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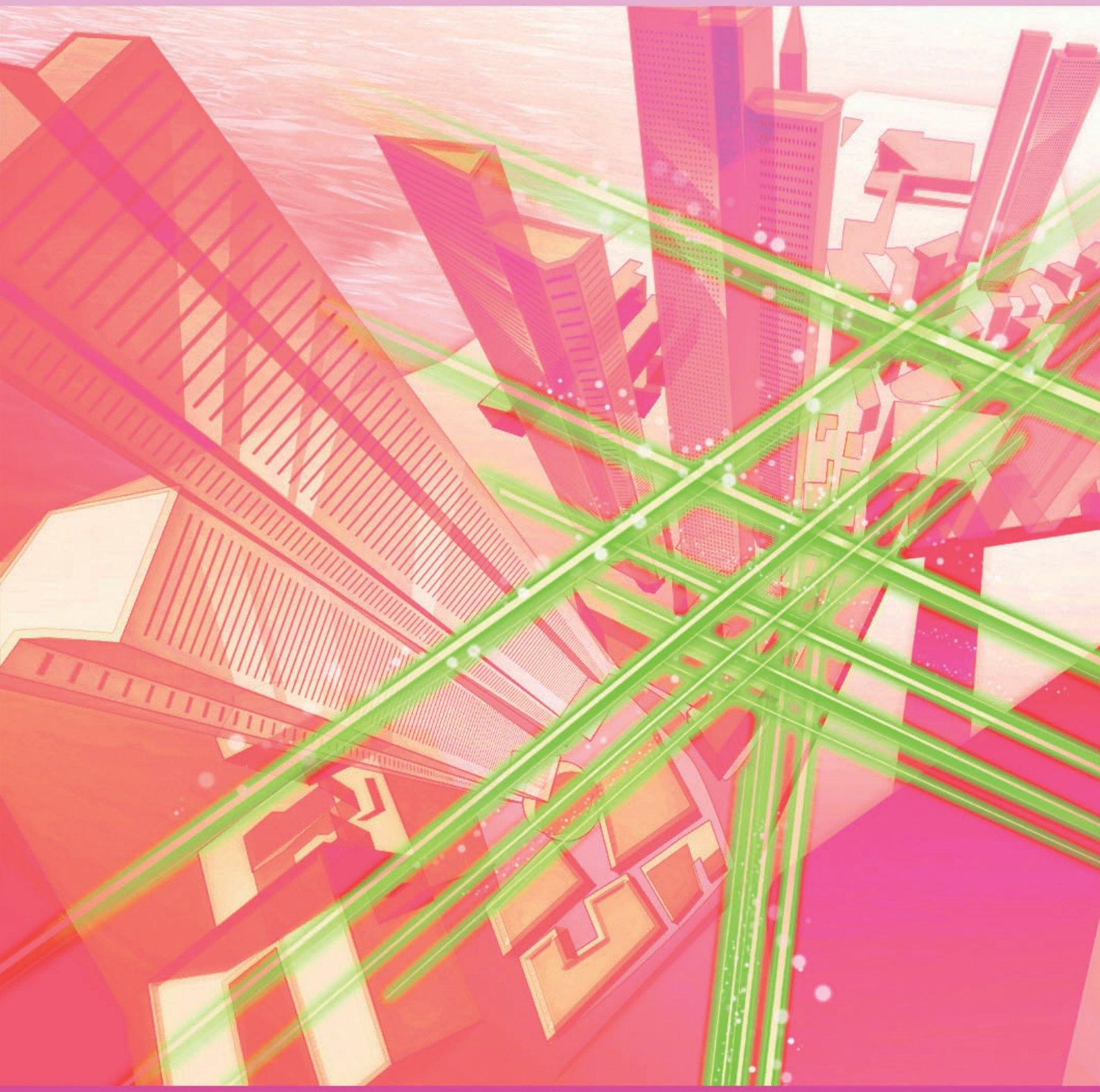

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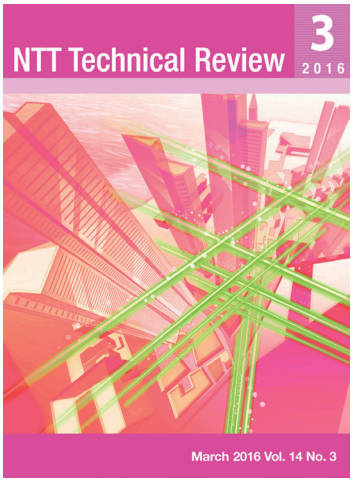


Changing the World for the Better! R&D as the Engine Driving Continued Corporate Growth

Seizo Onoe
Executive Vice President and Chief Technology Officer, NTT DOCOMO

Overview

NTT DOCOMO is the source of much innovative technology in the mobile industry, and with 2020 in view, it has already set in motion the research and development of 5G, the fifth-generation mobile communications system. We asked Seizo Onoe, NTT DOCOMO Executive Vice President and Chief Technology Officer, how the company is surviving the highly competitive environment and what it aims to achieve by making maximum use of the company's strengths.

Keywords: 5G, LTE (Long Term Evolution), R&D

Leveraging close contact with customers to develop new services

—Mr. Onoe, please tell us about the business environment surrounding NTT DOCOMO.

The last few years have seen severe competition in the business environment, but financial results for the third quarter of fiscal year 2015 showed an operating revenue of 3383.5 billion yen and an operating income of 685.5 billion yen, or a year-on-year increase of 1.7% and 16.8%, respectively, showing that the company has achieved two consecutive quarters of growth in both revenue and income. The Smart Life domain has been expanding favorably, and cost management such as in the area of capital investments is becoming increasingly more efficient. At the beginning of this fiscal year, NTT DOCOMO rolled out its "+d" initiative that aims to deliver new value to its customers through co-creation with partners. The plan is to make significant contributions to society under the themes of "solving social issues" and "revitalizing regional economies."

Combining the strengths of our partners with the diverse business assets of NTT DOCOMO creates new value. Being in charge of research and development (R&D), I also think in terms of "+d" from an R&D perspective. When we hear the words "NTT DOCOMO asset," perhaps the first thing that comes to mind is a business-like asset such as a customer base, but a technology asset can be just as valuable. Co-creation on the R&D side is already occurring in unexpected areas and producing results toward new business opportunities.

To give an example, NTT DOCOMO's natural-language dialog platform technology developed for the Shabette Concier voice-agent service and other applications has been incorporated in the OHaNAS interactive conversational toy robot developed jointly with TOMY Company, Ltd. The business environment is still as competitive as ever, but I would like to create a virtuous cycle in which the growth of NTT

DOCOMO itself results in the continuous provision of even better services for our customers.

—NTT DOCOMO has prospered despite the severely competitive environment—where do its strengths now lie?

Being a corporate enterprise, NTT DOCOMO must continue to generate profits, but on the other hand, it must also invest in the future. In a highly competitive environment, investment in the future would tend to be restricted, but I believe that the engine for achieving continued corporate growth into the future is R&D. For the past few years, we have been reviewing the methods used in R&D and working to make operations more cost-effective, and it is exactly because there are restrictions here that we have had to come up with new ideas and approaches. As a result, I believe that we have restructured ourselves in a way that enables us to produce R&D results in an ongoing and efficient manner.

Nevertheless, determining how much to invest and what to research in advance is difficult, to say the least. As you know, the range of R&D at NTT DOCOMO is quite broad, spanning the improvement and expansion of existing services as well as network operations and technical support. While it is necessary to continue our existing technology development efforts building upon past results, I also intend to prepare a growth engine that looks five years and more into the future taking technology trends into account.

Regarding the infrastructure development, NTT DOCOMO is focusing on the fifth-generation mobile communications system (5G), enhancement of the LTE-Advanced system, and network functions virtualization (NFV). We are proud of our role as a global leader in third- and fourth-generation (3G and 4G) system development, and we now have our sights set on deploying 5G services by 2020. In fact, we are conducting experiments and trials in cooperation with leading global vendors to contribute to the standardization of 5G technology.

The key issue here is how to go about creating new services. There are great expectations that the Internet of Things, big data, and artificial intelligence (AI) will lead to new business opportunities. NTT DOCOMO has been involved in this area from early on, and some services of this type are already being offered to customers. The natural-language dialog engine that was first used in Shabette Concier has undergone further development by incorporating

NTT research results to the maximum. These efforts led to the development of the OHaNAS robot that I mentioned. In this way, I believe that the way NTT DOCOMO maintains close contact with customers when creating new services is a key strength.

Moving forward with a global view 20 years into the future—contributing to the world with 5G

—Where is NTT DOCOMO headed in the years to come?

As you know, NTT DOCOMO's origins are in the mobile world. Up to the second-generation mobile communications system, specifications tended to be fragmented among countries and carriers, but from 3G on, it has been the earnest desire of the mobile industry to implement a common system worldwide. In this regard, 3G and LTE certainly played a role in achieving a world standard, but it was NTT DOCOMO that was recognized as a world leader in this process. Our R&D achievements are one reason for the high marks we have received, especially from parties overseas. Government ministers in Europe have been known to come here to visit our top executives largely because of our R&D. Of course, gaining such praise or respect is not our objective. Our aim through R&D is to make business-related contributions and to provide our customers with even better services.

On the other hand, the mobile industry on the whole has a very low reputation worldwide. Despite efforts at making people's lives more convenient and contributing to society through mobile communications, the reality is that these efforts are not generally recognized. To rectify this situation, I would like to demonstrate to the world in concrete ways just how useful mobile technology can be to society and how it can

contribute to the entire world community.

Recently, on the occasion of the Miss International Beauty Pageant held in Tokyo, we asked contestants from various countries to trial the 5G mobile communications technology. We received many messages expressing positive reactions such as "I would love to be able to use 5G in my country soon" and "I want 5G to change the world for the better," even from contestants representing regions having a relatively low penetration of mobile phones. Such reactions made us feel that 5G is generating great expectations from a wide range of people throughout the world, and we came away with a strong sense of responsibility to contribute to the world through 5G technology.

To date, the mobile industry has witnessed the birth of a new generation of technology about every ten years, and the immediate target is the launch of 5G in 2020. In Japan's advanced mobile communications market, the 1G and 2G systems discontinued operations after 20 years, reflecting a relatively quick transition in technology. Worldwide, however, history has shown that the diffusion of a certain generation of mobile technology peaks at the 20-year mark. We can say, therefore, that the development of a new generation of technology brings maximum benefit to the world 20 years later.

Technology trends in terms of infrastructure evolution can be predicted five or ten years into the future to some extent. However, I can honestly say that predicting the state of services five years from now is difficult. There are those who simply say that innovation does not occur in large corporations. However, I believe that services are about to become a very important area, and it's my aim to create an environment to achieve a lot of innovation at NTT DOCOMO. With the aim of creating new services using a mechanism different from that used for existing services, I have made organizational changes and put into place a new system and development process. Here, an open development environment is crucial, and we are working on creating new value centered about passionate and enthusiastic developers through collaboration with parties on the outside.

Returning to the topic of 5G, I can say that initiating studies on new generation technology generally gives rise to negative reactions, as in questioning the need for changing to a new generation when the current generation is still generating revenue and pointing out that constructing a new infrastructure will incur massive expenses. When studies on 3G were beginning, some people would ask, "What would a data rate of 2 Mbit/s be used for?" and in the case of LTE, a common question was "Is a rate of 100 Mbit/s really necessary?" NTT DOCOMO takes the initiative in technology development and makes investments where needed. Once a person has been placed in a pleasant environment and becomes accustomed to it, there's no turning back! When a more convenient environment is provided, a virtuous cycle will arise in which users come up with usage methods appropriate to that environment. In this way, people are now enjoying one of the world's leading mobile environments that we created. There is much excitement about 5G at such an early stage that the standardization discussion has not yet started. This is more than we expected, but in the period leading up to 2020, my goal is to make steady progress in developing 5G technology without losing any of that excitement.

There is one more thing concerning a dream of mine that I would like to purposely express to the outside world. I believe that the base technology of mobile phone systems, that is, cellular technology, will come to be used in all sorts of use cases and will eventually become the dominant communication technology. For the time being, we can expect a number of technologies to be used and operated in a complementary and coordinated manner, but my dream is that they will all converge to cellular technology one day. On the other hand, as we look out over a long time span of say 30 years, the reality is that cellular technology might again diverge into some different technologies. Over the next five years, however, I am confident that the various technologies now in use will converge to LTE-based cellular technology.

Easily achieved results soon become commonplace. Set targets that even you may have doubts about!

—Mr. Onoe, you are sometimes called the "father of LTE." Can you leave us with a message for the engineers working under you and all NTT DOCOMO employees?

I would be happy to. The emotional argument that "a person with passion can do anything" certainly is not true all the time, but it is very important that you continue to bring passion to your work. While this depends somewhat on each person's temperament, having a desire to seek out challenging themes and big dreams with persistence is important in an engineer. Looking back at myself in the past, I would say that perhaps I was like that, but only in the sense that I would become totally absorbed in the problem before me. However, through experience, I came to understand the importance of setting somewhat high targets. If you set a low hurdle for yourself, you will be able to achieve something very soon, but whatever it is that you developed will soon become commonplace and conventional.

I believe that "things that appear impossible" and "things for which people have doubts about" are ideal as five-year targets. In relation to 5G, I will usually tell my research team to achieve something difficult that even I myself have doubts about it. For example, I have told them that I want us to aim for a cellular system that can deliver signals up to a distance of 1 km even if using high frequency bands, despite the fact that I actually feel that only half that distance is feasible. In my experience, when I become absorbed in a project while thinking "there is no way that this can be done," I have sometimes experienced utter surprise when it turns out to be doable, exclaiming "What? It worked!"

The capability of doing anything on our own is sometimes referred to as being in the NTT Group's DNA. However, we will enter an era in which we cannot survive if we are not quick to adapt to changes in vendor and operator relations and in technologies and ecosystems while thinking closely about what we ourselves should be doing and where we should focus our energy. In today's world, technology tends to be controlled by vendors, but displeasure with this situation can be heard from operators. I want NTT DOCOMO to continue to have a big impact on the world and to be obsessed in a good way about doing so. In this endeavor, it is crucial that we know our customers better and have a global perspective. It is nonsense to think about what to create by looking only at Japan without learning about things going on in the outside world. With these ideas in mind, I would like all engineers and employees to think for themselves and let their opinions be known and to adopt the spirit of a world leader in their field.

Finally, I would like us to develop close links with the R&D departments within the NTT Group. We can expect NTT laboratories to have top-level technologies in the security field and elsewhere. I want to create services that change the world through intra-group collaboration that facilitates the mutual use of superb technologies. We need to form closer and stronger ties. And there are key areas being driven by NTT DOCOMO, too such as AI-based interactive and translation technologies, platforms for location-information services, and NFV. Going forward, I want us to develop strong collaborative practices to maximize the value of the entire NTT Group!

Interviewee profile

■ Career highlights

Seizo Onoe joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1982. After entering the company, he took on the R&D of mobile communications systems. He became NTT DOCOMO Senior Vice President and Managing Director of the R&D Strategy Department in 2008 and Executive Vice President, a member of the Board of Directors, and Managing Director of the R&D Center in 2012. He assumed his current position in July 2014 while retaining his position as a member of the Board of Directors.

Research Isn't Evolution—It's Revolution!

William John Munro
Senior Research Scientist, NTT Basic Research Laboratories

Overview

In this issue, we welcome Dr. William J. Munro, the first non-Japanese group leader within NTT laboratories, as our front-line researcher. Bill passionately tells us about quantum physics, which has the potential to bring great change to the world, and its application to the field of information and communications. He also tells us why out of all the research institutes in the world, he decided to join NTT laboratories, and how he approaches research to produce innovative results.

Keywords: quantum physics, quantum device, research

Overthrowing established theory and envisioning quantum networks of the future

—Dr. Munro, please tell us about your current research.

Well, I am researching the creation of new quantum technology through the exploration of the unique properties of quantum physics and the fundamental limits it has on information processing. For example, my pen consists of a variety of small parts (the case, spring, etc.,…). Each of these parts is made of smaller parts, some too small for the human eye to see (micron sized for instance). If we go even smaller, by factors of one thousand or more, we would eventually arrive at atoms, the building blocks of matter and nature.

What is of importance here are that the laws that govern the pen as a whole and the laws describing the atoms can be different. Classical mechanics governs our real macroscopic world while "quantum mechanics" is generally thought of as the laws that govern the atomic world. Throwing the pen at a wall, we all know it will bounce off, but throwing the atom can produce a really interesting result. It can tunnel through it but will never be found in the wall. This is one of the interesting effects quantum physics allows.

Technical innovation in electronic devices has become so familiar to us in our daily lives due to the miniaturization trend. Our automobiles we drive every day now contain many small computers that control many of its basic functions. The car is probably classical in nature, but it may have had quantum physics help in designing it. These quantum principles are used for instance in the construction of the microprocessors that make up the computers.

By embracing these quantum properties, we can bring about a true technological revolution. In short, it can make possible new things that could not be achieved in the past (or even thought of), such as building absolute secure networks on a global scale or next generation computers. Quantum computers (**Fig. 1**), which are currently attracting significant worldwide attention, could be billions of times more

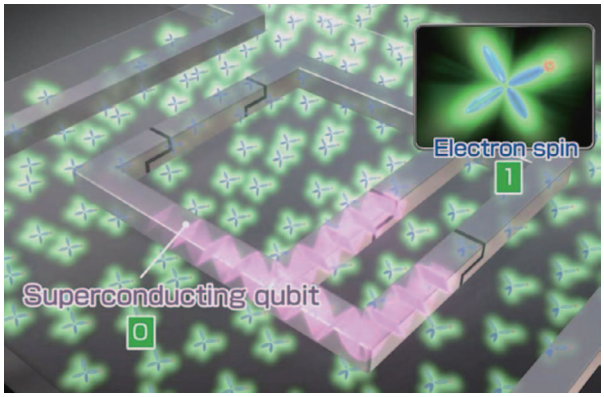


Fig. 1. Schematic of a super-conducting qubit. This is a key element for the quantum computer.

powerful than the computers we are using today or could exhibit a level of performance greater than all computers in the world combined. Quantum computers could in principle process more data than the total number of atoms in our Universe!!!

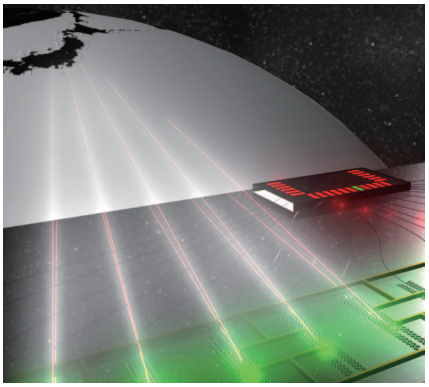
The quantum world is quite unique by the standards of classical physics. Quantum entanglement suggests, for instance, a phenomenon in which multiple quanta situated far apart from each other nevertheless are inextricably correlated is possible, much like the two sides of a coin. It is hard to believe, but this phenomenon exceeds time and space. The question is, how do we realize devices that exploit this, and how do we make quantum principles useful in our everyday lives? The phenomenon of quantum entanglement is turning into an indispensable resource for quantum communications, computing, and metrology. A focus of our group and other researchers in this field is to create technology roadmaps extending 20 to 30 years into the future on quantum information processing (QIP) systems using these quantum principles and to discover how to bring about great changes in the world through quantum technology.

—Can you tell us something about global research trends in this field?

The birth of quantum computers and quantum information enabled devices that will give rise to entirely new industries. For example, e-commerce in the conventional sense could cease to exist as its security is removed or may need to be completely reegineered. While this may seem a little negative for society, there could be some big gains as well. We will be able to achieve things that we can just not imagine now. In the field of medical care, it could become possible to design drugs tailor-made to the individual patient and their condition, or in the field of meteorology, the quantum computer could enable accurate weather predictions many weeks in advance. That would have an enormous impact on the harvesting of crops. This is our vision that some may treat as just a dream, but it will become a reality in the not too distant future.

In the field of information and communications, data security is becoming a major issue of concern around the world. To achieve a major breakthrough in this field, we need to change the rules. Today an encrypted message is unlikely to be opened unless one possesses the key for decrypting it or actively cracks it. However, quantum communications will make it possible to send messages with absolute security. If the sender and receiver of a message possess a random bit sequence called a “secret key” that cannot be predicted by anyone (other than the sender and receiver), and if that key is destroyed after use, then confidential communications can be carried out along a wireless communications path or a public communications path such as the Internet (Vernam cipher).

The questions is how to get this key. Quantum cryptography is a method of providing the sender and receiver with such a secret key by having them exchange the quantum mechanical superposition states between them. This process is called quantum key distribution (QKD). To give an example, let’s assume QKD apparatus operating over a distance of about 100 km (**Fig. 2**). The sender and receiver (Alice and Bob) can obtain a desirable secret key in this way. Here, Alice sends photons prepared in a few known states over a fiber to Bob who measures them in a random basis. When the basis of Alice send photons



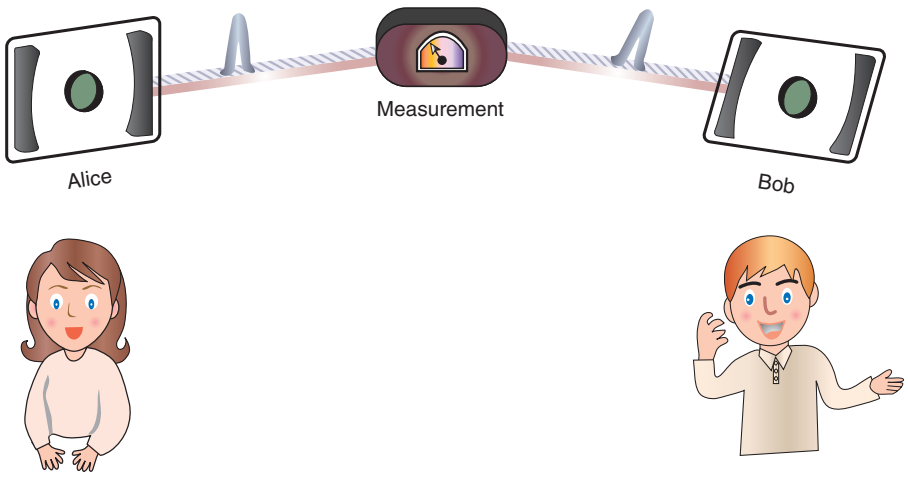


Fig. 2. Principal of QKD.

and Bob measured photon agree, they keep the resulting bits. Next, they correct for bit errors, and finally, they shorten the bit sequence to an appropriate length based on the level of information that can be leaked to eavesdroppers (nature or Eve).

By the way, I am proud to say that our group is at the forefront of quantum communications research, especially in QKD and quantum networks. Research in this area spans a period of nearly 15 years. In the beginning, communication rates were limited to about one quantum bit of information per hour. However, we are now proposing schemes for transmitting millions per second, which was initially doubted by the research community but is now widely accepted and admired.

—What made you think of NTT as a place to pursue your research?

The wonderful research environment! I have experienced research life in universities and companies overseas, but at NTT, I feel that I am quite fortunate to be in an environment in which theoretical researchers can interact smoothly with lots of experimental groups. Overseas, it is typical to have one experimentalist to ten theorists, but at NTT Basic Research Laboratories, the ratio is just the opposite: 10 experimentalist to one theorist (maybe even 20 to 1). When I get an unusual idea in my head, I can talk to my experimental colleagues and say "Is this a crazy idea or what?" I may quickly be told "It may not be so crazy. Maybe we should build it!" It is truly a unique and wonderful thing to have colleagues like this who can respond quickly to our ideas. The opposite is of course also true, we help them understand many of their experiments.

Our group is extremely interactive in its approach to research. Whenever a member of our group comes up with an interesting idea, we actively discuss it using the language of mathematics, and we might spontaneously start to write equations all over the board. Of course, these equations could be replaced by conventional words, but it might take about 50 pages of text in either Japanese or English to communicate what these equations are saying in a few lines.

In these last few years, leading overseas companies such as HP and IBM have been downsizing their research laboratories, but at NTT, the value of research and development continues to be appreciated, and basic research is still being given the importance it deserves.

On the other hand, in terms of job duties, rules, and discipline, the research laboratories when I entered NTT were like a typical Japanese company. So I talked about this with management, telling them that I wanted to place priority on results, and they allowed me to pursue my research in an open and transparent environment with a flexible work system. I believe that a researcher cannot be creative if stuck at a desk thinking only about what he or she should be doing.

Engaging with your colleagues in a Polo-shirt and half-pants—it's *results* that are important!

—Are you saying that, in the sense of research

technique and researcher behavior, a flexible approach is necessary?

Let me give you a typical day in our group as an example. The members of our group do not lead the life of a typical business person. I myself get to work by 7:00 a.m. and leave by 4:30 p.m. What is important for a researcher is not to work long hours but to be productive. I rarely wear a suit at work, and for most of the year I pursue my research activities in a polo-shirt and half-pants. The attitude toward research has also changed over time. Up to 20 years ago, it was thought that research was a task carried out by an individual researcher, but in recent years, this has changed to research achieved through teamwork. This can be understood by looking at recent NTT research papers that generally present the results of small teams of researchers all working in concert. Everyone in the team has their part to play! In fact, you are likely to be in several different teams.

When a Japanese researcher wants to get another opinion from someone, I think it's common for them to go to a meeting room with that colleague and have a long discussion just between themselves. However, I think a work environment conducive to dynamic and energetic discussions that can attract and involve other people in the area is essential to stimulating new ways of thinking.

Whether what you say in such discussions is right or wrong is not the issue. Making your point clearly without hesitation makes it possible to fine-tune the topic being discussed. My group and related laboratories are actually building such relationships. For me, such an environment and relationship is natural and matter-of-course. Japanese companies, however, tend to be caught up in vertical relationships, and a common scenario is to give the right to talk to senior staff first and to expect others to follow. In NTT laboratories, as well, there is a hierarchy as reflected by our titles (mine seems to have the word "senior" attached). However, if we strip this away, we are all just "researchers," and who talks depends on the situation. I hope many NTT researchers know that an open environment exists, and if they come across their colleagues engaged in a lively discussion, dive right in and join the discussion! (**Photo 1**)

—To maintain flexibility and creativeness in thought, what do you do in your private life?

When I want to relax, I cook, which is an activity that gives me much pleasure. In this regard, I'd like to mention that, in addition to being a physicist, I am really a chemist. In the sense of mixing together a variety of materials, cooking and chemistry have much in common. Even while I'm cooking, I will have my computer open with a divided screen so that I can enjoy, say, a rugby match on one window while checking out a recipe for a chocolate cake on the other. This enables me to receive two sets of stimuli at the same time. Actually, ideas come to me quite frequently in this way. In addition, having my computer always open enables me to write down any ideas that pop into my head at that time. Of course, writing down such a random sequence of ideas hardly results in clear and concise text, but I have fun putting them all together later, like pieces of a puzzle. Ideas don't come easy to me when I'm tired, so I also enjoy walking and cycling. I walk to and from work every day, and on weekends, I may walk as far as the Imperial Palace (20 km). I also enjoy my e-book collection of over 1000 works, and I like reading, in particular, science fiction and manga. I think that the world described by Arthur C. Clarke in his books has actually become a reality in many respects. The world of the Japanese manga *Dragon Ball Z*, on the other hand, is fantasy, but I enjoy it because it's different.

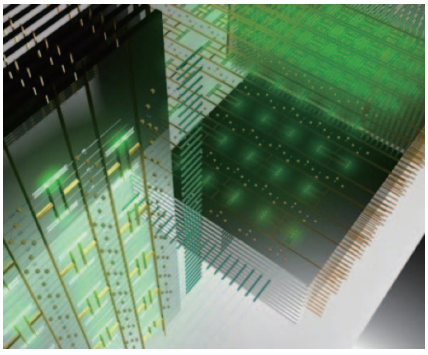
Photo 1. Promoting active discussions.

Its unorthodox ideas are "outside the box," much like day-to-day research.

Envisioning the future through a dynamic and flexible approach unrestrained by existing concepts

—Dr. Munro, what advice would you give to young researchers?

All in all, please think outside the box. Your idea may be crazy, it might seem ridiculous to other people, but out of 100 ideas, one may still be a very good idea. Pursue themes that can have a great impact on society, that can change the world. And in doing so, don't be afraid of failure. In fact, failing in solving problems is not a failure. Use it as an opportunity for thinking how you can do it better in the next step of your research. If you can't fail, you can't succeed. Actually, when a young researcher or postdoc comes to my office for consultation, I begin by throwing up about 100 different ideas in the air. We will sit in front of a whiteboard and talk nonstop about the feasibility of a certain idea, what might be attractive about it, and while it may not be achievable soon, how best to approach it. Research, in a word, is a *passion*. Without your own ideas, you are just doing standard work with little job satisfaction. A researcher has an objective in his or her research, such as "I want to solve something" or "I want to explore something." So without passion, it's hard to continue and accomplish something significant. Finally, I would like to emphasize the importance of communication. Actually, this holds true for all researchers, not just young staff. Don't think that you can do it all on your own at your desk—please talk to the people around you and ask questions. Your neighbor may be able to solve a problem that you have been stuck on in just five minutes. If you sometimes get away from your desk and research laboratory, it's easy to receive stimuli from the outside!



—Finally, what are your plans for the future?

It's very simple: realize these quantum devices! Actually, quantum mechanics itself is already being incorporated in high-tech devices. Our challenge is to make such devices that are actually using quantum principles even more powerful. This attempt of ours, however, is not simply an extension of ongoing technology development to make computers or communication devices smaller. Our goal, rather, is to do something radically new while using the same principles. In this way, we want to bring about not just change but a real revolution. To be more specific, we are working jointly with various experimental groups with the aim of creating a compact quantum device within the next five to ten years. We are still at the basic research stage, and talk on how such a device would actually function is still a bit further away, but we are steadily advancing.

As for myself, I enjoy my daily work immensely. In fact, I don't think of research as "work" but rather as something that I take extreme pleasure in doing. What is difficult is separating the pleasure of research from work. We are at the forefront in this field, and our role as researchers is to push the boundaries to fundamentally change society for the good. Research isn't evolution, it's revolution!

■ **Interviewee profile**

William John Munro

Senior Research Scientist, Group Leader, Theoretical Quantum Physics Research Group, Optical Science Laboratory, NTT Basic Research Laboratories.

He received a BSc in chemistry and physics in 1989, an MSc in physics in 1991, and a DPhil in quantum optics in 1994 from the University of Waikato, New Zealand. In July 1997 he accepted an Australian Research Council Fellowship at the Department of Physics at the University of Queensland, Australia, to undertake research on entanglement, methods to characterize it, and its practical use in QIP. After spending more than three years in Australia, he joined HP Labs in Bristol in November 2000 as a research scientist to investigate and develop various quantum technologies. After a decade there, he joined NTT Basic Research Laboratories in 2010 as a research specialist and was promoted to senior research scientist in 2014. He was elected as a 2015 OSA Fellow by the Optical Society of America. He is also currently a Fellow of both the Institute of Physics in the UK and the American Physical Society.

Development towards Building a New Generation Network Platform and Attractive Network Services

Hiroshi Tohjo, Katsuhiro Shimano, Tatsuya Fujii, Osamu Akashi, and Hitoshi Masutani

Abstract

At NTT Network Innovation Laboratories, we are working on developing the network and application technologies for a new generation network and new generation applications. In this article, we briefly describe some of our development activities including software-defined networking and network functions virtualization, a remote collaboration platform, and a distributed data analysis scheme.

Keywords: SDN, media collaboration, distributed data analysis

1. Introduction

Cloud computing has become a very popular service that makes it easy to access computing resources. It also makes it possible to build new network services using resources other than cloud computing resources, for example, using only static network resources such as mashup web services. Users can automatically manage cloud computing resources using application programming interfaces (APIs). However, networks still require manual operation, especially telecom carrier networks. Consequently, it takes a very long time to deploy network resources and to launch new network services. If the network infrastructure enabled rapid operation and automation of the network for operators and users, it would be possible to create attractive network services with cloud computing resources in the same manner as mashup services. Also, if it becomes possible to flexibly combine computing resources and network resources, then a new application platform should be developed for new generation applications.

Software-defined networking (SDN) is a technical networking concept that can provide programmability to network operation via APIs. Network functions virtualization (NFV) is a network architecture design concept in which network functions such as firewalls and NAT (network address translation) are implemented using network application software and a commodity server that enable the network operator to create network services with more than one network function. In NFV, network services are based on the software used and are managed via an orchestrator. Thus, SDN and NFV have attractive features, so we are researching SDN/NFV technologies to achieve network flexibility.

As mentioned previously, SDN/NFV enables the operator or users to exploit network resources and cloud computing resources. Existing application platforms will have to be reexamined to ensure they can be used with new generation applications because most of them were developed based on static network resources. We are currently developing a remote collaboration platform as a new generation application to obtain the ultimate communication capabilities.

If a network and applications deployed on it use many network and cloud computing resources, it will be difficult to apply the current management technology with them because network management is designed based on an assumption of limited network resources. Consequently, an effective data analysis technique is necessary in order to rapidly analyze an

enormous amount of data and a large number of logs and to determine the appropriate actions. Thus, we are also working on distributed analysis technology.

In this article, we introduce our activities focused on the development of a new generation network and a new generation application platform.

2. SDN/NFV activities

The software switch is one of the most important components in SDN because it is utilized as a virtual switch that allows packet processing between the outer network and an internal virtual machine, and also between virtual machines. Therefore, software switches should be capable of high performance packet processing. We are currently participating in the O3 project [1] whose goal is to achieve wide area SDN, and which is funded by the Ministry of Internal Affairs and Communications of Japan. In this project, we are developing the SDN software switch *Lagopus* [2] for high performance packet processing [3]. Lagopus is an OpenFlow software-based switch application that has already achieved a transmission speed of 10 Gbit/s and over 1 million flow rules. Furthermore, Lagopus is open source software.

In ETSI ISG[*1] NFV standardization, the network service orchestrator is one of the components of the NFV architecture. This component largely depends on the telecom carrier's operation logic, and therefore, we are currently developing an NFV service orchestrator called *vConductor*. vConductor can seamlessly connect multiple network resources to cloud computing resources in order to build various network services through simple operation.

Lagopus and vConductor are often referred to as backbone network components. However, in order to access various network services from a home or enterprise network, edge network equipment is needed. Customer premises equipment (CPE) is frequently used for connecting a local network, including a home or enterprise network, to a telecom carrier network. CPE often has only one telecommunication channel provided by a telecom carrier. However, CPE that can connect multiple telecommunication channels to achieve flexible network services is desirable because different types of network service traffic have different priorities. We are developing Smart CPE that can support multiple telecommunication channels for flexible traffic engineering in the manner of SDN/NFV [4].

3. Next generation remote collaboration platform

Telephone and video communication technology were originally designed and developed for simple communication functions. Although these services provide a remote communication function, it is not sufficient for rich communication. If SDN/NFV can be utilized to provide a network infrastructure with simple and automated operation, we believe that rich remote collaboration and communication can also be realized as a new generation application platform. In this context, we are developing remote collaboration technology that includes media time synchronization technology and highly reliable media packet transmission for audio and video signaling and signaling for IoT (Internet of Things) [5].

4. Distributed data analysis technique

The network is a very important infrastructure because it forms the basis of social communities; hence, it must be stably maintained through proper network management. However, the amount of data and logs being produced by the huge amount of network equipment is increasing as more services are being added. Furthermore, if SDN/NFV technologies are applied to the network infrastructure, the telecom network carrier has to analyze and process such data and logs to keep their infrastructure stable. Therefore, we are developing a distributed data analysis scheme for rapidly analyzing and predicting network failures or congestion [6].

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SDN Software Switch *Lagopus* and NFV Service Orchestrator *vConductor* for Developing SDN/NFV

Norio Sakaida, Hirokazu Takahashi, Masahiro Yoshida, and Tomoya Hibi

Abstract

In anticipation of the wide deployment of software-defined networking (SDN) and network functions virtualization (NFV), we at NTT Network Innovation Laboratories have been carrying out research and development (R&D) of SDN and related network virtualization. This article presents two of the R&D topics in this field, the software switch *Lagopus* that corresponds to OpenFlow 1.3, and the NFV service orchestrator *vConductor*, which is based on global standard techniques.

Keywords: network virtualization, SDN, NFV

1. Introduction

The implementation of *softwarization* and the virtualization of network functions are expected to enable flexible and rapid provision of various network services, and therefore, research and development (R&D) and standardization are advancing rapidly in the areas of software-defined networking (SDN) and network functions virtualization (NFV). Recently, the introduction of SDN technologies in datacenters has progressed a great deal with the spread of cloud computing and the progress in network virtualization technologies, and the application of SDN by telecommunications carriers and in large-scale corporate networks is fully underway. Furthermore, the application of NFV to mobile communication core networks is being actively investigated. In light of this, researchers at NTT Network Innovation Laboratories are working on developing a network platform in which new technologies and services can be rapidly introduced by utilizing software that has flexibility, and we have therefore quickly taken on the R&D of SDN and network virtualization.

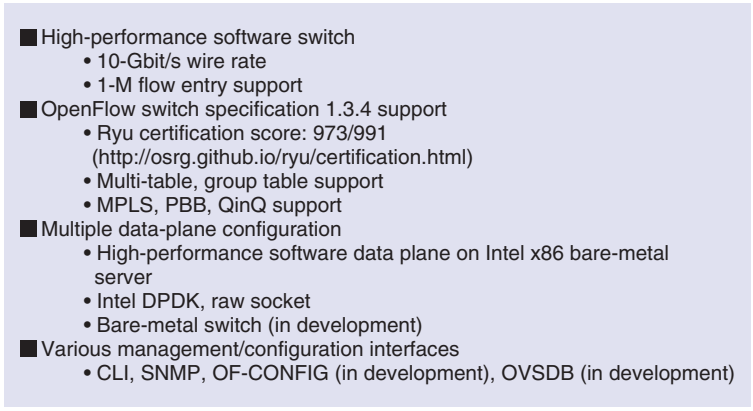
In this article, we introduce two of our research topics: the high-capacity, high-performance SDN software switch *Lagopus* and the important NFV service orchestrator *vConductor* actualized for NFV.

2. Lagopus: SDN software switch

Lagopus is not only intended for datacenters; we also plan to apply it to wide area networks utilized by telecommunications carriers, and we have therefore been actively conducting R&D in order to achieve the required performance and functionality. Some of the current specifications are listed in **Fig. 1**.

In terms of performance, Lagopus supports a transmission speed of 10 Gbit/s and over 1 million flow rules. Since 40-Gbit/s and 100-Gbit/s network interfaces have become less expensive, we are targeting even higher performance levels in the future.

In terms of functionality, Lagopus supports a wide range of OpenFlow specifications that include functions targeting wide area networks such as multiprotocol label switching (MPLS) and bandwidth control. Furthermore, we are expanding the range of applications from not only physical networks but also the functions that connect virtual machines and the combined resource allocation administrator that supports multiple management interfaces. By actualizing all of



CLI: command line interface
DPDK: Data Plane Development Kit
MPLS: multiprotocol label switching
OF-CONFIG: OpenFlow Configuration
OVSDB: Open vSwitch Database Management Protocol
PBB: provider backbone bridge
SNMP: Simple Network Management Protocol

Fig. 1. Lagopus specifications.

these types of performance and functions with software operating on generic x86 architecture servers, we can reduce equipment costs and achieve rapid introduction of network services.

In July 2014, we released Lagopus as open source software (OSS). We provided it as OSS so that it would be widely applicable and widely used. Various Lagopus events have been held and hands-on exhibits sponsored, which have resulted in an active SDN market. We and other users are continuing to investigate new SDN use cases.

Here, we present two proof-of-concept demonstrations involving the use of Lagopus as application examples of various SDN use cases.

2.1 SDN-IX

The ShowNet is a network constructed at venue sites during the annual Interop Tokyo event. It is not merely an experimental network; it is also a utilization network operated as Internet service providers and carriers for exhibiting companies and attendees.

At the Interop Tokyo 2015 ShowNet, an SDN-based Internet exchange (SDN-IX) (**Fig. 2**) was deployed as a new SDN use case. Its dynamism was demonstrated in the Internet exchange (IX)[*1] that connects networks used at the exhibition sites to external networks. The switch that actualizes the SDN-IX was the Lagopus switch. No failures occurred during the event, thus proving stable operation.

Furthermore, through cooperation with the NECOMA (Nippon-European Cyberdefence-Oriented Multilayer Threat Analysis) project, we were able to actualize flexible services through SDN that IXes up to now could not provide such as protection from attack traffic and mutual connections between different VLANs (virtual local area networks). The results of demonstrating various services and components were evaluated, and Lagopus received the Interop Tokyo 2015 Best of Show Award SDI (Software Defined Infrastructure) Special Prize.

2.2 Segment routing

Segment routing is a network path control method that utilizes the advantages of centralized management networks and distributed management networks. It is currently undergoing standardization by the Internet Engineering Task Force. In segment routing, segment identifications (IDs) are assigned to nodes and links. Route optimization in the network is autonomously and dispersively performed while advertising segment IDs using routing protocols such as the Open Shortest Path First (OSPF) protocol. In addition, when using MPLS labels, the traffic route can be autonomously and freely controlled by associating a segment ID with a specific traffic flow.

*1 IX: Equipment that interconnects Internet service providers.

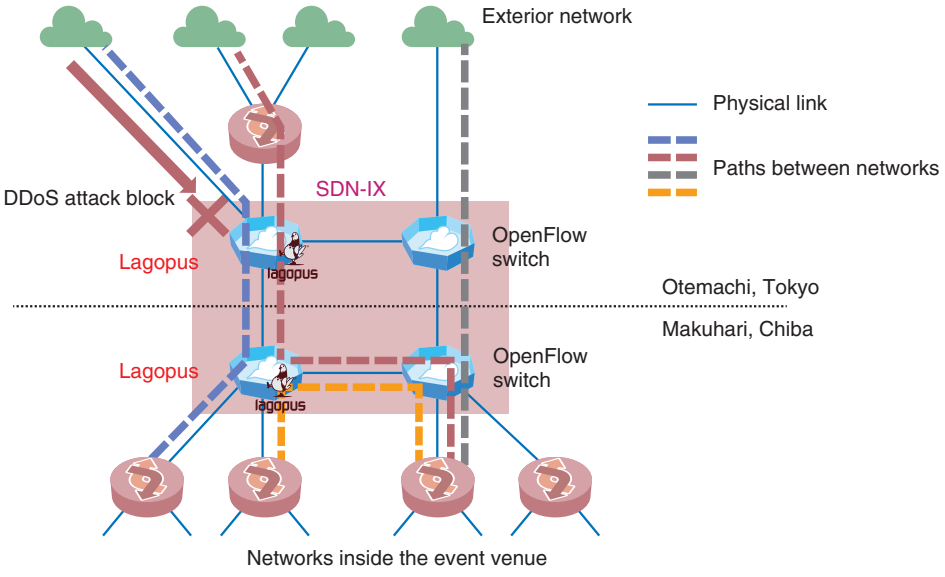


Fig. 2. Network configuration of SDN-IX for Interop Tokyo 2015 ShowNet.

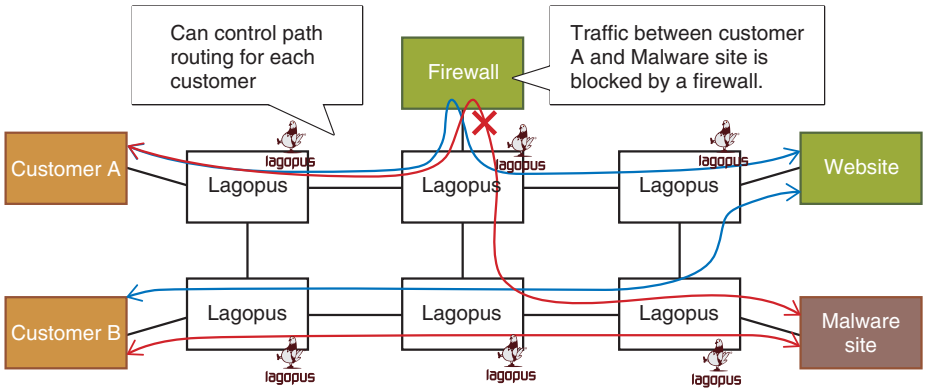


Fig. 3. Example of segment routing traffic control.

By coordinating our existing OSPF implementation with Lagopus, we achieved segment routing and presented a demonstration at the Intel Developer Forum 2015. In the demonstration, we conducted segment routing based traffic control as shown in **Fig. 3**, assuming that different network services must be provided depending on the contract conditions for each client. More specifically, we implemented control to see if we could pass through the client firewall based on the contract conditions of each client and showed that we could limit access to malware sites. As an actual use case for SDN, we presented an appealing case for simply controlling traffic using software, which received a high evaluation.

3. vConductor: NFV service orchestrator

vConductor is an NFV service orchestrator prototype developed by NTT Network Innovation Laboratories that connects multiple cloud services and enables construction of network services through simple operation.

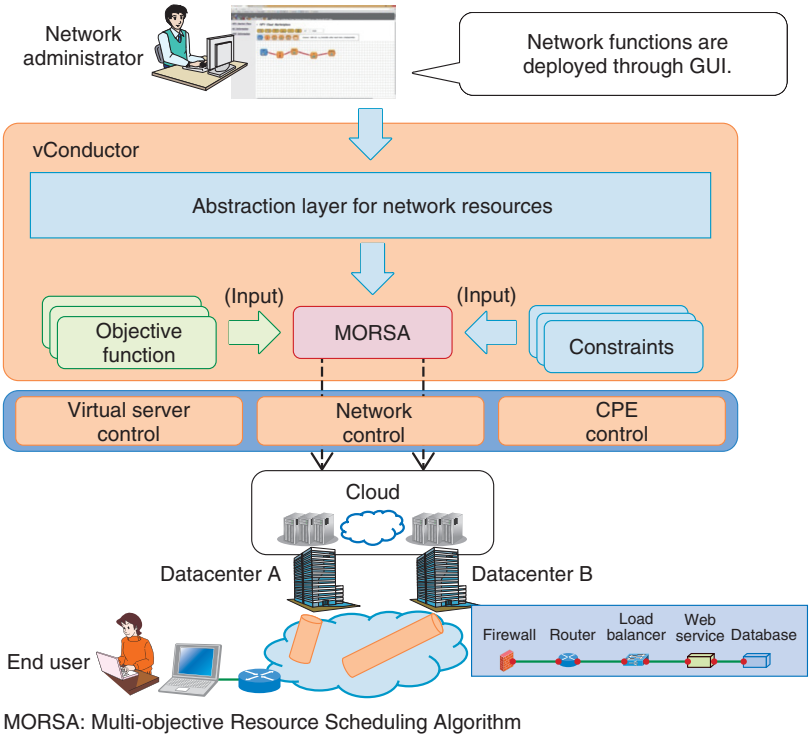


Fig. 4. vConductor features.

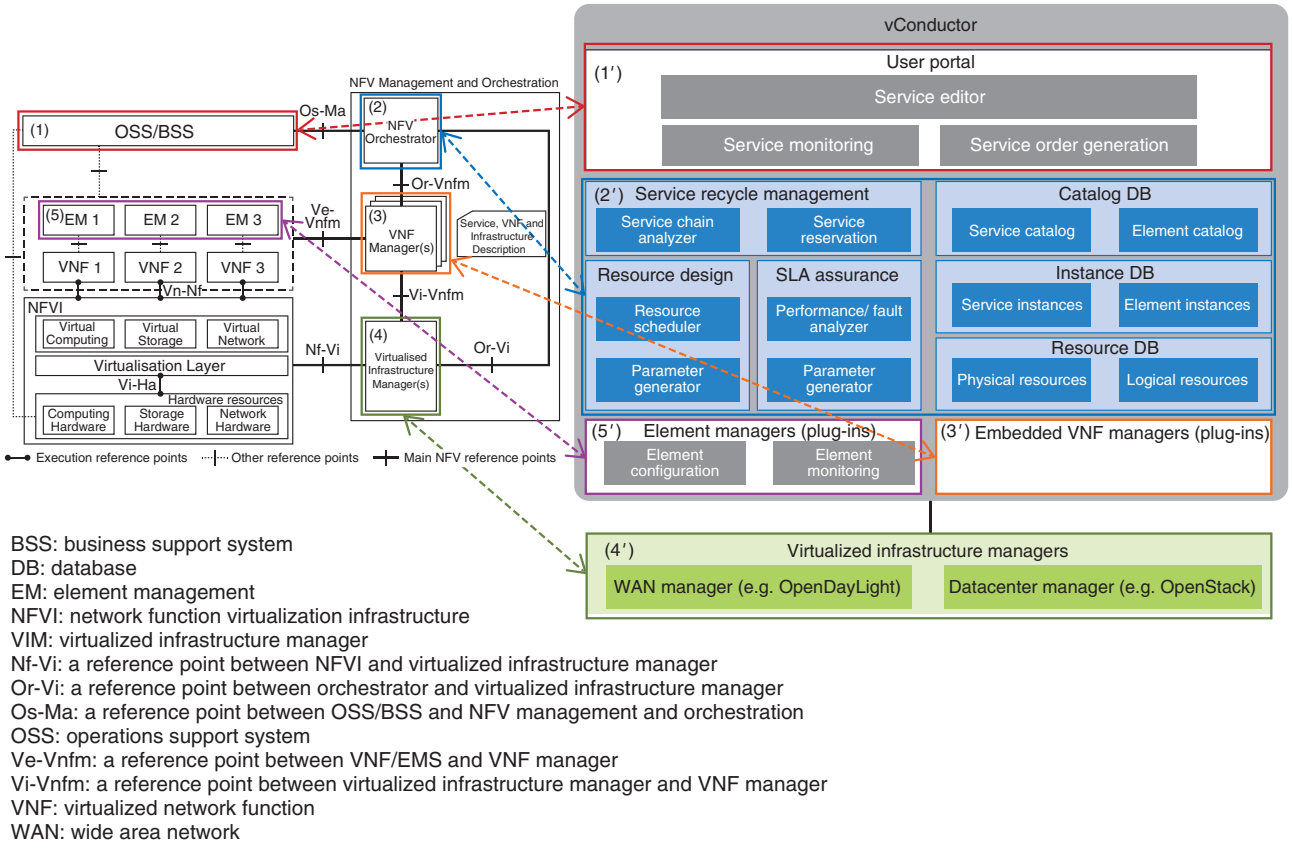
3.1 End-to-end (E2E) NFV service orchestrator

vConductor operates through a simple GUI (graphical user interface) and can automatically construct virtualized network functions (firewalls, routers, load balancers, etc.), web system functions (web services, databases, etc.), and applications, as shown in **Fig. 4**, by utilizing the infrastructure as a service (IaaS) of multiple cloud providers. In terms of CPE (customer premises equipment) for an enterprise user base, this prototype actualizes E2E NFV service orchestration that can create and control virtualized network services that combine multiple networks such as virtual private networks (VPNs), the Internet from telecommunications companies, and IaaS from cloud providers [1]. Through assignment of network functions, vConductor can create network services with a wide variety of cloud services and can automatically construct redundant virtual networks with backup datacenters. Thus, the user can easily recover the system by simply switching to the backup system when a failure occurs.

3.2 Architecture that extends global standard technology

We adopted the NFV specifications developed by the European Telecommunications Standards Institute Industry Specification Group for NFV (ETSI ISG NFV), an international standardization body, in vConductor as an architecture framework for extending NFV. The relationship between the NFV reference architecture framework prescribed by ETSI ISG and the vConductor architecture is shown in **Fig. 5**. In the ETSI ISG framework on the left, the (1) OSS/BSS (operations support system/business support system), (2) NFV orchestrator, (3) virtualized network function (VNF) manager, (4) virtualized infrastructure manager, and (5) EM (element management) system correspond respectively to the (1') user portal, (2') service recycle management, various databases, resource design, SLA (service level agreement) assurance, (3') embedded VNF managers, (4') virtualized infrastructure managers, and (5') element managers of vConductor.

In January 2014, ETSI ISG NFV released a technology standard document called Group Specifications that compiled the results of activities carried out over a period of about two years and included work on use cases, a framework, application management and orchestration (MANO) functions, and infrastructure construction. In the current Phase 2 activity,



BSS: business support system
DB: database
EM: element management
NFVI: network function virtualization infrastructure
VIM: virtualized infrastructure manager
Nf-Vi: a reference point between NFVI and virtualized infrastructure manager
Or-Vi: a reference point between orchestrator and virtualized infrastructure manager
Os-Ma: a reference point between OSS/BSS and NFV management and orchestration
OSS: operations support system
Ve-Vnfm: a reference point between VNF/EMS and VNF manager
Vi-Vnfm: a reference point between virtualized infrastructure manager and VNF manager
VNF: virtualized network function
WAN: wide area network

Fig. 5. Relationship between NFV reference architecture framework and vConductor system structure.

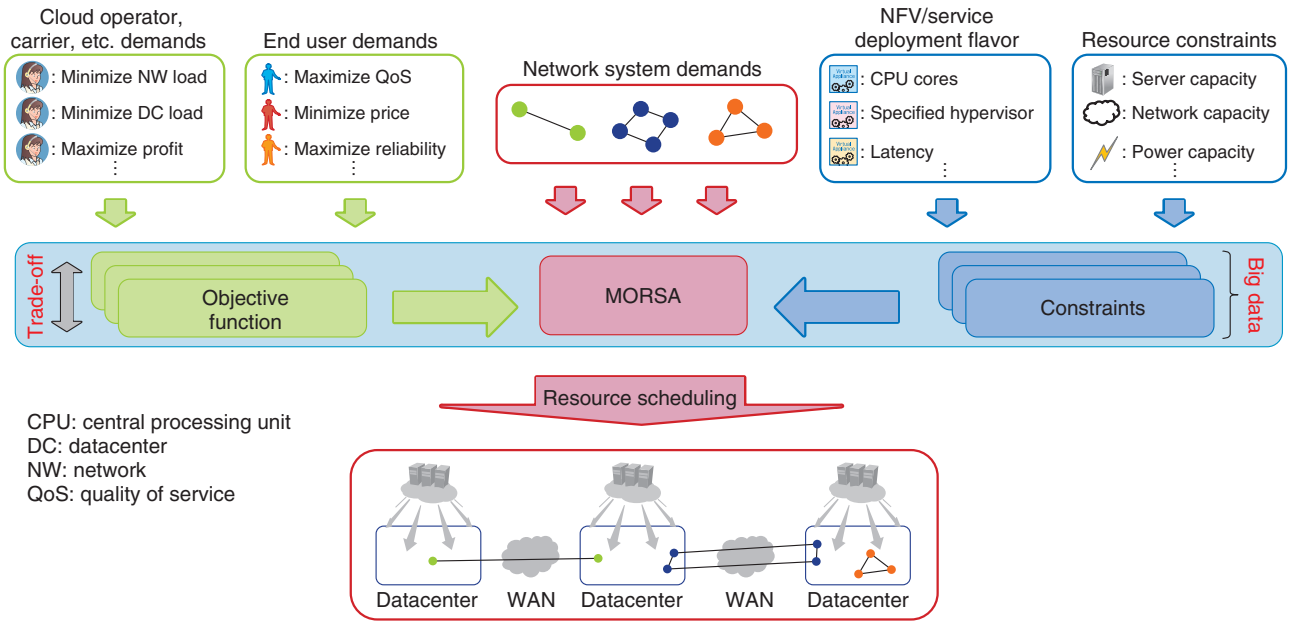
multiple vendors are developing the MANO functions, and progress is being made on formulating the technical specifications for the interface between each function block. In addition, we are furthering our investigations into abstraction models and APIs (application programming interfaces), reliability and quality, and application management related technologies.

We are developing a vConductor prototype while referring to the specifications of ETSI ISG NFV, including the defined interfaces between each function block (e.g., Or-Vnfm, Os-Ma, Or-Vi).

3.3 Multi-purpose scheduling function

In NFV, both physical resources such as hardware equipment and logical resources on virtual machines are managed objects, and therefore, resource management inevitably becomes complex. We are developing a multi-purpose optimization method called the Multi-objective Resource Scheduling Algorithm (MORSA) [2] that can assign NFV infrastructure (NFVI) resources while considering multiple constraints and stakeholder policies at the same time. MORSA is a new algorithm that is an improvement over the genetic algorithm [3] concept, and it has been adapted for NFVI resource optimization. In MORSA, two types of limiting conditions, namely NFVI resource constraints and VNF constraints, are converted to objective functions. Adjusting the weight balance between each function while performing calculations enables multiple limiting conditions and stakeholder policies to be considered at the same time, and a diverse Pareto solution set[*2] can be derived, as shown in **Fig. 6**. In this way, the optimal datacenter can be selected for the VNF arrangement based on the multiple service requirements (delay, cost, etc.).

*2 Pareto solution set: The generally obtained solutions when optimizing multiple functions, and a set of solutions showing the tradeoff among functions when changing any of the objective function values. This is also referred to as a Pareto optimal solution.



VNF resources are assigned to virtualized infrastructure based on the results of MORSA trade-off analysis.

Fig. 6. MORSA concept.

4. Future development

We are striving to achieve even higher performance and higher functionality of Lagopus. For vConductor, we are targeting better operating management technology and application preparation, contributing toward standardization, and pursuing a wide range of fruitful R&D.

To accelerate technological development, we are not only advancing OSS activities but also further cooperating widely with partners with expertise in various fields such as international and domestic vendors and research institutions while promoting the establishment of collaborative technology.

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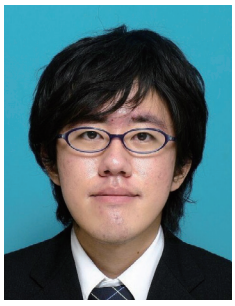

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REMOCOP: Remote Collaboration Platform for a Next Generation Remote Collaboration Support System

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Abstract

There is increasing demand for work environments that enable collaborative work by people at remote sites. However, existing systems such as video conferencing systems and interactive whiteboards are designed for video and teleconferences, and they do not satisfy requirements for capabilities that include wide-ranging actual workflows that use specific devices and applications for work. We propose the Remote Collaboration Open Platform (REMOCOP), an application platform for a real-time remote collaboration environment. REMOCOP provides functions for transmitting and presenting work support information via audio/video communication.

Keywords: remote collaboration, application platform, computer supported collaborative work

1. Introduction

With business activities being carried out around the globe, the demand for remote collaboration technologies is increasing. As a result, video conferencing systems and web-based teleconferencing systems designed for information sharing and decision making are widely used. However, these systems are not optimized for remote collaboration of work processes such as product design and content creation because they have not been designed for remote collaboration systems other than basic video and teleconferencing. Remote product design requires sharing design applications such as computer-aided design (CAD) software. Remote content creation requires sharing media assets such as videos and pictures and carrying out real-time previews. These shared applications and media assets might also need to be operated or edited by multiple remote users at the same time. The existing widely used video and teleconferencing systems, which include interactive remote whiteboards, are single-function systems, so it is not possible to create the remote collaboration environment described above or to implement additional customized functions.

A future collaborative and creative environment for users in remote locations will need a new framework that enables users to share tools and applications for work in real-time with audio/video communication, and that also enables transmitting and presenting work support information (**Fig. 1**).

2. Proposed application platform

To satisfy the previously mentioned requirements, NTT Network Innovation Laboratories is proposing the Remote Collaboration Open Platform (REMOCOP), which has been developed as a core framework of a future remote collaboration environment. The main elements and functions of the remote collaboration environment are expected to be:

- Audio/video transmission for real-time communication between users in remote locations
- Sharing, editing, and operation of working objects and applications

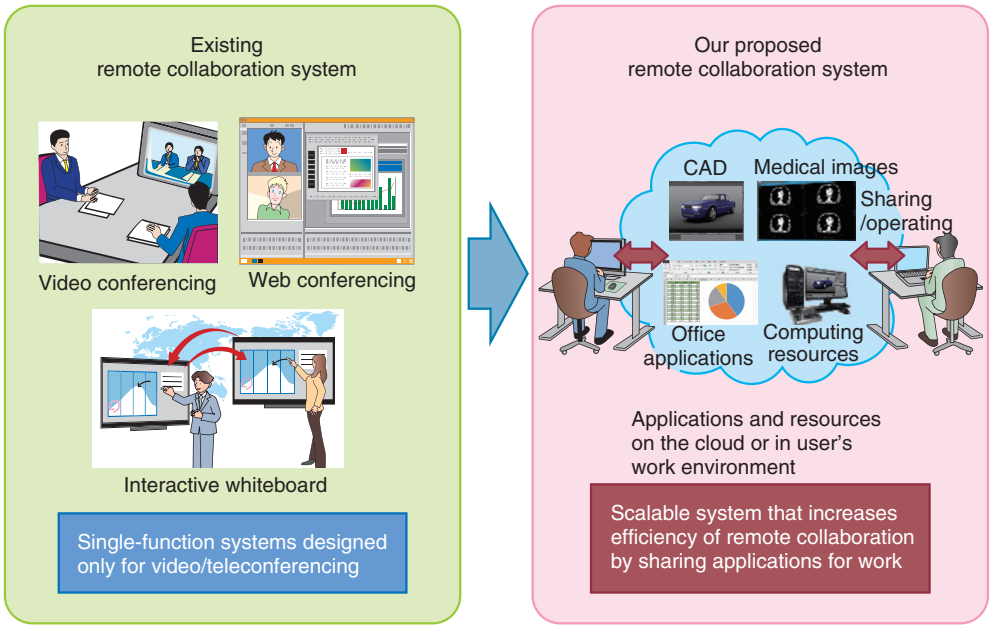


Fig. 1. Proposed remote collaboration system.

- Displaying work instructions and augmenting information to improve work efficiency
- Controlling input devices needed for work such as a mouse and keyboard, and transmitting their input data

However, the actual requirements for the remote collaboration environment depend on the type of work and workflow. How much audio/video quality is needed for sharing working objects or collaborative work? What kind of input devices and editing functions are needed? In addition, there is a need for network infrastructure control including a way to achieve a dynamic secure connection between various users and locations, as well as cloud resource provisioning. Thus, having to clarify every required function for every workflow or to develop a huge monolithic system that supports all those functions is not a realistic approach. The creation of a truly practical remote collaboration environment requires an application platform as illustrated in **Fig. 2**, which can replace, customize, or extend modularized components for remote collaboration so as to optimize the system for each workflow.

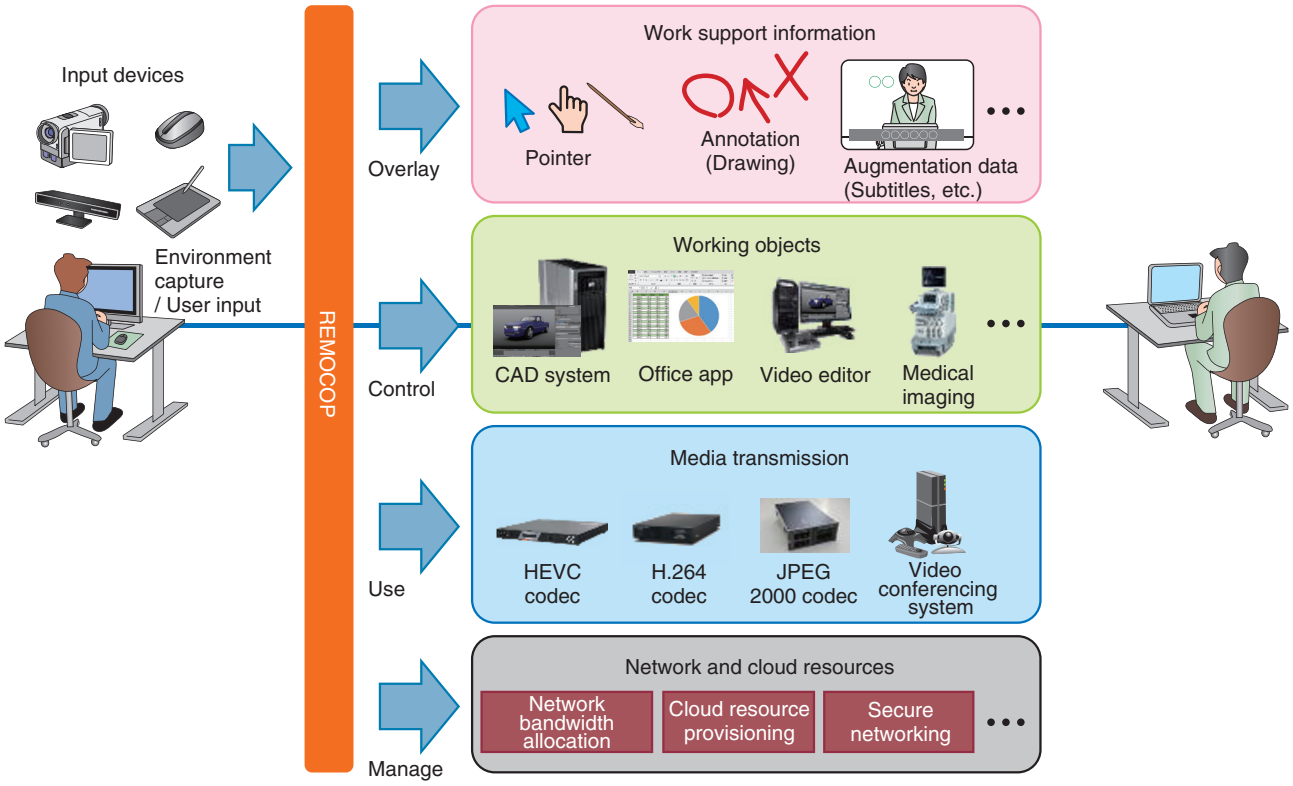
3. Components of REMOCOP

A block diagram of REMOCOP is shown in **Fig. 3**. REMOCOP is composed of three core modules: an Augmentation Layer, Media-Time Manager, and Collaboration User Interface (UI). These modules are described in more detail below.

3.1 Augmentation Layer for overlaying work support information

In remote collaboration, a real-time audio and video transmission function is necessary for real-time communication and for sharing working objects between users in remote locations. However, the required media quality and latency depend on the workflow. Current teleconferencing systems and remote collaboration systems are able to use only the embedded codec on the system; therefore, it is difficult to satisfy such a wide range of requirements. The Augmentation Layer provides the function that overlays work support information and other additional information on real-time audio/video. Because it works separately from the audio/video codec, any type of audio/video codec can be used regardless of whether it is hardware-based or software-based, according to quality requirements. An example in which the 4K H.264 codec is used for real-time communication, and the HD (high definition) JPEG 2000[*1] codec is used for sharing CAD software as a

*1 JPEG 2000: An image compression standard and coding system created by the Joint Photographic Experts Group.



HEVC: High Efficiency Video Coding

Fig. 2. Components of remote collaboration system.

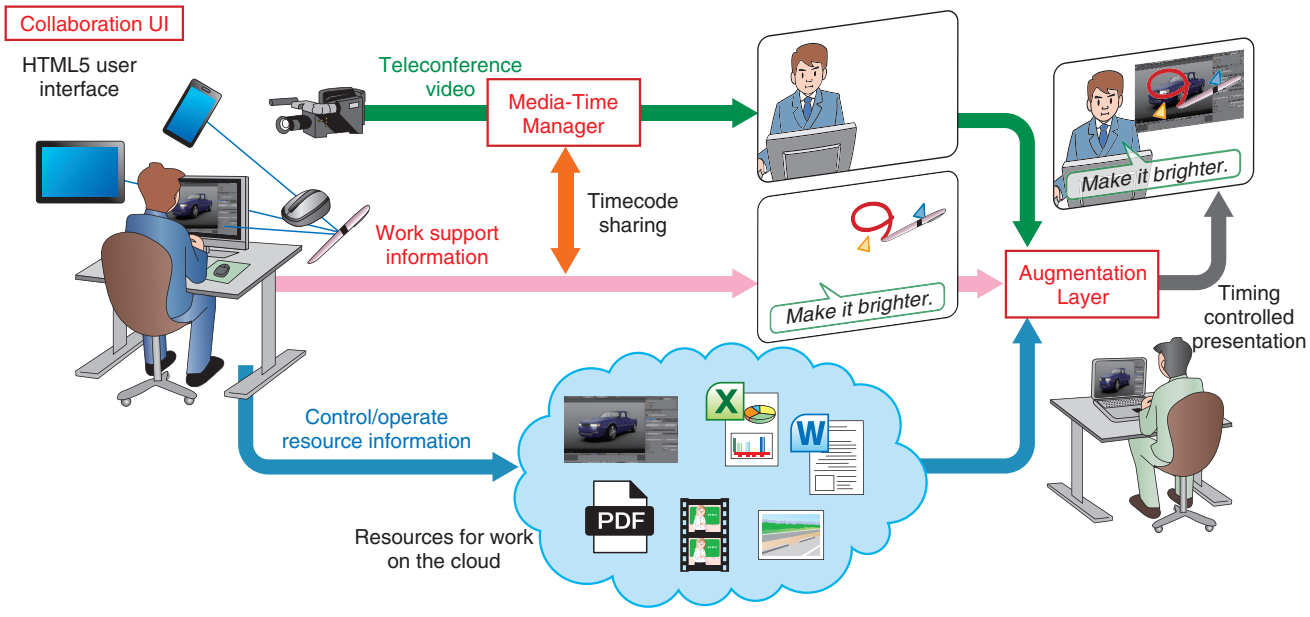


Fig. 3. Block diagram of REMOCOP.

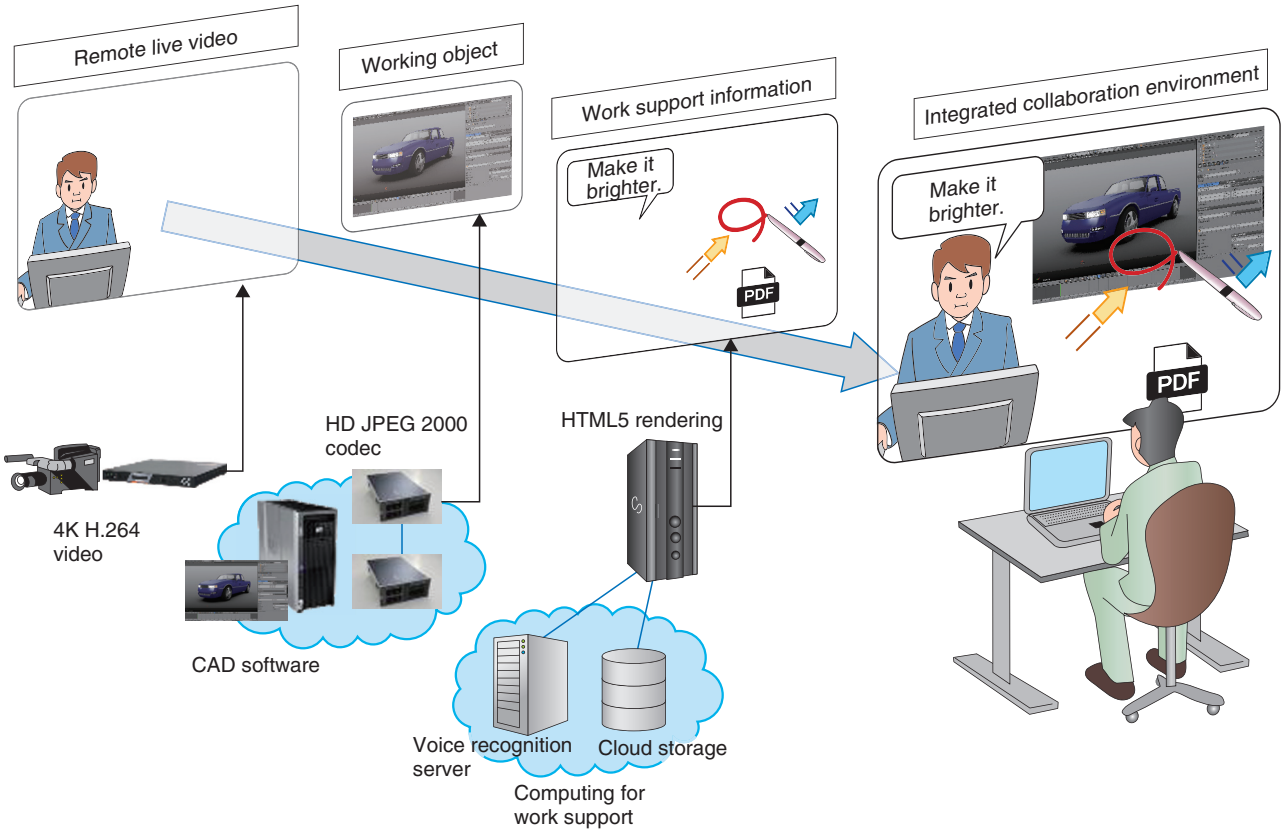


Fig. 4. Overview and application example of Augmentation Layer.

working object is shown in **Fig. 4**. The Augmentation Layer overlays work support information such as pointers, annotations, instruction text by voice recognition, and PDF (portable document format) files on the cloud storage. Additionally, the Augmentation Layer displays work support information with HTML5[*2] rendering, which works in synchronization with audio/video for communication. Hence, the separate components shown in Fig. 2 can work as an integrated remote collaboration system.

3.2 Media-Time Manager for controlling temporal synchronization between multiple types of media and information

To enable the Augmentation Layer to display work support information in synchronization with audio/video, a framework is needed that manages and controls temporal information on all types of media as well as information for remote collaboration. The Media-Time Manager extracts timecodes from packets in the audio/video stream for real-time communication. Then it transmits them to the Collaboration UI that manages user input interfaces; in doing so, it embeds timecodes in user input data packets—for example, the times of mouse movements—and sends the timecodes to remote locations. On the receiver side, the Augmentation Layer controls the presentation timing and overlays the data, receiving and referring to the embedded timecodes in the audio/video packets from the Media-Time Manager. It is also possible to present the data before or after the actual synchronized timing depending on the characteristics and requirements of the work support information.

3.3 Collaboration UI to build user interface optimized for each workflow

A function for sharing the pointer and a function for drawing and annotation are assumed to be common required functions for remote collaboration. Moreover, many other specific functions are required

*2 HTML5: The fifth revision of hypertext markup language (HTML), the standard programming language for creating web pages.

depending on the workflow such as those enabling operation with special input devices or those utilizing cloud storage. Demands for capabilities enabling users to join the collaboration environment from anywhere using devices such as tablet computers and smartphones are also increasing. The Collaboration UI makes it possible to implement these required functions easily with multi-device and multi-platform support by enabling us to build user interfaces using HTML5 and to run required functions on a web browser. The recent rapid advances in browser functions mean that various input devices including a keyboard, mouse, stylus, and gesture-based interfaces can be utilized by HTML5. Web APIs (application programming interfaces) also help us leverage external resources such as voice recognition and cloud storage. Therefore, the Collaboration UI makes the development of work support functions easy by utilizing various input devices and external resources with multi-platform support.

4. Application examples

Here, we discuss application examples of remote collaboration using REMOCOP.

4.1 Remote collaborative industrial design with CAD system

The first example involves remote collaborative industrial design with a CAD system running on virtualized GPU (graphics processing unit) resources, where the system is controlled by multiple remote users. In this workflow, by sharing the CAD software screen using a high quality video codec, remote users can discuss points to be fixed while drawing elements by hand. A system enabling two remote users to operate the CAD application running on the cloud and to communicate smoothly with multiple-channel 60p live video and multi-channel audio is shown in **Fig. 5**. In addition, pictures, movies, and documents needed for work as reference data can be overlaid. To instruct a remotely located person on design using hand drawing, the users only need to draw with a stylus pen and a tablet. To point out specific reference data, the users only need to use their finger to point at the object because the gesture interface senses hand movements. These intuitive uses of input devices in accordance with specific intentions dramatically accelerate the speed of collaboration work. Additionally, the HTML5 based implementation enables users to join the collaboration work even in a mobile environment simply by accessing the session URL (uniform resource locator), although there are limitations in media quality or spatial resolution of the work space.

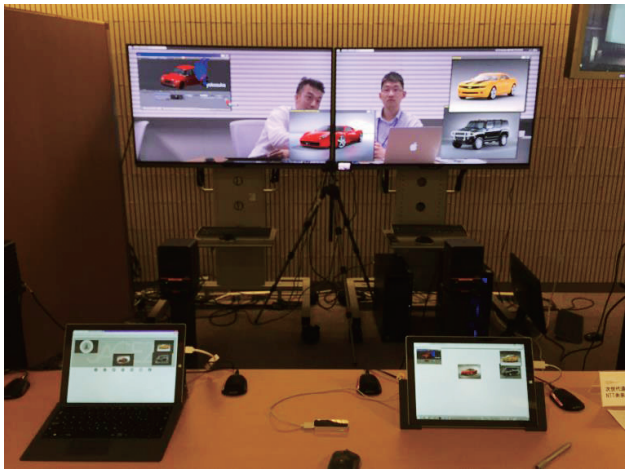


Fig. 5. Application example of remote collaborative industrial design.

4.2 Remote collaboration in the medical field

Another example is remote collaboration in the medical field, which requires sharing of medical images with remote users, searching for similar images from a database, and operating medical equipment remotely. In this case, the system has to support a display environment for sharing high resolution images. Functions that enable annotation on images and transmission of data between networked storage systems are also needed. REMOCOP enables us to build a very high resolution display environment using multiple computers and display devices in sync, and also to easily implement similar image searches with external resources using web APIs. Even in an operating room where use of physical interfaces such as a mouse and keyboard is prohibited, gesture-based interfaces enable users to control the system in order to browse or point at shared information.

5. Future prospects

As described in this article, REMOCOP allows us to create remote collaboration services that satisfy a wide variety of user needs. It is also expected that REMOCOP will be the leading platform for applying emerging technologies for real working environments such as new interface devices, machine-learning-based human thought process support, and cloud

functions. To achieve this, the business ecosystem consisting of users, application developers, device developers, and service providers should be created by making the platform open. Finally, we believe that the future remote collaboration environment using REMOCOP will provide higher work efficiency than a face-to-face environment will.

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Smart CPE R&D for Highly Intelligent Enterprise Networks

Katsuhiro Sebayashi, Osamu Kamatani, and Osamu Akashi

Abstract

Enterprise users' information and communication technology (ICT) demands vary widely from industry to industry and also depend on business conditions and company size. In this article, we present the status of our research and development of an enterprise business solution called Highly Intelligent Customer Premises Equipment, or Smart CPE, which can offer smart traffic control and advanced network management functions for existing wide area network services such as broadband Ethernet and virtual private network services. This solution makes it possible to construct optimal customer ICT environments and to meet individual needs.

Keywords: enterprise network, service customization, customer premises equipment

1. Introduction

The information and communication technology (ICT) demands of enterprise users vary widely from industry to industry and depend on business conditions and the size of the company. In addition, enterprise users must promptly respond to the changes in the business environment. Small- and medium-sized enterprise clients without dedicated network operators have particularly high expectations of carriers with respect to the construction and operation of their ICT infrastructure. However, when only existing network services and dedicated, off-the-shelf hardware virtual private network (VPN) routers are used, it can be difficult to quickly respond to many different kinds of requests. Users might request, for example, a service with a level of quality and price point that lies between a best-effort service and a guaranteed quality of service, or they may state that they want to run backup wide area network (WAN) services at all times. Consequently, a way of quickly and flexibly customizing services to meet individual customer needs is required.

NTT Network Innovation Laboratories has been researching and developing one promising solution called Highly Intelligent Customer Premises Equipment, or Smart CPE, to meet such requirements.

2. Conceptual overview

A conceptual diagram of Smart CPE is shown in **Fig. 1**. Smart CPE serves as a replacement for a VPN router. Like a conventional VPN router, it simultaneously connects to multiple WAN services. Unlike existing VPN routers, however, Smart CPE runs carrier services that can be customized according to individual customer needs.

Smart CPE's network concierge feature is one way in which it customizes original services. Ordinary VPN routers control traffic primarily by switching between active and backup circuits or simply assigning traffic to a fixed number of circuits. Smart CPE, on the other hand, assesses policies and usage along with the state of a client carrier's WAN services and equipment. Through a combination of optimal traffic controls and WAN service choices, Smart CPE then intelligently controls traffic for individual network flows. To customers, multiple WAN services thus appear to be a single WAN service that is suited to any situation.

Smart CPE's remote maintenance feature represents another way in which it customizes services. By

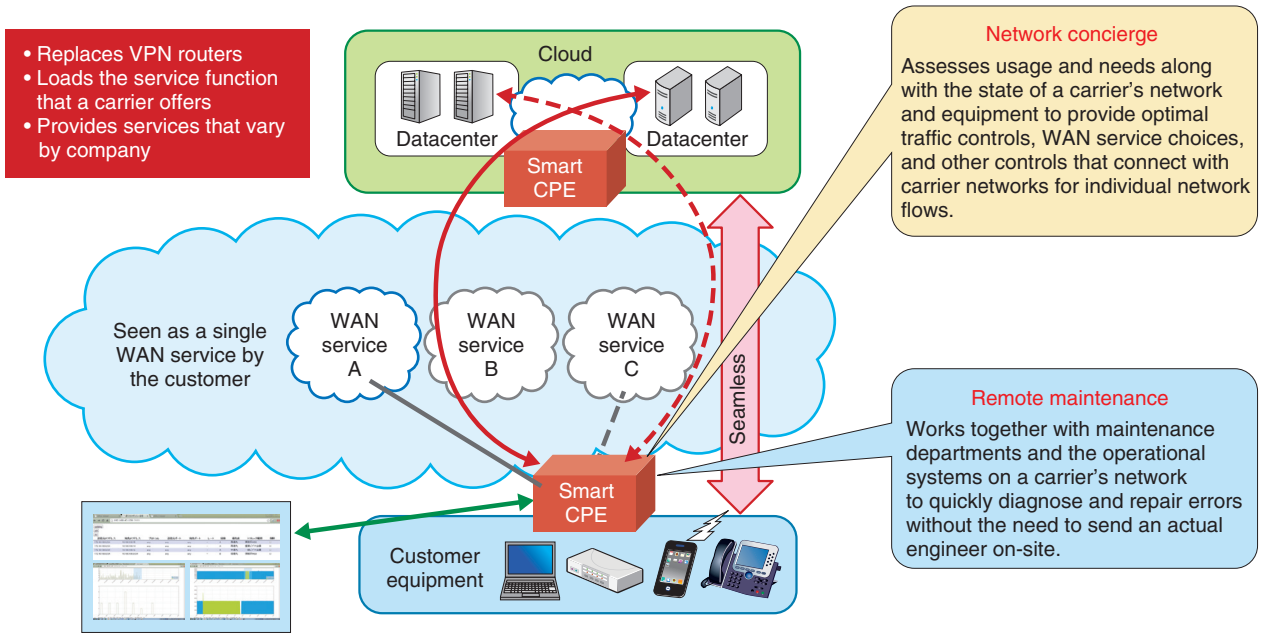


Fig. 1. Conceptual diagram of Smart CPE.

working together with a carrier's operational systems and maintenance departments, Smart CPE can quickly diagnose and repair errors without the need to dispatch an engineer to the site.

Our solution also provides a customer portal for enterprise users, network carriers, and partner companies of our Hikari Collaboration Model, which involves wholesaling fiber access service, in order to customize their services and check on the visualized service status.

3. Implementation approaches

One approach for implementing the aforementioned concepts is illustrated in **Fig. 2**. To implement services that can be quickly and flexibly customized to meet customers' needs, we use general-purpose Linux computers for Smart CPE rather than dedicated hardware because they offer ease of development as well as remarkable improvements in cost-performance ratios. When we receive a customer request, we can then customize Smart CPE with application software implementations of the appropriate services that would ordinarily be provided by a customer's servers and networking equipment. We implement services in application software using the existing software resources available from the Linux community.

Furthermore, we provide customer portals and element management system and network management system (EMS/NMS) web services for configuring and controlling Smart CPE services.

4. Architecture

Smart CPE uses a three-layer architecture, as shown in **Fig. 3**. The bottom layer has a traffic control component for packet forwarding and a packet monitoring component for high-resolution traffic measurement. Above this is the platform layer, which provides an abstraction layer for all the functionality below it. At the top is the application layer, in which service customization features are implemented. The platform layer currently provides a northbound application programming interface (API) with traffic control and packet monitoring features for the application layer, but later it will also provide a southbound API that allows the traffic control component to be replaced with OpenFlow and bare-metal switches without changing the platform or application layers. Both the northbound and southbound APIs will be REST (representational state transfer)/JSON (JavaScript Object Notation) APIs, which are widely used by web services, to make it easier to develop applications that provide prompt services and to then connect them to EMS/NMS.

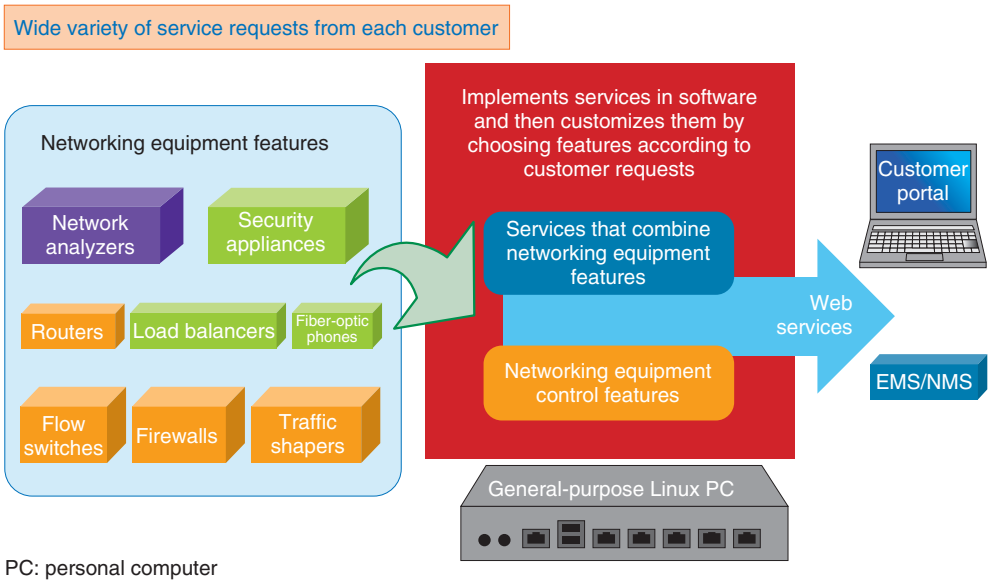
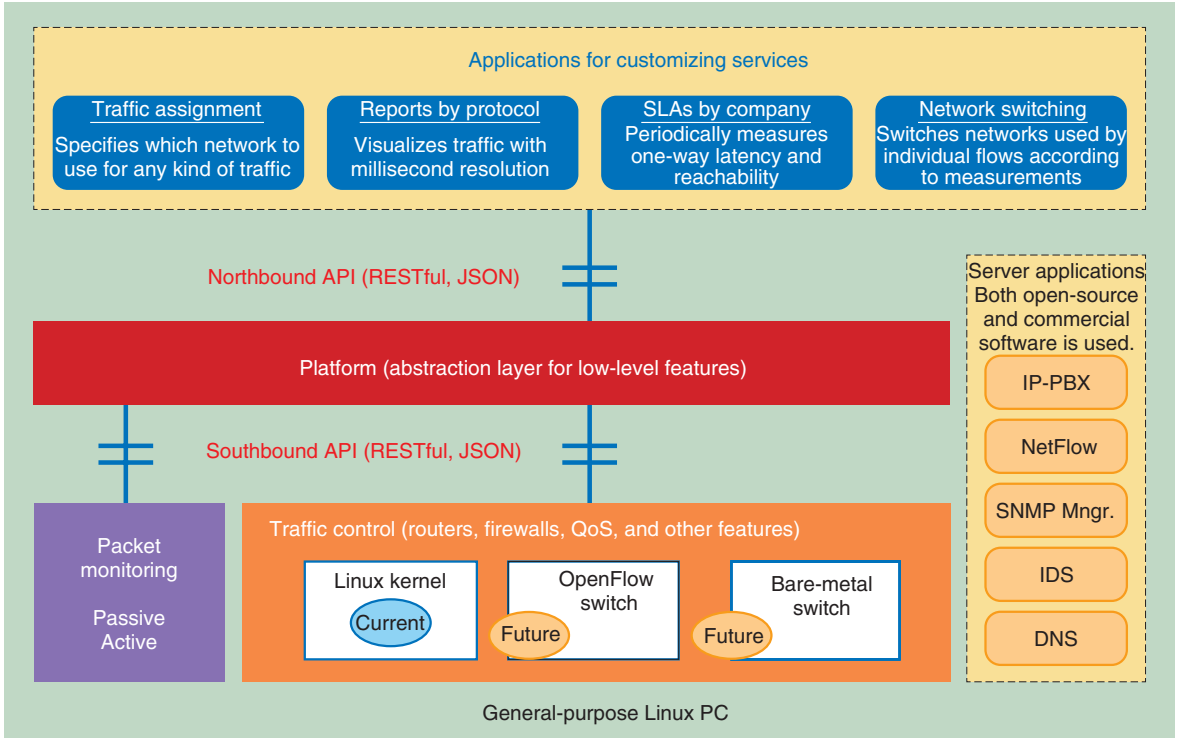


Fig. 2. Approach for a Smart CPE implementation.



DNS: domain name system
IDS: intrusion detection system
IP-PBX: Internet protocol-based private branch exchange
QoS: quality of service
SLA: service-level agreement
SNMP: Simple Network Management Protocol

Fig. 3. Smart CPE Architecture.

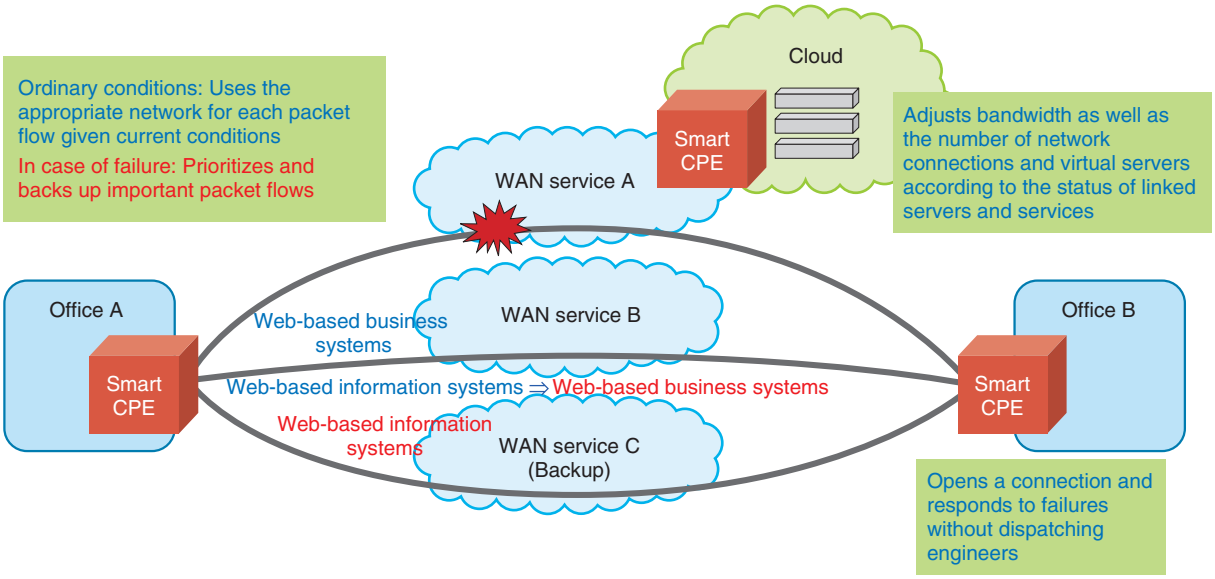


Fig. 4. Illustrated usage in enterprise networks.

5. Prototype development

We developed a prototype to verify the effectiveness of our Smart CPE concept and architecture, and we are currently testing it by connecting three offices via more than two WAN services including the Master's One Wireless VPN and FLET'S VPN WIDE (**Fig. 4**). We are using two types of hardware: desktop computers and 1U rack servers.

The Linux kernel has the same capabilities as a VPN router. It supports VLANs (virtual local area networks), PPoE (point-to-point over Ethernet), GRE (Generic Routing Encapsulation) tunnels, and other virtual interfaces, and also has NAT (network address translation), firewall, and QoS (quality of service) features. Our prototype's traffic control component manages individual traffic flows using the Linux kernel's standard packet forwarding features to the greatest extent possible. Furthermore, our prototype's packet monitoring component uses a 10-Gigabit network monitoring system (PRESTA 10G) [1] developed by NTT Network Innovation Laboratories. This implements active monitoring of one-way latency and packet loss between Smart CPE installations as well as passive monitoring with the same millisecond resolution as a network analyzer. This functionality is all available through the northbound API, which we use in our prototype to implement the following applications for our network concierge and on-site maintenance features. Every application can be configured and controlled through a customer portal GUI (graphical user interface) (Fig. 3).

- Traffic assignment
  This application specifies a WAN service to use for a per flow basis.
- Network switching
  This application configures upper bounds on the permissible one-way latency and packet loss rate for any network flow. When a WAN service metric exceeds these thresholds, its network flows are switched over to different circuits. This application can also save packet dumps for a fixed period of time around such a switch for use in future troubleshooting.
- SLA (service-level agreement) measurement
  This application measures one-way latency and packet loss rates between Smart CPE installations for each WAN service. The data appear in visualized graphs on customer portals and can also be exported in a comma-separated values (CSV) format.
- Traffic visualization
  This application measures traffic volume for any network flow—whether configured by protocol, application (e.g., web, VoIP (voice over Internet protocol), video streaming), or server—and visually plots them in real time with millisecond resolution on customer portals. This allows network administrators to notice sudden spikes (bursts) in network traffic, which lead to packet loss and

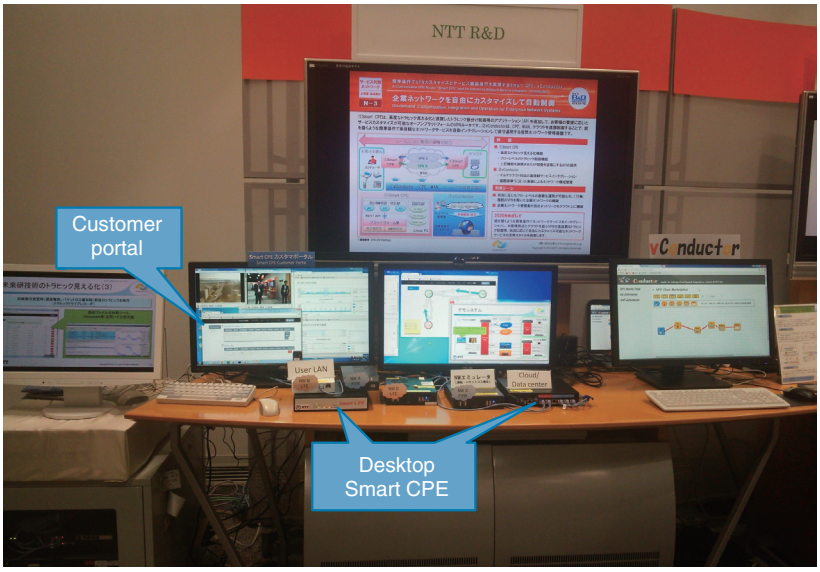


Fig. 5. Exhibit at NTT R&D Forum 2015.

cannot be discerned through ordinary SNMP (Simple Network Management Protocol) or NetFlow monitoring. The data can also be exported in CSV format.

- Network topology maps
  This application displays on customer portals a map of Smart CPE connections along with the real-time traffic volume between Smart CPE installations for each WAN service. This application also provides Smart CPE uptime monitoring and can show remote Smart CPE customer portals.

We exhibited this prototype at the NTT R&D Forum 2015 (**Fig. 5**). With multiple network flows using FLET'S VPN WIDE, we demonstrated how we could switch one particular video flow over to the Master's One Wireless VPN in response to variations in one-way latency. We also demonstrated this same functionality at the NTT R&D Messe 2015 using a commercial web conferencing system (MeetingPlaza) and IP-PBX (Internet protocol-based private branch exchange) (Crossway) installed on our Smart CPE.

6. Use cases

We plan to continue developing Smart CPE applications that allow enterprise network system integrator engineers at our Hikari Collaboration partner companies and in the enterprise sales departments of business firms to customize WAN services for small- and medium-sized enterprise users.

We specifically expect to encounter use cases like the one illustrated in **Fig. 6**. Under ordinary conditions, our Smart CPE's network concierge feature uses the appropriate WAN service to access particular servers or for individual application flows given a customer's operational policies and conditions. When there is a network failure or WAN services experience network congestion, the concierge feature switches network flows over to WAN services that are functioning properly, prioritizing flows that are most important for the customer's continued business operations. We believe that this can contribute to making our customers' businesses more efficient. Furthermore, because Smart CPE's remote maintenance feature can always check a customer's network status, we believe that it can lead to proposals for bandwidth and WAN service adjustments that match changes in the customer's network usage. Through the initial connections to customer networks without dispatching engineers and by speeding up failure response times, adding and removing virtual servers, controlling traffic in conjunction with network failures, and integrating with cloud services, we will strive to provide customized ICT environments to our customers.

As shown in Fig. 6, we are also considering how we can apply our Smart CPE technology to the movable ICT units [2] developed by NTT Network Innovation Laboratories. When a disaster occurs, we could use

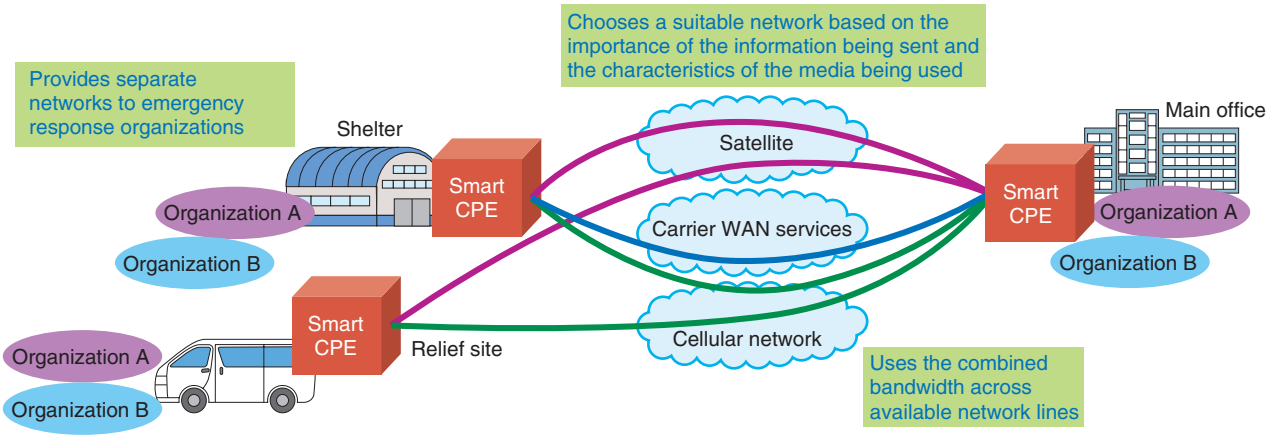


Fig. 6. Usage for emergency response.

our Smart CPE for multiple types of WAN connections (e.g., fiber-optic cables, LTE (Long Term Evolution), and satellite) to main offices both inside and outside the affected areas, as well as for wireless LAN connections provided by each of the emergency response organizations both at the disaster site and at shelters for disaster victims. This would allow the emergency response organizations to share information using a suitable WAN given its current throughput, the importance of the information being shared, and the characteristics of the media (e.g., text, audio, images, or video) being shared. We thus hope to make Smart CPE capable of sharing information efficiently when communication resources are limited.

7. Future development

We have so far developed a prototype with Smart CPE's basic functionality. We think that our most important task in bringing Smart CPE to market is to continue to develop applications while collecting feedback from actual customers, partner companies, and other businesses; this includes careful investigation of our expected use cases. Ultimately, we believe that we will also need to build application development environments that can be tailored to our partner companies and other businesses. In our continued research and development efforts in which we take Smart CPE from field trials to a finished product, we plan to exchange ideas related to the development of services and scenarios with wider business uses.

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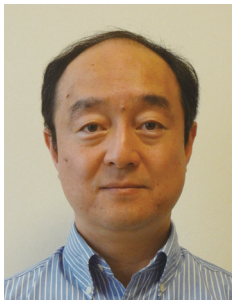

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Distributed Time Series Data Management and Analysis

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Abstract

At NTT Network Innovation Laboratories, we are studying sophisticated network management schemes based on network data analysis. In this article, we focus on a distributed data analysis scheme for large amounts of network data. With this scheme, the amount of network data transported among datacenters for analysis can be reduced, which will also reduce costs.

Keywords: distributed database, distributed data analysis, skiplist

1. Introduction

Sensor data and traffic data have recently come to be stored in datacenters. Analyzing such data makes it possible to predict traffic jams and network congestion. These data are generated with high frequency, and the amount becomes increasingly larger as time goes on. This means that data cannot be managed in a general relational database because a relational database constructs a rigorous data structure and sacrifices the scalability of data management.

A key-value store (KVS)[*1] is a simple data storage architecture widely used to manage large amounts of data because it stores only simple key-value pairs (**Fig. 1**). MapReduce[*2] is a well-known distributed data analysis scheme that has good scalability for analyzing large data sets in parallel, and it is easily built and deployed on KVS [1]. If all data are distributed fully into KVS, MapReduce quickly achieves parallel data analysis. The performance of MapReduce can be guaranteed in simple cases of data analysis; however, it is difficult to apply it for complex analysis such as time series data analysis and distributed machine learning. The specific difficulties are as follows.

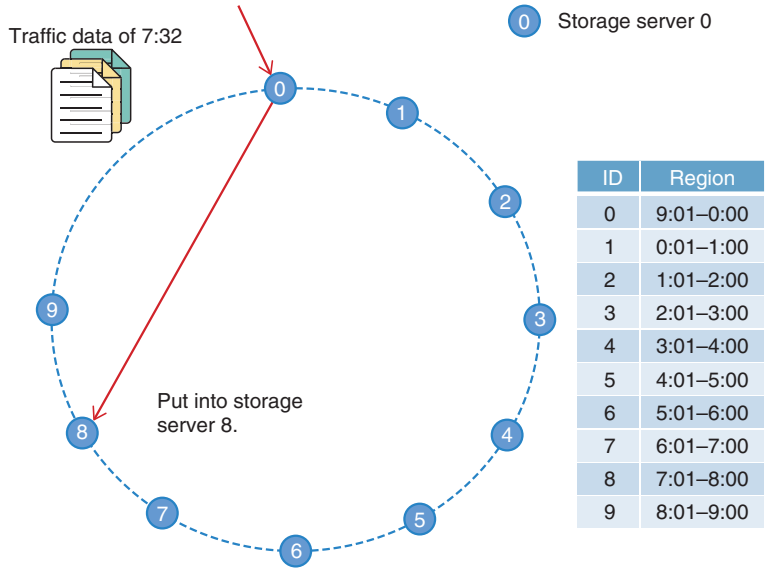
(1) Currently, the nodes' states are managed in a centralized server in a general MapReduce platform such as Hadoop [2]. Therefore, the load on the centralized server may exceed capacity as the number of analysis executions increases.
(2) The ideal parallel performance of MapReduce is guaranteed in that all data sets are fully distributed in KVS. However, time series data may be non-uniformly distributed in KVS. For example, if a large amount of data is concentrated on certain servers, the performance of MapReduce analysis will be degraded.
(3) In machine learning analysis using MapReduce, there is frequent data communication among all nodes (i.e., the shuffle phase), and this causes heavy traffic and network congestion.

We have been researching a MapReduce architecture to solve these problems. In this article, we introduce an efficient MapReduce architecture based on distributed skiplist tree (DST) [3].

2. MapReduce scheme based on DST

DST is a hybrid data structure consisting of both a balanced tree and a linked list such as a skiplist, which takes only $O(\log N)$ operations to search/put/remove data. To construct a DST in a distributed environment, each node has two values: the location

*1 Key-value store (KVS): A database storing pairs of data and their key (e.g., <key, data>).
*2 MapReduce: A parallel programming model for analyzing large data sets.



ID	Region
0	9:01–0:00
1	0:01–1:00
2	1:01–2:00
3	2:01–3:00
4	3:01–4:00
5	4:01–5:00
6	5:01–6:00
7	6:01–7:00
8	7:01–8:00
9	8:01–9:00

Fig. 1. Data management in KVS.

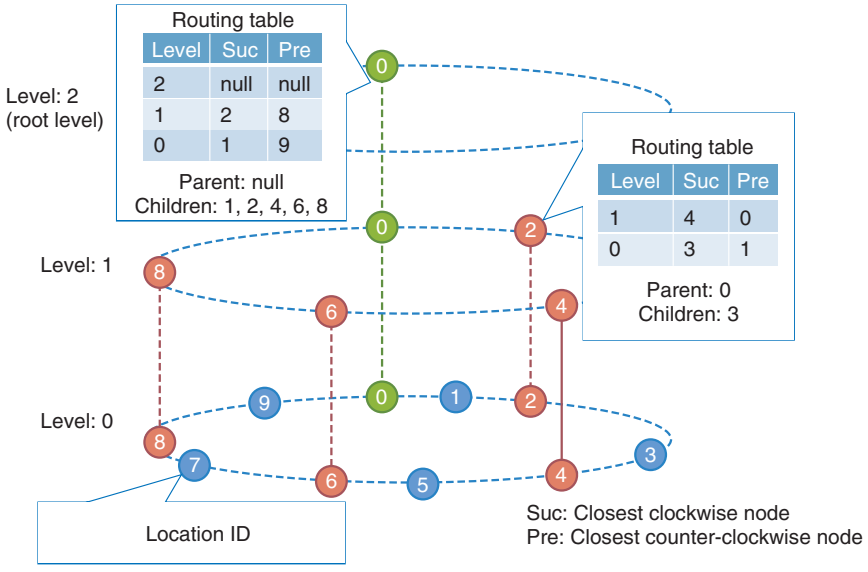


Fig. 2. Topology and management of DST.

identification (ID) and the level. The location ID is the circulated hashed ID, which is used to determine the ID space region of a node. The level refers to the hierarchy level in the DST, which is determined by the function of $[-\log_K RAND]$, where K and RAND are denoted as the balancing factor and the random value among [0,1], respectively. Using this function to determine the hierarchy level, we obtain the probability $(1/K)^l$ of a node being located at level l. All nodes in the hierarchy of the node at level 1 must be placed below level 1, and that node connects all nodes between the node location ID and its neighbor at level l. In this way, all of the connections form a DST (**Fig. 2**). The DST achieves a balanced tree without balancing operations; therefore, the maintenance cost of a balanced tree is very low.

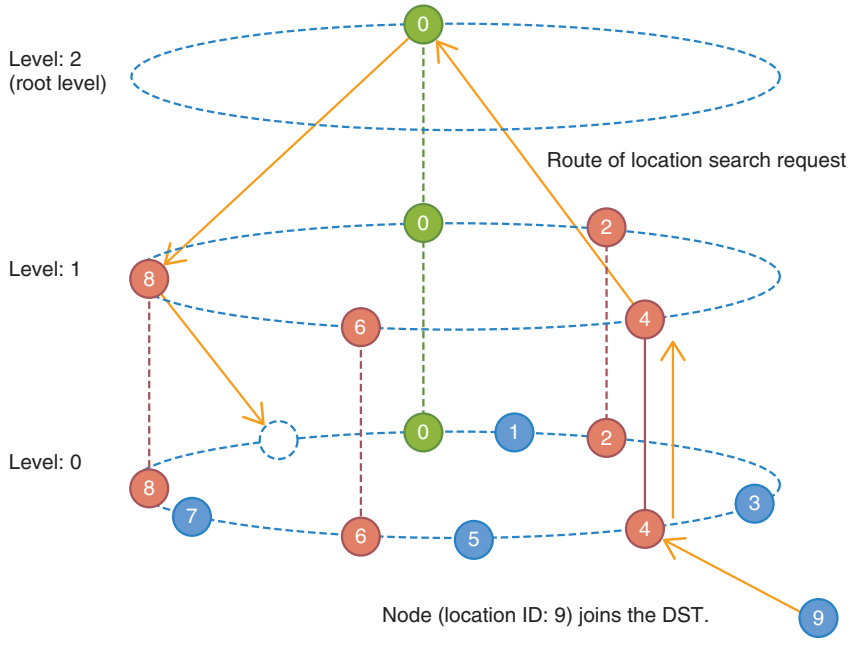


Fig. 3. Node join process in DST.

Next, we describe the DST construction procedure consisting of node join/leave operations. When node *P* (location ID *p* and level *l*) joins the DST, it requests an existing node to search its own location in level *l*. The node receiving the request checks whether location ID *p* is between its own ID and its neighbor's ID in level *l*. When the location ID *p* is not in the ID region, the receiving node forwards the request to its own parent node. In contrast, when the location ID *p* is in the ID region, the receiving node forwards the request to the child nodes closest to location ID *p*. In repeating the request forwarding, the request arrives at the node containing *p* in its own location ID region. Then, that node divides its own ID region into two ID regions for itself and for node *p*, and becomes the neighbor of node *P*. The summarized procedure for a node to join the DST is that a neighbor search operation using *O(log N)* request forwarding is carried out (**Fig. 3**).

When a node leaves the DST, the node does not inform the other nodes of its leaving. Therefore, the nodes must monitor each other using a heartbeat[*3] protocol in order to handle the situation when nodes leave. The heartbeat protocol involves simple synchronize/acknowledge (SYN/ACK) communications among nodes. The protocol sends a SYN message to a node and checks whether a corresponding ACK reply is received. In DST, each node checks child node states using the heartbeat protocol. If a parent node detects that a child node has left, the parent node searches for the node neighbor and replaces the leaving node. If the parent node recognizes the neighbor node, the leave is fixed by a few network communications. In the worst case, the parent node must search for the neighbor node from the entire DST. However, it takes only *O(log N)* message forwarding by using the search protocol introduced in the node join procedure. The cost of these node join/leave operations is only *O(log N)* message forwarding; therefore, DST achieves scalable/distributed node management and solves problem (1) mentioned in section 1.

Next, we introduce the load balancing function in DST. A root node located at the highest level periodically requests load information (e.g., the number of receiving queries per hour) from its child nodes, and the receiving nodes forward the requests to their child nodes recursively. When the request arrives at the nodes in level 0, the nodes send information about their own load to the parent node. The parent node sorts the information in descending order of load and forwards the top and bottom *A* load information to its own parent node. Through recursive execution of this process, the root node obtains the top and bottom *A*

*3 Heartbeat: A protocol to confirm the server state (i.e., dead or alive) through keep-alive messaging.

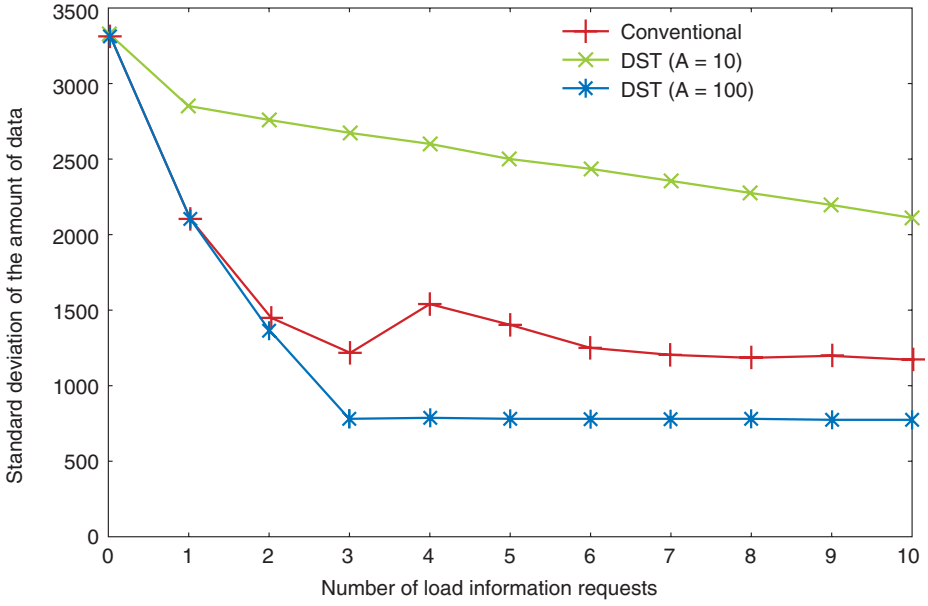


Fig. 4. Number of load information requests vs. standard deviation of the amount of data.

load information from the DST and balances the popular data among the *2A* nodes. This process is repeated periodically, and the DST is able to balance the entire load step-by-step, solving problem (2) mentioned in section 1.

Finally, we introduce a traffic reduction scheme generated by the MapReduce process in the DST. All data in the MapReduce process are delivered to their destination nodes through the DST. Then, each parent node combines the delivered data destined for the same nodes and redelivers them. The efficiency of this traffic reduction scheme depends on the characteristics of the time series data, but it is expected to achieve a significant reduction in traffic compared with naive delivery and to solve problem (3) mentioned in section 1.

3. Evaluation

We evaluated the performance of DST through computer emulation. In this emulation, there were 1000 nodes, and each node had [0, 10,000] time series data with a time range of [00:00, 23:59]. For comparison, we also evaluated the MapReduce platform based on Microsoft Azure [4].

First, we evaluated the effectiveness of load balancing. In the evaluation, we set variable *A* as 10 or 100 and measured the standard deviation of the amount of data among nodes while changing the number of load information requests (**Fig. 4**). We observed from the results that the effectiveness of load balancing in DST was higher as *A* became larger even if the number of requests was small.

Next, we evaluated the amount of data transported in the MapReduce process when the target time range was changed. The results indicated that DST effectively reduced the amount of transported data as the target range was expanded (**Fig. 5**).

Finally, we evaluated the stability of DST in a churn environment, which is where some nodes frequently join/leave the DST and also replicate data to other nodes more frequently. The frequencies of joining/leaving were set at 0.5, 1, and 2 per second, and each node replicates data it holds in one to three of its closest neighbors. In this environment, each node repeatedly sends certain kinds of data to the other node/s at an interval of 0.2 s. We measured the average success rate of the data transportation (**Fig. 6**). The results indicated that the success rate is significantly improved as the number of replicas increases.

4. Summary and future work

In this article, we introduced the DST and evaluated its effectiveness through emulation. The next step is to discuss the DST architecture with skiplist experts and work on making it even more effective. In addition, we will verify the effectiveness of DST

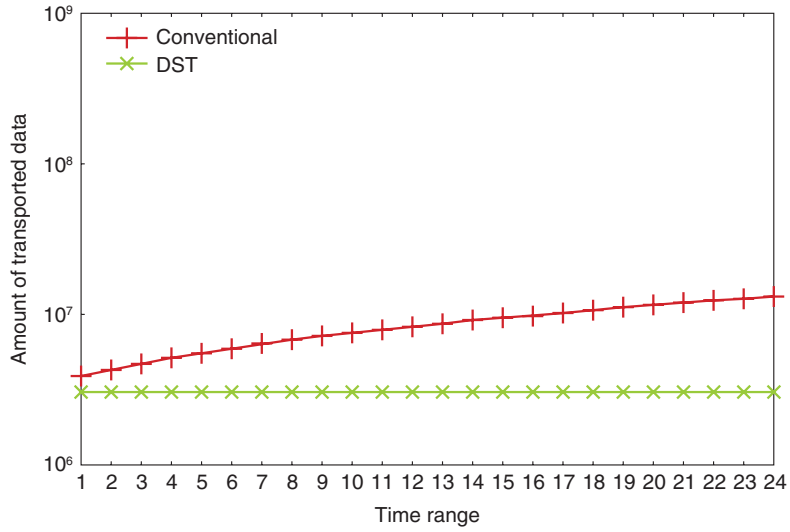


Fig. 5. Time range vs. amount of data transported in MapReduce.

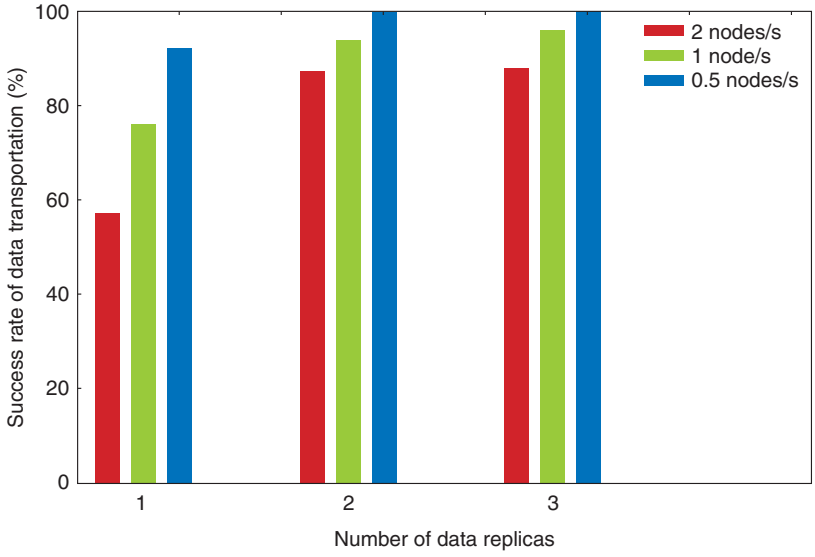


Fig. 6. Success rate of data transportation vs. the number of data replicas.

when it is used to analyze real traffic data.

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Development of Highly Efficient Group Modem Module and Turbo Codec Module for Next Generation Satellite Communication Systems

Fumihiro Yamashita, Katsuhiko Yamanaka, and Kiyoshi Kobayashi

Abstract

NTT Access Network Service Systems Laboratories has been developing the key components for a new satellite communication system named Highly Efficient Satellite Communication System (HESCS), which will supersede the existing satellite communication systems in the near future.

The key modules we developed in order to achieve HESCS are a highly efficient group modem module (HEGMM) and a highly efficient turbo codec module (HETCM) that can respectively modulate/demodulate and encode/decode a maximum of 64 channel signals. This article introduces the concept of HESCS and the details of the HEGMM and HETCM.

Keywords: satellite communications, modem, error correction

1. Introduction

The NTT Group has been providing various satellite communication services for the purpose of disaster-relief, as a backup line for a submarine cable for remote island communications, and for maritime broadband communications (**Fig. 1**).

Meanwhile, since the rental cost of satellite transponders remains high, the use of a satellite transponder must be as efficient as possible in order to reduce operating expenses (OPEX). Consequently, NTT Access Network Service Systems Laboratories is now developing the key components for a new satellite communication system named Highly Efficient Satellite Communication System (HESCS), which improves the spectrum utilization efficiency of satellite transponders. In the near future, HESCS is expected to supersede the existing satellite communication systems.

HESCS is aimed at solving the problems that the existing satellite communication systems suffer from. HESCS is advantageous in that it reduces OPEX by improving the spectrum efficiency of the satellite transponder, simplifies network satellite communication facilities by adopting a commonly used network interface, and provides skill-free monitoring and control functions by adopting an operation system commonly used in the terrestrial network.

This article introduces the concept of HESCS and the components developed for it, specifically, a highly efficient group modem module (HEGMM) and a highly efficient turbo codec module (HETCM) that can respectively modulate/demodulate and encode/decode a maximum of 64 channel signals.

2. Features of satellite modem (Group Modem) currently in use

The Group Modem is the satellite modem currently in use, as shown in **Fig. 2** [1]. It consists of the group

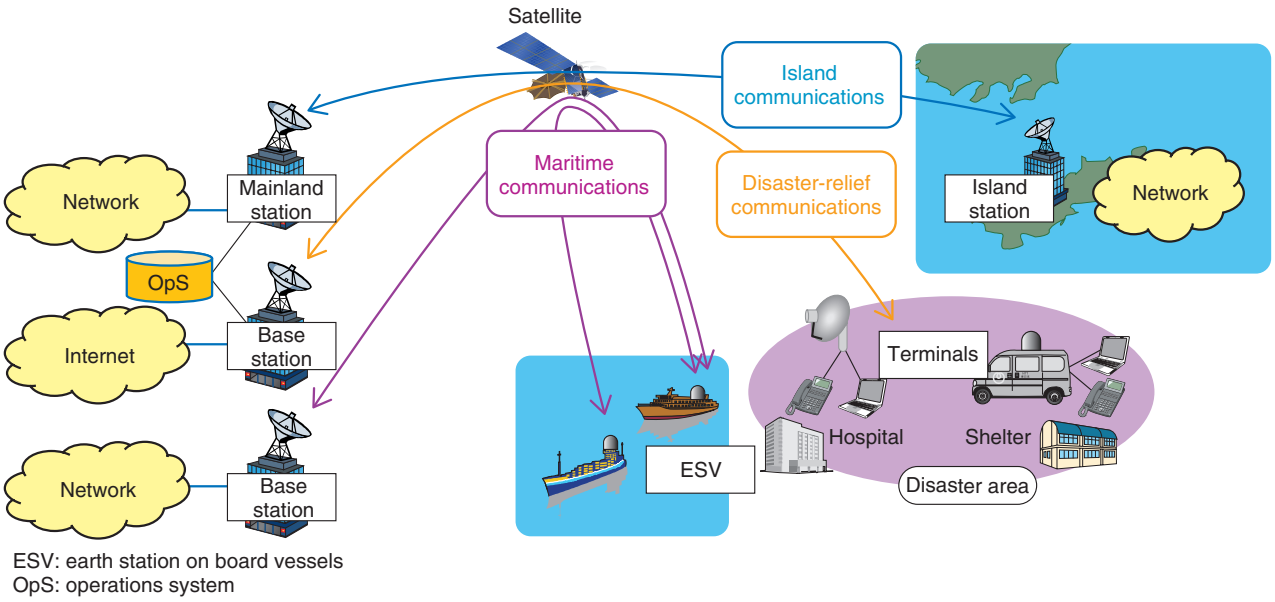

Fig. 1. Highly Efficient Satellite Communication System (HESCS).

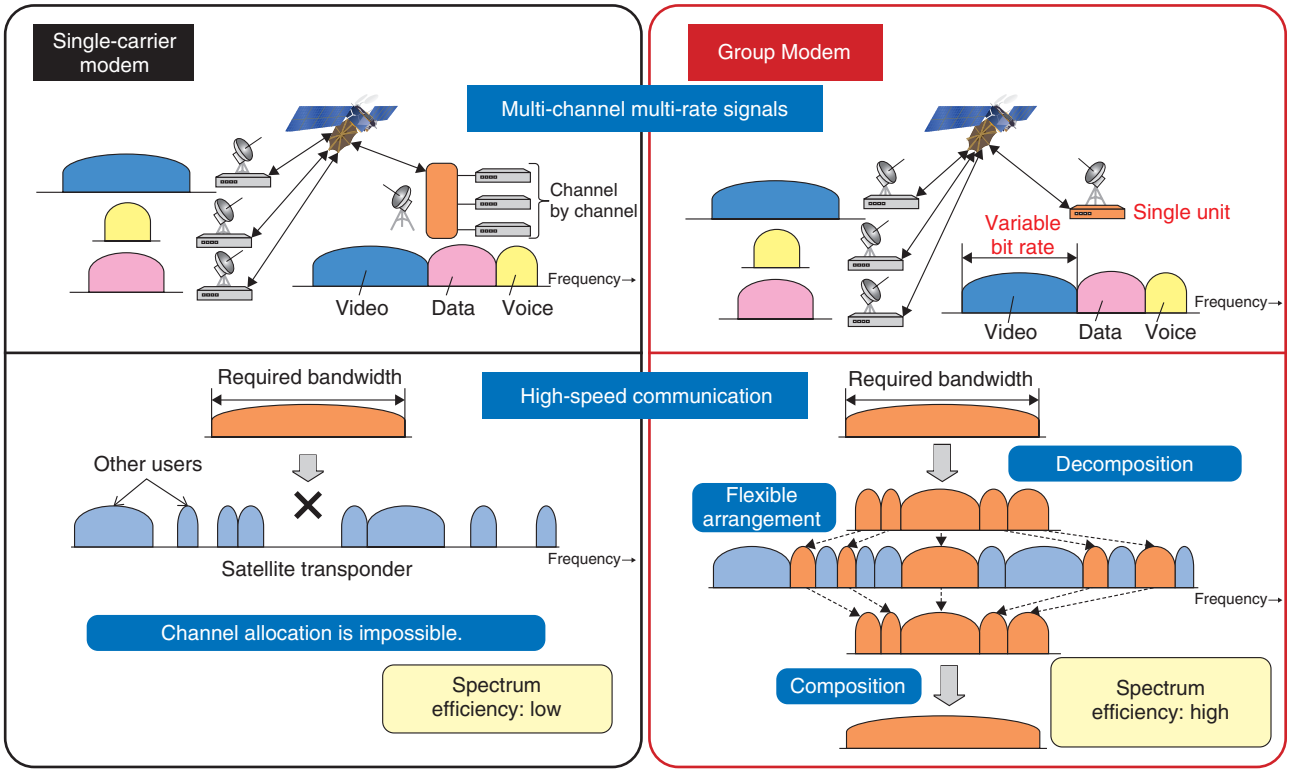

Fig. 2. Features of satellite modem (Group Modem) currently in use.

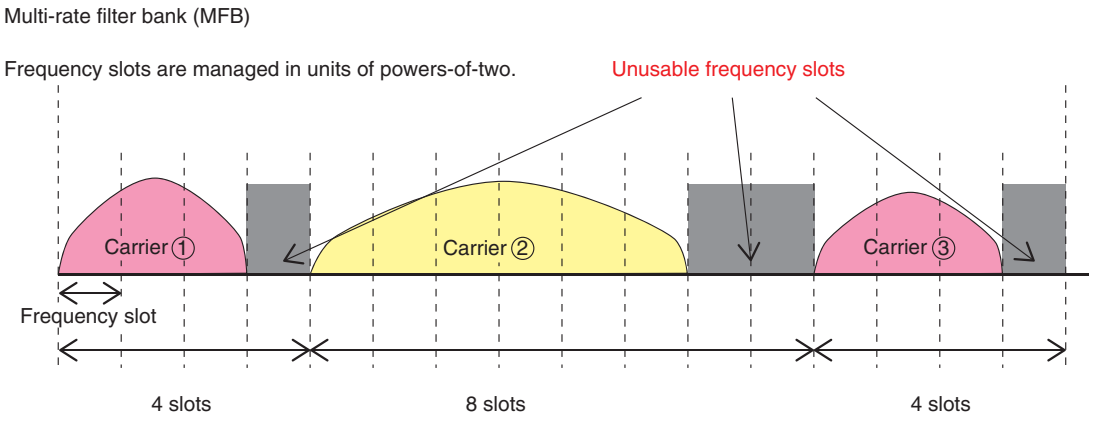

Fig. 3. Problem of unused frequency slots with GMM.

modem module (GMM)[*1] and the turbo codec module (TCM)[*2]. Conventionally, when many channels are handled in parallel, it is necessary to prepare multiple satellite modems corresponding to the number of channels. However, one feature of Group Modem is that the distinctive functions of multi-carrier modulation/demodulation in GMM and those of multi-channel encode/decode in TCM enable Group Modem to handle up to 25 channels at various communication speeds simultaneously.

Another major feature is the multi-carrier decomposition/composition of high bit rate signals. An example of multi-carrier decomposition is also shown in Fig. 2. A single-carrier modem cannot accommodate a broadband signal if the contiguous unused bandwidth is less than the required bandwidth. However, by decomposing the broadband signal into multi-carrier signals and arranging them in the unused frequency slots, the broadband signal can be flexibly accommodated in the limited satellite transponder. This function greatly improves the utilization efficiency of the satellite transponder by reducing the number of unused frequency slots.

3. Technical issues with GMM and TCM

Nevertheless, GMM and TCM do have some technical issues. One such issue with GMM is depicted in **Fig. 3**. GMM adopts a multi-rate filter bank (MFB) that consists of cascaded two-channel filter banks in a tree-like configuration for multi-carrier signal decomposition/composition [2]. Each two-channel filter bank has a high-pass filter and a low-pass filter followed by a downsampler, and it hierarchically divides the input bandwidth. In the MFB, the bandwidth and center frequency of each pass band can be arranged by selecting an appropriate signal in an appropriate hierarchy. While various bandwidths and center frequencies are supported by the MFB, there are strict rules. Namely, their bandwidth ratio must be a power-of-two, and their center frequencies are restricted to certain limited positions. With these constraints, the conventional GMM cannot support arbitrarily assigned FDMA (frequency division multiple access) signals. This means the number of unusable frequency slots increases when a required signal bandwidth and its center frequency mismatches the available pass band of the MFB.

In contrast, the existing TCM can handle as many as 25 channels per unit. However, the functionality of the next generation disaster-relief satellite communication systems was reconsidered in the aftermath of the Great East Japan Earthquake that occurred in 2011, and it was concluded that the capability of handling up to 50 channels per unit was needed in the event of a major disaster. For this reason, modifying the TCM to accommodate 50 channels has become an urgent task.

4. Features of developed HEGMM and HETCM

We propose a multi-rate arbitrary-arrangement-type fast Fourier transform filter bank (MR-FFTFB)

*1 GMM: A group modem module that can decompose/compose multi-carrier signals in the frequency domain and demodulate/modulate multi-channel signals in the time domain.

*2 TCM: A turbo codec module that can encode/decode multi-channel signals.

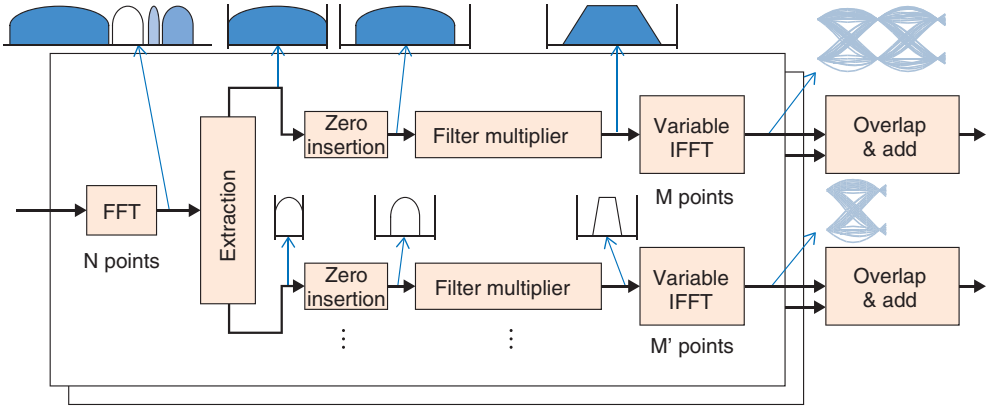

Fig. 4. Configuration of proposed multi-rate arbitrary-arrangement-type FFT filter bank (MR-FFTFB) in the receiver.

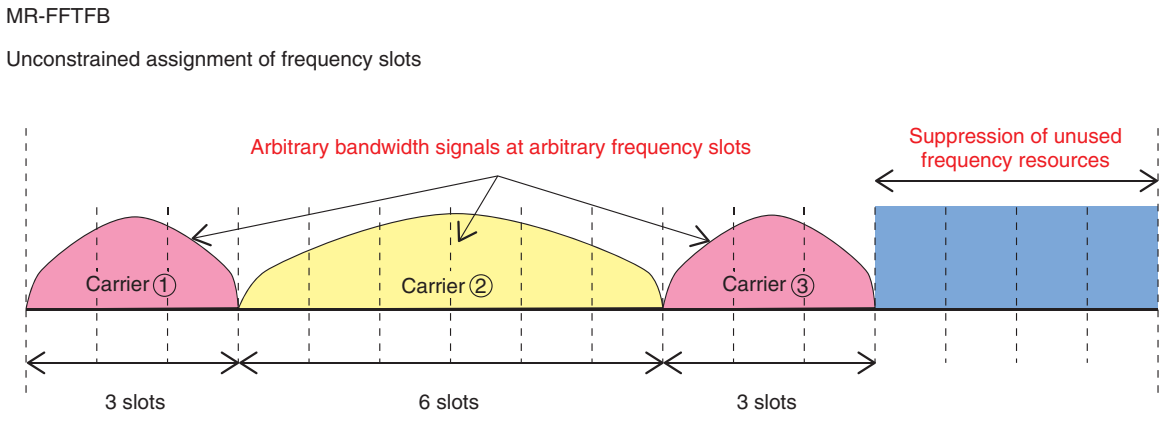

Fig. 5. Improved spectrum efficiency with HEGMM.

that employs frequency domain signal processing (**Fig. 4**) [3]. Unlike conventional MFB schemes, the MR-FFTFB can handle arbitrary bandwidth signals at arbitrary frequency slots simultaneously. The operational principle is as follows. The received signals are converted into the frequency domain by N-point FFT. The FFT points of the desired signal are extracted, and the number of points is adjusted so that it becomes the smallest power-of-two by inserting 0. Then, the extracted FFT points are converted to time domain signals by variable length IFFT (inverse FFT) and demodulated.

Since MR-FFTFB can extract the arbitrary bandwidth signal of the arbitrary center frequency, the constraints on signal bandwidth and its center frequency imposed on the MFB are removed. This means that unlike the conventional GMM, the HEGMM that adopts MR-FFTFB can handle the arbitrarily assigned, arbitrary bandwidth signals simultaneously. As a result, HEGMM improves the spectrum efficiency of the satellite transponder (**Fig. 5**).

The developed HEGMM provides another functionality that improves usability. Since GMM currently in use cannot demodulate burst signals, an additional modem for a burst control channel is required other than GMM. To solve this problem, we have newly implemented the functions of modulation and demodulation of burst signals as well as contiguous communication signals. As a result, in HESCS, the modem for the communication channel and that for the control channel are satisfactorily integrated into a single modem unit.

The configurations of HEGMM and HETCM are shown in **Fig. 6**. On the transmitter (Tx) side, the HEGMM modulates Tx data received from the

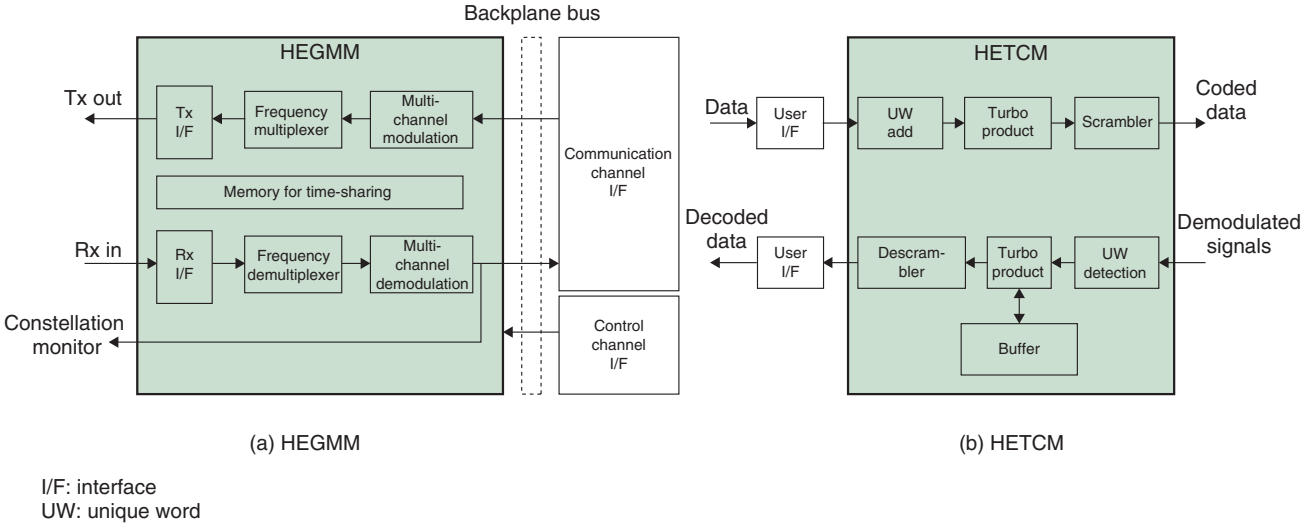

Fig. 6. Configurations of HEGMM and HETCM.

interface (I/F) board through a backplane bus carrier-by-carrier and arranges each carrier at the desired frequency slots using the frequency multiplexer. On the receiver (Rx) side, the frequency demultiplexer of HEGMM decomposes the received muti-carrier signals carrier-by-carrier in the frequency domain and demodulates each signal carrier-by-carrier. Then the demodulated signals are passed to the I/F board through the backplane bus.

In contrast, the signal processing algorithm implemented in HETCM is the same as that implemented in the TCM currently in use. A single turbo encoder/decoder is repeatedly used in a time sharing manner among all the channels. Thanks to the adoption of a higher sampling clock, the number of available channels is increased to up to 64 channels, and the total available communication speed is also improved to 25 Mbit/s.

Finally, the specifications of the current modules and newly developed modules are summarized in **Table 1**. This table indicates that the newly developed modules greatly improve the performance.

5. Performance evaluation

The fundamental performance of HEGMM and HETCM was experimentally evaluated. An example of multi-channel multi-carrier signal transmission using the developed HEGMM and HETCM is shown in **Fig. 7**. We confirmed that many multi-carrier multi-rate signals with different modulation schemes were transmitted and received simultaneously in one module, as can be seen in the figure.

In addition, we confirmed that the bit error ratio performance of the newly developed HEGMM/HETCM is approximately similar to that of the GMM/TCM currently in use. The 8PSK (phase shift keying) and 16QAM (quadrature amplitude modulation), which are newly implemented in HEGMM, also showed good performance. The use of 8PSK and 16QAM is expected to improve the spectrum efficiency of the satellite transponder further in the future.

6. Future developments

The HEGMM/HETCM will be implemented in the satellite communication modem unit (COM-U), which is now under development. An overall performance evaluation including functional verification of operability and connectivity (between COM-Us and between COM-U and the satellite terminals currently in use) will be carried out in 2016.

We are aiming to apply COM-U to future satellite communication services of the NTT Group for disaster-relief, remote island communications, and broadband maritime communications.

Acknowledgment

This work is supported by the Ministry of Internal Affairs and Communications of Japan through the

Table 1. Specifications of GMM/TCM and HEGMM/HETCM.

	GMM	HEGMM
No. of carriers	Tx/Rx 256 carriers	Tx/Rx 256 carriers
Frequency de-multiplexer/multiplexer	MFB	MR-FFTFB
Max. bandwidth	25.6 MHz	51.2 MHz
Max. no. of channels	Tx/Rx 64	Tx/Rx 64
Burst signals	Modulation	Modulation/Demodulation
Modulation	BPSK, π/4QPSK, OQPSK, QPSK	BPSK, QPSK, 8PSK, 16QAM
Roll-off ratio	0.2, 0.35, 0.4, 0.5	0.2, 0.35
	TCM	HETCM
Turbo block size	(32, 26) × (32, 26) or (64, 57) × (64, 57)	(32, 26) × (32, 26) or (64, 57) × (64, 57)
No. of iterations	5 or 10	1-10
Max. bit rate	6.4 Mbit/s	25 Mbit/s
Max. no. of channels	Tx/Rx 25	Tx/Rx 64

BPSK: binary phase shift keying
QPSK: quadrature PSK
QAM: quadrature amplitude modulation

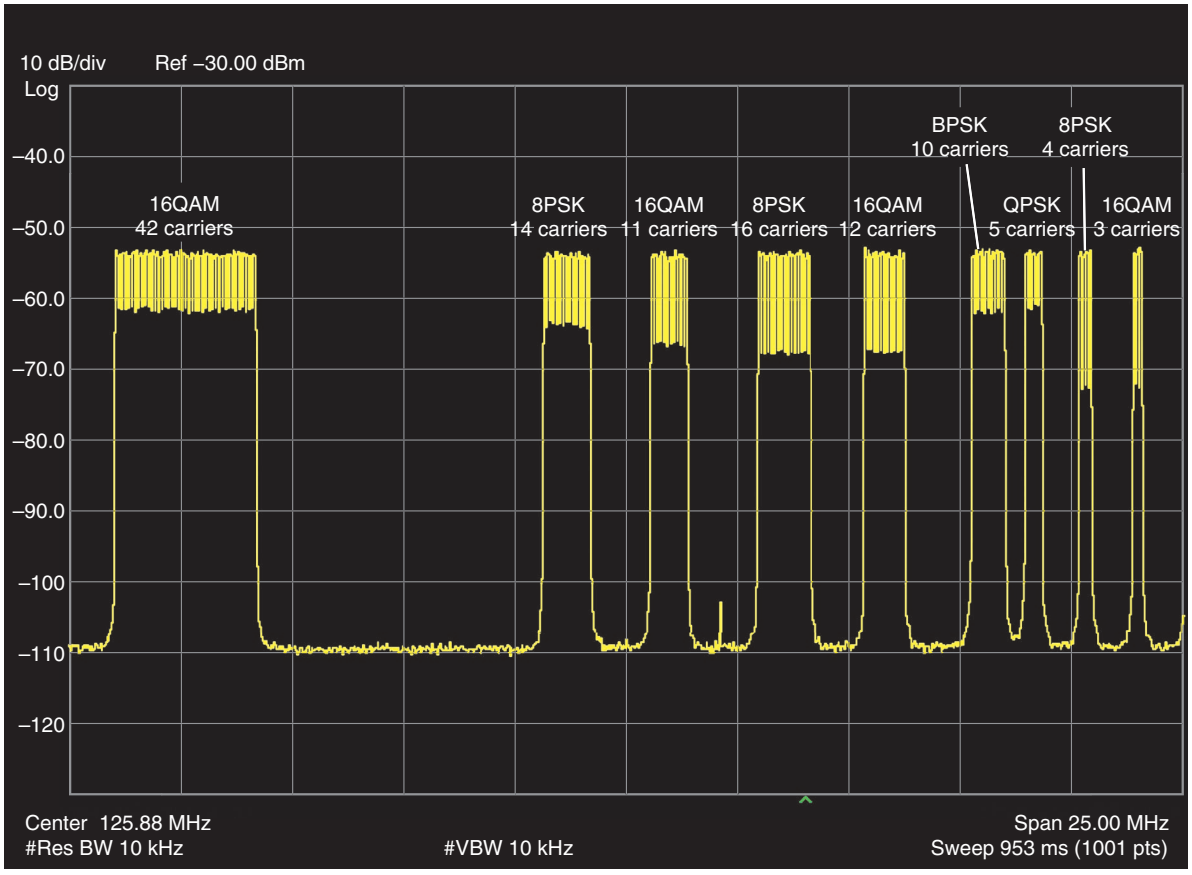

Fig. 7. Transmission of multi-channel multi-carrier signals.

funds “Research and Development of Highly Efficient Frequency Use Technique for the Communication Satellite Transponder” and “Research and Development of Capacity Enhancing Technology for Satellite Communications by Employing Dynamic Polarization and Frequency Control.”

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Standardization Activities on EMC for Telecommunication in ITU-T SG5

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Abstract

The NTT Group participates in the development of international standards related to electromagnetic compatibility for telecommunication equipment as part of its effort to protect its telecommunication equipment from electromagnetic disturbances and lightning surges and to provide high-quality, high-reliability telecommunication services. This article reports on the standardization activities at the ITU-T SG5 (International Telecommunication Union - Telecommunication Standardization Sector, Study Group 5) meeting held in October 2015.

Keywords: EMC, ITU-T, standardization

1. Introduction

With a view to maintaining and enhancing the quality and reliability of its telecommunication services, the NTT Group defines standard specifications on electromagnetic compatibility (EMC) in the form of technical requirements, which must be met for development or procurement of telecommunication systems (**Fig. 1**). The basic global EMC specifications are created by the International Electrotechnical Commission (IEC) and Comité International Spécial des Perturbations Radioélectriques (CISPR). The requirements for telecommunication systems are developed by Study Group 5 (SG5) of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) in the form of ITU-T K series recommendations. NTT technical requirements conform to these international standards for the most part, and are instrumental in maintaining the quality and reliability of telecommunication services provided by the NTT Group. This article introduces the latest standardization activities of ITU-T SG5.

2. Overview of ITU-T SG5 WP1/WP2

Headquartered in Geneva, Switzerland, ITU-T issues ITU-T recommendations, which serve as international standards in the field of telecommunications. ITU-T consists of 11 Study Groups (SGs). Recommendations on EMC for telecommunication systems are developed by SG5 (Environment and climate change). SG5 consists of three Working Parties (WPs). Questions related to overvoltage, earthing (grounding), and safety for telecommunication systems are studied by WP1, and questions related to tolerable levels of electromagnetic disturbance emissions, immunity requirements, and human exposure to electromagnetic fields are studied in WP2.

WP1 and WP2 are addressing the questions indicated in **Fig. 2** in the current study period (2013–2016). This article reports on the content of discussions held at the SG5 meeting in Geneva October 12–23, 2015. Draft revisions to existing recommendations and new draft recommendations that were accepted in this meeting are listed in **Table 1**.

3. Discussions in WP1

WP1 studies how to protect telecommunication systems from overvoltage generated by lightning, and electromagnetic interference due to electromagnetic induction from power systems and electrified railway systems. The following discussions were held regarding

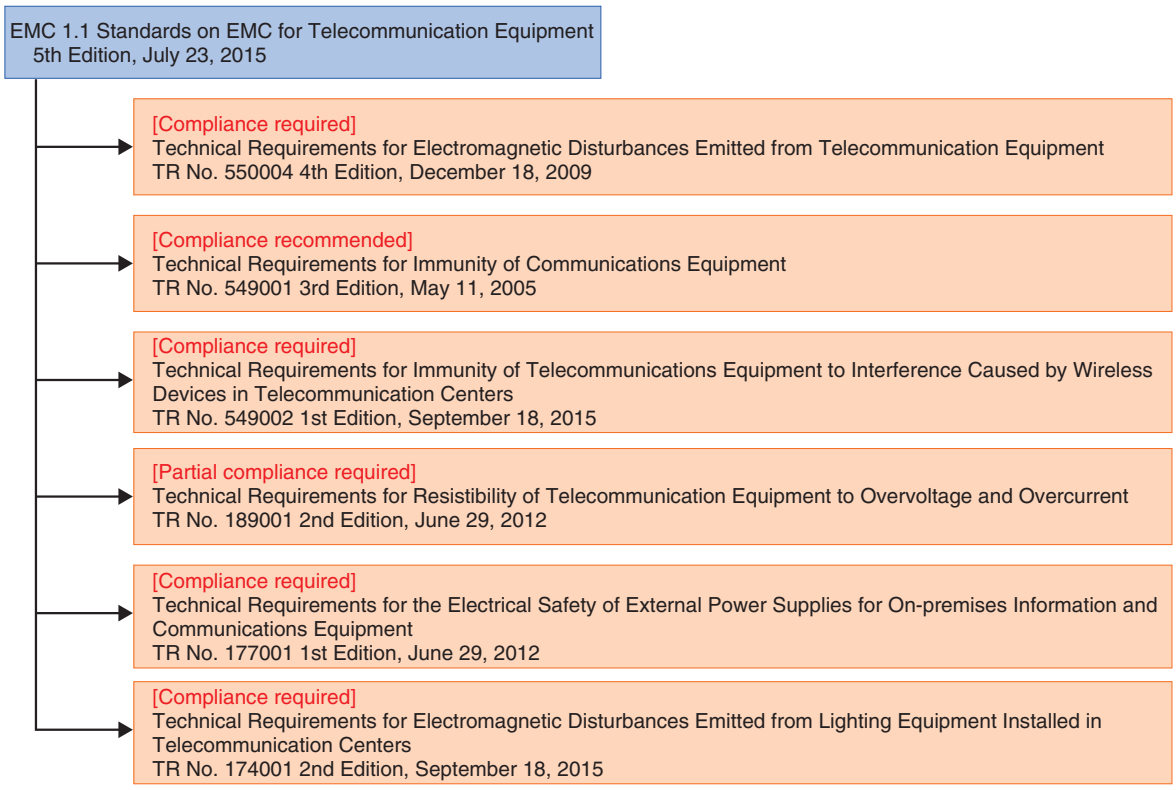


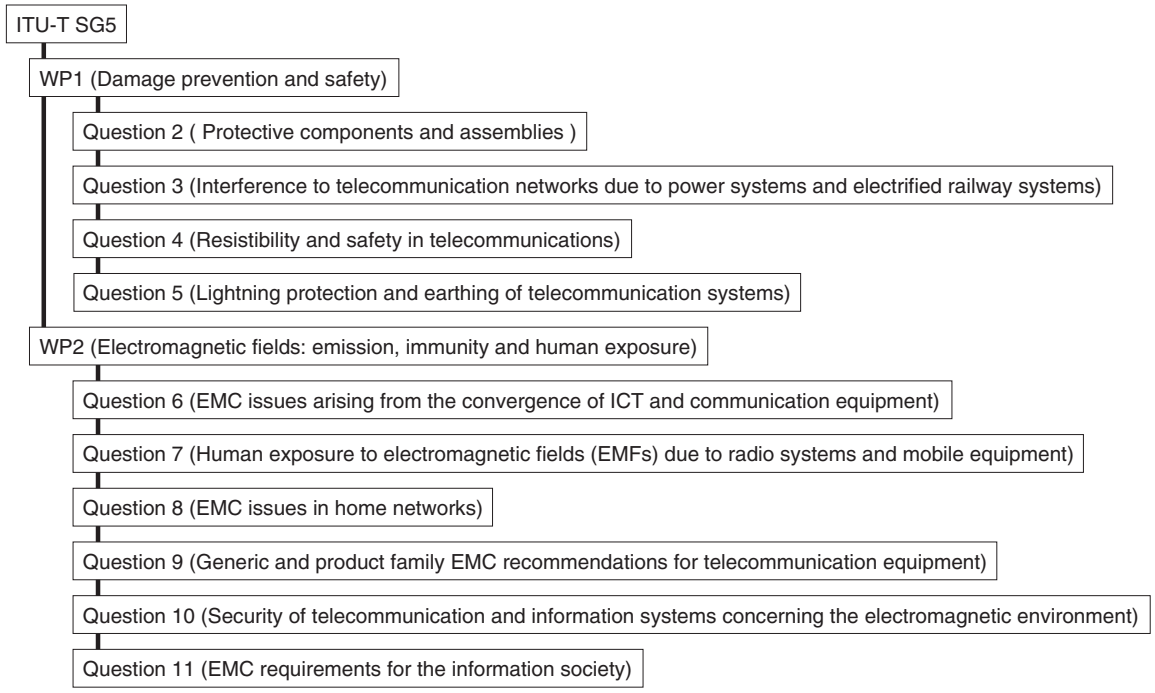
Fig. 1. NTT Group's standard and technical requirements related to EMC.

Questions 2 to 5.

Question 2 concerns test methods and requirements related to protective components and assemblies such as varistors and surge arresters against overvoltage. The UK and Germany submitted a contribution that pointed out the vulnerability of Ethernet ports of PoE (Power over Ethernet)-compatible devices to lightning surges in differential mode, and proposed a test method in which a 1500-V surge is applied between pair wires. Whether this test is needed will be discussed in the next and future meetings. A description of the problem of heat being generated when telecommunication cables come into contact with power cables was added to K.20, K.21, K.45, and K.82 as a supplement.

Question 3 relates to the issues of electromagnetic induction from power systems and electrified railway systems, and of the safety of workers in the event of ground faults. The meeting adopted the final draft of a new draft recommendation, K.hvps2, which defines the method of measuring ground impedance. The method takes into consideration a rise in the ground potential that occurs when a power substation suffers a ground fault. Consent was also given to a new draft recommendation, K.tup, which defines methods of protecting telecommunication devices installed on utility poles, and to another new draft recommendation, K.jup, which defines the method of protecting telecommunication cables from short-circuit accidents with power cables in cases where telecommunication cables and power cables share the same poles.

Question 4 addresses requirements for overvoltage resistibility at interfaces of telecommunication systems, methods of protecting against overvoltage, and electrical safety. NTT submitted a contribution that explained the problems with the method of testing lightning surge at Ethernet ports. It was agreed that these problems will be studied in the next and future meetings as draft revisions to the existing recommendations, K.20, K.21, K.44, and K.45. NTT also proposed a lightning protection method that bridges power and telecommunication lines. It was decided to begin studying this method in collaboration with IEC TC (Technical Committee) 108. The meeting accepted



ICT: information and communication technology

Fig. 2. Questions studied by ITU-T SG5 WP1/WP2.

Table 1. List of recommendations agreed on at the last meeting.

Work item	Recommendation name
K.44 (revision)	Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation
K.59 (revision)	EMC, resistibility and safety requirements and procedures for connection to unbundled cables
K.60 (revision)	Emission levels and test methods for wireline telecommunication networks to minimize electromagnetic disturbance of radio services
K.67 (revision)	Expected surges on telecommunications and signalling networks due to lightning
K.hvps2 (new)	Method for determining the impedance to earth of earthing systems
K.tup (new)	Installation of telecommunication equipment on utility poles
K.jup (new)	Joint-use of poles by telecommunication and solidly earthed power lines
K.ldt (new)	Lightning protection of the dedicated transformer for radio base station
K.ntt (new)	Protection of surrounding structures of telecommunication towers against lightning
K.maps (new)	Generation of radiofrequency electromagnetic fields (RF-EMF) level maps
K.bts_emc (new)	Electromagnetic compatibility requirements and measurement methods for digital cellular mobile communication base station equipment
K.secmiti (new)	Mitigation methods against electromagnetic security threats
K.ter_emc (new)	EMC requirements and test methods for radio telecommunication terminal equipment

the draft revised K.44 version 2, which describes the configuration of the circuit that generates a surge waveform to be applied in an overvoltage test.

Question 5 concerns the earthing of telecommunication systems and risk management. The meeting adopted final drafts proposed by China for several

new draft recommendations: K.ldt, which concerns protection of power transformers for wireless base stations against lightning; K.tot, which specifies earthing and bonding of wireless base stations; and K.ntt, which specifies methods of protecting structures near wireless base stations against lightning. Brazil proposed a revision to K.67, which specifies the level and waveform of lightning surges that may arise in a telecommunication network. The meeting gave consent to it after a discussion was held on the calculation model for a direct lightning strike on telecommunication lines. In addition, the meeting agreed to create a new work item in order to develop a new recommendation, K.psp, which addresses lightning protection methods in the TT earthing and IT earthing systems.

4. Discussions in WP2

WP2 is studying emissions from telecommunication systems, immunity to such emissions, and how to protect the human body against potential harm from radio waves. The following discussions were held regarding Questions 6 to 11.

Question 6 concerns EMC problems that arise from the shared use of telecommunication networks by different providers, a situation brought about by the liberalization of telecommunications. A discussion was held on a draft revision to the existing recommendation, K.59, which specifies EMC, voltage resistibility, and safety requirements and countermeasures for cables. The final draft for this revision was accepted after the longitudinal conversion loss values specified in ITU-T Recommendation G.993.2 had been incorporated. The draft revision to the existing recommendation, K.60 (Emission levels and test methods for wireline telecommunication networks to minimize electromagnetic disturbance of radio services), received consent after a formula for conversion of tolerable emission levels for a variety of measurement distances was added.

Question 7 deals with human exposure to electromagnetic fields near radio system antennas. The meeting adopted a new draft recommendation, K.maps, which describes a method of mapping an electromagnetic field, after a discussion on it from a practical viewpoint was held. This discussion included issues such as the selection of colors to be used in electromagnetic distribution maps to indicate different levels of electric field strength. The National Institute of Information and Communications Technology and NTT DOCOMO jointly proposed to add a provision that the output measurement of mobile phone base stations be exempt from the application of the existing recommendation, K.52 (Guidance on complying with limits for human exposure to electromagnetic fields). It was agreed to study this proposal in the next and future meetings.

Question 8 covers EMC specifications for telecommunication devices that make up a home network. Since CISPR is planning to merge CISPR 20 (Sound and television broadcast receivers and associated equipment immunity standard) and CISPR 24 (Information technology equipment immunity standard) into the new CISPR 35 (Multimedia equipment immunity standard), the meeting started the study to revise the existing recommendation closely related to the above, K.93 (Immunity of home network devices to electromagnetic disturbances).

Question 9 relates to the study of EMC specifications for new telecommunication services, and to maintaining the existing recommendations. The meeting also discussed K.e_faci version 2, a new draft recommendation being studied at the initiative of NTT to specify the emission requirements for electronic equipment installed in telecommunication centers, and K.prox version 1, a new draft recommendation that specifies immunity requirements for radio systems located adjacent to telecommunication systems. In the discussion on K.e_faci, it was agreed to make the tolerable emission level of electric equipment equal to the level defined in CISPR 32 in order to maintain the existing electromagnetic environment of telecommunication centers. It was agreed to start the study of K.prox with the assumed radio systems limited to wireless LANs (local area networks) working in the 2.4/5.2/5.6 GHz band, and then gradually expand the scope of the frequency band of the assumed radio systems, taking the ongoing study at IEC 61000-4-39 (Radiated fields in close proximity - immunity test: being studied) into consideration. In addition, NTT's proposal to develop a draft recommendation for specifying EMC requirements for lighting devices installed in telecommunication centers was adopted as a new work item under the name of K.light.

Question 10 focuses on issues pertaining to the electromagnetic security of telecommunication systems. NTT submitted the final draft for the new draft recommendation, K.secmiti, which addresses measures to mitigate the effect of electromagnetic wave attacks. The draft was adopted after a modification was made to clarify the scope of its application. This adoption completes the standardization of a series of

recommendations related to electromagnetic field security, which has been studied at the initiative of NTT: K.78, K.81, K.84, K.87, and K.secmiti. A draft recommendation proposed by NTT to prevent cosmic radiation-caused soft error (phenomenon of malfunctions of LSIs (large-scale integrated circuits) and other semiconductors in electronic systems caused by neutron rays, etc. included in secondary cosmic rays) was approved. It was agreed to divide the proposed recommendation into four recommendations: overview (K.soft_ba), test method (K.soft_test), quality determination method (K.soft_mes), and design method (K.soft_des).

Question 11 addresses EMC issues related to radio systems. The meeting discussed the final draft of a new draft recommendation, K.ter_emc, which specifies EMC requirements for wireless terminals, and consent was granted after some modifications were made to the glossary. The next and future meetings will study a new draft recommendation, K.bwenv, which specifies the electromagnetic environment for wearable devices functioning in the 2.4-GHz band.

5. Conclusion

This article introduced the latest standardization activities in ITU-T SG5 WP1/WP2. The global penetration of telecommunication systems and mobile terminals has brought about dramatic changes in the electromagnetic environment surrounding telecommunication equipment. This has prompted the United States, European countries, Japan, and also developing countries to actively propose a wide range of new questions. ITU-T recommendations are international standards specifying test methods and requirements tuned to the characteristics of telecommunication equipment, and they are therefore directly linked to NTT technical requirements, which are used by the NTT Group as procurement standards. NTT will enhance the quality and reliability of telecommunication services by pursuing standardization activities in a way adapted to changes in the environment surrounding telecommunication equipment.

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He received a B.E. and M.E. in electrical engineering from Tokyo University of Science in 2002 and 2004. He joined NTT Energy and Environment Systems Laboratories in 2004 and studied EMC technology for telecommunication. He is currently researching a radiation immunity test method for vicinity use of wireless devices. He is a member of IEICE.

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He received a B.E. and M.E. in electrical and electronic engineering from Okayama University in 1993 and 1995. He joined NTT Telecommunication Network Laboratory in 1995. He is researching electromagnetic interference in wireless and wired communication systems and disaster prevention countermeasures using communication systems. He is currently a group leader at EMC Technology Group. He is a member of IEICE.

New NTT Colleagues
—We welcome our newcomers to the NTT Group

This is a corner of the NTT Technical Review where we introduce our new affiliate companies.

Wizardsgroup
IT (information technology) consulting and learning solutions provider; established in 1996; a major partner with Oracle and Microsoft in the Philippines

Founded in 1996, Wizardsgroup, Inc. has consolidated its strength in high value IT consulting and learning solutions for Oracle and Microsoft technologies, mainly in the Philippine market. Headquartered in Metro Manila, the company now employs more than 200 staff in total and also has a satellite office located in the United States.

In December 2015, NTT DATA Corporation, through its subsidiary NTT DATA Asia Pacific Pte. Ltd., reached an agreement to obtain 100% of outstanding shares in Wizardsgroup. The transaction is a part of NTT DATA's core strategy to accelerate its global business and to widen its global customer base, offering a portfolio and presence outside of Japan. The collaboration with Wizardsgroup will help NTT DATA drive business in the Philippines faster and also enables it to leverage the Philippine company's capabilities in the Asia-Pacific, North American, and European regions.

For further information about Wizardsgroup, please visit: http://www.wizardsgroup.com/

Contact:
Global Business Sector
NTT DATA Corporation
http://www.nttdata.com/global/en/news-center/pressrelease/2015/122102.html

Taiwan Application Service Management Consulting
IT consulting service provider; established in 2010; a major partner with SAP in Taiwan

Headquartered in Taipei, Taiwan Application Service Management Consulting Co., Ltd. (TASMC) employs the largest number of SAP professionals in Taiwan and has a solid track record of implementing SAP solutions for local companies while building stronger cloud solution capabilities, especially for Salesforce.com.

In December 2015, NTT DATA Corporation reached an agreement to obtain 100% of outstanding shares in TASMC. The transaction is a part of NTT DATA's core strategy to accelerate its global business and to widen its global customer base, offering a portfolio and presence outside of Japan. The collaboration with TASMC will help NTT DATA drive business in Taiwan faster and also enables it to leverage TASMC's capabilities in China and the Asia-Pacific region.

For further information about TASMC, please visit: http://www.tasmc.com.tw/?lan=en_US

Contact:
Marketing Department
NTT DATA (CHINA) Co., Ltd.
http://www.nttdata.com/global/en/news-center/pressrelease/2015/122200.html

External Awards

IPSJ Kiyasu Special Industrial Achievement Award

Winner: Kenji Takahashi, NTT Innovation Institute, Inc.; Kuniaki Naoi, NTT Software Innovation Center; Hiroshi Kumeta, Yan Li, and Ichiro Nagano, NTT Software Corporation
Date: June 3, 2015
Organization: Information Processing Society of Japan (IPSJ)

For the contribution to international standardization and practical use of a user identification management technique.

OpenStack Superuser Award

Winner: Toshikazu Ichikawa, Kota Tsuyuzaki, Mitsuhiro Shigematsu, Masahito Muroi, Sampath Priyankara, Takashi Natsume, Hirofumi Ichihara, Kentaro Tanaka, Tomoko Inoue, Daisuke Morita, Kazuhiro Miyahara, Tomonori Fujita, Tomoya Mizobuchi, Koji Iida, Shintaro Mizuno, Kenichi Sato, and Hiroshi Sakai, NTT Software Innovation Center
Date: October 27, 2015
Organization: OpenStack Foundation

The NTT Group has three OpenStack use cases in production, and its team has contributed 1054 total commits, ranking 18 out of 263 organizations. The OpenStack Foundation launched the Superuser Awards to recognize, support and celebrate teams of end-users and operators that use OpenStack to meaningfully improve their businesses while contributing back to the community.

IE Award

Winner: Yukihiro Bandoh, Seishi Takamura, and Atsushi Shimizu, NTT Media Intelligence Laboratories
Date: December 9, 2015
Organization: Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Image Engineering (IE)

For "A Study of Complexity Reduction for Optimal Design of Rate-constraint Quantizer."

We formulate the design of an optimal quantizer as an optimization problem that finds the quantization indices that minimize quantization error. As a solution to the optimization problem, an approach based on dynamic programming, which is called DP quantization, is proposed. However, conventional DP quantization does not consider the design of the rate-constraint quantizer. In this paper, we propose an optimal design for the rate-constraint quantizer by extending DP quantization.
Published as: Y. Bandoh, S. Takamura, and A. Shimizu, "A Study of Complexity Reduction for Optimal Design of Rate-constraint Quantizer," IEICE Tech. Rep., Vol. 115, No. 350, IE2015-97, pp. 105–110, Dec. 2015.

Specially Selected Paper

Winner: Hideharu Nakajima, NTT Media Intelligence Laboratories; Hideyuki Mizuno, Tokyo University of Science, SUWA; and Sumitaka Sakauchi, NTT Service Innovation Laboratory Group
Date: December 15, 2015
Organization: IPSJ Journal Editorial Committee

For "Emphasized Accent Phrase Prediction from Advertisement Text for Text-to-expressive Speech Synthesis."

Realizing expressive text-to-speech synthesis requires development of both text processing and the rendering of natural expressive speech. This paper focuses on the former as a front-end task in the production of synthetic speech, and investigates a novel method for predicting emphasized accent phrases from advertisement text information. For this purpose, we examine features that can be accurately extracted by text processing based on current text-to-speech synthesis technologies. Among features, the word surface string of the main content and function words and the parts of speech of the main function words in an accent phrase are found to have higher potential to predict whether the accent phrase should be emphasized or not through the calculation of mutual information between emphasis labels and features of Japanese advertisement sentences. Experiments confirmed that emphasized accent phrase prediction using support vector machine offers an encouraging degree of accuracy for systems which require emphasized accent phrase locations as context information to improve speech synthesis quality.
Published as: H. Nakajima, H. Mizuno, and S. Sakauchi, "Emphasized Accent Phrase Prediction from Advertisement Text for Text-to-expressive Speech Synthesis," IPSJ Journal, Vol. 56, No. 12, pp. 2384–2394, Dec. 2015.

HCG Symposium 2015 Interactive Presentation Award/ Organized Session Award

Winner: Shiro Kumano, Kazuhiro Otsuka, Ryo Ishii, and Junji Yamato, NTT Communication Science Laboratories
Date: December 17, 2015
Organization: IEICE Human Communication Group (HCG)

For "Automatic Gaze Analysis in Medium-sized Multiparty Conversations Based on Collective First-person Vision."
Published as: S. Kumano, K. Otsuka, R. Ishii, and J. Yamato, "Automatic Gaze Analysis in Medium-sized Multiparty Conversations Based on Collective First-person Vision," HCG Symposium 2015, Toyama, Japan, Dec. 2015.

HCG Symposium 2015 Interactive Presentation Award

Winner: Ryo Ishii, Shiro Kumano, and Kazuhiro Otsuka, NTT Communication Science Laboratories
Date: December 17, 2015
Organization: IEICE Human Communication Group (HCG)

For "Predicting Next Speaker Using Gaze and Respiration in Multi-party Meetings."
Published as: R. Ishii, S. Kumano, and K. Otsuka, "Predicting Next Speaker Using Gaze and Respiration in Multi-party Meetings," HCG Symposium 2015, Toyama, Japan, Dec. 2015.

ASRU 2015 Best Paper Award Honorable Mention

Winner: Takuya Yoshioka, Nobutaka Ito, Marc Delcroix, Atsunori Ogawa, Keisuke Kinoshita, Masakiyo Fujimoto, NTT Communication Science Laboratories; Chengzhu Yu, The University of Texas at Dallas; Wojciech J. Fabian, Miquel Espi, Takuya Higuchi, Shoko Araki, Tomohiro Nakatani, NTT Communication Science Laboratories
Date: December 17, 2015
Organization: ASRU 2015 (The 2015 IEEE Automatic Speech Recognition and Understanding Workshop) Committee

For "The NTT CHiME-3 System: Advances in Speech Enhancement and Recognition for Mobile Multi-microphone Devices."

Published as: T. Yoshioka, N. Ito, M. Delcroix, A. Ogawa, K. Kinoshita, M. Fujimoto, C. Yu, W. J. Fabian, M. Espi, T. Higuchi, S. Araki, and T. Nakatani, "The NTT CHiME-3 System: Advances in Speech Enhancement and Recognition for Mobile Multi-microphone Devices," Proc. of ASRU 2015, pp, 436–443, Scottsdale, Arizona, USA, Dec. 2015.

IEICE Electronics Society LQE Young Researchers Award

Winner: Ryo Nakao, NTT Device Technology Laboratories
Date: December 18, 2015
Organization: IEICE Technical Committee on Lasers and Quantum Electronics (LQE)

For "High-speed Operation of GaAs/InGaAs Metamorphic Lasers Emitting at 1.3 μm."

We demonstrate a lattice relaxation control by in situ curvature measurement for a metamorphic buffer. Using this relaxation control, we investigated a thin (240 nm) $In_{0.15}Ga_{0.85}As$ metamorphic buffer for fabricating an un-strained $In_{0.10}Ga_{0.90}As$ quasi-substrate on a GaAs substrate and succeeded in fabricating a 1.3-μm metamorphic InGaAs multiple-quantum well laser diode (LD) on the metamorphic buffer. We confirmed that the LD was directly modulated at 25 Gbit/s with a high-characteristic temperature (T_0 = 187 K).
Published as: R. Nakao, M. Arai, W. Kobayashi, T. Yamamoto, and S. Matsuo, "1.3-μm InGaAs MQW Metamorphic Laser Diode Fabricated with Lattice Relaxation Control Based on In Situ Curvature Measurement," IEEE J. Sel. Top. Quantum Electron., Vol. 21, No. 6, p. 1501407, Nov. 2015.

Papers Published in Technical Journals and Conference Proceedings

Adaptive Pre-equalization Using Bidirectional Pilot Sequences to Estimate and Feed Back Amplitude Transfer Function and Chromatic Dispersion

S. Okamoto, M. Yoshida, K. Yonenaga, and T. Kataoka

Proc. of the Optical Fiber Communication Conference and Exhibition (OFC) 2015, Th2A.29, Los Angeles, CA, USA, March 2015.

We propose an adaptive pre-equalization system that compensates the amplitude transfer function and chromatic dispersion using estimates transmitted from the receiver. Two kinds of pilot sequences are used for estimation and mutual communication.

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5 x 1-Tb/s PDM-16QAM Transmission over 1,920 km Using High-speed InP MUX-DAC Integrated Module

A. Sano, M. Nagatani, H. Nosaka, and Y. Miyamoto

Proc. of OFC 2015, M3G.3, Los Angeles, CA, USA, March 2015.

We demonstrate wavelength division multiplexed transmission of 75-Gbaud PDM (polarization-division multiplexed)-16QAM (quadrature amplitude modulation) signals over 1,920 km. An InP-based high-speed and compact MUX-DAC (multiplexer-digital-to-analog converter) integrated module with bandwidth exceeding 40 GHz enables the long haul transport of 1-Tb/s superchannels composed of just two subcarriers.

Dense SDM (12-core × 3-mode) Transmission over 527 km with 33.2-ns Mode-dispersion Employing Low-complexity Parallel MIMO Frequency-domain Equalization

K. Shibahara, T. Mizuno, H. Takara, A. Sano, H. Kawakami, D. Lee, Y. Miyamoto, T. Ono, M. Oguma, Y. Abe, T. Kobayashi, T. Matsui, R. Fukumoto, Y. Amma, T. Hosokawa, S. Matsuo, K. Saito, H. Nasu, and T. Morioka

Proc. of OFC 2015, Th5C.3, Los Angeles, CA, USA, March 2015.

We demonstrate 12-core × 3-mode dense SDM (space division multiplexing) transmission over 527-km graded-index multi-core few-mode fiber without mode-dispersion management. Employing a low baud rate multicarrier signal and frequency-domain equalization enables 33.2-ns differential mode delay compensation with low computational complexity.

120.7-Tb/s MCF-ROPA Unrepeatered Transmission of PDM-32QAM Channels over 204 km

H. Takara, T. Mizuno, H. Kawakami, Y. Miyamoto, H. Masuda, K. Kitamura, H. Ono, S. Asakawa, Y. Amma, K. Hirakawa, S. Matsuo, K. Tsujikawa, and M. Yamada

Journal of Lightwave Technology, Vol. 33, No. 7, pp. 1473–1478, April 2015.

We demonstrate the unrepeatered transmission of over 100 Tb/s by employing a multicore-fiber-based remote optically pumped amplifier. We establish 120.7-Tb/s, 204-km seven-core fiber transmission with the aggregate spectral efficiency (SE) of 53.6 b/s/Hz, a record capacity per fiber and the highest SE for unrepeatered transmission. We also realized the highest capacity per core of 17.2 Tb/s (180 × 95.8 Gb/s) and SE of 7.6 b/s/Hz by using the polarization-division-multiplexed 32-quadrature amplitude modulation format for unrepeatered transmission.

Filtering-tolerant Transmission by the Walsh-Hadamard Transform for Super-channel beyond 100 Gb/s

K. Shibahara, A. Masuda, H. Kishikawa, S. Kawai, and M. Fukutoku

Optics Express, Vol. 23, No. 10, pp. 13245–13254, May 2015.

Super-channel transmission is a promising solution to increase the capacity of a channel beyond 100 Gb/s in next-generation optical networks. The performance of a super-channel comprising multiple subcarriers, however, degrades if optical filtering distortions occur in particular subcarriers. In this paper, we propose a method that improves super-channel performance by dispersing the distortions over all subcarriers. We also numerically demonstrate that the method effectively mitigates the filtering induced penalty suffered by super-channels.

Optical 8-dimensional Time-polarization Modulation Using Square-QAM-constellation and a Simple Decoding Algorithm

M. Nakamura, M. Yoshida, F. Hamaoka, and K. Yonenaga

Proc. of the 20th Opto-Electronics and Communications Conference (OECC 2015), JThA.93, Shanghai, China, June/July 2015.

We propose optical 8D time-polarization modulation using square-QAM-constellation and a simple decoding algorithm. Experiments show that the proposed modulation format can achieve significant gain and that the decoding algorithm has the same performance as conventional maximum-likelihood-detection.

High-capacity Multicore Fiber Transmission Technology

H. Takara, T. Mizuno, A. Sano, and Y. Miyamoto

Proc. of OECC 2015, JThA.11, Shanghai, China, June/July 2015.

This paper reviews recent work on and issues with high-capacity multicore fiber transmission for terrestrial systems. Unrepeatered transmission of over 100 Tb/s by employing an MCF-ROPA (multi-core-fiber-based remote optically-pumped amplifier) is also described.

Multi-stage Successive Interference Cancellation for Spectrally-efficient Super-Nyquist Transmission

K. Shibahara, A. Masuda, S. Kawai, and M. Fukutoku

Proc. of ECOC 2015 (the 41st European Conference on Optical Communications), Valentia, Spain, September/October 2015.

The use of multi-stage successive interference cancellation (M-SIC) for super-Nyquist transmission is proposed. Simulation and transmission experiment results showed carrier spacing was reduced by 20% for QPSK (quadrature phase-shift keying) signals. Signal performance was enhanced when M-SIC was used with non-uniform power transmission.

Impact of Management Data Placement in NFV Service Coordinated across Multiple Datacenters and WANs

A. Taniguchi, T. Yamazaki, Y. Yoshida, T. Kawabata, N. Sakaida, and T. Shimizu

Proc. of CNSM (the 11th International Conference on Network and Service Management), Barcelona, Spain, November 2015.

As network functions virtualization (NFV) technologies have emerged, some standardization bodies such as the European Telecommunications Standards Institute have advanced standardization activities on their functional blocks and interfaces. However, several issues such as where virtual network configuration information should be placed or how a virtual network configuration among Virtualized Infrastructure Managers (VIMs) should be handled have not been standardized yet. This paper proposes several candidates to address these issues, and discusses their advantages and disadvantages from various viewpoints such as security.

The Behavior Generation Modeling Method to Extract the Reason to Select Shops

N. Takaya, K. Esaki, K. Ishiguro, and Y. Ichikawa

IPSJ Journal, Vol. 57, No. 1, pp. 145–156, January 2016 (in Japanese).

We propose SHOP-LDA, which captures latent patterns of user product adoption behaviors. The proposed model is a probabilistic generative model that extracts "topics," explaining why users select shops and items. Experimental results with real-world e-commerce user log data show that the proposed model is able to estimate user segments that are interpretable and possibly are beneficial for business practices. Furthermore, this method is applicable to emerging services that use several shop orchestration services such as ID cooperation and point alliance.

Commuting Quantum Circuits with Few Outputs are Unlikely to be Classically Simulatable

Y. Takahashi, S. Tani, T. Yamazaki, and K. Tanaka

Quantum Information and Computation, Vol. 16, No. 3&4, pp. 251–270, March 2016.

We show that there exists a commuting quantum circuit that is not classically simulatable unless the polynomial hierarchy collapses to the third level. This is the first formal evidence that a commuting quantum circuit is not classically simulatable even when the number of output qubits is exponentially smaller than that of input qubits.
