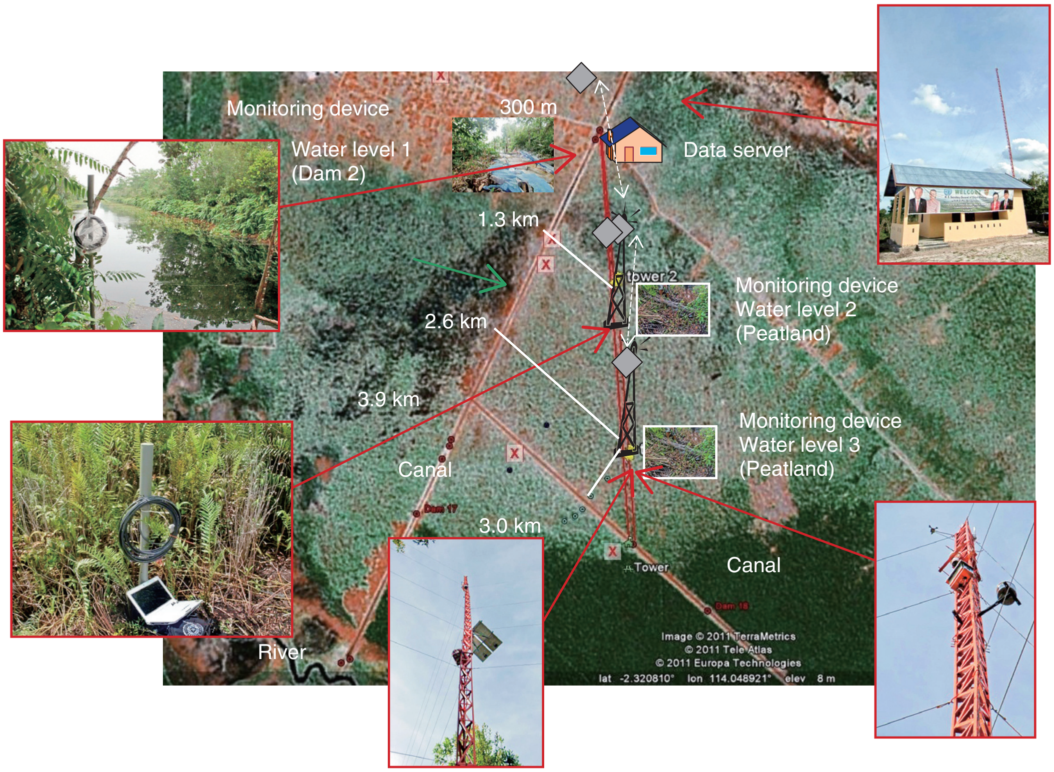

Fig. 1. Solution to suppress peat fires in Kalimantan, Indonesia.

aquaculture (**Fig. 2**). This study was carried out in cooperation with Ateneo de Manila University.

(5) Agricultural and fishery solution in Ho Chi Minh City, Vietnam. An M2M network was constructed in order to improve yields from shrimp aquaculture. This study was carried out in cooperation with Ho Chi Minh City University of Technology.

3. Compilation of a handbook to introduce ICT solutions for rural communities

The five ICT solutions that have been implemented in the Southeast Asian countries mentioned above can also be effectively applied in rural areas in other emerging nations that are facing similar problems. Therefore, we compiled the *Handbook to Introduce ICT Solutions for the Community in Rural Areas* to facilitate the provision of similar solutions in other countries. The handbook describes the case studies that were carried out and also notes items that are universally applicable and can be adopted in different countries. At APT Standardization Program-24 (ASTAP-24) held in April 2004, the handbook was approved as an ASTAP report.

4. Formulation of guidelines

After the handbook was compiled so that generic information from the case studies could be presented, the next step was to develop, with the support of APT, guidelines that provide know-how on how to implement, operate, and maintain the ICT-assisted social issue solutions that were developed from the case studies and adapted to local conditions. Specifically, the case studies carried out by the EG-BSG of ASTAP were scrutinized to develop guidelines that could provide know-how for implementation.

The guidelines can be summarized as follows:

(1) Requirements and implementation procedure for the survey of existing conditions in the area where the selected solution is to be introduced

(2) Requirements and implementation procedure for verifying the effect of introducing the selected solution into the target local area

(3) Steps to estimate the cost of introducing the

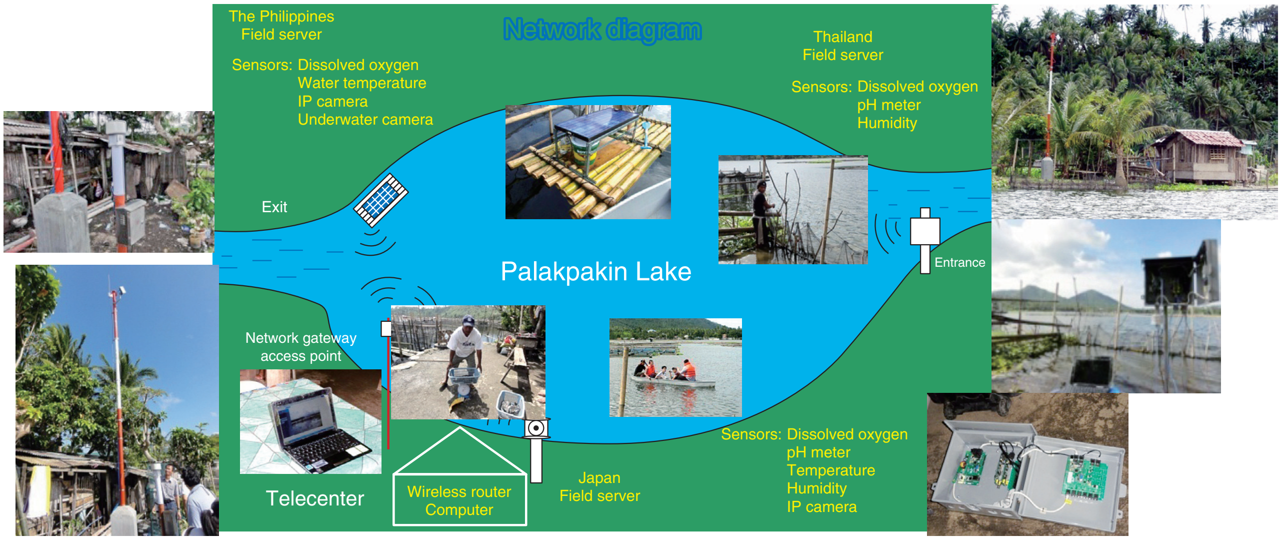

Fig. 2. Solution to improve yields from aquaculture in the Philippines.

selected solution

(4) Requirements and implementation procedure for verifying the cost-effectiveness of introducing the selected solution

(5) Methods to design the network needed to implement the selected solution and select the necessary equipment

(6) Requirements for appointing the person who will be responsible for formulating the selected solution and for data analysis

(7) Requirements for securing appropriate staff for solution operation and maintenance

(8) Development of the ICT staff for operation and maintenance

(9) Issues related to business continuity

The guidelines were mainly developed by members from the University of Malaysia Sarawak (Malaysia), Ateneo de Manila University (Philippines), the University of Palangka Raya (Indonesia), and Kasetsart University (Thailand), which are all project partners in their respective countries, from their own perspectives.

5. Outlook

The term *standardization* generally implies standardization of technical items, but emerging countries require more practical standardization of implementation procedures. As part of the activities to bridge the standardization gap, we are developing guidelines (usage standards) for the provision of ICT-assisted solutions to social issues. These guidelines can also be useful in non-Asia-Pacific areas such as Africa. The pilot models that combine Japan's ICT systems and solutions developed by local universities can be deployed in a manner adapted to specific local conditions. Ensuring business continuity is the greatest challenge, so it is therefore necessary to develop sustainable business models and to encourage local stakeholders to drive the selected solution forward and bring it to fruition.

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everis and the Next Generation of Digital

Marc Alba
Steering Committee Member, Chief Innovation Officer, Head of everis NextGen, everis, an NTT DATA company

Abstract

The firm everis joined the NTT DATA family in January 2014 to achieve together a dream: become the global number one. Innovation and entrepreneurship have always been a must for us at everis, which has grown organically from 5 employees back in 1996 to more than 16,000 across 13 countries and 4 continents. In May 2014, we launched a strategy to lead the next wave of digital revolution beyond SMAC (social, mobile, analytics, and cloud) technologies and leverage the new CRAVIB (crowdsourcing, robotics, artificial intelligence, virtual reality, Internet of Things, and blockchain) exponential technologies. Today, in the year of our 20th anniversary, we want to share the first outcomes of this strategy and its huge potential to contribute to NTT DATA and NTT's global leadership.

Keywords: innovation, entrepreneurship, disruption

1. everis: attitude makes the real difference

In October 1996 in Spain, a group of entrepreneurs you could count on the fingers of one hand left their managerial positions at a leading consulting company to create a new concept of consulting. The idea was simple to explain, yet complex to implement: build from scratch a unique company model designed to attract and retain the best talent, while fostering good people and collective values. Our talent management model, the main asset of everis, is taught as a case study in leading business schools, as it excels in smartly feeding both the brain (skills and professional growth) and the heart (attitudes and values) of our employees. The result is summarized in our claim: attitude makes the difference.

From our early days in Spain, we have grown organically, in double digits, to become a highly reputed multinational group of 16,000+ professionals in EMEA (Europe, the Middle East, and Africa)*1, Latin America*2, and the US. From our original focus on information technology (IT) services, we have moved to cover the full range of consulting, integration, and operation services, from strategic consulting to managed services. From a pure services company, we have transformed our portfolio to provide our customers with services as well as products (e.g., in health, aerospace & defense, big data, or cloud) [1]. However, for us, achieving all of that was still not enough; we humbly thought we had just begun our journey and the best was yet to come.

This led us to join the NTT DATA family in 2014, seeking to become part of a group that would, on one hand, preserve and leverage our unique company model and, on the other hand, complement us with global and world class assets in order to achieve our goal and dream: become the global number one in

*1 Belgium, Italy, Morocco, Portugal, Spain, and UK
*2 Argentina, Brazil, Chile, Colombia, Mexico, and Peru

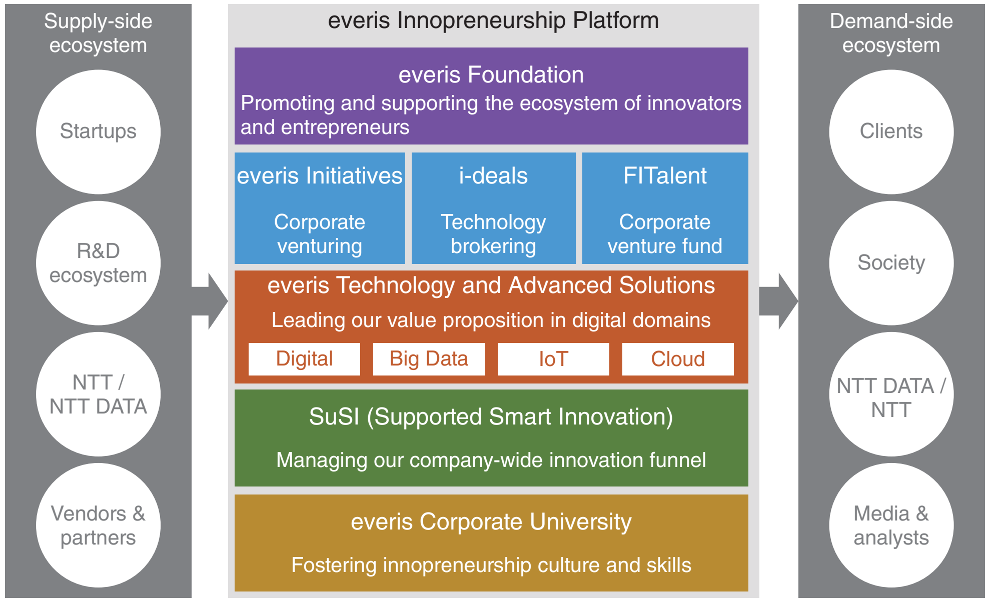

Fig. 1. everis Innopreneurship (Innovation and Entrepreneurship) Platform.

consulting and professional services. Today, we can proudly say we made the right decision by joining the NTT DATA family and the NTT Group.

2. Innovation and entrepreneurship as a way of life

Since the original innovation to create our unique company model, innovation and entrepreneurship have been our best qualities to achieve double-digit growth and a strong market reputation. During the last 20 years, we have been constantly reinventing our company to preserve the original entrepreneurial mindset and transform everis into an innovation and entrepreneurship platform. This platform relies on seven main foundations that foster throughout the entire company what we like to call *innopreneurship*, that is, the symbiosis between innovation and entrepreneurship (**Fig. 1**):

(1) **SuSI** (Supported Smart Innovation) is our corporate unit that manages the company-wide innovation funnel, focusing on product & service innovation and leveraging instruments such as consortia and research and development (R&D) funds.

(2) **everis Initiatives** is our corporate venturing division aimed at developing and launching new businesses. It selects fast growth domains and creates new companies to lead them by building world class capabilities and assets.

(3) **i-deals** is a firm of the everis Group. It is a pioneering technology broker that valorizes novel technologies of the global R&D ecosystem and promotes their commercialization in our customers. Technologies range from ICT (information and communication technology) to biotech, clean tech, or new materials.

(4) **FITalent** is our corporate venture fund that invests in technology-based firms whose main assets are people and talent. Its portfolio and scope range from IT to manufacturing, energy, biotechnology, pharmaceuticals, and digital business.

(5) **everis Technology and Advanced Solutions** is our new unit that is unifying and strengthening our integrated digital offering through the development of services and assets in our so-called *key lines* (at the moment, Digital, Big Data, Internet of Things, and Cloud).

(6) The **everis Foundation** is our non-profit entity supporting innovators and entrepreneurs and the entire talent ecosystem to bring back to society what it has given us.

(7) **everis Corporate University** is our corporate training and education unit. Among other functions, it provides our employees with innovation and entrepreneurship courses to nurture the innopreneurship culture and skills.

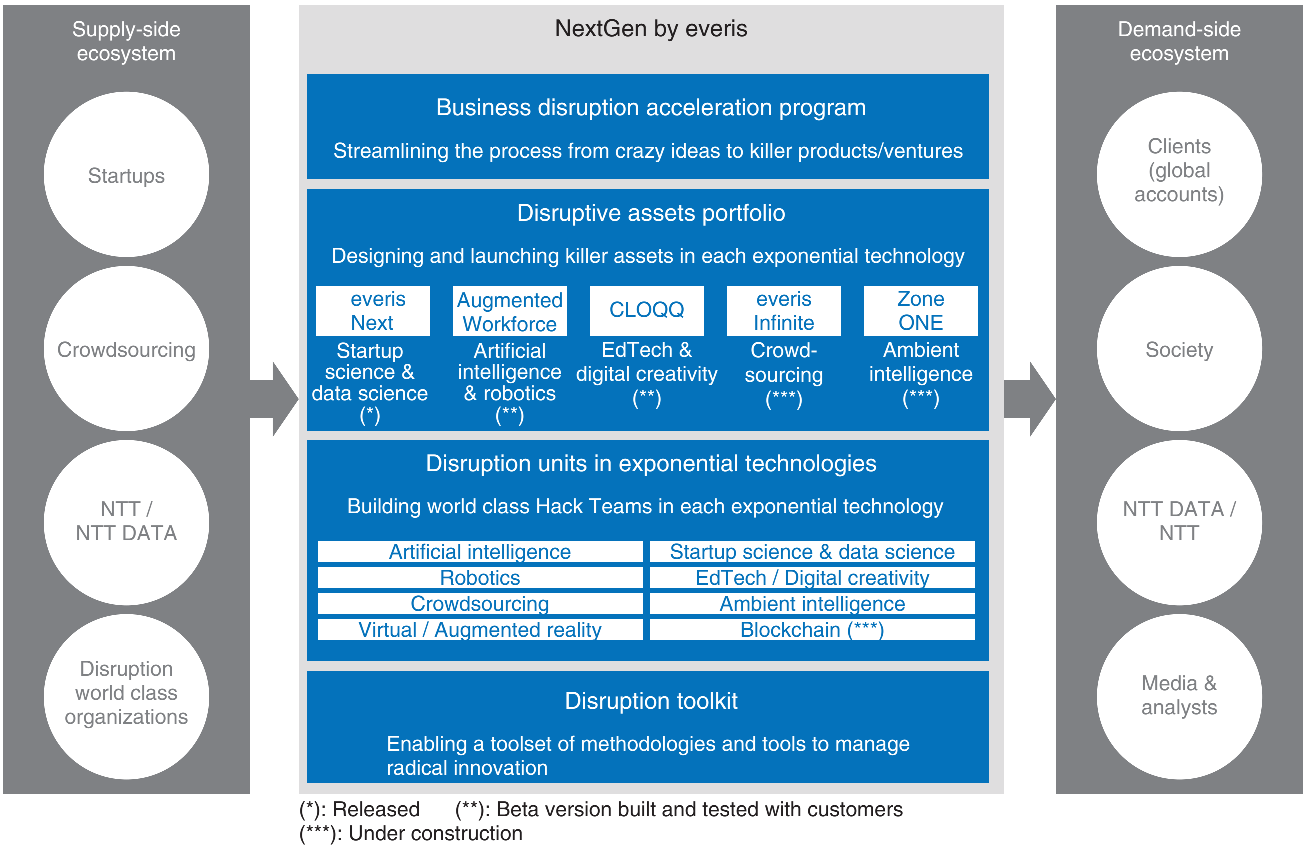

Fig. 2. NextGen by everis.

All in all, the objectives of these seven instruments are twofold: on one hand, to preserve an innovative spirit and entrepreneurial mindset as two core ingredients of our corporate DNA and a way of life for our entire talent base across divisions, offices, and continents, and on the other hand, to constantly renew our customers' value proposition and corporate assets.

3. The next frontier: from everis NextGen to the NTT DATA Disruption Hub

In 2014, while our competitors were focusing their efforts and investments in building digital offerings and assets around SMAC (social, mobile, analytics, and cloud) technologies, we decided at everis to opt for a different strategy: complement our innopreneurship platform with the creation of a new strategic unit that reports to our chief executive officer and is focused on the next generation of digital. Established in May 2014, this new unit called *NextGen* (for next generation) was created to pave the way for our leadership in the new crowdsourcing, robotics, artificial intelligence, virtual reality, Internet of Things, and blockchain (CRAVIB) exponential technologies, the next generation of digital.

After two years of intense activity in stealth mode, this early mover strategy is proving to be a smart step. NextGen provides us today with world class assets, teams, connections, and client references in the new domains that are beginning to change the world and our customers: artificial intelligence, robotics, crowdsourcing, virtual reality, and ambient intelligence. If we move smartly and quickly, this will provide us with the opportunity to lead globally the next generation of the digital revolution.

NextGen relies on four main pillars (**Fig. 2**):

(1) A **business disruption acceleration program** to streamline the process of transforming unconventional ideas into killer products/business models, both for us and our customers. All the disruptive assets of NextGen have been developed through this acceleration program, and it is now helping our customers to reinvent their own businesses.

(2) A growing **portfolio of disruptive assets** in each of the exponential technologies we are addressing. All these assets are co-created and tested in real world environments with our customers, moving us beyond R&D to last-mile radical innovation. NextGen assets need to fulfill three conditions: (a) be one-of-a-kind (i.e., surpass all our competitors); (b) be scalable (i.e., leverage the power of digital to really make us "go" digital and leverage the scalability of digital platforms); and (c) apply open innovation strategy (i.e., switch from building products from scratch to enabling co-creation platforms). As an example of such assets, the first one we launched, everis NEXT (www.everisnext.com), has become the largest online repository of innovation ecosystems on the Internet. Leveraging startup science, data science, and crowdsourcing, we have created a technology that automatically gathers the knowledge of startups (more than 1.6 million at the moment), leading venture capitalists, and GAFAA (Google, Apple, Facebook, Amazon, Alibaba), in order to help large companies reinvent their businesses and launch new and innovative ventures. We currently have more than 500 C-level and senior executives of Global Fortune 2000 companies operating through the everis NEXT platform [2].

(3) A series of small but **world class teams of subject-matter experts (disruption units) in each exponential technology**. We call them *Hack Teams*, and their role is to master the generation of business value in each disruptive technology.

(4) A **disruption toolkit** as a combination of all the methodologies and tools to manage and deliver business disruption and radical innovation.

In April 2016, a new corporate initiative called ICC (*Innovation Coordination Council*)*3 was launched at NTT DATA to foster innovation (especially open and radical innovation) and connect the main existing initiatives that are currently promoting innovation at NTT DATA*4. Under the umbrella of the ICC, everis NextGen is evolving to become the corporate Disruption Hub of NTT DATA. In addition to extending the four pillars mentioned above throughout the NTT DATA Group, we are now launching new group-wide verticals to address sectorial disruption (e.g., *NextGen Banking*, the first vertical we are working on for our banking customers).

4. Expectations of the NTT Group

At everis as a whole and at NextGen/NTT DATA Disruption Hub in particular, we have three major expectations regarding the NTT Group:

(1) Provide us with access to the broad and rich R&D portfolio of the NTT Group. Our approach in NextGen, fully based on open innovation, would help to connect the NTT R&D assets to the needs of our customers and industries, while in turn improving the ROI (return on investment) of our R&D investments at NTT.

(2) Leading the next generation of digital goes beyond the scope of everis and NTT DATA and implies synergies between all NTT Group companies. A joint plan for collaboration in innovation and CRAVIB exponential technologies across all Group companies would strongly boost our global positioning in the next generation of digital.

(3) NTT global accounts are our most strategic customers. They should become the focal point of our value proposition in the next generation of digital.

Fulfilled altogether, these expectations would contribute to positioning the NTT Group as a global leader in business disruption and the next generation of digital and also to achieving more quickly and effectively NTT DATA's global leadership. Let's change the world and make it better together!

References

[1] everis, http://www.everis.com/global/en-US/home/Paginas/home.aspx
[2] everis NEXT, http://www.everisnext.com

*3 The ICC is chaired by Tsuyoshi Kitani, Director and Executive Vice President of NTT DATA.
*4 TIG, Open Innovation, Silicon Valley Office, Global Business, and NextGen

Marc Alba

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Marc Alba is a leading expert in disruptive innovation, entrepreneurship, exponential technologies, digital transformation, regional development, and socioeconomic transformation. Throughout the past 20 years, he has served in diverse positions (researcher, entrepreneur, chief innovation officer, transformation director, founder of non-profit movements, and advisor of a large and varied set of both private and public organizations) that in combination provide him with a holistic perspective of the key socioeconomic challenges that businesses and societies are facing worldwide. He has carried out his activities in multiple sectors, including automotive, telecom, industry, banking, insurance, government, energy, and non-government/non-profit organizations.

Marc is the (co-)author of 5 books and has written more than 100 publications and articles. His latest books are *i-Leaders (Innovation Leaders): From the Business of Innovation to the Innovation of Business* and *The Key to Spain's Transformation: Civil Society Takes the Floor*. He is also the co-founder of the civil society initiatives TransformaEspaña and TransformaTalento (TransformTalent), and the originator of the innovation management methodology COTIM (Cash-Oriented Total Innovation Management).

Currently, Marc works as a Managing Partner of the everis Group. He sits on the company's Steering Committee as the Chief Innovation Officer. He is the founder and head of everis NextGen and the NTT DATA Disruption Hub. He is also a Fellow of the everis Foundation and President of the TransformaEspaña Association. He is actively involved in various boards and think tanks related to innovation, entrepreneurship, regional development, and education.

He was born in Africa (Kinshasa, Congo). His collaborators define him as a citizen of the world, humanist, and work lover. He is 43 years old, married, and the father of four-year-old triplets, Maria, Miguel, and Marc.

Reviewing Inspection Methods for Efficient Operation and Maintenance of Steel Towers

Abstract

Regular maintenance of NTT facilities is necessary to ensure the provision of high-quality information and communication services. In this article, we review methods used to inspect steel towers. This is the thirty-seventh article in a series on telecommunication technologies. This contribution is from the Materials Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: steel tower, inspection method, aging degradation

1. Introduction

Information and communication services are enabled by the operation and maintenance of outdoor structural facilities such as utility poles, conduits, and service tunnels. Of these facilities, steel towers (hereafter, pylons) are the largest in size as single NTT facilities. These facilities are important because they house relay antennas that connect zones over long distances and mobile communications antennas (**Fig. 1**).

Outdoor structures and facilities such as pylons are exposed to natural environments and are therefore continuously corroding. Accordingly, that corrosion must be prevented by painting pylons with anti-corrosion paint. Although it is necessary to maintain and repair pylons as they corrode, doing so for such large-scale facilities incurs considerable expense. It is therefore necessary to improve anti-corrosion performance by repainting pylons at appropriate times before corrosion becomes serious and also to manage corrosion so as to stop it progressing as much as possible. To determine the appropriate time for repainting, it is important to precisely identify the degradation state of paint coatings, and to do so, it is imperative to carry out inspections on a regular basis. Consequently, NTT EAST and NTT WEST are reviewing their inspection methods for pylons as part of their objective to maintain and repair pylons in a more appropriate and efficient manner than before. In this article, the challenges concerning conventional inspection methods are reviewed, and results achieved with a new inspection method are presented.

Fig. 1. External appearance of a steel tower.

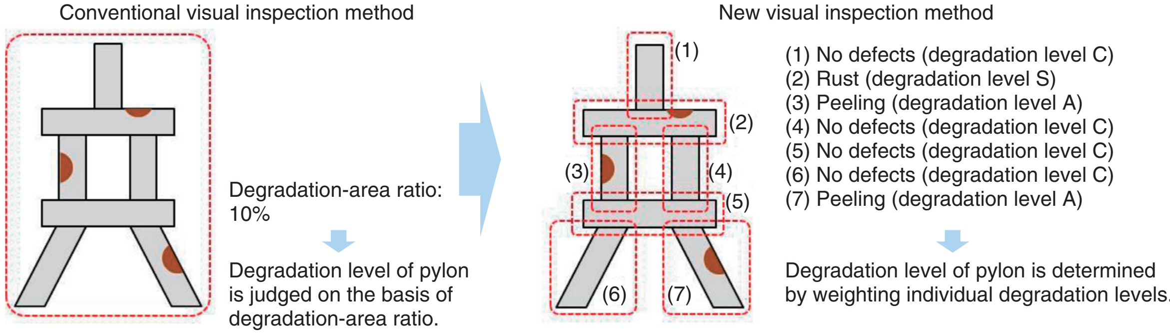


Fig. 2. Revised visual inspection method.

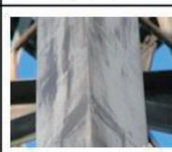
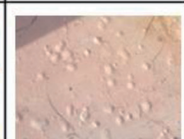
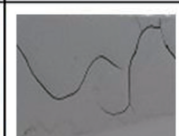
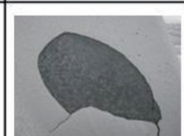
State of degradation	No abnormalities	Lack of hiding	Blistering	Cracking	Peeling	Rust
Sample						
Degradation level	C	B			A	S

Fig. 3. Degradation level for each degradation state identified during visual inspection.

2. Conventional inspection method and challenges

The conventional inspection method involves determining the degradation occurring on pylons by conducting a visual observation. The degradation level is determined as the ratio of the degraded areas of the pylon to the entire surface area of the pylon. For example, if the entire surface area of the pylon is 100 m^2 and the degraded areas account for 5 m^2 of that area, the degradation level is 5%. In other words, the degradation level is determined based on the degradation area in the conventional method. Although it is easy to determine the degradation level with this method, there are three problematic issues:

- Inspection results vary greatly because the ratio of degraded areas is judged subjectively by individual inspectors.
- Minor degradation of paint coatings and serious corrosion of structural steel are judged to have the same degradation levels because the type of degradation is not considered.
- It is not possible to pinpoint paint degradation in its initial stage (that is not shown by the external appearance) by visual inspection only, and it is not possible to define the degradation level of pylons in relatively sound conditions.

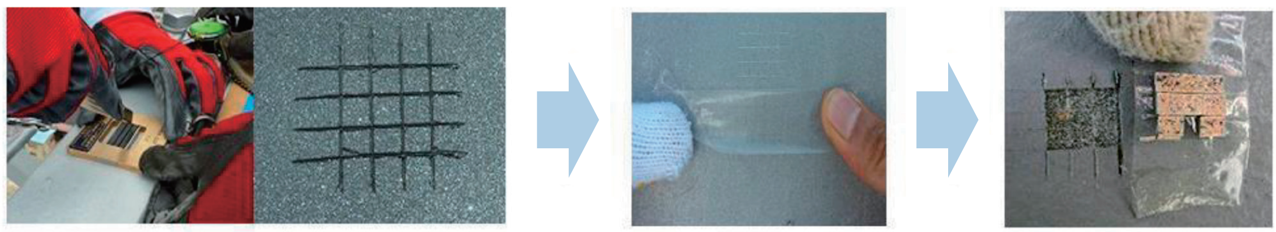
Furthermore, pylons are inspected once a year regardless of their degradation conditions, and the ongoing cost burden of such inspections is becoming a serious problem.

3. Review of inspection methods

3.1 Review of visual inspection method

The method used up until now in visual inspections (namely, determining degradation level based on the ratio of the degraded area) was reviewed, and it was replaced with a method to ascertain the extent of degradation by segmentalizing inspection areas (**Fig. 2**). In the new inspection method, a degradation level for each degradation state is set in advance, and the presence (or absence) of degradation in the segmented inspection areas is determined as shown in **Fig. 3**. After that, each degradation state is weighted according to its degradation level, and a degradation level for the whole pylon is obtained.

The variation in the inspection results (due to



(1) Cross cuts are made by incisions with a cutter (along a guide line) to form a pattern of 3 × 3 squares (nine squares in all).

(2) Cellophane tape is stuck over the entire grid and torn off in one go.

(3) Adhesive strength is judged according to the number of squares remaining on the test piece.

Fig. 4. Procedure of cross-cut adhesion test.

different inspectors) is low with this method because the existence (or not) of degradation in the inspection areas can be ascertained, and it is possible to precisely discriminate minor degradation of paint coatings from serious degradation of structural steel thanks to the weighting on the basis of degradation level. Moreover, when determining the presence or absence of degradation, omitting minor degradation with an area of 5 cm^2 or less makes it possible to evaluate the degradation level in terms of aging degradation only. A review of past investigations revealed that the state of a certain extent of degradation could be observed when pylons degraded with age. Accordingly, by removing minor degradation from the evaluation target, damage other than that due to aging degradation (such as minute paint stripping that occurs during antenna construction) can be excluded, and the degradation level of the pylon can be estimated on the basis of aging degradation only.

3.2 Cross-cut adhesion test

With the conventional inspection method, only certain inspection points are visually inspected. In contrast, the new inspection method involves introducing a cross-cut adhesion test by which the adhesive strength of a paint coating is easily and quantitatively evaluated. The procedure of the cross-cut adhesion test involves first making cross cuts in a paint coating using a cutter to form a pattern of incisions of 3 × 3 squares (nine squares in all), as shown in **Fig. 4**. Then, cellophane tape is stuck over the entire grid of squares and torn off in one go. Finally, the adhesive strength of the paint coating is evaluated according to the number of squares remaining in the test area. Degradation of a paint film generally starts with *latent* degradation, which proceeds in such a manner that it is not evident in the external appearance of the paint; namely, the adhesive strength decreases. Then *overt* degradation occurs; namely, cracking and peeling.

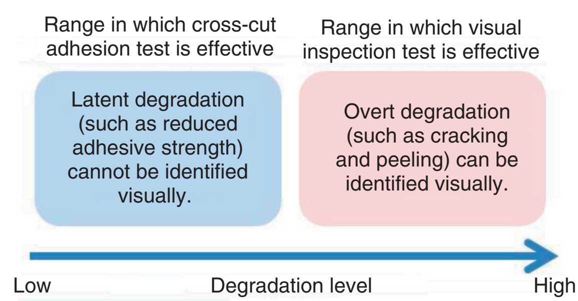


Fig. 5. Effective ranges in which cross-cut adhesion test and visual inspection are effective.

The introduction of the cross-cut adhesion test in addition to visual inspection makes it possible to quantitatively evaluate the latent degradation in the initial stage of degradation. As a result, it is possible to clarify the degradation extent in the case of relatively sound pylons (**Fig. 5**). However, it was necessary to ensure that the workload on inspectors was not increased by introducing the cross-cut adhesion test. Accordingly, a rule was added stating that the test will be omitted after repainting has been done or when peeling of a paint coating is noticeable, and the locations where the test is performed are limited to the minimum necessary.

3.3 Review of inspection frequency

With inspection methods used up until now, inspections were performed once a year regardless of the results of earlier inspections. Consequently, with relatively sound pylons, the frequency of inspections may have been excessive. The introduction of the cross-cut adhesion test (after reviewing the visual inspection method) enabled degradation levels to be determined with improved accuracy. For pylons with low degradation levels, the period between inspections (the inspection cycle) can be extended to every other year. As a result, it is possible to increase inspection accuracy while reducing the number of inspection operations. However, regions with high exposure to a salt atmosphere were not subject to an extension of the inspection cycle since degradation occurs rapidly in such regions. Investigating whether the inspection cycle can be extended in such regions has been set as a future challenge.

4. Concluding remarks

This article discussed inspection methods for pylons. In reviewing inspection methods, 12 prefectural regions in the east and west of Japan were targeted. The effectiveness of the renewed inspection methods was ascertained, and the opinions of inspectors were collected and applied to realistic inspection operations. From now on, the plan is to accumulate the results of the new inspection method and optimize the extension of the inspection cycle and the periods between repainting. The inspection method reviewed in the present study was instituted at the end of the 2014 fiscal year (in the fourth editions of both NTT EAST's and NTT WEST's *Pylon Paint Inspection Manuals*), and full-scale inspections using the new method started in 2015.

External Awards

IEEE VTC2016-Spring Best Paper Award

Winner: Katsuyuki Haneda, Aalto University; Lei Tian, BUPT; Yi Zheng, CMCC; Henrik Asplund, Ericsson; Jian Li, Yi Wang, and David Steer, Huawei; Clara Li and Tommaso Balercia, Intel; Sunguk Lee and YoungSuk Kim, KT Corporation; Amitava Ghosh and Timothy Thomas, Nokia; Takehiro Nakamura, NTT DOCOMO; Yuichi Kakishima, DOCOMO Innovations; Tetsuro Imai, NTT DOCOMO; Haralabos Papadopoulas, DOCOMO Innovations; Theodore S. Rappaport, George R. MacCartney Jr., Mathew K. Samimi, and Shu Sun, NYU WIRELESS; Ozge Koymen, Qualcomm; Sooyoung Hur, Jeongho Park, and Charlie Zhang, Samsung; Evangelos Mellios, University of Bristol; Andreas F. Molisch, University of Southern California; Saeed S. Ghassamzadeh and Arun Ghosh, AT&T
Date: May 17, 2016
Organization: The Institute of Electrical and Electronics Engineers (IEEE) Vehicular Technology Society

For "5G 3GPP-like Channel Models for Outdoor Urban Microcellular and Macrocellular Environments."
Published as: K. Haneda, L. Tian, Y. Zheng, H. Asplund, J. Li, Y. Wang, D. Steer, C. Li, T. Balercia, S. Lee, Y. Kim, A. Ghosh, T. Thomas, T. Nakamura, Y. Kakishima, T. Imai, H. Papadopoulas, T. S. Rappaport, G. R. MacCartney Jr., M. K. Samimi, S. Sun, O. Koymen, S. Hur, J. Park, C. Zhang, E. Mellios, A. F. Molisch, S. S. Ghassamzadeh, and A. Ghosh, "5G 3GPP-like Channel Models for Outdoor Urban Microcellular and Macrocellular Environments," Proc. of the 2016 IEEE 83rd Vehicular Technology Conference (VTC 2016-Spring), Nanjing, China, May 2016.

OECC/PS 2016 Best Paper Award

Winner: Koh Ueda, Yojiro Mori, and Hiroshi Hasegawa, Nagoya University; Hiroyuki Matsuura, Kiyo Ishii, Haruhiko Kuwatsuka, and Shu Namiki, National Institute of Advanced Industrial Science and Technology; Toshio Watanabe, NTT Device Innovation Center; Ken-ichi Sato, Nagoya University, National Institute of Advanced Industrial Science and Technology
Date: July 7, 2016
Organization: The 21st Optoelectronics and Communications Conference/International Conference on Photonics in Switching 2016 (OECC/PS 2016) organizing committee

For "Demonstration of 1,440x1,440 Fast Optical Circuit Switch for Datacenter Networking."
Published as: K. Ueda, Y. Mori, H. Hasegawa, H. Matsuura, K. Ishii, H. Kuwatsuka, S. Namiki, T. Watanabe, and K. Sato, "Demonstration of 1,440x1,440 Fast Optical Circuit Switch for Datacenter Networking," OECC/PS 2016, WF1-3, Niigata, Japan, July 2016.

IPSJ SIG SE Excellent Research Award

Winner: Shinobu Saito and Yukako Iimura, NTT Software Innovation Center; Hirokazu Tashiro, NTT DATA; Aaron K. Massey, University of Maryland; Annie I. Antón, Georgia Institute of Technology
Date: September 2, 2016
Organization: Information Processing Society of Japan (IPSJ) Special Interest Group (SIG) on Software Engineering (SE)

For "Visualizing the Effects of Requirements Evolution."
Published as: S. Saito, Y. Iimura, H. Tashiro, A. K. Massey, and A. I. Antón, "Visualizing the Effects of Requirements Evolution," Proc. of the 38th International Conference on Software Engineering, pp. 152–161, Austin, USA, May 2016.

Papers Published in Technical Journals and Conference Proceedings

Maximizing Lifetime of Multiple Data Aggregation Trees in Wireless Sensor Networks

H. Matsuura

Proc. of NOMS 2016 (2016 IEEE/IFIP Network Operations and Management Symposium), pp. 605–611, Istanbul, Turkey, April 2016.

Sensor data aggregation trees in a wireless sensor network (WSN) are used to gather data from an area that the WSN covers. In this paper, a hierarchical sensor network routing is proposed in which a base station (BS) cooperates with its underlying multiple cluster heads (CHs) to determine the best routes in each tree-cluster. A routing metric proposed in this paper represents the rate of energy increase on a tree when a new sensor is connected to the tree, and the BS can always select the smallest metric route among all the trees; thus, the architecture can reduce the energy consumption of the trees and extend their lifetime significantly. In addition, the proposed routing sets a backup route for each primary route on a tree by choosing the second smallest metric route after the primary route. Therefore, the lifetime of aggregation trees even after some percentage of sensors die is longer compared with other routings.

Impact of Highly Adaptive Elastic Optical Paths on Dynamic Multi-layer Network Planning

T. Tanaka, T. Inui, A. Kadohata, and W. Imajuku

Proc. of iPOP 2016 (the 12th International Conference on IP + Optical Network), Yokohama, Japan, June 2016.

We incorporated a frequency slot resizing scheme into a multilayer network planning method. Firstly, the method assigns optical path demands to existing optical paths that are provisioned in previous phases. Frequency slot resizing is applied if the optical path demand cannot be assigned without resizing, and the removal of unused optical paths is applied after all optical path demands are assigned. Additional optical paths are provisioned if optical path demands cannot be assigned using the proposed approaches. In the evaluations that examined various combinations of transponder types and traffic models, we quantified the effectiveness of the frequency slot resizing scheme on transponder count and spectrum requirements.

Multiperiod IP-over-Elastic Network Reconfiguration with Adaptive Bandwidth Resizing and Modulation

T. Tanaka, T. Inui, A. Kadohata, W. Imajuku, and A. Hirano

Journal of Optical Communications and Networking, Vol. 8, No. 7, pp. A180–A190, July 2016.

Elastic optical networks (EONs) represent a promising network architecture that accommodates a wide variety of traffic demands in the optical layer. Thanks to the functionality of bandwidth flexibility of elastic optical paths, we can now accommodate Internet protocol (IP) traffic directly into the optical layer by configuring, for example, the modulation format and subcarrier counts to client demands (optical path demands). At the same time, to accommodate temporally and geographically changing IP traffic demands efficiently in optical networks, cooperation between the IP and optical layers is essential. This paper proposes a multilayer network reconfiguration algorithm that supports periodically changing IP traffic patterns. We incorporate two schemes, which make IP over EONs more flexible, into the heuristic iterative multilayer network reconfiguration (IMNR) algorithm. The first scheme involves bandwidth resizing achieved through subcarrier expansion and reduction, and the second employs energy-efficient adaptive modulation according to the data rate and distance of the client demands. We evaluated the impact of the following on energy efficiency: the IMNR algorithm, the proposed adaptive bandwidth resizing and modulation schemes, and some multicarrier-based transponder architectures including a bandwidth-variable transponder (BVT) and sliceable BVT (SBVT). The evaluation results show that the IMNR algorithm with the proposed schemes significantly reduces the energy consumption compared with traditional network planning schemes and equipment.

A Static Traffic Grooming Algorithm for Elastic Optical Networks with Adaptive Modulation

T. Tanaka, T. Inui, and W. Imajuku

Proc. of OECC2016 (the 21st Optoelectronics and Communications Conference), TuA1-3, Niigata, Japan, July 2016.

We propose a novel static traffic grooming algorithm for elastic optical networks, which are aware of multiple modulation formats. An evaluation showed the algorithm significantly saves optical paths compared to other algorithms in various network conditions.

Rapid Restoration Sequence of Fiber Links and Communication Paths from Catastrophic Failures

A. Kadohata, T. Tanaka, W. Imajuku, F. Inuzuka, and A. Watanabe

IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. E99-A, No. 8, pp. 1510–1517, August 2016.

This paper addresses the issue of implementing a sequence for restoring fiber links and communication paths that have failed due to a catastrophe. We present a mathematical formulation to minimize the total number of steps needed to restore communication paths. We also propose two heuristic algorithms: Minimum spanning tree-based degree order restoration and Congestion link order restoration. Numerical evaluations show that integer linear programming based order restoration yields the fewest number of restoration steps, and that the proposed heuristic algorithms, when used properly with regard to the accommodation rate, are highly effective for real-world networks.

Shallow Quantum Circuits with Uninitialized Ancillary Qubits

Y. Takahashi and S. Tani

arXiv:1608.07020 [quant-ph], August 2016.

We study the computational power of shallow quantum circuits with n input qubits, one output qubit, and two types of ancillary qubits: $O(\log n)$ initialized and $O(\mathrm{poly}(n))$ uninitialized qubits. The initial state of the uninitialized ancillary qubits is arbitrary, and we have to return their state into the initial one at the end of the computation. First, to show the strengths of such circuits, we consider a class of symmetric functions on n bits, including those (such as threshold functions) for which it is not known whether there exist shallow quantum circuits with only $O(\log n)$ initialized ancillary qubits. We show that there exists an $O(\log^2 n)$-depth quantum circuit for any function in the class with $O(\log n)$ initialized and $O(n \log^2 n)$ uninitialized ancillary qubits. Its existence shows the possibility that augmenting uninitialized ancillary qubits increases the computational power of shallow quantum circuits. The depth decreases to $O(\log n)$ when we use unbounded fan-out gates and unbounded Toffoli gates. Then, we consider the limitations of shallow quantum circuits with uninitialized ancillary qubits, which include unbounded fan-out gates and unbounded Toffoli gates. We show that, when the number of qubits on which unbounded fan-out gates act is $O(\mathrm{poly}(\log n))$, for any constant $0 \leq \delta < 1$, there does not exist an $O(\log^\delta n)$-depth quantum circuit for the parity function on n bits with $O(\log n)$ initialized and $O(\mathrm{poly}(n))$ uninitialized ancillary qubits.

Smooth Motion Parallax Projection Displays for Highly Realistic Applications

M. Date

Proc. of IMID 2016 (the 16th International Meeting on Information Display), p. 204, Jeju, Korea, August 2016.

The image quality of displays has advanced greatly so that almost everyone is satisfied with displayed 2D images or videos. Though 2D displays cannot reproduce directional information due to the Mona Lisa effect, it is an advantage for entertainment use. However, when users communicate through electronic displays, the lack of directional information is a severe problem because users cannot understand who a remote user is addressing. Using a smooth and exact motion parallax display, users can only see the facial direction but can also perceive the direction of interest, a slight change of mind, a sense of material, and a feeling of existence. In this presentation, a conceptual demonstration system of Space Composite Telecommunication, which can connect remote and local places, is shown. It uses a life-size glasses-type 3D projection display with smooth motion parallax by head tracking of remote and local users. Our recent trial with glasses-free displays is also demonstrated.

Drive-amplitude-independent Auto Bias Control Circuit for QAM Signal and Its Demonstration with InP Based IQ-modulator

H. Kawakami, S. Kuwahara, and A Hirano

Proc. of ECOC 2016 (the 42nd European Conference on Optical Communication), Düsseldorf, Germany, September 2016.

A novel auto bias control technique for various types of IQ modulators is proposed. The technique can generate any order quadrature amplitude modulation signals with no dependence on drive amplitude. The measured penalty was found to be almost negligible.

Video Extrapolation Method Based on Time-varying Energy Optimization and CIP

H. Sakaino

IEICE Transactions on Image Processing, Vol. 25, No. 9, pp. 4103–4115, September 2016.

This paper proposes a physics-based method to extrapolate new videos from a few images with data compression free under image energy constancy. State-of-the-art methods rely on data compression and no physical rules, where significant image degradations, i.e., blur and artifacts, and insufficient motion changes, have been generated. With highly detailed image features, our proposed video extrapolation method shows the effectiveness of physics-based equations and CIP (constrained interpolation profile) with less computation cost.
