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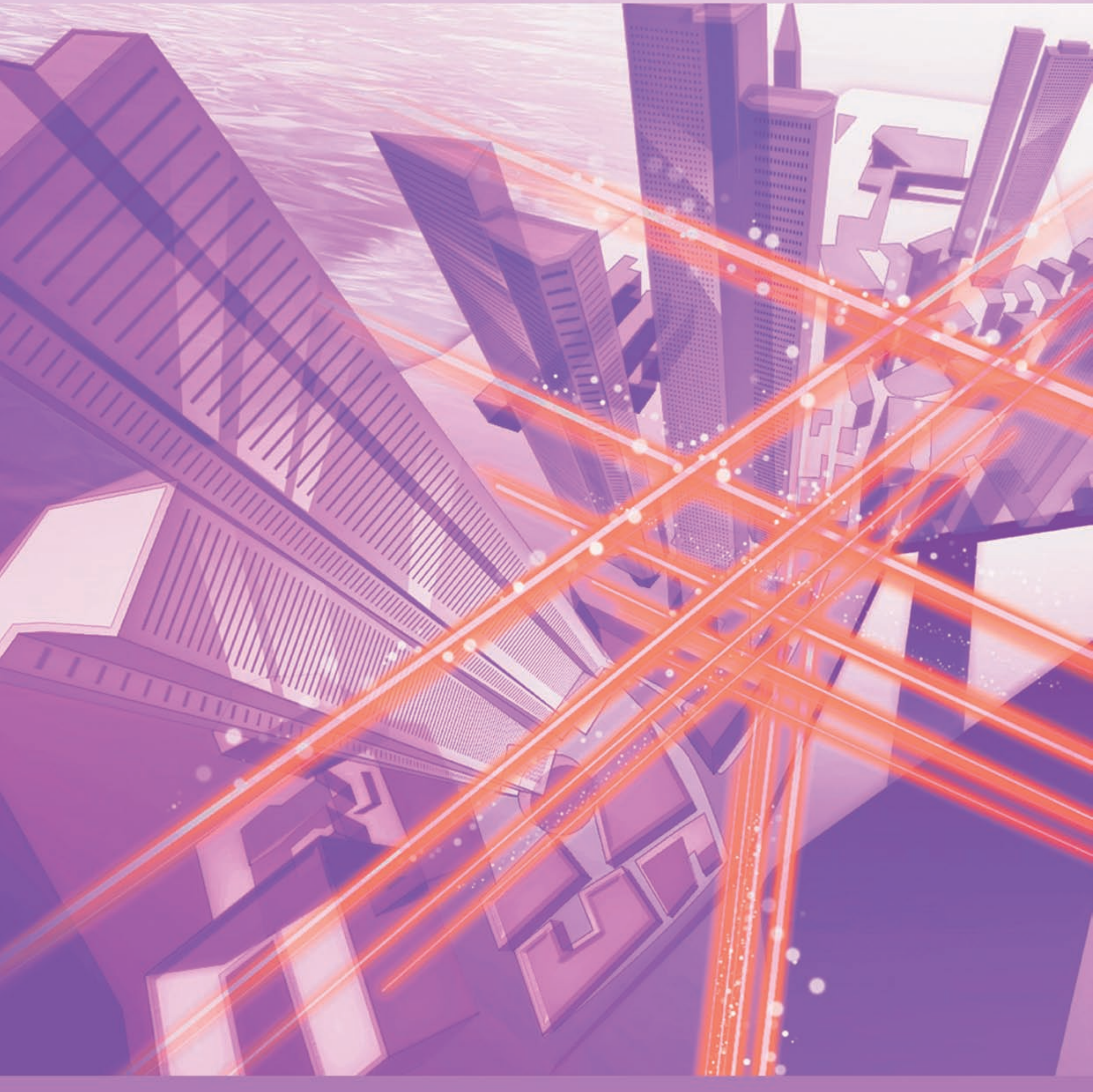

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Current Status of Development of Network Virtualization Technologies

Hidehiro Arimitsu, Kimihide Matsumoto, Yasunori Matsubayashi, Masao Aihara, Yasuo Makibayashi, Hisashi Kojima, and Tomoya Kosugi

Abstract

NTT laboratories have been active in researching and developing network virtualization technology as a key technology of *future networks*, which will be next-generation carrier networks. In this article, we outline the carrier network architecture, focusing specifically on the network virtualization technology implemented in it. We also introduce the research on elemental technologies being conducted by NTT laboratories.

Keywords: network virtualization, NFV, SDN

1. Introduction

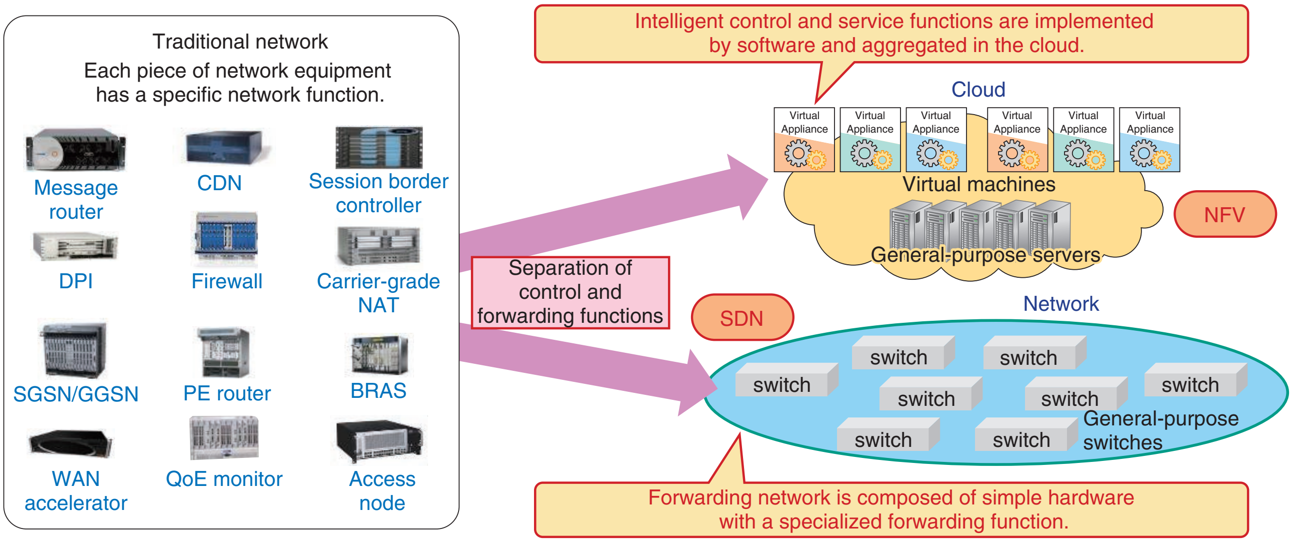
The increased performance of general-purpose servers and the technological advancements in software have accelerated the deployment of virtualization technologies in datacenters. Network virtualization technology, in which such information technology advancements apply to carrier networks, has been the focus of a lot of attention recently and is expected to improve the scalability and reliability of carrier networks at low cost. Here, we introduce the network virtualization technology applied to the architecture of a future carrier network and also describe its elemental technologies.

2. Network virtualization technology

Traditional carrier networks have been composed of many kinds of dedicated equipment, where each network function is implemented in a different piece of equipment. In contrast, the introduction of network virtualization technology, in which control functions and forwarding functions are distinctly separate, is changing the existing network architecture (**Fig. 1**). In the new architecture, intelligent control and service functions are implemented by software and aggregated in the cloud, while a forwarding network is composed of simple hardware with a specialized forwarding function. The development of two technologies—network functions virtualisation* (NFV) and software-defined networking (SDN)—has recently been accelerated in order to structure this kind of network architecture.

NFV is a technology in which network functions that are conventionally implemented in dedicated hardware are implemented by software on general-purpose servers. Performance increases in general-purpose servers and technological advances in virtualization technologies have led to NFV with carrier-grade performance, scalability, and reliability. The application of NFV to carrier networks is expected to enable high scalability and reliability at low cost, as well as rapid service deployment, flexible resource assignment according to the demand for each service, and service deployment without the EoL (end of life) restrictions of hardware-based equipment. Additionally, because many different network functions are aggregated in general-purpose servers, reductions in CAPEX (capital expenditures) and OPEX (operating

* The British spelling used by the European Telecommunications Standards Institute



BRAS: broadband remote access server
CDN: content delivery network
DPI: deep packet inspection
NAT: network address translation
PE: provider edge
QoE: quality of experience
SGSN/GGSN: serving GPRS (general packet radio service) service node/gateway GPRS service node
WAN: wide area network

Fig. 1. Network virtualization technology applied to future carrier network.

expenses), lower power consumption, and a reduced equipment footprint are also expected. ETSI (European Telecommunications Standards Institute) has played a leading role in studying NFV under an Industry Specification Group. Participants from many major carriers and equipment vendors from all over the world are actively focusing on NFV and are pushing the work forward.

SDN consists of technology to control and manage network equipment in a centralized fashion by means of software techniques. Applying SDN to carrier networks makes it possible to separate control and forwarding functions, which have been implemented in a single piece of equipment until now, and to aggregate control functions in a cloud. Network carriers expect to reduce OPEX drastically and to provide consumers and service providers with flexible network services through the use of SDN's centralized control and management features. Major elemental technologies applied to realize SDN include OpenFlow, which was standardized by ONF (Open Networking Foundation), and I2RS (Interface to the Routing System), standardized by IETF (The Internet Engineering Task Force).

3. Network architecture in virtualization era

3.1 Future networks

NTT laboratories have been actively researching and developing future networks, which will be next-generation carrier networks. As in the past, future networks are expected to offer steady communication services as a vital social infrastructure. These include fixed consumer services such as Internet access and voice services, mobile services such as mobile voice and broadband services, and enterprise services such as virtual private networks and wide-area LAN (local area network) services. Such future networks are also required to have the capability to offer new services rapidly and flexibly in order to meet diversified needs. Furthermore, these networks will have some mechanisms developers can use to create brand new services in cooperation with service providers. From a carrier viewpoint, operating and managing a network that can become increasingly complicated and sophisticated is a critical issue. NFV and SDN are expected to be key technologies to build the future networks, which must meet various demands and needs. Next, we outline the architecture of these future networks and describe the network virtualization technologies used in them.

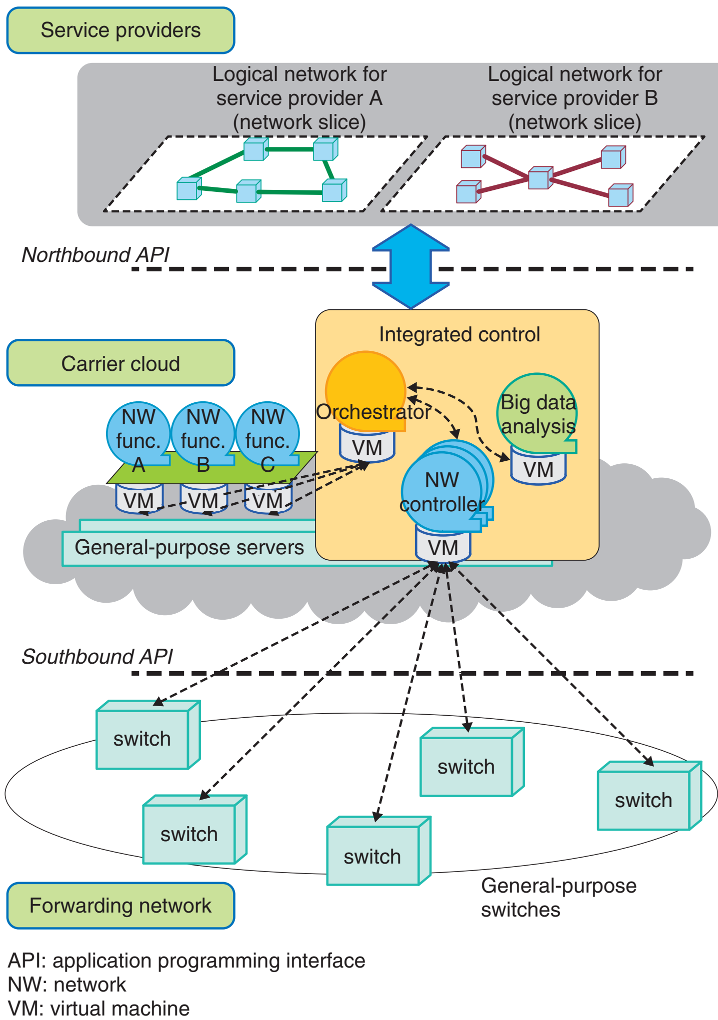


Fig. 2. Structure of future networks.

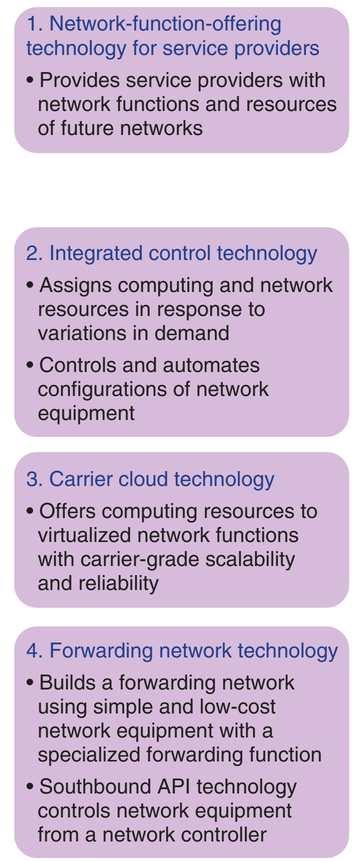


Fig. 3. Network virtualization technology for future networks.

3.2 Network virtualization technologies in future networks

Future networks are composed of two hierarchical structures—a forwarding network and a carrier cloud—and are connected to service providers that can offer network services using the future networks' resources (**Fig. 2**). There are four key network virtualization technologies that compose the future networks, as follows (**Fig. 3**).

(1) Network-function-offering technology for service providers

This technology provides service providers with network functions and resources owned by the future networks. For instance, a service provider can easily create its own network service by combining its own application with a logical network offered by the future networks. We can use SDN technologies to build a logical network.

(2) Integrated control technology

This technology manages and controls both computing resources and network resources. Computing resources are deployed in a carrier cloud as general-purpose servers, whereas network resources are deployed as network equipment. Integrated control technology consists of an orchestrator, which manages the assignment of resources throughout the network, and a network controller, which controls the network equipment. The orchestrator reassigns resources in response to variations in the demand for each service and resource requests from service providers. The network controller controls a forwarding network composed of general-purpose switches upon request from the orchestrator. The interface and protocol specifications between a network controller and a piece of network equipment is referred to as a southbound API (application programming interface). OpenFlow is one of the most popular southbound API protocols. Additionally, work is proceeding to advance network operation using big data. For instance, the network controller manages a network based on big data analysis of traffic variations in order to improve QoE (quality of experience) at low cost.

(3) Carrier cloud technology

This technology offers computing resources to virtualized network functions with carrier-grade scalability and reliability. It is a fundamental technology that enables various carrier network functions to be implemented as NFV. It is expected to achieve rapid and efficient development of services and improved tolerance for traffic variations. Furthermore, it can build a disaster-resistant network which, for instance, concentrates network resources on the most basic communication services—such as voice services—as a lifeline in the event of a large-scale disaster.

(4) Forwarding network technology

This technology builds a forwarding network using simple and low-cost network equipment with a specialized forwarding function. Extracting intelligent control and service functions from traditional routers and transport systems to be virtualized and implemented by a software application as a network controller enables network equipment to be specialized to provide a forwarding function. Carriers expect this trend to result in the commoditization of network equipment and low-cost procurement. Additionally, it can lead to a reduction in the amount of network equipment needed since SDN technology can integrate multiple network devices used for each layer into a single device. For instance, traditional routers and layer-2 switches might be integrated into a single general-purpose switch. In the NFV environment where a lot of network functions are accommodated in a single physical server, virtual switches are also necessary in order to forward packets to an appropriate virtual machine. High-performance virtual switches are required in a carrier network in order to prevent bottlenecks in the forwarding performance.

4. Research and development of elemental technologies for network virtualization

The network virtualization technologies for future networks cover a very broad range of application areas. NTT laboratories are broadly promoting research and development of the elemental technologies that compose network virtualization technology. We introduce some of these concrete efforts in these Feature Articles.

In the article "Service Function Chaining Technology for Future Networks," we introduce a service function chaining technology as one of the network-function-offering technologies for service providers [1]. In the article "Network Virtualization Technology for Implementing Future Networks," we introduce an orchestration technology as an example of integrated control technology, a server platform technology as an example of carrier cloud technology, and a centralized control technology for transport networks as an example of forwarding network technology [2]. In the article "Ryu SDN Framework—Open-source SDN Platform Software," we introduce an SDN controller technology (Ryu SDN Framework), which is an essential technology for controlling a virtualized network [3]. Finally, in the article "Fundamental Research Activities on Network Virtualization," we introduce an SDN software switch (Lagopus), which is a core technology for packet forwarding on top of general-purpose servers and switches and a substantive industry-academia-government experimental collaboration to deploy an end-to-end virtual network on a research network [4].

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Service Function Chaining Technology for Future Networks

Hiroyuki Kitada, Hisashi Kojima, Naoki Takaya, and Masao Aihara

Abstract

Service function chaining enables various network functions to be used rapidly and flexibly. This article describes methods of implementing service function chaining technology and also presents use cases.

Keywords: SDN, NFV, service function chaining

1. Introduction

As the development of network functions virtualisation* (NFV) technology continues in the future, network functions will become concentrated in datacenters and will be operated as a cloud service. This will make it easier to implement new network functions and will enable network function resources to be allocated flexibly on request and according to demand. We expect that NFV will lead to more advanced carrier networks. For example, network functions have conventionally been deployed in the network using dedicated equipment. This means that when services are added or software is updated, modifications must be made to every piece of equipment (**Fig 1(a)**). In contrast, network functions are centralized in the cloud when NFV is used to virtualize network functions (**Fig. 1(b)**). This makes it possible to change or add network functions simply by updating the software on commercial-off-the-shelf (COTS) servers.

However, concentrating network functionality in the cloud means that user packets must be sent through the COTS servers in the cloud, where the network functions are located. Also, if individual users contract different services, each user uses different network functions, and consequently, routing per user or flow is required. The technology to control packet routing through the applicable network functions is called service function chaining technology.

2. Service function chaining use case

We consider the example of a content service provider (CSP) that provides a service to end users through a carrier network as a use case for service function chaining technology (**Fig. 2**). In the current network, the CSP must purchase, install, and configure customer-premises equipment (CPE) to connect to the carrier network as well as to other equipment such as a firewall to ensure security. However, with service function chaining technology, functions such as the CPE and firewall can be implemented in software and set on a carrier cloud, and the carrier can offer them as network services. As a result, the CSP can contract network services easily and immediately, simply by clicking a button on the service contract website. Thus, even if the CSP is under attack, it could immediately contract for security services and defend itself against the attack.

3. Service function chaining system

Some challenges arise in implementing service function chaining with existing Internet protocol (IP) network technology. Generally, when carrier and other large-scale networks use IP routing, routing is implemented based on aggregated network addresses

* The British spelling used by the European Telecommunications Standards Institute (ETSI)

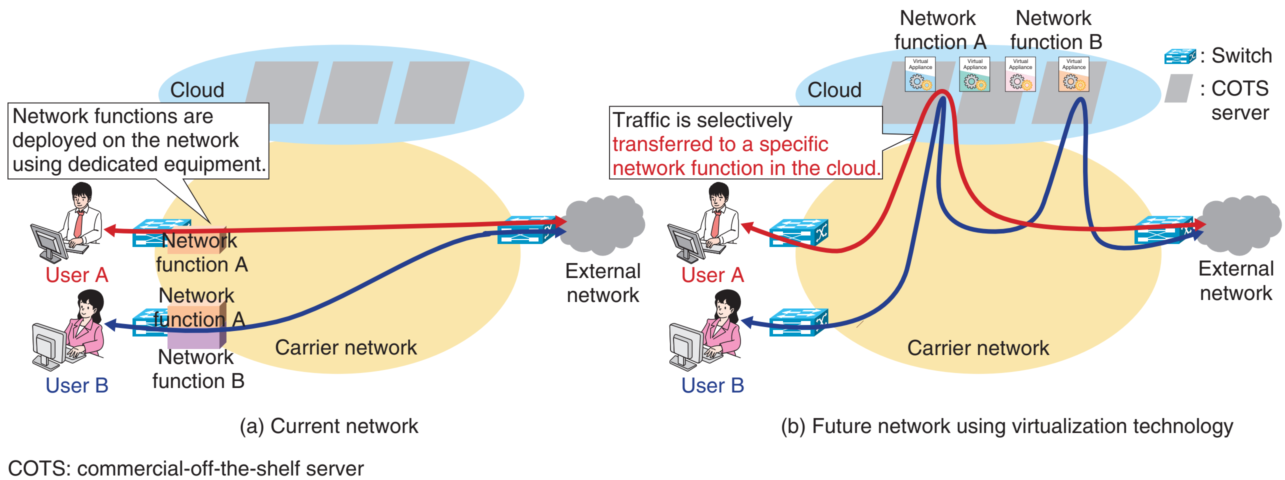

Fig. 1. Routing required when network functions are virtualized on the cloud.

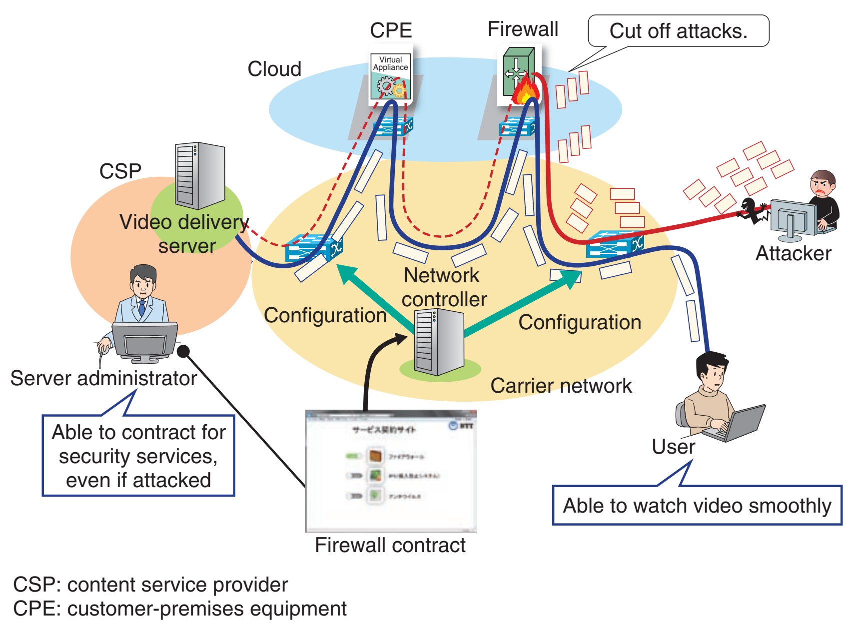

Fig. 2. Use case for CSP.

to increase scalability. However, if user-based routing as in the previously described use case is implemented with IP routing, the network equipment must learn routing tables that contain a huge number of IP routes. This is impractical in terms of scalability. Therefore, a new routing method was necessary that was independent of the existing IP routing.

NTT Network Technology Laboratories has proposed a packet-labeling method to implement service function chaining technology. In this method, switches in the carrier network attach labels to each packet to identify network functions that the packets must pass through (**Fig. 3**). If a packet passes through multiple network functions, multiple labels are attached, and the order they must pass through the functions is indicated. Within the carrier network, routing is implemented according to the labels attached to a packet. A feature of this method is that information

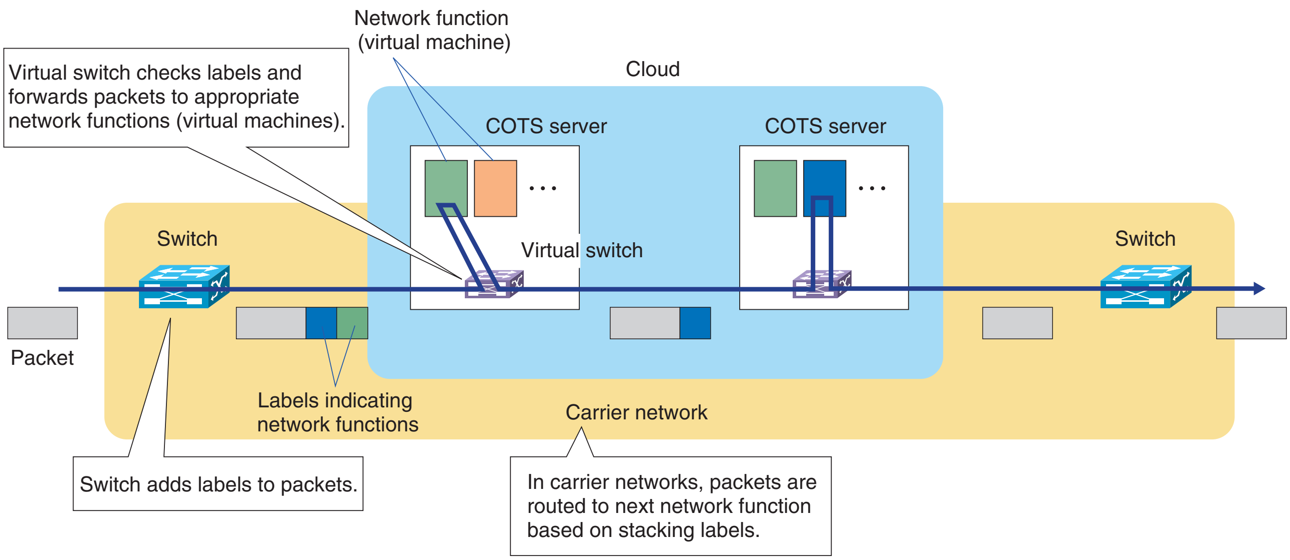

Fig. 3. Service function chaining system.

about service function chaining is attached to the packets themselves. Even as the user contract status dynamically changes, the control is only needed for the switches, so the method is highly scalable.

4. Prototype demonstration

To demonstrate service function chaining, we built a prototype using actual equipment based on the method described in the previous section (**Fig. 4**). The service function chaining prototype consists of switches, COTS servers handling the network functions, and a network controller. A service contract site was also prepared, enabling users to easily add or cancel services.

When a user subscribes to a service on the site, the information is passed to the network controller, and a flow entry on the switch is configured using the southbound API (application programming interface). The network controller consists of an application and a switch controller. The application computes the labels to be attached to packets using information about subscribers and network functions in the cloud. The switch controller receives the information on the labels from the application and generates flow entries to control the switches. In our prototype implementation, the controller and application were implemented on a platform called the Ryu SDN Framework, which was developed by the NTT Software Innovation Center.

Also, to apply the service function chaining on existing IP networks by adding minimal functionality, we used an overlay connection method in the prototype. IP tunneling is used to connect switches in the carrier network and virtual switches on the COTS servers. Packets with labels are transmitted through IP tunnels, so label processing is hidden from the core network, which minimizes the amount of equipment necessary for processing labels.

This environment enabled us to demonstrate that services can be provided to users more rapidly and with greater flexibility through use of service function chaining technology.

5. Issues

Various issues must be addressed in order to apply service function chaining on a real carrier network. We describe some of the issues that were identified in building the prototype described above.

5.1 Ensuring interoperability

There are currently no standard methods or protocol technologies for implementing service function chaining, so we developed original methods and used them to implement the prototype. This meant that existing network functions such as virtual appliances could not process the labels. Therefore, the virtual switches running on our COTS servers first removed the labels before packets were sent to the network

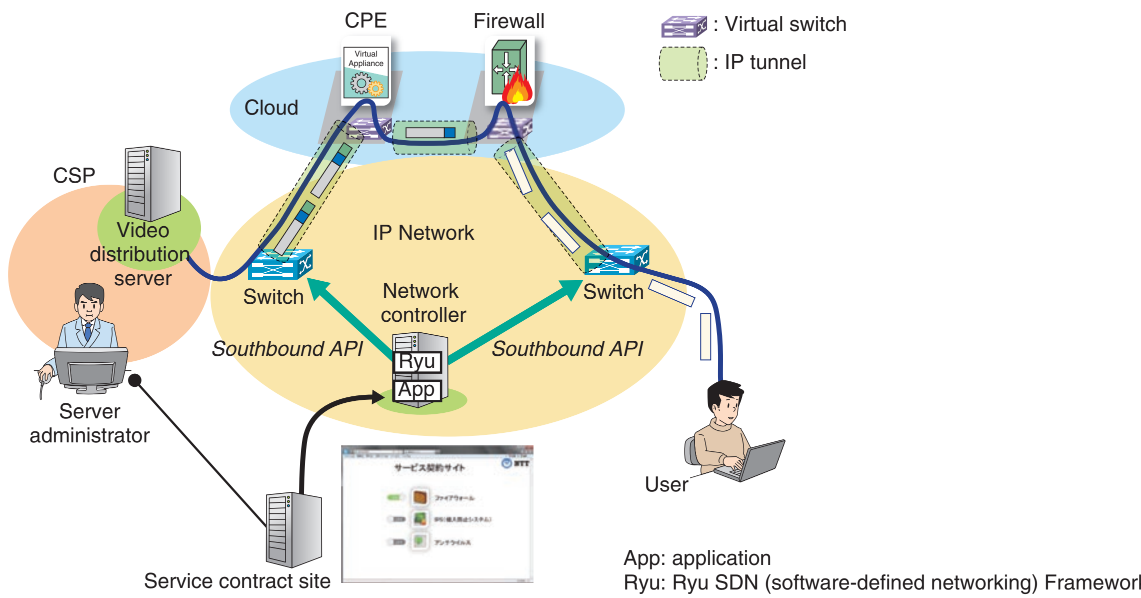

Fig. 4. Prototype implementation example.

function and then re-attached them after they returned from the network function. This implementation enabled us to use existing virtual appliances as-is, although we sacrificed some transmission performance due to the processes of attaching and removing labels. Fully introducing service function chaining on a carrier network would require securing the interoperability by standardizing the service function chaining technology, and making sure that virtual appliances from various companies support the protocols.

5.2 Ensuring scalability

An environment that fully incorporates NFV on a carrier network, where many network functions are running on COTS servers, would require many of these servers in order to process large amounts of traffic. Specifically, we assume that many servers would be operating for a virtual machine implementing a single network function. To implement service function chaining under such conditions, the labels would need to indicate not only the type of network function but also the virtual machine running the network function. Thus, in addition to multiple users, multiple virtual machines would need to be identified on the carrier network. As such, a method of implementing this processing without losing scalability is needed.

5.3 Improving the control plane system

An important factor with large-scale networks such as carrier networks is how information such as subscriber information and service function chaining labels will be managed in order to control the network and provide fine-grained services. In the method described above, subscriber and label information is managed centrally by the network controller and attached to packets in the form of labels, so servers in the cloud do not maintain any individual subscriber information. In this way, when a subscriber changes contract conditions, network function changes can be propagated quickly by simply changing the labels attached when packets enter the network, and without controlling the cloud at all.

However, the network controller has all of the information, so network controller performance and reliability are very important. It would not be feasible for a single network controller to manage and control a large-scale carrier network. Therefore, redundancy in the network controller—through scaling out or using distributed processing—must be considered. In these ways, the control-plane architecture will also need to be improved to satisfy the requirements of a carrier network.

6. Future prospects

Service function chaining is an important technology for *future networks* that can provide new services rapidly and with flexibility. However, it is currently still a concept-level technology, and various issues such as protocol standardization need to be resolved before it will be practical. Standardization of methods and protocols for implementing service function chaining are currently in progress by the Service Function Chaining Working Group of the Internet Engineering Task Force. At the NTT Network Technology Laboratories, we are working toward achieving a scalable technology that can be applied to a carrier network based on the knowledge gained from the methods introduced here and the prototype we have built. We are also working on related standardization activities.

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Network Virtualization Technology for Implementing Future Networks

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Abstract

NTT Network Service Systems Laboratories has been applying network virtualization technologies such as NFV (network functions virtualisation) and SDN (software-defined networking) as part of efforts to develop the architecture of *future networks* that are efficient, flexible, and intelligent. This article gives an overview of these efforts.

Keywords: orchestration, open innovation, transport network simplification

1. Introduction

Anticipation has been increasing recently for the application of network virtualization technologies such as network functions virtualisation* (NFV) and software-defined networking (SDN) in carrier networks. NTT laboratories have been carrying out research and development (R&D) aiming to achieve innovations in network structures and development schemes by applying virtualization technologies. The objectives are to: (1) centralize service and management functions in the cloud; (2) simplify transport equipment and integrate layer processing; (3) use orchestration functions to automate operations and reduce operations expenses (OPEX); and (4) promote open innovation with global cooperation among carriers and vendors, as shown in **Fig. 1**.

NTT Network Service Systems Laboratories has been conducting R&D focused on implementing the architecture of future networks based on these technology trends. We introduce three such initiatives in this article. The first is to implement orchestration functionality to handle virtual networks; the second is to establish new server platform technologies through co-innovation and promotion of open innovation; and the third is to develop centralized transport network control technology to simplify transport networks.

2. Operations suitable for network virtualization

With virtualized networks, equipment design can be carried out for all resources, rather than for individual, dedicated hardware, so reductions in design and construction work can be expected through economies of scale. Also, general-purpose standby servers can be allocated flexibly to the services experiencing faults, so it is no longer necessary to have standby equipment for each type of dedicated hardware, and there are fewer faults that require urgent attention. In these ways, network virtualization can lead to reductions in OPEX (**Fig. 2**).

We have been studying ways to automate virtual network operations (adding equipment, initiating fault recovery, etc.) more than ever before using orchestration functionality. Specifically, we have been examining functions that detect when set thresholds are exceeded and automatically add resources, functions that detect faults and automatically recover from them, and other functions. We aim to achieve dramatic reductions in OPEX through the following orchestration technologies (**Fig. 3**).

* The British spelling used by the European Telecommunications Standards Institute

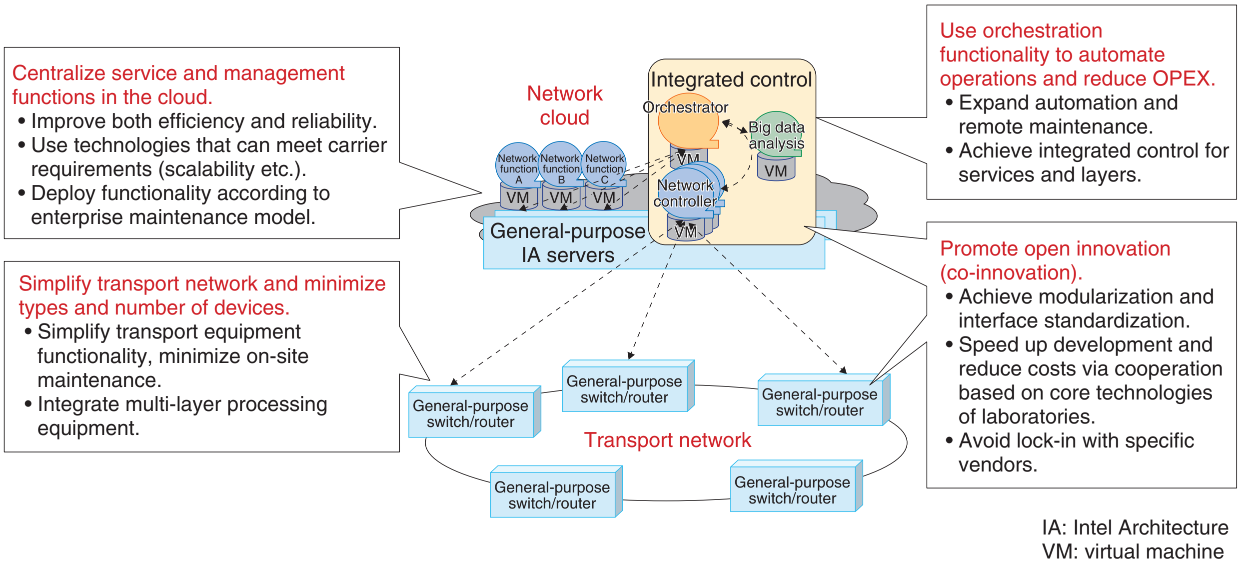


Fig. 1. Innovations of network architecture and development schemes with virtualization technologies.

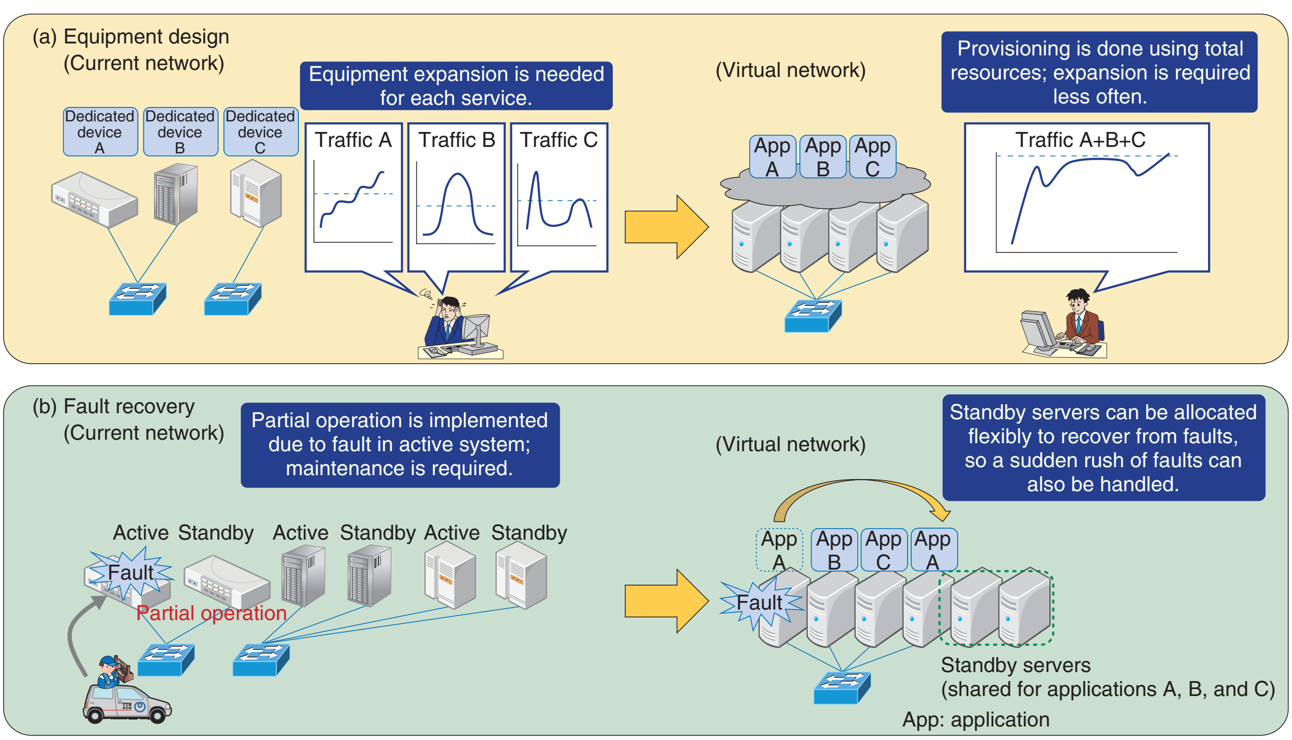
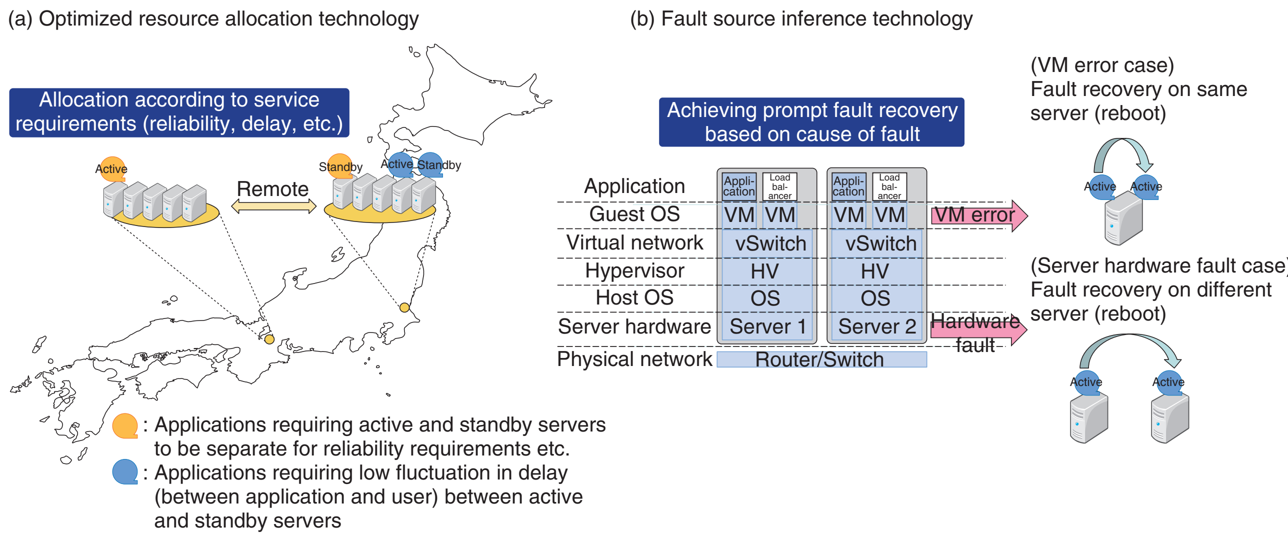


Fig. 2. Reducing OPEX with virtual networks.

2.1 Optimized resource allocation technology

When general-purpose servers are allocated in order to add resources or enable fault recovery, the resources used on each server must be equalized, and resources must be allocated according to service requirements (reliability, delay, etc.). Our goal is to



OS: operating system

Fig. 3. Technical elements of orchestration functionality.

establish optimized resource allocation technology that makes it possible to set and control multiple policies related to allocation, including (1) selecting servers in geographically separate locations when allocating active and standby servers for services requiring reliability and (2) selecting servers by location so that any network delay that occurs is equivalent between active and standby servers (for applications that are affected by delay).

2.2 Fault source inference technology

Virtual networks are implemented using multiple layers (virtual servers, physical servers, virtual networks, physical networks), which makes administering the configuration and determining the state of equipment rather complex. The goal of fault source inference technology is to infer the location of a fault when a fault occurs by combining alarms and other information from each layer, and to use it to speed up fault recovery.

3. Server platform technologies supporting service provision

A lot of research has been done recently on virtualization of network functions using NFV, including software implementations of service application functionality on communication networks. Here, we describe initiatives to implement new server architectures that will enable rapid provision of such service applications.

Conventionally, communication network advances have been driven by developments in hardware, switching, and data processing technology. Software has been developed and communication services provided that satisfy quality and reliability requirements over a diversity of network devices. Consequently, selecting hardware and middleware for each network device, achieving reliability and extensibility with service applications on each device, developing service applications, and building equipment and maintenance systems have consumed an enormous amount of time. As the services provided on communication networks become more diverse, and as network functions are increasingly implemented in software on future networks, we expect that the types and numbers of network devices will increase further, and increasing numbers of service applications will be developed, so it is important to resolve this issue.

NTT Network Service Systems Laboratories has proposed new server architecture as a common distributed processing platform. This architecture maximizes the common components of communication network functionality and is designed to be built using only the required number of general-purpose hardware devices by using virtualization technologies, and to realize the reliability, extensibility, and operability cultivated by communication providers and their partner companies (**Fig. 4**). By using this architecture, network operators and service providers

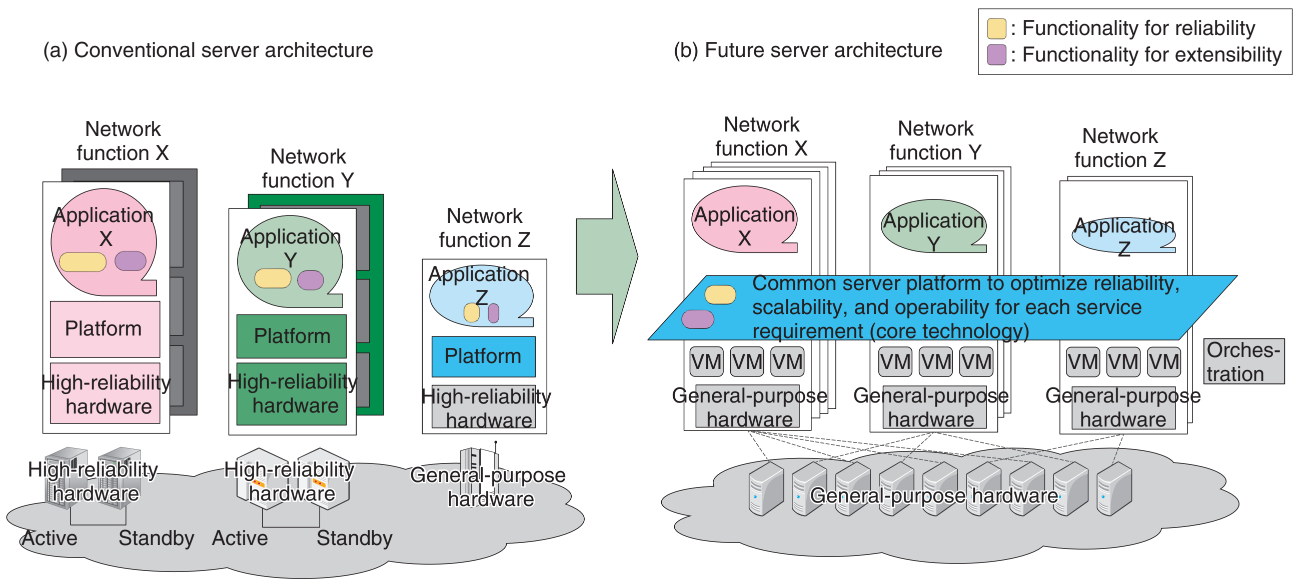


Fig. 4. Proposed server architecture.

can focus on the functional logic of their service applications and implement them on the network quickly and efficiently.

NTT laboratories and our partner companies have cooperated from the conceptual stages in order to realize this server architecture. We have utilized our respective strengths and promoted co-innovation through collaborative research (**Fig. 5**). In this collaborative research, we aim to refine technologies for distributed processing, virtualization, and maintenance and operations from multi-faceted perspectives of the three corporations, and to create technology through synergistic effects. NTT laboratories are providing the distributed processing technology (the engine component) related to carrier server requirements, scale-out capabilities, and redundant configurations. This technology enables system performance to be increased in proportion to the number of general-purpose servers comprising the system. It also distributes load appropriately across multiple servers and controls the backup servers that load is assigned to when hardware faults occur. Our partner companies are providing system requirements based on global markets, server virtualization technology, orchestration technology, the distributed processing system technology (the core software development capabilities), and maintenance and operations technology.

In this way, we aim to establish new server architectures that will enable service applications to be developed quickly and to develop technologies that will provide support in fields beyond future communications networks (such as finance and medicine) that require the results of this research: reliability, extensibility, and operability. By advancing the level of sophistication, we also aim to promote these technologies globally and to create global standards.

4. Centralized transport control technology to simplify transport networks

The capacity of transport networks must continually be increased in order to handle the communication traffic that increases each year, mainly due to Internet traffic. A major issue for telecommunications carriers in such conditions is the need to achieve dramatic reductions in transport network equipment and maintenance costs. Telecommunications carrier transport networks generally build a transport layer using technologies such as Internet protocol (IP) and Ethernet for flexible transport; that layer is on top of a transmission layer that economically handles long-distance transport through the use of high-capacity optical-wavelength or packet-transport paths. To substantially reduce costs in transport networks, it is important to simplify them by re-examining the implementation of functionality within the transport and transmission layers.

Next, we describe centralized transport control technology, which can reduce equipment costs when

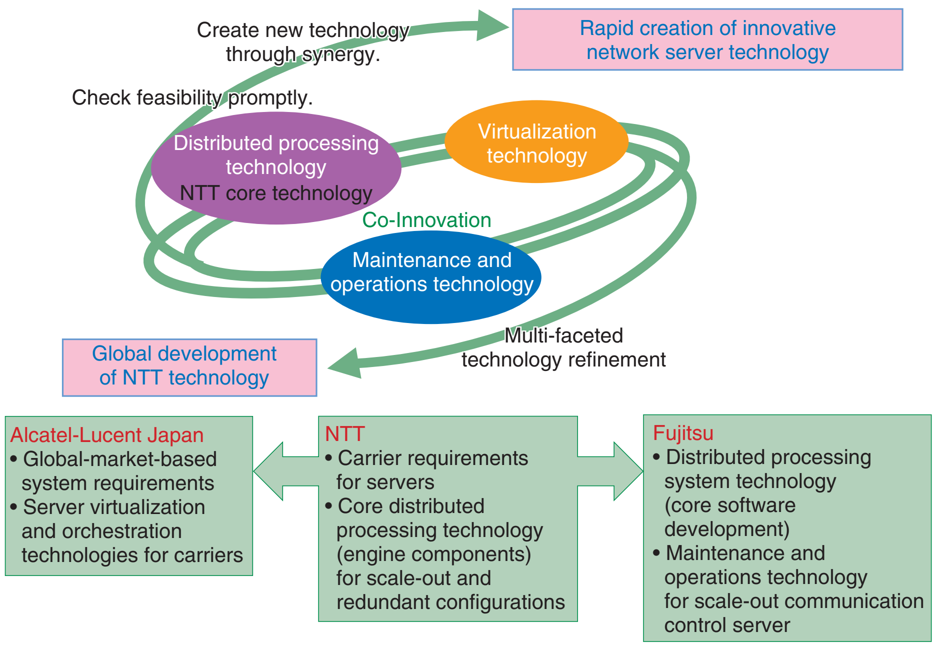


Fig. 5. Co-innovation initiatives.

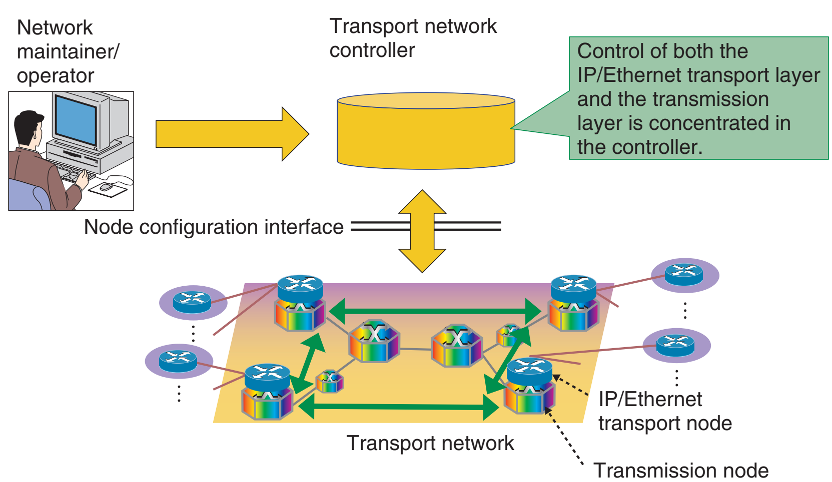
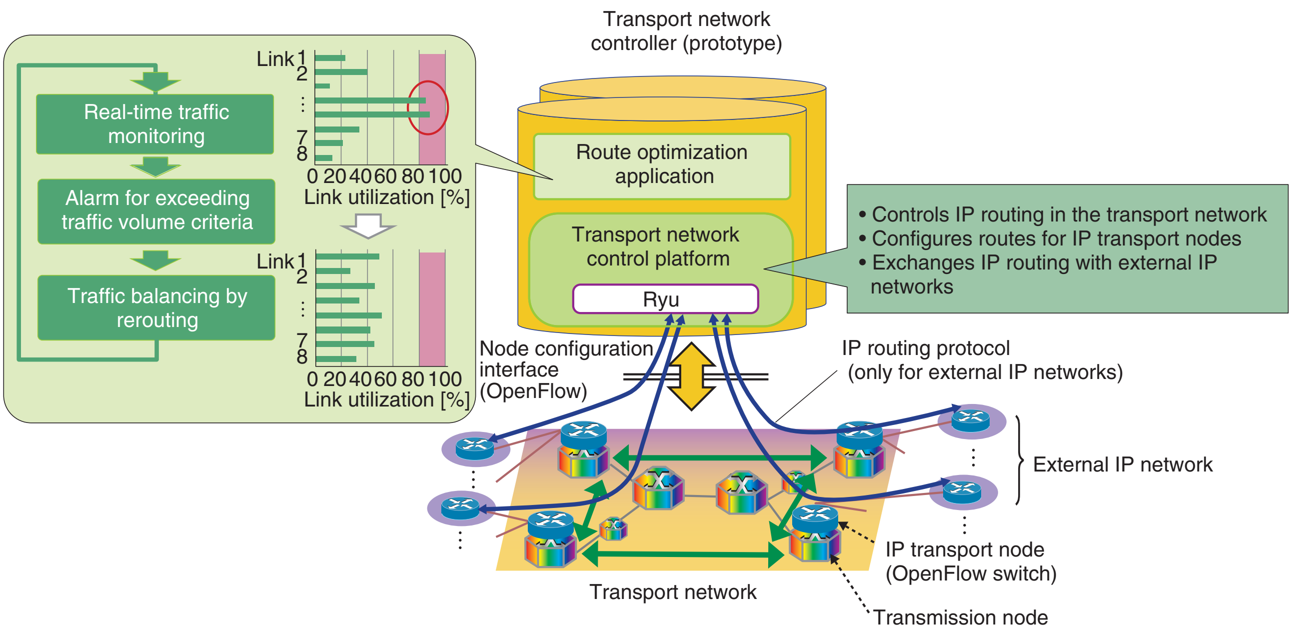


Fig. 6. Transport network architecture applying centralized transport control.

used in combination with another technique such as substituting high-capacity optical transmission nodes for transport nodes or integrating transmission and transport layer equipment.

A transport network architecture that uses centralized transport control is shown in **Fig. 6**. A transport network controller (controller) is placed on the transport network, and the control of the IP and Ethernet transport layer and the transmission layer is centralized in this controller. Centralized transport control technology is a network virtualization technology that separates the control plane and the data plane for the transmission and transport layers, which facilitates control that spans these layers. There are two objectives in using this technology:

(1) Reducing operational costs by providing a single interface for maintenance and operations of the transmission and transport layers.



Ryu: Ryu SDN Framework

Fig. 7. Network architecture used in concept demonstration.

(2) Reducing the maintenance time and operational costs required to update functionality of transport and transmission layer transport network control (path and bandwidth control, etc.) when extending service layer functionality.

NTT Network Service Systems Laboratories has prototyped a controller that controls IP routes centrally without using the IP routing protocols that perform distributed IP route control autonomously between routers. This prototype was designed in order to evaluate the feasibility of applying centralized transport control technology to the IP layer. This prototype uses the Ryu SDN Framework [1] open source software developed by NTT laboratories. It implements an architecture that enables various add-on functionalities to be flexibly combined on a common platform that performs basic IP route control functions. A demonstration of the concept using this prototype was given at the NTT R&D Forum 2014, held in February 2014. The configuration for the concept demonstration is shown in **Fig. 7**. The prototype demonstrated the feasibility of centralized IP route control by combining controls to reroute faulty links and select optimized routes in order to equalize traffic volumes based on real traffic measurements.

5. Future developments

In this article, we have introduced some of our virtualization technology initiatives at NTT Network Service Systems Laboratories. We will continue to develop and actively promote various technologies for implementing the architectures of future networks.

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Ryu SDN Framework—Open-source SDN Platform Software

Rui Kubo, Tomonori Fujita, Yuji Agawa, and Hikaru Suzuki

Abstract

We introduce Ryu SDN Framework, an open source software (OSS) system developed by NTT, and describe our efforts toward promoting its wider adoption. Ryu SDN Framework is a platform that provides tools and libraries for easy use of SDN (software-defined networking). We have taken advantage of the strengths of OSS in developing Ryu, which conforms to the most recent industry-driven OpenFlow specifications. Ryu is used by a variety of experts including SDN application developers, network device developers, and network service maintainers.

Keywords: SDN, OpenFlow, open source software

1. Introduction

Server virtualization and cloud computing technologies have created an unprecedented need for network adaptability, expandability, and flexibility. An approach to solving those problems that has been attracting attention is SDN (software-defined networking), which enables configuration of networks and the programming of network functions by operating software [1].

The network configuration function is divided into a data plane for handling data transfers and a control plane for handling control of the data plane. In the conventional approach, the two planes are tightly linked within individual network devices, so interworking between the control planes of the devices is necessary when constructing a single network with multiple network devices.

In the SDN approach, on the other hand, the data plane and control plane are separated, and their independence is maintained by specifying an application programming interface (API). Using the API to develop programs according to purpose and use enables higher independence of data plane control. A program that uses this kind of API is called an SDN application.

2. Ryu SDN Framework

Ryu SDN Framework (Ryu) is a framework that provides the libraries and tools that are required in order to develop SDN applications (**Fig. 1** and **Fig. 2**). The framework facilitates development by providing the basic functions for controlling the data plane and the functions that are common to SDN applications. The functions that are features of Ryu are described in the following subsections.

2.1 OpenFlow controller function

OpenFlow is a set of API specifications for the control plane and the data plane formulated by the Open Networking Foundation (ONF); it has been attracting broad attention as the most important API specifications for implementing the SDN approach. *OpenFlow switch* is the term used for the data plane that conforms to the specifications, and *OpenFlow controller* similarly refers to the control plane. SDN applications can be implemented by using these functions.

Ryu has the OpenFlow controller function, so SDN applications that use OpenFlow switches can easily be developed using Ryu. Although various versions of the OpenFlow API specifications exist, Ryu is compatible with a greater variety of versions than other OpenFlow controllers (versions 1.0, 1.2, 1.3,

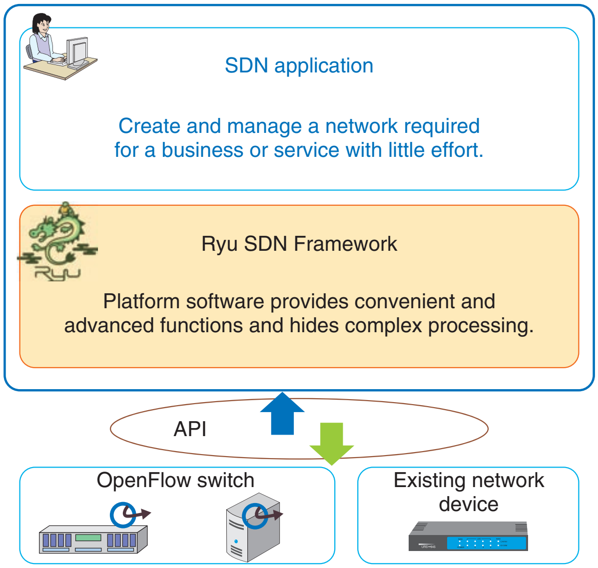


Fig. 1. Overview of Ryu SDN Framework.

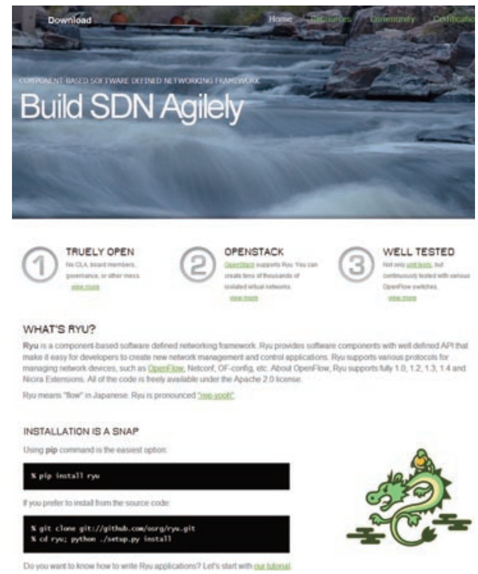


Fig. 2. Ryu public site (http://osrg.github.io/ryu/).

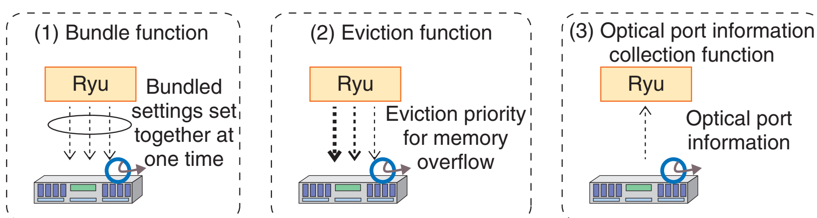


Fig. 3. Functions of OpenFlow version 1.4.

and 1.4), so more OpenFlow switches can be used.

The functions of the most recent version, 1.4, which was released in the fall of 2013, are explained as follows and presented in **Fig. 3**.

(1) Bundle function: This function is for setting multiple commands for an OpenFlow switch at the same time. In the previous versions, it was necessary to confirm the setting of each command individually on the application side. This bundle function facilitates development by making it possible to set multiple commands together as a bundle.

(2) Eviction function: This function enables processing to be done when memory overflow occurs in OpenFlow switches. The memory capacity for storing the switch settings can vary with the type of machine. In the previous versions, it was necessary to implement the required processing on the application side for each type of machine in order to prevent memory overflow. This eviction function facilitates development of applications through automatic selection of the eviction command based on the priorities set by the application.

(3) Optical port information collection function: This enables OpenFlow switches to have 10-Gbit/s or 40-Gbit/s broadband optical ports in the same way as other network devices. With previous versions, it was not possible to obtain the signal wavelength and strength or other information that is specific to optical ports, and it was necessary to use special functions outside the OpenFlow specifications for specific device types to obtain such information. OpenFlow switches that work with this function can obtain the information that is specific to an optical port

in the same way as for an ordinary Ethernet port, reducing the machine-specific implementation required in application development.

2.2 Functions for cooperating with existing network devices

It has been difficult to replace all of the network devices in an existing network with new OpenFlow switches. An OpenFlow switch can transmit various types of data in the same way as the existing network devices, so it is also possible to construct a network in which the devices of the existing network co-exist with OpenFlow switches. For example, when expanding an existing network or dealing with devices that have complex management settings, a practical approach would be to partially and gradually introduce OpenFlow switches by using an SDN application. Ryu provides functions for such introductions of OpenFlow switches in an existing network.

2.2.1 Obtaining management information

Even in existing networks, it is generally common to collect data such as the amount of traffic flow, link status, and other kinds of information from network devices that are compatible with SNMP (Simple Network Management Protocol), NetFlow, sFlow, etc., via network management systems, monitoring systems, or other such means, and to perform total, overall management of the data. The same kinds of information concerning OpenFlow switches can also be collected by the OpenFlow controller function. Ryu provides a function for collecting information from conventional network devices as well as from OpenFlow devices to avoid splitting the management system into two systems when a network configuration includes both OpenFlow switches and conventional network devices. Using Ryu to develop the management system makes it possible to collect information on various network devices other than OpenFlow switches and to perform total, integrated management. When the existing system is taken as the parent system, the functions of the Ryu OpenFlow controller can be called from the existing system so that information collection and total management that includes OpenFlow switches can be performed.

2.2.2 Settings

Some users use provisioning tools for implementing automatic changes in network device ports and bandwidth settings, for example, and also for entering settings. The NETCONF (Network Configuration Protocol) specifications are intended to provide a common procedure for such tasks for conventional network devices.

ONF is also addressing the issue of a common procedure for entering settings, which is not covered by OpenFlow specifications, by establishing the OF-CONFIG (OpenFlow Management and Configuration Protocol) specifications. Ryu accommodates both OF-CONFIG and NETCONF in the switch settings management function, so it is also possible to develop provisioning tools for unified settings changes for OpenFlow switches and existing network devices. The Ryu OF-CONFIG function can also be called from existing provisioning tools.

2.2.3 Exchange of routing data

The exchange of routing information based on the Border Gateway Protocol (BGP) is often used for overall cooperative operation of existing network devices as a single network. For example, data can be efficiently transferred by synchronizing the routing information possessed by network devices in different locations. Because Ryu conforms to the BGP specifications, it is possible, for example, to receive the routing information that is exchanged among existing network devices and send that data to OpenFlow switches. Also, changes made to routing information on the OpenFlow switch side can be sent to existing network devices via Ryu. Thus, when OpenFlow switches coexist with an existing network, routing information can be synchronized by the same mechanism as used previously, and obstacles to the introduction of OpenFlow switches can be reduced.

2.3 Sample applications

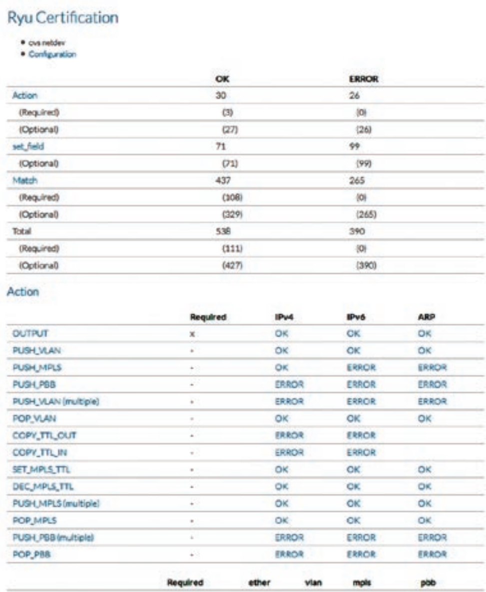
Ryu mainly provides tools and libraries that facilitate SDN application development, but sample applications that are easily referenced are also included. The examples include applications that implement firewalls and routers of the kinds that are familiar to most of us as well as applications that implement functions that are often used when constructing networks, such as link aggregation and spanning trees.

3. Efforts to achieve widespread adoption

In addition to developing Ryu, the NTT laboratories are actively encouraging the wider use of this platform. By making Ryu known and available to many people and obtaining feedback on it that can be used to develop an even better platform, we hope to contribute to the overall development of SDN/OpenFlow.

3.1 OSS development

Ryu is open source software (OSS). The source



Ryu Certification

- ovs netdev
- Configuration

	OK	ERROR
Action	30	26
(Required)	(3)	(0)
(Optional)	(27)	(26)
set_field	71	99
(Optional)	(71)	(99)
Match	437	265
(Required)	(108)	(0)
(Optional)	(329)	(265)
Total	538	390
(Required)	(111)	(0)
(Optional)	(427)	(390)

Action

	Required	IPv4	IPv6	ARP
OUTPUT	x	OK	OK	OK
PUSH_VLAN	-	OK	OK	OK
PUSH_MPLS	-	OK	ERROR	ERROR
PUSH_PBB	-	ERROR	ERROR	ERROR
PUSH_VLAN (multiple)	-	ERROR	ERROR	ERROR
POP_VLAN	-	OK	OK	OK
COPY_TTL_OUT	-	ERROR	ERROR	
COPY_TTL_IN	-	ERROR	ERROR	
SET_MPLS_TTL	-	OK	OK	OK
DEC_MPLS_TTL	-	OK	OK	OK
PUSH_MPLS (multiple)	-	OK	OK	OK
POP_MPLS	-	OK	OK	OK
PUSH_PBB (multiple)	-	ERROR	ERROR	ERROR
POP_PBB	-	ERROR	ERROR	ERROR

	Required	ether	vlan	mpls	pbb

Fig. 4. Test results for the OpenFlow switch (http://osrg.github.io/ryu/certification.html).

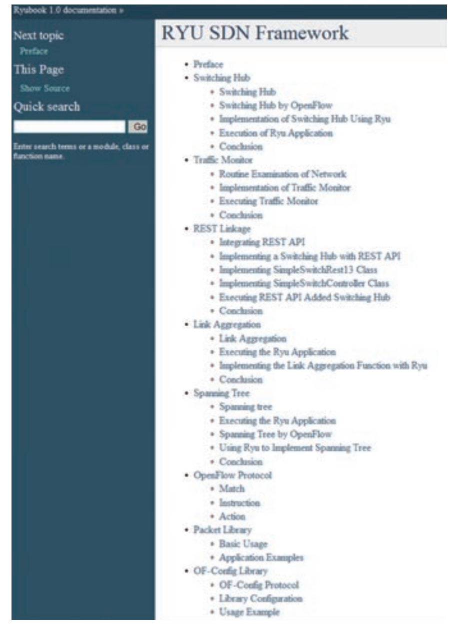


Fig. 5. E-book reference for Ryu (http://osrg.github.io/ryu/resources.html#books).

code is published and can be downloaded and used freely under an Apache license [2]. Anyone can incorporate Ryu into their products, commercial or otherwise, and some products that incorporate Ryu are already on the market [3]. The platform was published in 2012, and development has been vigorous ever since, with participation by switch vendors, network providers, systems integrators, academic organizations, and various others.

3.2 Wider use of OpenFlow specifications

The OpenFlow specifications do not necessarily define all functions as essential, and there are some functions whose application depends on the switch. There are also cases in which specific conditions must be satisfied for proper operation, even when conformance to OpenFlow specifications has been achieved. Currently, specific development may be needed for each particular switch because of ambiguities in the OpenFlow specifications themselves.

We are taking advantage of the high degree of Ryu conformity to the OpenFlow controller function specifications to develop a tool for checking the degree of conformance to OpenFlow switch specifications. We are using that tool to test the connection to various OpenFlow switches and are publishing the results on the Ryu website [4] (**Fig. 4**). Those who are developing SDN applications can understand the basic characteristics of various OpenFlow switches by browsing the published results.

This tool is also provided together with Ryu and is being used by many switch developers. Using this tool from the beginning of switch development can raise the level of product conformance with the specifications and aid in product quality management.

3.3 Documentation and publications

Although there was little documentation right after Ryu was published as OSS, more and more documentation is being made available. Currently, an e-book that compiles that documentation is being distributed (**Fig. 5**). Like the software, the book is also in open development, so interested persons are welcome to access it from any handy terminal.

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[3] Introduction examples of Ryu, http://osrg.github.io/ryu-book/en/html/introduction_example.html
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Fundamental Research Activities on Network Virtualization

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Abstract

NTT Network Innovation Laboratories has been conducting a great deal of research in the areas of network virtualization and software-defined networking (SDN). In this article, we describe *Lagopus*, a high-performance OpenFlow 1.3 capable SDN software switch from the O_3 Project. We also briefly explain our research activities involving network virtualization.

Keywords: NFV, SDN, OpenFlow

1. Introduction

One requirement in building *future networks* or next-generation networks is to construct a virtualized network in which its QoS (quality of service), performance, and functions are adaptable to each user's needs. Thus, technology for expanding the applicable area of fine flow control via software-defined networking (SDN) and technology for adapting the deployment, correction, and removal of high-performance and highly functional software by means such as network functions virtualisation (NFV)[*1], are becoming increasingly important. In this article, we introduce NTT Network Innovation Laboratories' research activities on SDN and network virtualization.

2. O_3 Project: automating the configuration of network nodes

We aim to establish network virtualization technology that enables many network operators and service providers who share network resources to design and build networks and to manage network operations for their own purposes. This will enable network operators to reduce the time needed to design, build, and modify their networks to only about 10% of the time previously required over a wide area network. As a result, service providers will be able to dramatically reduce the time required to initiate and withdraw services. Moreover, user satisfaction is expected to increase as users gain faster access to their desired services.

This project is known as the *O_3 (O Three) Project*[*2] (**Fig. 1**) and is based on research on network virtualization technology consigned via the Ministry of Internal Affairs and Communications. It is being jointly promoted by five companies.

This project aims to verify and commercialize research and development (R&D) results through prototypes and verification testing of network virtualization technology. At the same time, the project also aims to share and standardize research results globally, making some of the results open to the public and providing them to domestic and overseas

*1 The British spelling used by the European Telecommunications Standards Institute

*2 O_3 stands for the overall concepts of this project: open, organic, and optima. In June 2013, five companies (NEC Corporation, Nippon Telegraph and Telephone Corporation, NTT Communications Corporation, Fujitsu Limited, and Hitachi, Ltd.) began working jointly on R&D to conduct verification tests. The five companies aim to verify and commercialize these technologies and will promote the sharing and standardization of the research results globally.

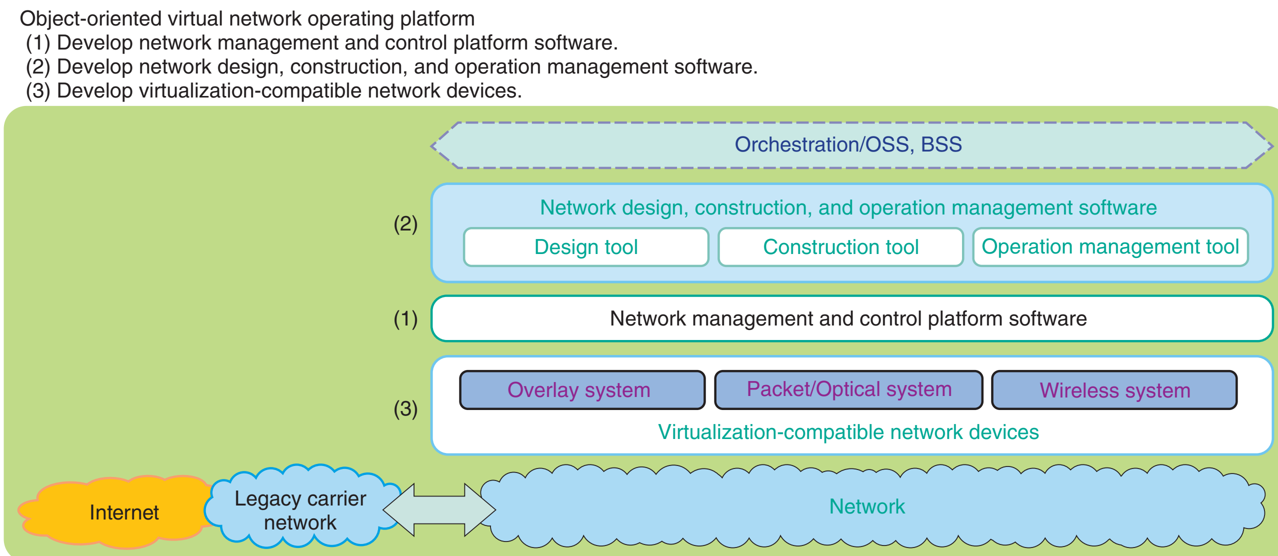

Fig. 1. Overview of O_3 project.

telecommunications carriers and service providers and vendors. An outline of the target R&D areas in this project is as follows:

(1) Technology for developing network management and control platform software

This technology is used to develop SDN platform software that enables the construction of networks while meeting service requirements and enabling fast provision of services. Specifically, it integrates a wide area network by ensuring common handling of information to control diverse networks such as optical, wireless, and packet communication networks (network configuration information, communication status information, etc.), and enables development of platforms for flexibly and promptly performing control functions.

(2) Technology for developing software for network design, construction, and operation management

This technology is used to develop software for network design, construction, and operation management that runs on the platform mentioned in item (1). Specifically, it is used to develop design software (to verify designed networks) that is necessary in order to apply SDN to a wide area network, construction software (to interconnect with existing networks and transition from existing networks to SDN), and operation management software (to identify faults between layers and respond to them faster and to control service quality).

(3) Technology for developing virtualization-compatible network devices

This is used to develop SDN network devices that can be controlled by technologies outlined in (1) and (2). Specifically, it is used to develop the interfaces and driver functions that enable use of low-cost, high-performance resources through all layers, optimization of service construction costs, and control of existing optical, wireless, and packet transport network devices, as well as software communication devices that can freely change configurations and functions.

NTT Network Innovation Laboratories is developing software communication devices that are compatible with SDN ((3) in the list above) and that consist of software programs on general-purpose server hardware.

3. SDN software switch: Lagopus

The use of software-oriented network nodes on general-purpose servers is important in order to simplify transfer networks and reduce their cost. These nodes are now more common than hardware-oriented network nodes for this purpose. NTT Network Innovation Laboratories successfully launched a prototype high-performance SDN software switch called *Lagopus* as part of the O_3 project. Although SDN has already been introduced in corporate networks such

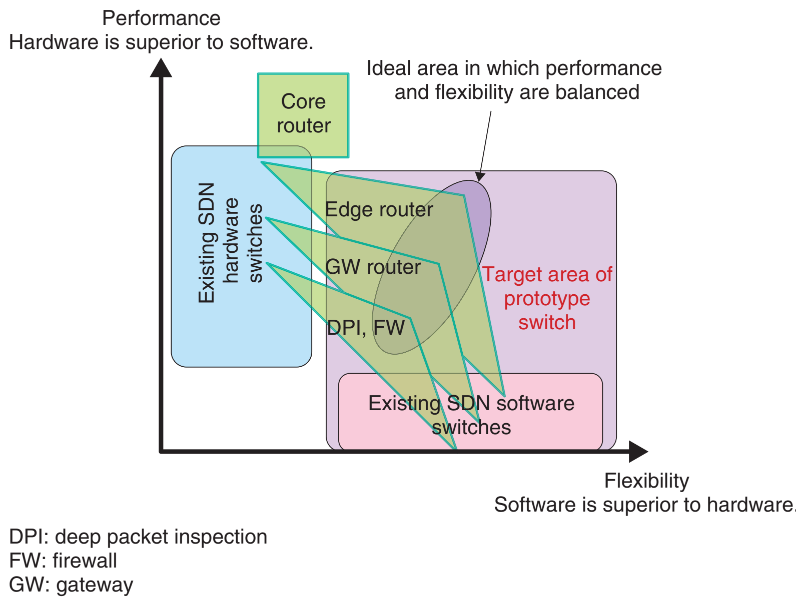

Fig. 2. Flexibility and performance target of Lagopus switch.

as those at datacenters, this prototype SDN software switch achieves high performance even when large scale flow entries are set, and it functions as a technical element enabling application of SDN to wide area networks such as those of telecommunications carriers and Internet providers [1].The target performance and flexibility of this prototype switch are shown in **Fig. 2**. In preparation for using this prototype switch for NFV in the future, the switch was given a modular architecture with remarkable expandability that makes it easy to expand and upgrade.

This prototype is compliant with long-term-support OpenFlow 1.3, the SDN-enabling specification, and also achieves good results in OpenFlow conformance tests. Furthermore, the development and implementation of the Flexible parallel Flow processing Framework (*fff*: **Fig. 3**) makes high-performance packet transfer possible with the prototype.

In general, a kernel space program is superior to a user space one in terms of processing speed. There are a number of problems with kernel space programs, however, including the need for the program to be maintained for the latest kernels. This prototype is a user space program and is implemented in parallel, with multiple threads enabling sufficient performance to be achieved.

Problems with SDN software switches are solved as follows:

(1) Faster forwarding with parallelization (multiple threads enabled)

Flows are identified, and packets in a flow are handled in a single set of pipelines to avoid order reversal of packets. The sets of pipelines are parallelized and multi-threaded to achieve greater speed [1].

(2) Faster searching of large scale flow entries with an '*fff*' look-up algorithm

A novel algorithm has been developed in order to speed up the process of looking up large scale flow entries under complicated search conditions, such as the *don't care* tolerance usually used in SDN (OpenFlow) in each set of pipelines. The prototype achieves high performance in searching flow tables, and the performance does not decrease much even if large scale flow entries are set into the flow tables. In addition, an *fff* look-up algorithm is implemented with as high a cache hit ratio as possible in order to reduce the number of times the memory needs to be accessed [1].

When 100K entries, which suffice as the first target, are added to flow tables, and all packet headers are rewritten, this prototype achieves 10-Gbit/s wire rate transferring of large packets. This makes it one of the highest performance SDN software switches ever.

We developed an agent function, which interprets the OpenFlow control protocol from the SDN controller and controls our software switch, in collaboration with the NTT Software Innovation Center, which has developed Ryu, as mentioned in one of the Feature

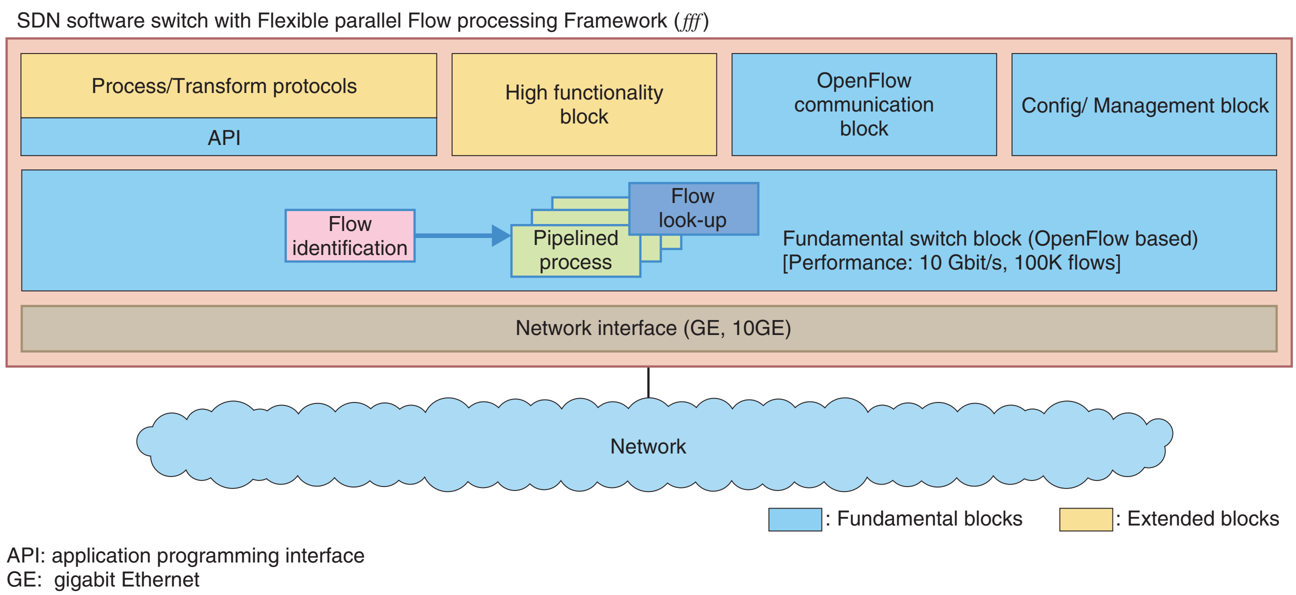

Fig. 3. SDN software switch with *fff*.

Articles in this issue [2]. In the O_3 project, our prototype is connected via Ryu with SDN control platform software.

The prototype will be extended to enable it to handle larger flow entries. R&D to achieve higher performance in applying software nodes to wide area networks will be promoted, as well as R&D for handling new protocols and management functions with high reliability in order to make software nodes more reliable and better operable.

4. Research to provide virtual networks to service providers

A virtual technology that can provide functions of future networks and network resources on a logical network is necessary for service providers. Network virtualization technology, which is one of the technologies applied to achieve SDN and NFV, can divide a physical network into multi-layered subnetworks. In each subnetwork, a different transport control protocol can be used, and specific applications or services can also be assigned. This is a major advantage that enables new services to be built quickly and flexibly on a carrier network.

We have taken part in developing the *Network Platform for Flexibly-Programmable Advanced Service Composition*. This platform includes routers, switches, servers, and network processors. It was developed during the period from fiscal year (FY) 2008 to FY2010 in a joint research project launched by NICT (National Institute of Information and Communication Technology), the University of Tokyo, NTT, NEC, Hitachi, and Fujitsu Laboratories in order to study network technology after the NGN (next-generation network).

Since 2011, a new research project to promote research on a next-generation virtual network platform has been executed under the Commissioned Research of NICT. The same organizations are participating in this project, and KDDI Laboratories and other organizations have also joined it. In this project, we have developed a virtual network platform consisting of a node system called *VNode*, which enables connections with nodes in other networks, as well as a network management system for the entire virtual network platform. The basic components of the VNode system are shown in **Fig. 4**.

Our VNode prototype system is shown in **Fig. 5**. We conducted experimental trials on a testbed (**Fig. 6**) that is based on overlay networks on JGN-X (Japan Gigabit Network-eXtreme), which is operated by NICT. As part of efforts to realize a global virtual network, we conducted experimental trials on interconnecting our platform with foreign virtual network platforms. Some challenges arose in the trials between the virtual network testbed on JGN-X and a testbed on GENI (the Global Environment for

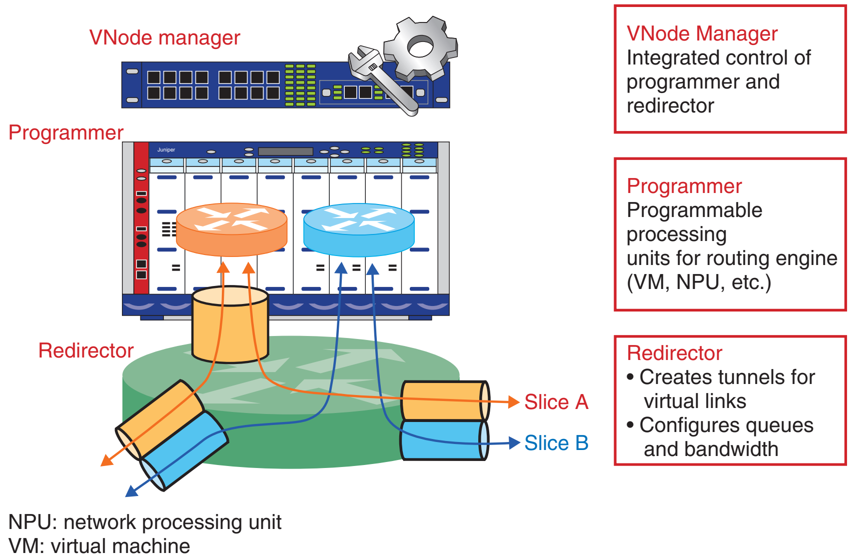

Fig. 4. Basic components of VNode system.

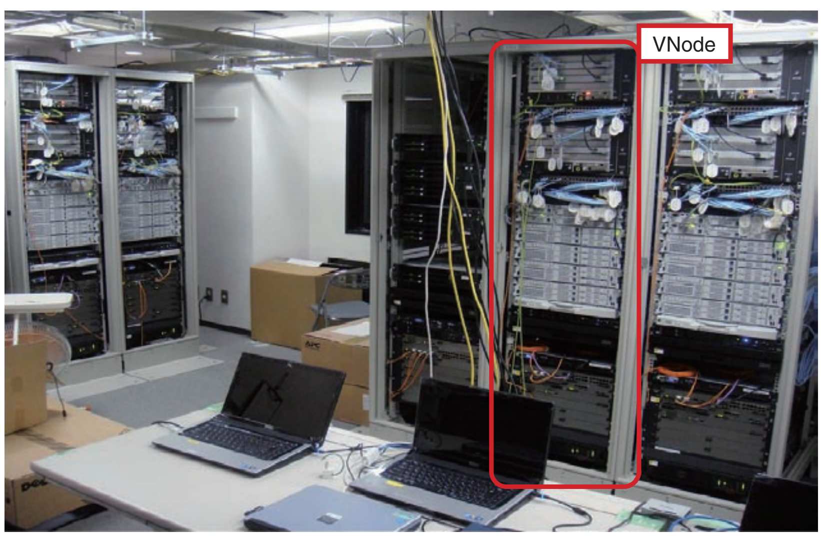

Fig. 5. Prototype VNode system.

Network Innovation), which is promoted by the National Science Foundation in the USA. Their architecture and implementation are so different that it was difficult to interconnect them. Furthermore, ordinary virtual network technology cannot guarantee QoS (the number of transmitted packets and latency). Thus, it is difficult to provide high-quality service. We installed our newly developed VNode at the University of Utah, which is a research partner of NICT, and we connected VNode to the ProtoGENI testbed. We then carried out the world's first successful trial to control multi-domain networks between Japan and the USA.

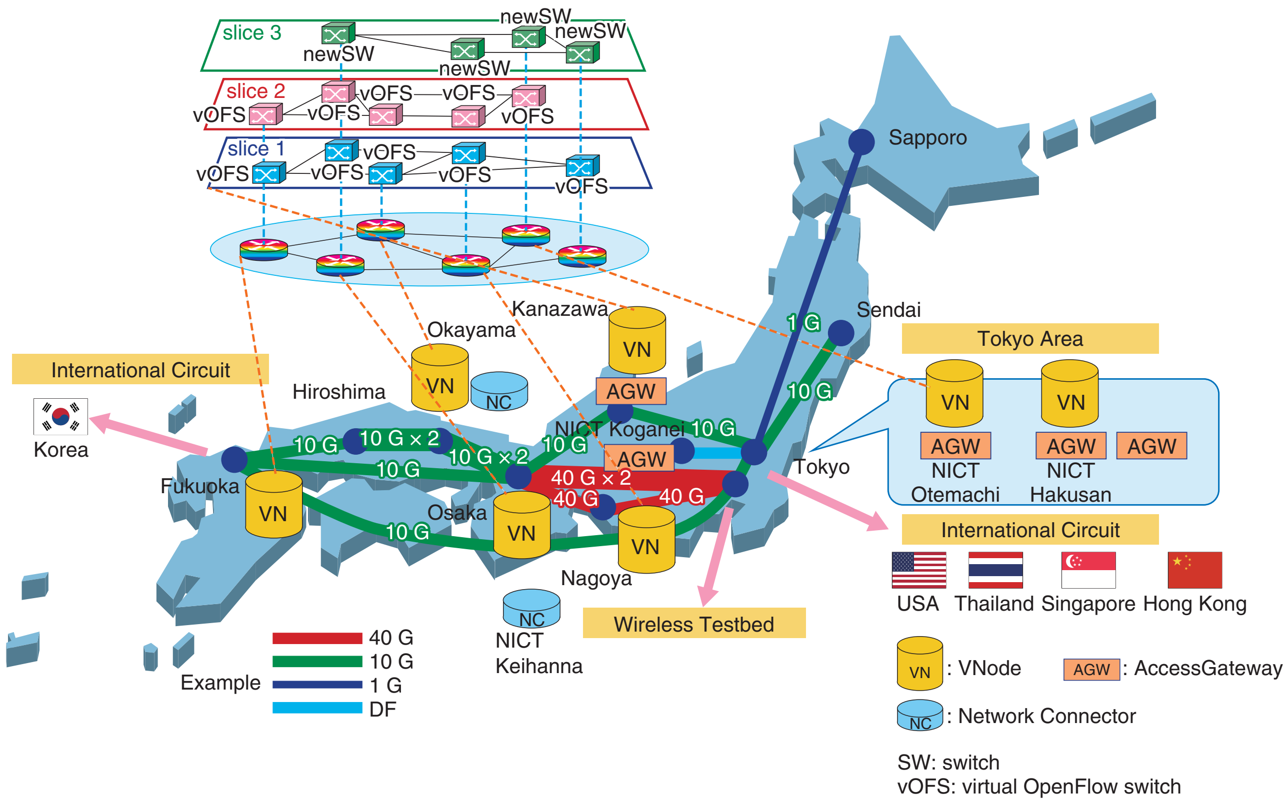

Fig. 6. Testbed on JGN-X.

5. Future work

We will continue to promote the implementation of many kinds of applications on our testbed and to conduct experimental trials. We will also work to create the environment that will encourage many users to install our VNode system.

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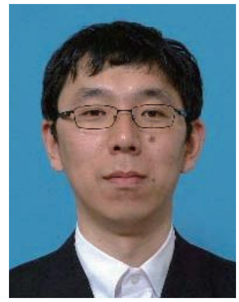

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High-temperature Superconductivity without Doping—Synthesis of Conceptually New Superconductors

Yoshiharu Krockenberger and Hideki Yamamoto

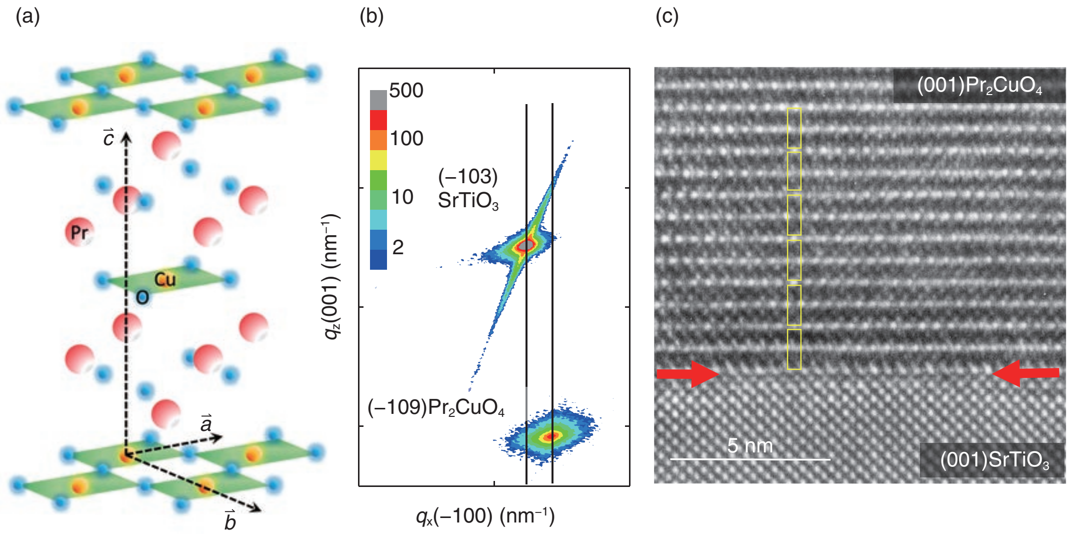
Abstract

High-temperature superconductivity is commonly associated with cuprate superconductors as their superconducting transition temperatures are still highest among all of the superconducting materials. It is these cuprate superconductors that drive scientists to reveal the very mechanism of its superconductivity and to derive models capable of predicting new superconducting material systems. Cuprate superconductors are built up of copper-oxygen planes, sandwiched by rare-earth or alkaline-earth oxide layers. The copper-oxygen layers form infinitely long planes, and it is those planes where superconductivity takes place. In particular, the copper ions in those planes may have three distinct coordinations, i.e., octahedral, pyramidal, and square-planar. Quite generally, electronic states are a function of crystal structure, crystal symmetry, and the elements building up the crystal structures. Nevertheless, it has been widely assumed that the copper-oxygen planes are inherently insulating and superconductivity is induced by doping carriers into those copper-oxygen planes. Indeed, such an approach is suitable for the copper-oxygen layers with octahedral and pyramidal coordinated copper, where superconductivity is induced by hole doping. For cuprates with square-planar coordinated copper, however, we demonstrate here that elimination of defects by annealing is the key to inducing superconductivity and doping is not a prerequisite for the emergence of superconductivity.

Keywords: undoped superconductor, high-T_c cuprates, molecular beam epitaxy

1. Introduction

High-temperature superconductivity is a key technology for many present and future milestones ranging from transportation [1], over medical applications [2] towards elementary particle physics [3]. Among all superconducting materials known so far, the discovery of cuprate superconductors was not only awarded by the Nobel prize [4] but still hold record high superconducting transition temperatures as high as 150 K [5]. Despite all efforts and progress made to understand the underlying mechanism driving superconductivity in those cuprates, conclusive theoretical models remain elusive. Solving the enigma of cuprate superconductivity, however, holds the key for materials with even higher superconducting transition temperatures. One of the crucial factors that drives superconductivity in cuprates are the copper-oxygen planes and the local environment of the Cu ions in those planes. Generally, three different geometries are stabilized in cuprate superconductors, i.e., octahedral, pyramidal, and square-planar. In many cases, those coordination cages do not appear exclusive but as combinations, e.g., pyramidal and square-planar in $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$. The local coordination of the copper ions has far reaching implications on the electronic structure. Revealing electronic structures subject to a specific coordination is therefore of importance. $La_{2-x}Sr_xCuO_4$ is a cuprate with solely octahedrally coordinated copper and it is one of the most widely studied systems among cuprate superconductors and commonly termed “T-phase.” Cuprates with solely square-planar coordinated copper are much less studied owing to the difficult and cumbersome



The CuO_2 planes are green shaded for clarity reasons.

Vertical lines indicate that the film is entirely relaxed.

Fig. 1. (a) Crystal structure of Pr_2CuO_4, (b) high-resolution reciprocal space map of Pr_2CuO_4 grown on (001) $SrTiO_3$ substrate, and (c) high-resolution transmission electron microscopy image of Pr_2CuO_4 grown on (001) $SrTiO_3$ substrate taken at the interface.

process in synthesis as well as inducing superconductivity to them. Hence, data reported for these systems are significantly dressed and dominated by electronic correlations stemming from impurity and defect related influences. In contrast to those earlier reports, we can synthesize cuprate superconductors by molecular beam epitaxy under oxidizing conditions. Molecular beam epitaxy is a well-known and widely used technique for synthesizing semiconductors and semiconductor-related devices. We further refined and optimized this technique with the scope of ultra-high quality cuprate materials [6]. Crystalline materials with the utmost degree of perfection are mandatory prerequisites in revealing electronic and magnetic correlations in cuprates with respect to the various coordination geometries of copper. Two cuprates, where copper is square-planar coordinated, are known, i.e., Nd_2CuO_4–structure [7, 8] and infinite-layer structure [9]. While the Nd_2CuO_4–structure (T'-structure) can be synthesized under ambient conditions, the formation of bulk infinite-layer cuprates occurs only under high pressure. The T'-structure belongs to the Ruddelsden-Popper series of transition metal oxides [10–12], which is also the case for the T-structure. In contrast to other transition metal oxides, where the transition metal ion is octahedrally coordinated, the copper ion is forced to be square-planar coordinated in the T'-structure and the force is brought by the tolerance factor [13]. The defects appear at the apical position of copper, forming locally pyramidal coordinated copper. Electronically, this situation represents an insulating and antiferromagnetic ground state. Upon elimination of those defects (by elaborate annealing), the entire electronic structure changes from an antiferromagnetic insulator to a superconducting metal. In the following we focus on our efforts to elucidate the electronic structure of ultra-high quality T'-cuprate superconductors where such defects have been eliminated by annealing.

2. Experimental

High quality thin films of Pr_2CuO_4 are grown by molecular beam epitaxy onto (001) $SrTiO_3$ substrates [14]. Pr and Cu are evaporated by e-beam evaporation from metal-sources and the evaporation rate is controlled by electron impact emission spectroscopy [15–18]. Ozone or radio frequency (RF) activated oxygen is used as an oxidizing agent. The growth is monitored by reflection high energy electron diffraction (RHEED) which allows not only fine tuning of growth conditions but a real-time feedback of film growth. In **Fig. 1**, the crystal structure of Pr_2CuO_4, high-resolution reciprocal space map (HRRSM) of the epitaxial relation, and high-resolution transmission electron microscopy (HRTEM) image of Pr_2CuO_4 films on (001) $SrTiO_3$ substrates are shown, respectively. Here, growth conditions are tuned in order to allow for a relaxed but epitaxial growth of single phase and *c*-axis oriented Pr_2CuO_4 on $SrTiO_3$. Throughout the following experiments and discussions, the film thickness was kept constant at 100 nm. In **Fig. 2**, X-ray diffraction of a Pr_2CuO_4 film on (001) $SrTiO_3$ substrate is shown. Using a Nelson-Riley [19] function allows for a precise determination of *c*-axis lengths as this is an important control parameter.

As discussed in the introduction, the as-grown Pr_2CuO_4 is insulating due to the presence of over-stoichiometric oxygen occupying the apical sites of copper [20–24]. As it is well known from Ce doped $Pr_{2-x}Ce_xCuO_4$, annealing is required for the induction of superconductivity—otherwise, the system remains insulating and antiferromagnetic. During the annealing process, the apical oxygen leaves the Pr_2CuO_4 crystal. Such a process is a diffusion process though in case of Pr_2CuO_4 a detailed understanding remains elusive owing to the three different oxygen positions in the T'-crystal structure [25–29]. Here, we applied a two-step annealing process [15], which allows for an effective evacuation of apical sites, while regular oxygen positions are not affected. The annealing procedure requires that thermodynamic constraints of Pr_2CuO_4 itself are not violated (this leads to decomposition). At the same time, an appropriate annealing is achieved only near or on thermodynamic boundary on a delicate balance of kinetically driven competition.

3. Results and discussions

3.1 Standard annealing

The term "standard annealing" may seem confusing though it simply describes annealing conditions used for the induction of superconductivity at doping levels of $x = 0.15$; *i.e.*, $Pr_{1.85}Ce_{0.15}CuO_4$ [30, 31]. As annealing of Ce doped Pr_2CuO_4 is carried out under ultra-high vacuum, only two annealing parameters, time and temperature, are to be considered. Applying the standard annealing approach leads to phase diagram of $Pr_{2-x}Ce_xCuO_4$ as shown in **Fig. 3**. At low Ce doping levels ($x < 0.11$) the system is insulating and superconductivity sets in for $x > 0.12$. This phase diagram (Fig. 3) inevitably is identical to what has been reported for single crystals or powder samples.

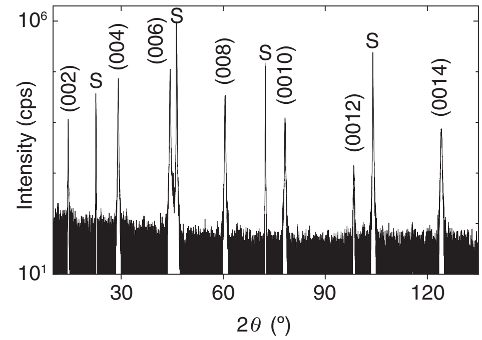


Fig. 2. X-ray diffraction pattern taken of Pr_2CuO_4 grown on (001) $SrTiO_3$ substrate.

3.2 2-step annealing

Applying standard annealing conditions to $Pr_{2-x}Ce_xCuO_4$ is effective for the induction of superconductivity for $x > 0.11$. In $Pr_{2-x}Ce_xCuO_4$, the addition of Ce not only acts as a dopant but as a defect [32]. If less Ce is incorporated into the $Pr_{2-x}Ce_xCuO_4$ crystal, the crystallite dimensions rapidly increase. The path taken by oxygen leaving $Pr_{2-x}Ce_xCuO_4$ crystals is predominantly along the CuO_2 planes until reaching a grain boundary. The thermodynamic environment under standard annealing conditions is unsuitable for establishing such a condition over long periods of time or at elevated temperatures due to the simultaneously occuring defects at regular oxygen sites. This diffusion problem of identical species at competing sites is not limited to thin film but to a much larger extent to single crystals owing to their reduced surface/volume ratio. However, this problem can be overcome by introducing an intermediate annealing step. This situation is visualized in the thermodynamic phase diagram plotted in **Fig. 4**. In contrast to the standard annealing procedure, Pr_2CuO_4 is kept at a temperature comparable or even higher than the synthesis temperature used during its growth [33]. Moreover, an environment with small but finite partial oxygen pressure is stabilized for 60 min before the sample temperature is cooled to the second annealing step. In **Fig. 5**, the temperature dependence of resistivity is plotted for all three positions of the thermodynamic phase diagram. The as-grown Pr_2CuO_4 is insulating and its resistivity further increases after the 1st annealing step. This behavior indicates that additional defects, tapering the electron mobility, are created. Schematically, this is shown in **Fig. 6**. While the as-grown Pr_2CuO_4 posseses defects primarily related to occupied apical sites, the first

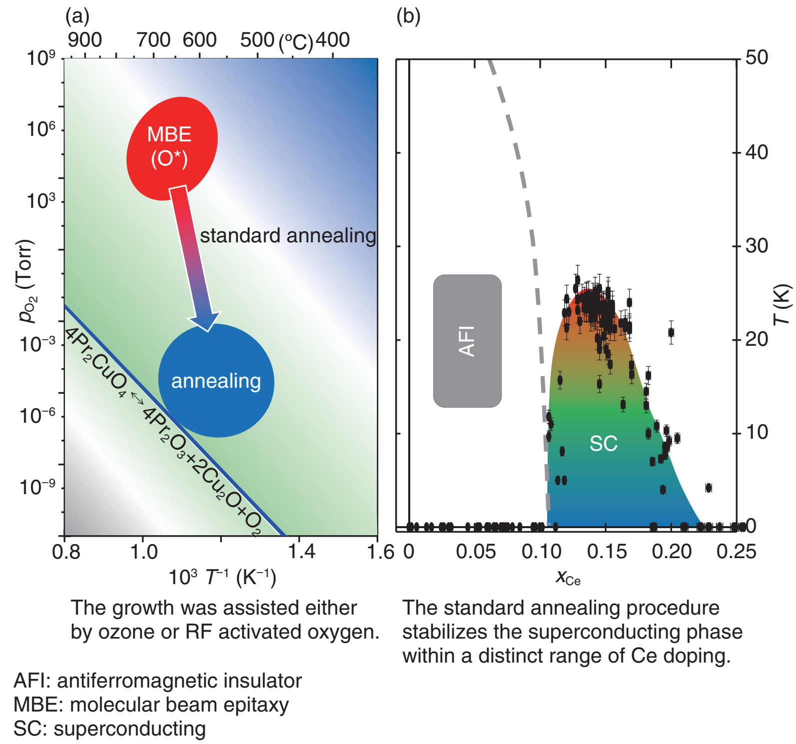


Fig. 3. (a) Thermodynamic phase diagram in the vicinity of the growth conditions of $Pr_{2-x}Ce_xCuO_4$ (red area) and annealing conditions (blue area) and (b) superconducting phase diagram of $Pr_{2-x}Ce_xCuO_4$ grown on (001) $SrTiO_3$ substrates as a result of the annealing procedure shown on the left.

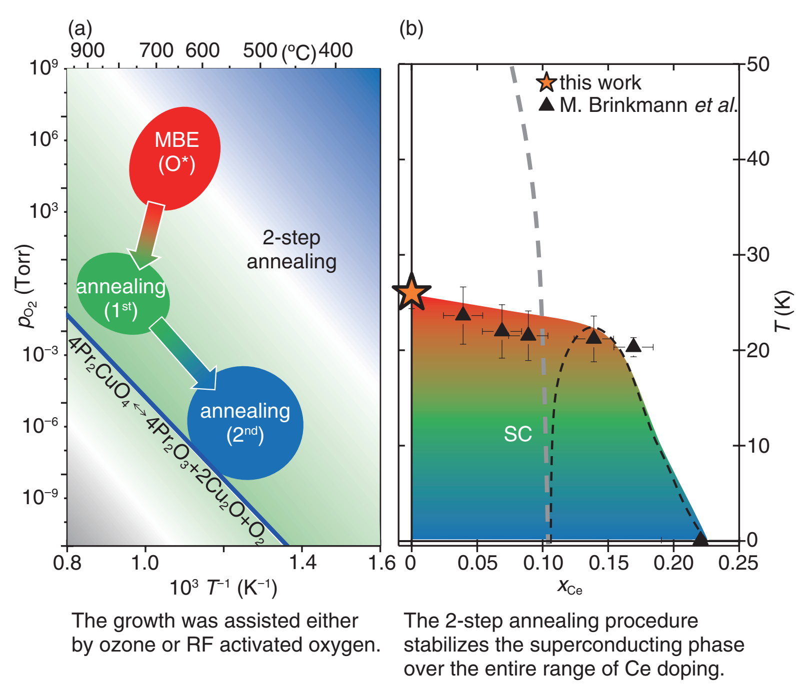


Fig. 4. (a) Thermodynamic phase diagram in the vicinity of the growth conditions of $Pr_{2-x}Ce_xCuO_4$ (red area) and annealing conditions (green and blue area) and (b) superconducting phase diagram of $Pr_{2-x}Ce_xCuO_4$ grown on (001) $SrTiO_3$ substrates as a result of the annealing procedure shown on the left. Data denoted by triangles are taken from Ref. [34].

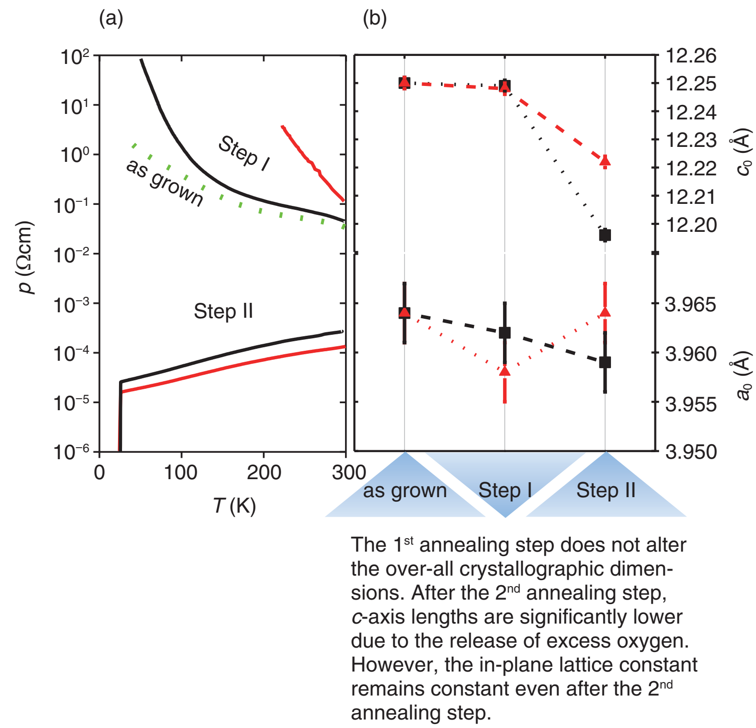


Fig. 5. (a) Temperature dependence of resistivity of Pr_2CuO_4 thin films in as-grown state (green dashed line), after the 1st annealing step (step I), and after the 2nd annealing step (step II) and (b) trace of the crystallographic lattice parameters of Pr_2CuO_4 thin films.

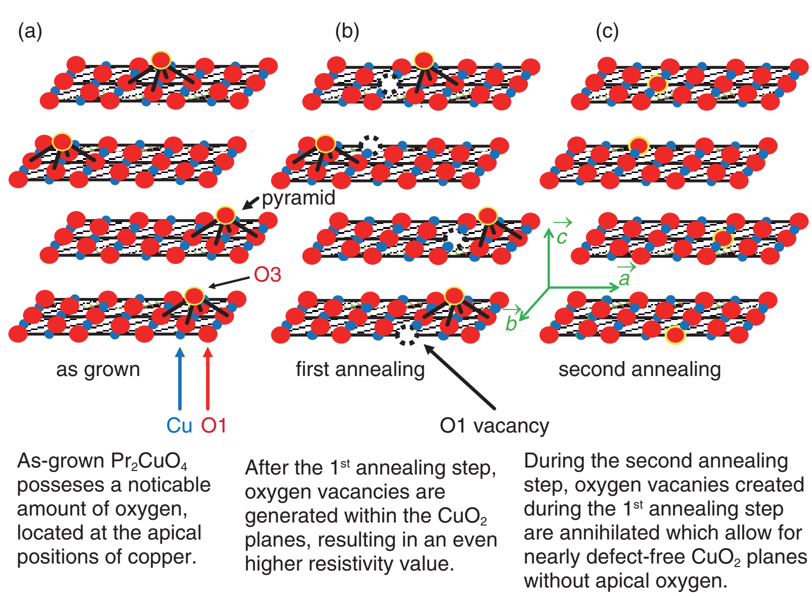


Fig. 6. Microscopic view of oxygen vacancies and defects at each synthesis or annealing step.

annealing step is about to increase the defects within the CuO_2 planes. Consequently, the absolute resistivity value increases. Simultaneously, the overall crystallographic dimensions remain nearly unaffected.

This does change, however, dramatically after the second annealing step and the *c*-axis value shrinks noticably. Most dramatic is the influence on the resistivity behavior as it not only changes from an insulating to a metallic state but to superconductivity. This behavior is again common to what is known to happen during the conventional annealing process for Ce-doped $Pr_{2-x}Ce_xCuO_4$ (x > 0.11). Accordingly, our study has revealed an intrinsic electronic phase diagram for $Pr_{2-x}Ce_xCuO_4$, which was hampered by enigmatic and cumbersome processes in optimizing annealing conditions.

4. Conclusion

It has been assumed that the high-T_c cuprates universally have an insulating ground state in their undoped state due to electronic correlations, and doping is necessary to change the correlations and induce superconductivity. However, a series of our studies have revealed that the cuprates with the square-planar coordinated Cu have a metallic ground state and show superconducting transition after removal of defects from the playground of high-T_c superconductivity, *i.e.*, the copper-oxygen planes. This observation is against the main paradigm in theories of high-T_c superconductivity. Although, at the moment, this conclusion is still under intense debate, the very result of our research will be a turning point in the quest for high-T_c superconductivity once further investigations support it.

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Standardization Activities of oneM2M

Akihiro Tsutsui and Yoshinori Goto

Abstract

Machine-to-machine (M2M) services have been developed independently in a diverse range of fields such as industrial machinery and logistics. Demand has been increasing recently for an expansion of the market by building a common M2M platform and using mutual exploitation of M2M data across different industries. In 2012, major regional standards development organizations of Europe, the United States, and Asia established a unified standardization body named 'oneM2M' for M2M-associated technologies. This article presents the current status and future activities of oneM2M.

Keywords: M2M, standardization, oneM2M

1. Introduction

The major regional telecommunications standards development organizations (SDOs) established oneM2M in July 2012 in order to develop a set of common technical specifications for machine-to-machine (M2M) technologies. These SDOs are:

Europe: ETSI (European Telecommunications Standards Institute)

USA: ATIS (Alliance for Telecommunications Industry Solutions)
TIA (Telecommunications Industry Association)

China: CCSA (China Communications Standards Association)

Korea: TTA (Telecommunications Technology Association of Korea)

Japan: ARIB (Association of Radio Industries and Businesses)
TTC (Telecommunication Technology Committee)

These SDOs involved in establishing oneM2M are referred to as *Partners Type 1*. As of March 2014, through these type-1 SDOs, more than 200 companies had joined oneM2M as *Members* who are committed to contributing to the development of common specifications. In addition, some industry organizations such as Continua Health Alliance, HGI (Home Gateway Initiative), and OMA (Open Mobile Alliance) have joined oneM2M as *Partners Type 2*. Members are made up of a majority of the companies that are also ETSI members. This is because ETSI was involved in creating standards for M2M technologies before oneM2M was established. Most Members consist of telecommunications operators and device vendors. The Partners Type 2 are considered to be key players in the dissemination of standards. However, only a few organizations have joined oneM2M as a Partner Type 2, and the industry segments represented by them are limited as of now. Promoting the activities of oneM2M is one of the tasks the Partner Type 2 organizations are required to carry out.

The main goal of oneM2M is to create specifications of a common platform for M2M services that have been vertically integrated until now. One of the important benefits of this standardization is reducing the cost of deploying M2M systems by using common hardware and software specifications. Common interface specifications provided by oneM2M will enable various applications to access M2M systems and devices in a uniform way. In addition, various data coming from M2M devices can be distributed across different business fields. This is expected to help enlarge the market associated with M2M. After collecting typical use cases, oneM2M creates M2M

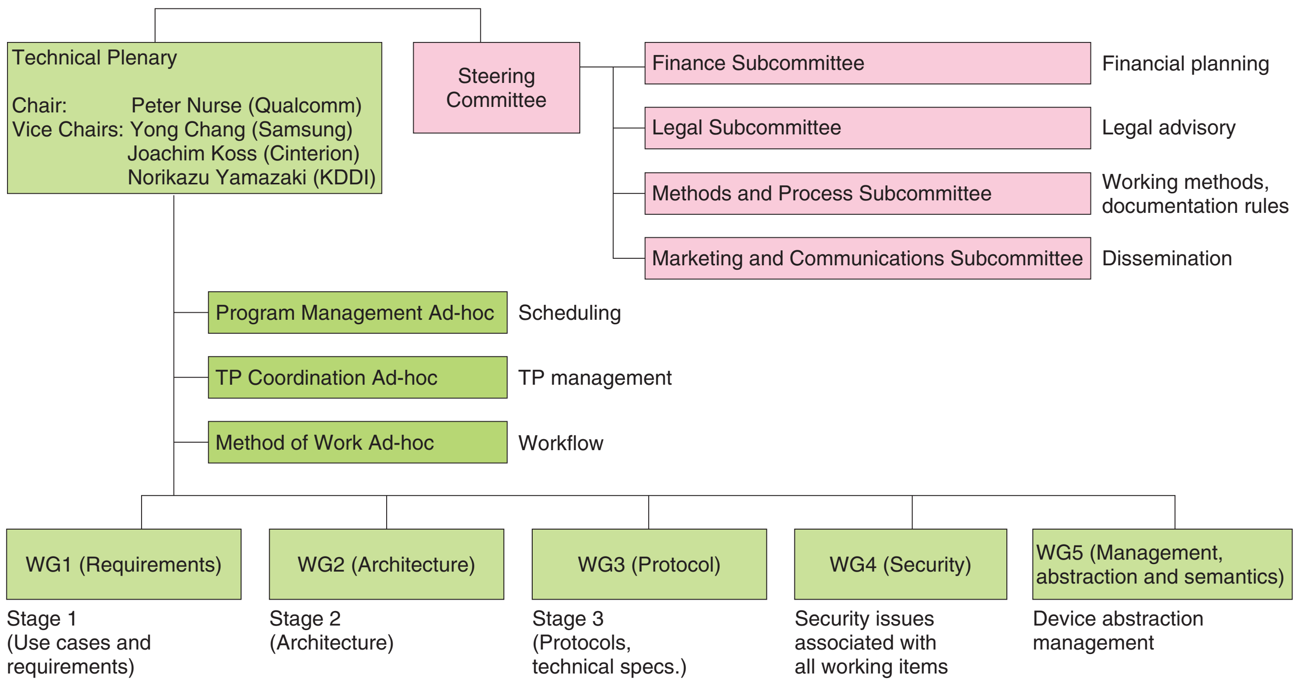

Fig. 1. Organization chart of oneM2M.

technical specifications using a three-step approach: requirements (stage 1), architecture (stage 2), and protocols (stage 3). In addition, security and management technologies for operating M2M platforms safely and reliably are discussed. All of these work items are discussed in working groups (WGs). An organization chart of oneM2M is shown in **Fig. 1**. The Technical Plenary (TP) is the main body working on technical specifications and consists of five WGs. Each WG primarily handles requirements, architecture, protocols, security, and management. The SC (Steering Committee) deals with strategic issues including budget and IPR (intellectual property rights). In addition, MARCOM (MARketing and COMmunications) was established in order to strengthen marketing activities. Currently, oneM2M is promoting dissemination of its activities.

2. Current activities

oneM2M initiated technical discussions at its first TP meeting held in September 2012. As of March 2014, nine TP meetings had been held (six times per year). The meeting location rotates between Europe, the USA, and Asia. Some WGs hold teleconferences once a week or every two weeks, and their technical discussions are very active.

The status of standardization work is shown in **Fig. 2**. In the early stage of oneM2M's establishment, the members planned to issue the first release of specification documents at the end of 2013. However, their work plan was delayed as a result of some exhaustive discussions. Consequently, the first release of the common specifications is expected to be in the middle of 2014. As of April 2014, the technical specifications of the requirements and the associated technical reports had been completed. The architectural work is in the final stage. At the 8th and 9th TP meetings, held respectively in December 2013 and February 2014, many contributions regarding architectural work were discussed and agreed. Moreover, the protocol WG also started technical discussions on protocol specifications.

oneM2M has accelerated standardization activities as mentioned before, and some completed deliverables have been published. The documents of use-case collections and requirements have been approved by a oneM2M TP and have been published by some SDOs. The oneM2M standards release 1 will be approved in the 12th TP meeting scheduled for August 2014. This release is called the *minimum deployable model*. Further discussion will be required in order to create more practical and detailed specifications. After the first version of specifications is released,

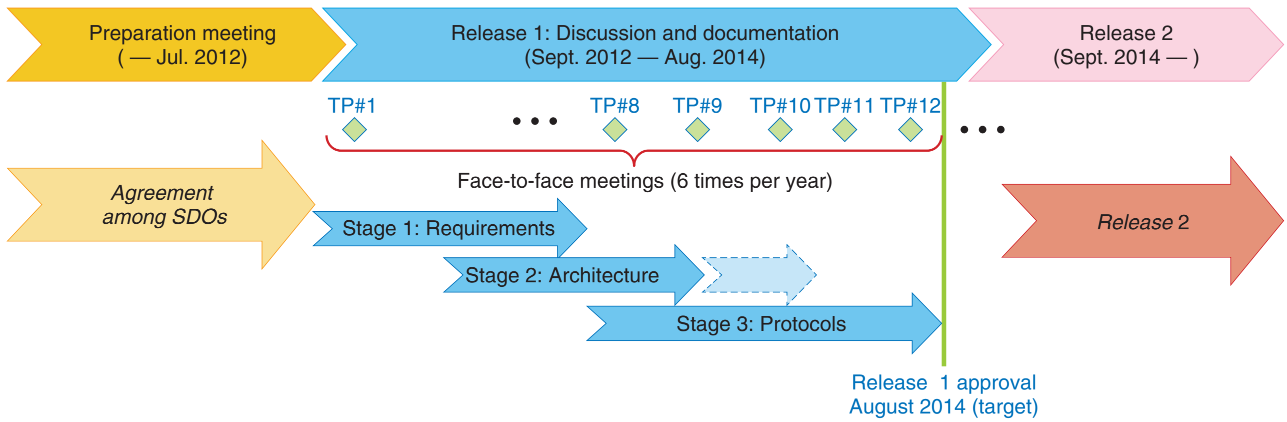

Fig. 2. oneM2M working status.

oneM2M will continue its standardization work and produce documents using the point release method, which means that specification documents will be released sequentially as soon as they are approved. The following documents will be included in release 1.

- Definitions and Acronyms
- M2M Architecture
- M2M Requirements
- oneM2M Security Solutions
- oneM2M Protocol Technical Specifications

At least one of the following documents will also be included.

- ✧ oneM2M Management Enablement (OMA)
- ✧ oneM2M Management Enablement (BBF: Broadband Forum)

Finally, at least one of the following documents will be included.

- ✧ CoAP (Constrained Application Protocol) Protocol Binding Technical Specification
- ✧ HTTP (Hypertext Transfer Protocol) Protocol Binding Technical Specification
- ✧ MQTT (Message Queuing Telemetry Transport) Protocol Binding Technical Specification

Continua Health Alliance, a Partner Type 2, provided feedback in the form of an analysis of the gap between their own architecture model and a model discussed in oneM2M. However, other Partners Type 2 do not seem to be as actively involved. The expectation is that the first release will trigger greater interest from these partners and other specification users.

3. Overview of architecture specifications

The basic architecture model discussed in oneM2M is shown in **Fig. 3**. CSEs (Common Service Entities) are defined as entities located between an AE (Application Entity) and NSE (Network Service Entity). These three basic entities communicate with each other in this model. Generally, M2M services should be deployed on a wide variety of networks, both mobile and fixed. Therefore, detailed technical issues that are specific to the underlying network technologies are avoided in principle. This basic architecture model enables M2M applications to communicate with CSEs implemented in servers, M2M terminal devices, and gateways via reference points (Mca, Mcc, Mcn, and Mcc' in Fig. 3). CSEs are collections of common functions utilized by various M2M services such as device management. When CSEs are implemented in M2M servers and devices, the M2M applications can easily handle various sensors and actuators. This platform architecture supports installation and separation of applications. It is possible to utilize an M2M device by using different applications independently of each other. Data separation and sharing is also supported between different applications using the appropriate authentication mechanism. The physical components such as M2M servers and devices with CSEs are called nodes. An example structure of a network and M2M nodes is shown in **Fig. 4**. The CSEs are the key of this architecture model, and they include 12 functions, as shown in **Fig. 5**. These functions include device discovery, device and application management, data management and repository, and authentication and security

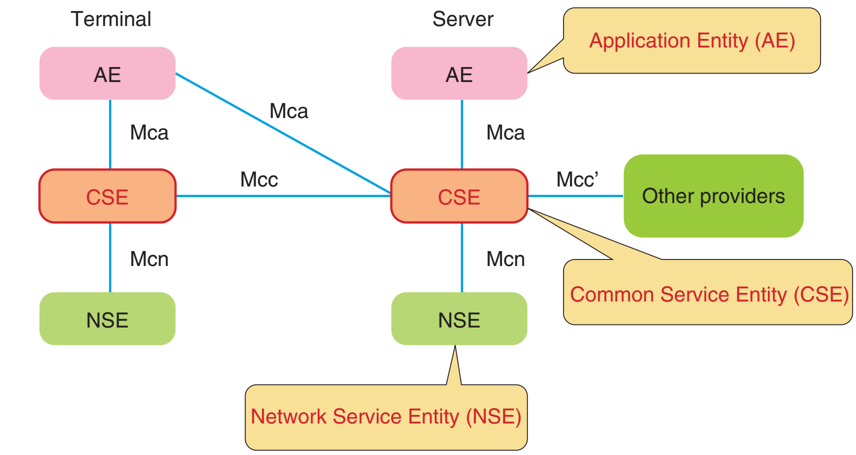

Fig. 3. Basic architecture model.

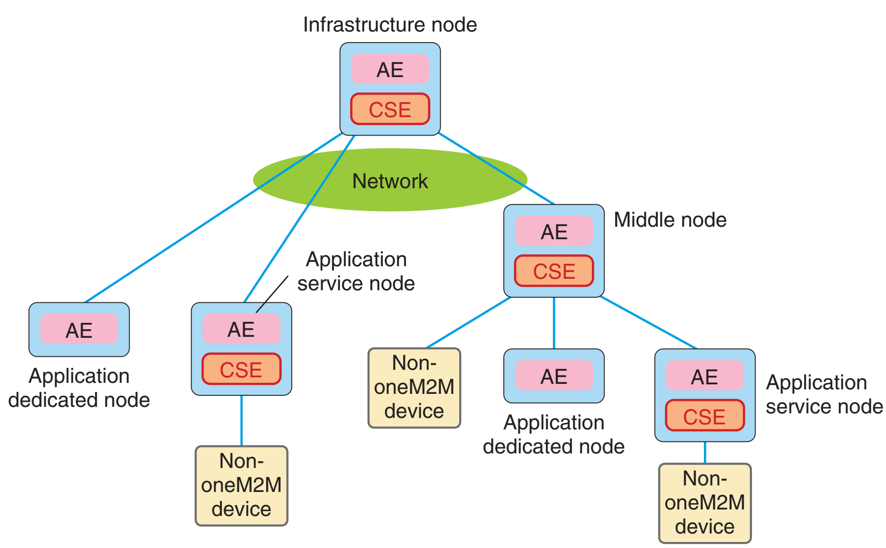

Fig. 4. Example structure of nodes and network.

associated functions. Completing the protocol specifications for communication between nodes is one of the most important tasks of oneM2M. WG3 is currently discussing this issue. As of June 2014, they had finished analyzing existing protocols related to M2M services. HTTP, CoAP (a lightweight HTTP), and MQTT (a scalable protocol designed for M2M communication), are the presumed standardization targets.

4. Future work

oneM2M is accelerating its activities as it prepares to issue the first release of specifications. The first release will, however, provide limited capabilities. Further work will be necessary to produce more detailed and practical specifications that can be utilized for implementation of actual M2M platforms. TP meetings will continue to be held six times per year, and further technical specifications will be released sequentially as soon as they are approved. Global attention on oneM2M is expected to increase

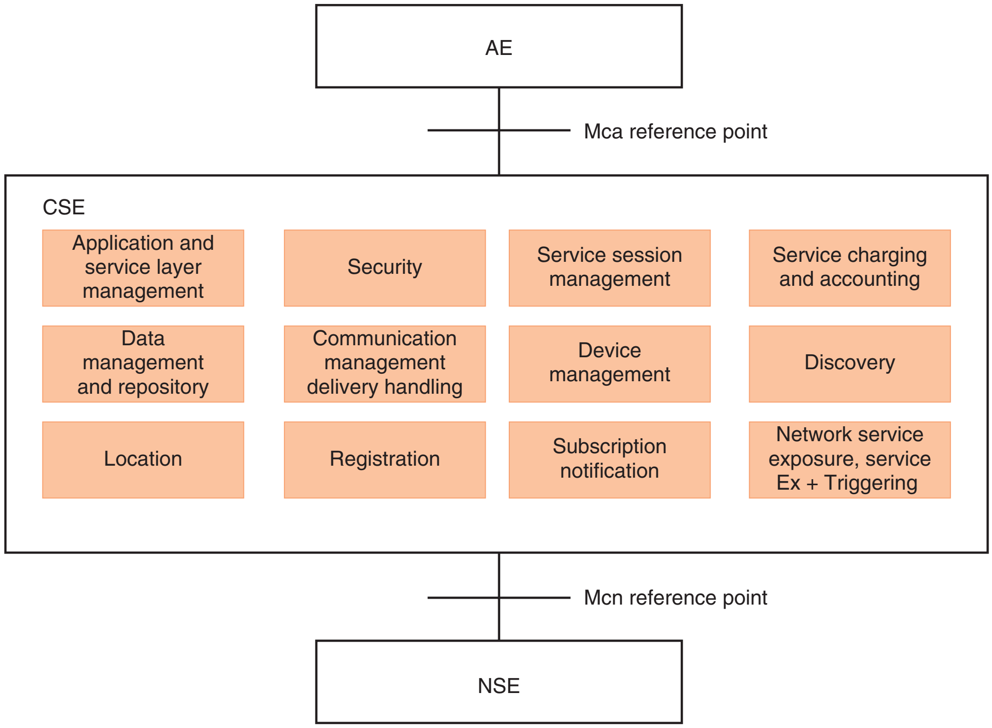

Fig. 5. CSE functions.

when its first set of specifications is released.

Reference

Website of oneM2M, http://www.onem2m.org/

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Fault Cases in an IP Phone Circuit Accommodating a PBX via a VoIP-GW

Abstract

This article introduces fault cases in an Internet protocol (IP) phone circuit accommodating a PBX (private branch exchange) via a VoIP-GW (voice over IP gateway). This is the twenty-fourth of a bimonthly series on the theme of practical field information on telecommunication technologies. This month's contribution is from the Network Interface Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: IP phone, PBX, VoIP-GW

1. Introduction

The penetration of broadband services has also reached telephone services, which has led to a migration from analog phones to Internet protocol (IP) phones. We introduce here two cases of faults occurring in a configuration that accommodates a private branch exchange (PBX) via a voice over IP gateway (VoIP-GW) in an IP phone circuit. These examples show how faults can be investigated by collecting data at various troubleshooting points, and they also demonstrate the importance of maintaining the required values stipulated in product specifications.

2. Overview of fault cases

2.1 Line disconnect occurs when PBX receives an outside call

2.1.1 Equipment configuration

The equipment configuration of a customer that uses NTT's IP phone service called *Hikari Denwa* is shown in **Fig. 1**. The PBX is connected to the optical network unit (ONU) through the VoIP-GW with three analog lines. One of the lines leads to the interactive voice response (IVR) equipment as a result of branching off the path from the VoIP-GW into the PBX equipment. The VoIP-GW is also connected to an Ethernet line, and it bidirectionally converts analog signals into IP packets or IP packets into analog signals.

2.1.2 Fault description

When incoming calls came in from the outside, the line would sometimes disconnect before answering. This problem had been occurring since the time of analog-line use prior to introducing Hikari Denwa.

2.1.3 Inspection method

Since we could not confirm the occurrence of a line disconnect before answering in an on-site incoming-call connection test, we decided to conduct long-term monitoring and analyze the collected data. The inspection setup is shown in **Fig. 2** and described below.

a) We used a maintenance console installed in a personal computer (PC) to collect and analyze the VoIP-GW call log.
b) We used a packet capturing tool installed in a PC to capture packets in the Ethernet section between the ONU and the VoIP-GW and then analyzed the captured data.
c) We used a waveform recorder to monitor signals in the analog-interface section between the VoIP-GW and the PBX equipment.

2.1.4 Inspection results

a) The call log collected from the VoIP-GW

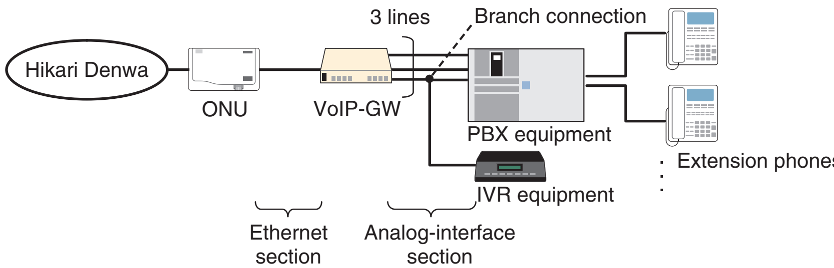

Fig. 1. Equipment configuration.

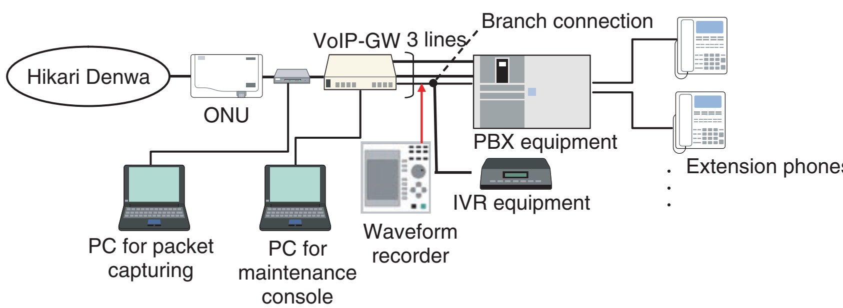

Fig. 2. Inspection setup.

Call-response time	Disconnect time	Line	Disconnect source
3/07T15:04:37	3/07T15:04:37	A1	G=200
3/07T14:14:08	3/07T14:14:09	A1	G=200
3/07T13:59:38	3/07T13:59:39	A1	G=200
3/07T13:26:52	3/07T13:26:52	A1	G=200
3/05T16:48:34	3/05T16:48:35	A1	G=200

Within 1 s

Line
A: Analog
1: Line number

Disconnect source
G: This equipment
200: Normal disconnect

Fig. 3. Excerpt of VoIP-GW call log.

revealed the existence of calls in which the time interval from incoming-call response to line disconnect was less than one second. It was confirmed that all of these calls were disconnected by the VoIP-GW on the call-terminating side. These results are shown in **Fig. 3**.

b) No packets that could be considered abnormal were found from the analysis of packet-capture data. However, packet sequences also revealed calls in which the time interval from call initiation to termination was less than one second, which was in agreement with the VoIP-GW call log. These results are shown in **Fig. 4**.

c) At the times this fault occurred, signal monitoring between the VoIP-GW and PBX equipment revealed that the line would disconnect immediately after the PBX responded to the interrupted ringing (IR) signal sent by the VoIP-GW. The signal waveform at this time is shown in **Fig. 5**.

2.1.5 Cause of fault

Given that all incoming-call responses and disconnect operations were normal up to the analog-interface section between the VoIP-GW and PBX equipment, we surmised that a problem existed on the PBX side. We considered, for example, that a defective hook switch on a specific extension phone to the PBX could cause the line to disconnect when responding to an incoming call.

2.1.6 Countermeasure and effect

To further troubleshoot this fault, we decided to equip the PBX with a function for saving and managing the call history, which would enable us to collect and analyze data and thereby identify the extension

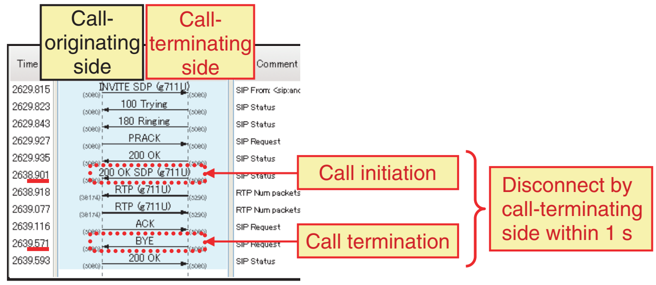

Fig. 4.   Capture data (packet sequence) at time of fault occurrence.

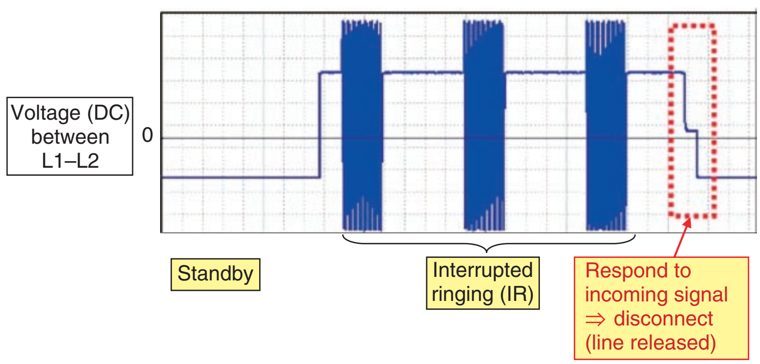

Fig. 5.   Respond/disconnect waveform at time of incoming call.

phone of the PBX that was disconnecting the line when responding to an incoming call. The results of troubleshooting after implementing this countermeasure showed that the cause of this fault was an operational error by the customer of this PBX. In other words, the cause of this fault lay on the PBX side as we had surmised.

2.1.7 Summary

In this inspection, we collected and analyzed the VoIP-GW call log and inferred that equipment positioned below the VoIP-GW was disconnecting the calls. Although checking the analog-interface interval with instrumentation normally used in fault troubleshooting presents some difficulties, checking the logs of various types of equipment is relatively easy and makes for a useful and important fault-troubleshooting technique.

2.2 No ringing sound when the PBX receives an outside call

2.2.1 Equipment configuration

This configuration was the same as that in the fault case described in 2.1.

2.2.2 Fault description

After the analog line was changed over to Hikari Denwa, sometimes no ringing would occur at the time of an incoming call even though the caller could hear a ring sound. It had already been confirmed that this would not occur if the IVR equipment were disconnected.

2.2.3 Inspection method

After confirming the occurrence of no incoming-call ringing in an on-site incoming-call connection test, we configured some test equipment and conducted a reproducibility experiment. This configuration is shown in **Fig. 6**.

a) In this reproducibility experiment, we monitored signals in the analog-interface section between the VoIP-GW and PBX equipment using an oscilloscope while varying the resistance using a variable resistor in place of the IVR equipment.
b) We examined the conditions under which no ringing occurred when a call came in from the outside.

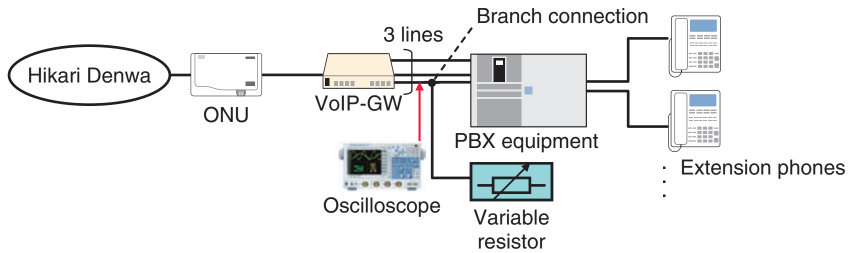

Fig. 6. Configuration of test equipment.

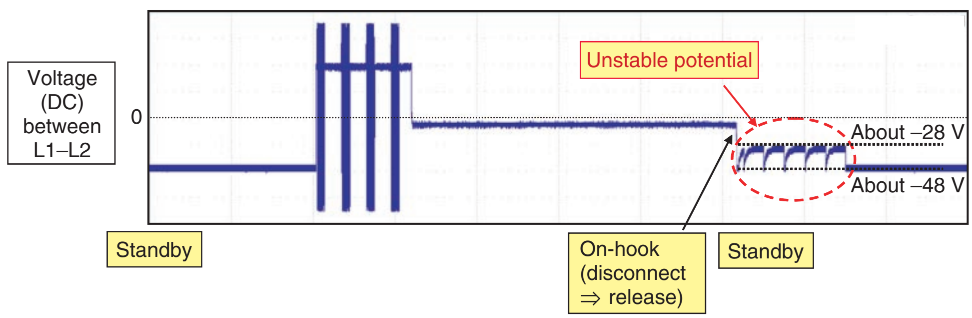

Fig. 7. Waveform depicting unstable potential (when DC resistance between L1–L2 is 0.62 MΩ).

2.2.4 Inspection results

a) Signal monitoring in the analog-interface section revealed the following. If the value of DC (direct current) resistance between the L1–L2 lines at the time of circuit release happened to be less than 0.74 MΩ, the potential between L1–L2 would become unstable, fluctuating roughly between –48 V and –28 V directly after the on-hook operation*. The waveform at this time is shown in **Fig. 7**.

b) We confirmed that no IR signal would be issued if an incoming-call polarity reversal occurred while the L1–L2 potential in the analog-interface interval was unstable. The waveform at this time is shown in **Fig. 8**.

2.2.5 Cause of fault

Specifications of the VoIP-GW installed on the customer's premises stipulated various electrical conditions with respect to branch connections, so we checked whether the customer's equipment setup conformed to those conditions. One of the conditions was that the value of DC resistance between L1–L2 was to be 1 MΩ or greater, but we found from measurements that the value was only 0.6 MΩ.

We therefore surmised that VoIP-GW operation would be unstable and that this fault would occur since the stipulated conditions for branch connections were not being observed.

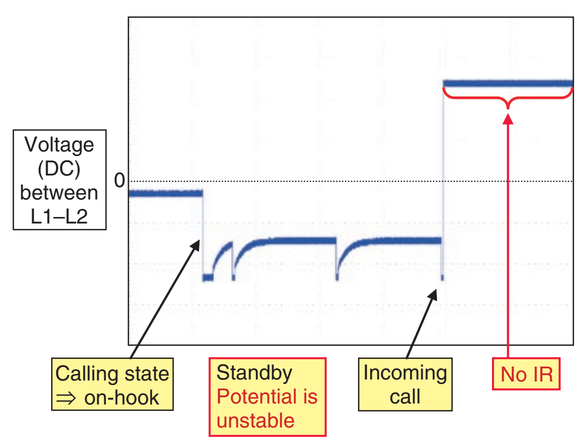

Fig. 8. Waveform at time of incoming call with no ringing sound.

* Potential was stable when using another analog-interface circuit.

2.2.6 Countermeasure and effect

The countermeasure that we implemented to keep DC resistance between L1–L2 at 1 MΩ or greater and to prevent this fault from occurring was to install a switching device instead of branch connections and to apply a switching method to be used in the PBX and IVR equipment.

2.2.7 Summary

We surmised that no ringing occurred when receiving calls from the outside since branch-connection conditions stipulated in the specifications of VoIP-GW equipment installed after the change from an analog line to Hikari Denwa were not being observed.

3. Conclusion

This article introduced two case studies of faults occurring in an IP phone circuit accommodating a PBX via a VoIP-GW. The first case was solved by analyzing a call log and the signals/packets in the analog-interface/Ethernet sections. In the second case, investigating the customer's network system to determine whether it satisfied the required specifications led to the solution. To achieve these troubleshooting results, it is necessary to be familiar with analog and IP technologies as well as the equipment or system requirements. With current technologies, a switchover to an analog interface can occur by using a VoIP-GW when accommodating a PBX in an IP phone circuit, so it is essential that knowledge of legacy systems in addition to that of IP systems be brought to the troubleshooting process.

External Awards

Spectroscopy & Innovation Award

Winner: Yuko Ueno, NTT Basic Research Laboratories
Date: May 29, 2014
Organization: Spectroscopy & Innovation Consortium

For "Introduction of My Research Career at NTT R&D Center".

The lecture discussed applications of spectroscopy in the industrial field.

Best Paper Award

Winner: Akisato Kimura, NTT Communication Science Laboratories; Ryo Yonetani, The University of Tokyo; Takatsugu Hirayama, Nagoya University
Date: June 11, 2014
Organization: IEICE-ISS (Information and Systems Society of The Institute of Electronics, Information and Communication Engineers)

For "Computational Models of Human Visual Attention and Their Implementations: A Survey".

We humans are easily able to instantaneously detect the regions in a visual scene that are most likely to contain something of interest. Exploiting this pre-selection mechanism called visual attention for image and video processing systems would make them more sophisticated and therefore more useful. This paper briefly describes various computational models of human visual attention and their development, as well as related psychophysical findings. In particular, our objective is to carefully distinguish several types of studies related to human visual attention and saliency as a measure of attentiveness, and to provide a taxonomy from several viewpoints such as the main objective, the use of additional cues, and mathematical principles. This survey finally discusses possible future directions for research into human visual attention and saliency computation.

Papers Published in Technical Journals and Conference Proceedings

Giving Context to Sounds through Mediation of Physical Objects

S. Sato, M. Takahashi, and M. Matsuo

Proc. of The 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2013), Session of Poster, Demo, & Video Presentations, pp. 91–94, Zurich, Switzerland, September 2013.

We describe the concept of and approach for combining conceptual information produced by humans and data that convey situations of the real world without any modification or interpretation, which can be thought of as a method for bridging the web and the real world. We conducted an experiment to validate our concept by making associations between everyday topics or situations and their characteristic sounds. We discuss the preliminary results obtained in the experiment.

An Evaluation of Method for Encouraging Participation

H. Kawasaki, A. Yamamoto, H. Kurasawa, H. Sato, M. Nakamura, and R. Kakinuma

Proc. of UbiComp 2013, Session of 2nd ACM International Workshop on Mobile Systems for Computational Social Science, pp. 883–890, Zurich, Switzerland, September 2013.

Much attention is being focused on participatory sensing, in which real-world data are collected using personal mobile devices as sensor nodes to sense various conditions of the world we live in. In participatory sensing, there is a problem in that the supply of data is insufficient if users are not motivated to participate in sensing services. We previously proposed Top of Worlds, a method for encouraging user participation by presenting rankings in multidimensional hierarchical sets. In this paper, we describe the development of a ranking system and a real-world evaluation to confirm that Top of Worlds can encourage user participation.

Maximum Likelihood Factor Analysis with a Large Number of Missing Values

K. Hirose, S. Kim, Y. Kano, M. Imada, M. Yoshida, and M. Matsuo

Proc. of ERCIM 2013 (The 6th International Conference of the ERCIM WG on Computational and Methodological Statistics), pp. 585–612, London, England, December 2013.

We considered the problem of full information maximum likelihood (FIML) estimation in a factor analysis model when a majority of the data values are missing. The expectation-maximization (EM) algorithm is often used to find the FIML estimates, in which the missing values on observed variables are included in complete data. However, the EM algorithm has an extremely high computational cost when the number of observations is large and/or plenty of missing values are involved. We propose a new algorithm that is based on the EM algorithm but that efficiently computes the FIML estimates. A significant improvement in the computational speed is realized by not treating the missing values on observed variables as part of the complete data. Our algorithm is applied to a real data set collected from a web questionnaire that asks about first impressions of human; almost 90% of the data values are missing. When there are many missing data values, it is not clear if the FIML procedure can achieve good estimation accuracy even if the number of observations is large. In order to investigate this, we conduct Monte Carlo simulations under a wide variety of sample sizes.

Dynamic Load-distribution Method of uTupleSpace Data-sharing Mechanism for Ubiquitous Data

Y. Arakawa, K. Kashiwagi, T. Nakamura, and M. Nakamura

IEICE Trans. on Information and Systems, Vol. E97-D, No. 4, pp. 644–653, April 2014.

We propose a new load-distribution method using a DHT (distributed hash table) called the dynamic-help method. The proposed method enables one or more peers to handle loads related to the same hash value redundantly. This makes it possible to handle the large load related to one hash value by distributing the load among peers. Moreover, the proposed method reduces the load caused by dynamic load-redistribution. Evaluation experiments showed that the proposed method achieved sufficient load-distribution even when the load was concentrated on one hash value with low overhead. We also confirmed that the proposed method enabled uTupleSpace to accommodate the increasing load with simple operational rules stably and with economic efficiency.

Evaluating Translation Quality with Word Order Correlations

T. Hirao, H. Isozaki, K. Sudoh, K. Duh, H, Tsukada, and M. Nagata

Journal of Natural Language Processing, Vol. 21, No. 3, pp. 421–444, June 2014.

Automatic evaluation of machine translation (MT) quality is essential to develop high-quality MT systems. Various evaluation metrics have been proposed, and among them, BLEU is widely used as the de facto standard metric. However, the previous methods have some problems. BLEU does not care about global word order, and this severe mistake is not penalized very much. In order to consider global word order, this paper proposes a lenient automatic evaluation metric based on rank correlation of word order. By focusing on only words common between the two translations, this method is lenient with the use of alternative words. The difference of words is measured by the precision of words, and its weight is controlled by a parameter. When the proposed method was applied using submissions of NTCIR-7 & 9's Patent Translation task, it outperformed conventional measures in terms of system level comparison.

Automatic Vocabulary Adaptation Based on Semantic and Acoustic Similarities

S. Yamahata, H. Masataki, Y. Yamaguchi, A. Ogawa, O. Yoshioka, and S. Takahashi

IEICE Trans. on Information and Systems, Vol. E97-D, No. 6, pp. 1488–1496, June 2014.

Recognition errors caused by out-of-vocabulary (OOV) words lead to critical problems when developing spoken language understanding systems based on automatic speech recognition technology. Automatic vocabulary adaptation is an essential technique to solve these problems. In this paper, we propose a novel and effective automatic vocabulary adaptation method. Our method selects OOV words from relevant documents using combined scores of semantic and acoustic similarities. With this combined score that reflects both semantic and acoustic aspects, only necessary OOV words can be selected without registering redundant words. In addition, our method estimates probabilities of OOV words using semantic similarity and a class-based N-gram language model. Experimental results show that our method improves OOV selection accuracy and recognition accuracy of newly registered words in comparison with conventional methods.

Creating Stories from Socially Curated Microblog Messages

K. Duh, A. Kimura, T. Hirao, K. Ishiguro, T. Iwata, and A. Yeung

IEICE Trans. on Information and Systems, Vol. E97-D, No. 6, pp. 1557–1566, June 2014.

Social curation is characterized as a human-in-the-loop and sometimes crowd-sourced mechanism for exploiting social media as sensors. Although social curation web services such as Togetter, Naver Matome, and Storify are gaining popularity, little academic research has been done to study the phenomenon. In this paper, our goal is to investigate the phenomenon and potential of this new field of social curation. First, we perform an in-depth analysis of a large corpus of curated microblog data. We seek to understand why and how people participate in this laborious curation process. We then explore new ways in which information retrieval and machine learning technologies can be used to assist curators. In particular, we propose a novel method based on a learning-to-rank framework that increases the curator's productivity and breadth of perspective by suggesting which novel microblogs should be added to the curated content.

Probing the Time Course of Head-motion Cues Integration during Auditory Scene Analysis

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Frontiers in Neuroscience, Vol. 8, No. 6, Article 170, June 2014.

We showed that motor cues had a different time course compared to acoustic or subjective location cues; motor cues impacted perceptual organization earlier and for a short time than other cues, with successive positive and negative contributions to auditory streaming. An additional experiment controlled for volitional control components, and found that arm or leg movements did not have any impact on scene analysis.

Mechanical Resonance Characteristics of a Cylindrical Semiconductor Heterostructure Containing a High Mobility Two-dimensional Electron Gas

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Physical Review B, Vol. 89, 245304, June 2014.

We investigate the mechanical resonance characteristics of semiconductor rolled-up tubes containing a high-mobility two-dimensional electron gas (HM2DEG) by optical and electrical means. The observed mode frequencies are in an excellent agreement with the theoretically calculated frequencies for the ground bending and excited bending and axial modes. The effect of the curvature is to increase the frequencies of the ground bending modes and the axial wave modes, while decreasing the frequencies of the first excited bending modes. We find significant splitting of the bending and twisting modes by the residual stress effects due to axial shear relaxation in z-dependent modes. The HM2DEG interacts with the mechanical motion due to Eddy currents and embedded impedances. A prominent asymmetry appears in the vibration amplitude with respect to the direction of the magnetic field. This originates from the broken symmetry of the HM2DEG on the curved surfaces.

Single-electron Thermal Noise

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We report the observation of thermal noise in the motion of single electrons in an ultimately small dynamic random access memory (DRAM). The nanometer-scale transistors that compose the DRAM resolve the thermal noise in single-electron motion. A complete set of fundamental tests conducted on this single-electron thermal noise shows that the noise perfectly follows all the aspects predicted by statistical mechanics, which include the occupation probability, the law of equipartition, a detailed balance, and the law of kT/C. In addition, the counting statistics on the directional motion, i.e., the current, of the single-electron thermal noise indicate that this noise can be described as hot noise as well.
