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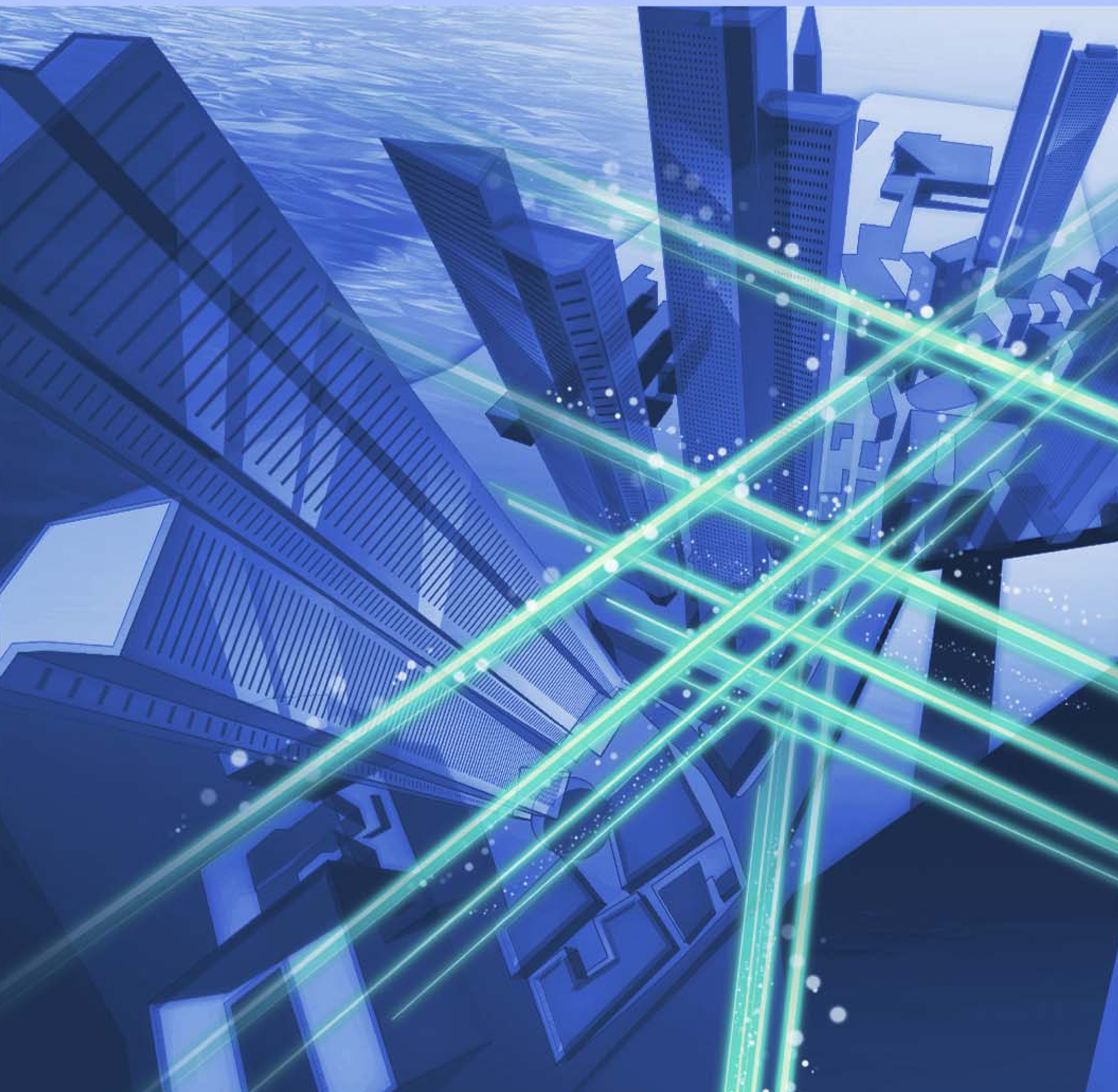

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Future Network Technologies for the 5G/IoT Era

Yukari Tsuji, Arata Itoh, and Masaki Kobayashi

Abstract

The social environment is changing rapidly, and with these changes, society is coming to have great expectations for the future network. NTT is researching and developing technologies for achieving a flexible and smart network as a new social infrastructure that will be able to meet a wide variety of needs. This article describes the direction of research and development at NTT with an eye to 2020 and beyond centered on the three pillars of 5G/IoT (fifth-generation mobile communications/Internet of Things), Network-AI (NTT's artificial intelligence applied to networks), and open source software, while providing an overview of activities done in collaboration with NTT Group companies.

Keywords: 5G/IoT, Network-AI, OSS

1. Environmental changes and social issues surrounding the network

The social environment and structure are changing against a background of technical innovations and paradigm shifts in many fields. The field of information and communication technology (ICT) is no exception. Numerous social problems and issues in business operations are occurring due to external factors such as globalization, a decline in the working-age population, climate variability, natural disasters, and internal factors originating within the network such as digitization, the explosive growth in Internet traffic, and cyberattacks. Despite these issues, the ICT industry is rapidly entering an era highlighted by the convergence of communications and information thanks to the Internet and by co-creation driven by mobile communications and cloud computing. In response to these changes, NTT has defined a business-to-business-to-X (B2B2X) model, and with an eye to new business and market formats, it has undertaken the research and development (R&D) of technologies to support changes in the business models of service providers and changes in lifestyle brought on by subsequent creation of new value.

In this era of change, we consider fifth-generation mobile communications and Internet of Things (5G/IoT) and artificial intelligence applied to networks (Network-AI) to be key underlying technologies for achieving a smart and flexible network to meet the diverse demands of society and to solve the social and business issues surrounding the network. Additionally, as part of this flow, we are studying open source software (OSS) for use as the core technology in the transformation of network system development at NTT. We therefore treat these three technologies as pillars of R&D targeting the NTT network system. In this article, we describe how each of these three key technologies relates to the NTT network, and we touch on future challenges.

2. Future network architecture toward the 5G/IoT era

In anticipation of the arrival of the 5G/IoT and B2B2X era, NTT aims to contribute to new services and value creation by providing many and varied functions desired by diverse service providers in diverse industries in a simple and speedy manner [1].

Here, the virtualization of network functions (softwarization) is an underlying technology to be implemented in the next-generation network. In recent years, the R&D of virtualization technologies, namely, network functions virtualization and software-defined networking, has been progressing along with the standardization of interfaces between segmented functions. A network or computing resource that has been virtually constructed on a physical resource or device is called a *network slice*. To achieve such slices as part of a telecommunications carrier's network, the NTT laboratories have undertaken R&D of slice-management and slice-isolation technologies [2].

In the future, the access network, which serves as the customer's gate to services, will provide higher speeds and capacities, guaranteed and optimal end-to-end quality, and flexible placement of functions (including softwarization). The aim here is to provide high-value-added services and enable new lifestyles by giving the access facilities supporting the access network smart design, maintenance, and operation capabilities [3].

3. Advanced and smart network operation through AI technologies

In May 2016, the NTT Group unified its AI-related technologies and some initiatives using those technologies under the brand name corevo® [4]. The AI technologies that make up corevo are classified into Agent-AI, Heart-Touching-AI, Ambient-AI, and Network-AI. In the following, we report on Network-AI technologies.

In an environment of diversified ICT services driven by various changes happening in society (e.g., a decline in the working population) and expansion of the B2B2X business model, the technical development of AI for networks (Network-AI) is progressing with the aim of making network operation more efficient and providing greater value [5]. The business areas deemed favorable to the application of Network-AI and issues surrounding its practical use have been clarified based on a series of technical developments and field trials.

The NTT laboratories have selected two business areas for further R&D of Network-AI applications. The first area is the use of AI to achieve automated and skill-less processes. In this area, the target is to find cause-and-effect relationships (rules and logic) using AI. The second area is the use of AI to provide human assistance. The target here is to uncover abnormal trends in a process from massive amounts of log data by using deep learning or other techniques to give the operator of that process an enhanced sense of awareness.

An example of the former would be using AI to infer cause-and-effect in the occurrence of alarms and failures or to visualize work traditionally performed by people and to formulate rules with respect to that work. This would be accomplished by using machine learning to analyze documents that freely record behavior when responding to a failure and visualizing the procedures taken in response to a problem (implicit knowledge) as workflow. The goal here is to raise efficiency by having AI do the work that people have been doing up to now. An example of the latter would be using AI in failure judgment and proactive (design and) operation that up to now has been based on threshold values. In particular, AI would be used to spot the seeds of an abnormal occurrence that a human operator has not been capable of noticing and to then predict future behavior and provide feedback to the operator.

To achieve practical use of Network-AI, it is becoming clear that (1) correct answers (correct decisions) must be continuously learned, (2) the decision-making process is a black box unknown to people, and (3) 100% correct answers cannot be derived. Here, a mechanism that uses AI while continuously learning is necessary, and since 100% accuracy in detecting signs of a failure cannot be guaranteed, there is a need for an operation that uses AI output skillfully, taking this limitation into account. At the time of its introduction, AI will not be adept at all business tasks but will be more like an entry-level employee that has to learn and develop just like the rest of us. However, a day will come when this *entry-level employee* starts to provide human employees with assistance.

To resolve these issues surrounding the practical use of AI, the plan is to further accelerate trials using actual data (set up learning environments) and to promote a revolution in work style making good use of AI-based support tools toward advanced and smart network operation.

4. An open and community-based development of network system

The types of participants in the ICT product market including communications equipment is diversifying thanks to the growing influence of OTT (over-the-top) operators, the use of ICT products in the communications industry, the increasing percentage of communication functions and services provided by software, and the standardization of procurement specifications by industry groups. At the same time, the movement promoting the use of OSS is growing in the network and network-management area while continuing in the cloud area, and the network-related OSS community continues to expand.

In response to these changes, the NTT laboratories are working to transform their network system development techniques. While the future network system will be based on the *right product in the right place* principle that places demands on business and service needs, the use of OSS and white box-type hardware is expected to increase even further. The NTT laboratories will explore network system development techniques using the wisdom of the open community and will become actively involved in community activities while leveraging the technological competence and know-how of a telecommunications carrier [6]. In this way, we hope to reduce development investment costs and to heighten corporate value through dissemination of our technical capabilities.

From the perspective of those who advocate using an open network system, the problem arises as to who takes responsibility for handling frequent version upgrades and fatal security holes that become evident in OSS operation. To deal with this problem, the entire NTT Group and global players, including both developers and operators, need to create and enhance OSS products and raise the skills of personnel who use OSS on an ongoing basis. This effort will proceed in collaboration with NTT Group companies.

Another issue of a medium- and long-term nature is the building of collaborative and co-creative relationships with commercial vendors that have many and varied products. Far from becoming fixed on only the open community, the NTT laboratories seek to establish a scheme of applying the knowledge and techniques obtained through OSS to commercial products in cooperation with diverse vendors. In this way, we aim to reduce investment costs and operating expenses and improve service quality through the use of commercial products [7, 8].

5. Challenges for 2020 and beyond

In the world of 2020 and beyond, where cyberspace and physical space converge, the information and communication network will come to support mission-critical social infrastructures. One example of such an infrastructure is connected cars. There is also no doubt that information and communication networks will support high-definition video transmission, remote medicine, and other functions and will become increasingly important as new social infrastructures. Becoming a social infrastructure requires that the quality, reliability, fault resilience, neutrality, and security demanded by society be satisfied.

Amid these changes, we can expect an exponential increase in digital service traffic. The nature of traffic is also bound to change. For example, we can expect an increase in geographically restricted traffic and inter-device traffic as in IoT. NTT is working to solve these problems by developing technologies for increasing the capacity of the optical access and core networks, controlling quality and traffic on a software-implemented network, and dealing with local traffic. Multi-access edge computing (MEC) is one such promising technology. There are growing expectations that MEC will enable distributed placement of optimal functions by bringing the network even closer to devices and enabling diverse forms of access. To this end, the technical development of MEC is progressing.

Going forward, the NTT Group plans to use network, AI, IoT, and security technologies and promote open collaboration with diverse industries with the aim of solving social problems, increasing industrial value and competitiveness, and creating a more secure and enriching society.

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Yukari Tsuji

Vice President, NTT Network Technology Laboratories.

She received a B.S. and M.S. in information science from the University of Tsukuba, Ibaraki, in 1987 and 1989, and an MBA in the Sloan Fellows Program from Massachusetts Institute of Technology, USA, in 2005. She joined NTT in 1989 and began researching and developing asynchronous transfer mode (ATM) switches and various services. She was promoted to Executive Director of the R&D Center at NTT WEST in 2013. She has been in her present position since July 2016. She is a member of the Science Council of Japan.

Arata Itoh

Vice President, NTT Network Service Systems Laboratories.

He received a B.E. and M.E. from Tokyo Institute of Technology in 1986 and 1988. Since joining NTT in 1988, he has conducted R&D of ATM based multimedia switching architecture and NGN (Next Generation Network). He has also been involved with the NTT EAST/WEST R&D Center and the R&D vision group of the NTT R&D Planning Department.

Masaki Kobayashi

Vice President, NTT Access Network Service Systems Laboratories.

He received a B.E. in engineering from Hokkaido University in 1989. He joined NTT in 1989 and was primarily involved in facility management and planning of telecommunication systems at NTT EAST. He was a Senior Manager of the Corporate Strategy Planning Department at NTT-ME from 2007 to 2010. He also served as a Senior Manager of the General Affairs and Personnel Department at NTT EAST. He has been in his current position since July 2017.

Leveraging General-purpose Technology and Open Community Activities

Masafumi Shimizu, Yasuyuki Matsuoka, and Junko Sasaki

Abstract

The NTT laboratories are revolutionizing their development techniques for network systems in order to support a collaboration model and respond flexibly to market changes and technology trends. This article describes our approach to building function groups using open source software and hardware components and introduces our activities in the open community.

Keywords: OSS, open innovation, community activities

1. Environment surrounding network systems

The environment surrounding network systems can be described from three key perspectives: a change in technology trends, a change in trends of Japanese/overseas telecom carriers and vendors, and a change in business structure.

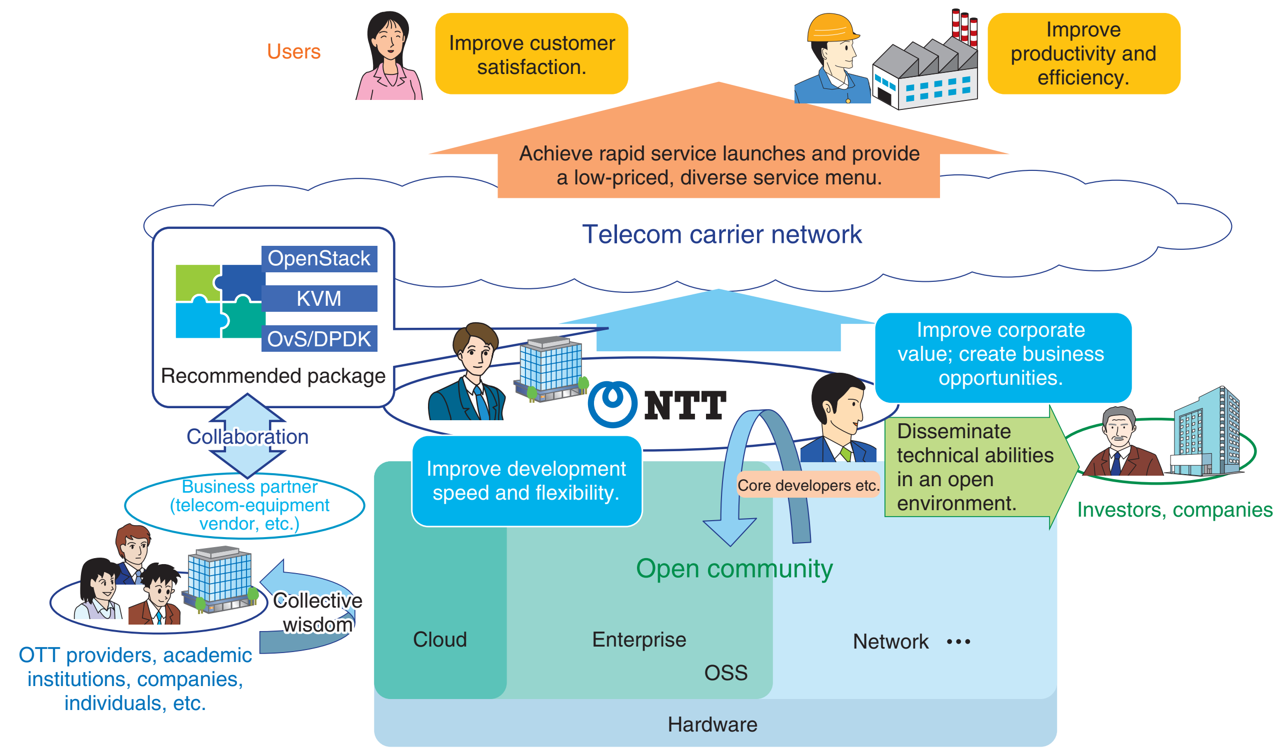
1.1 Change in technology trends (conversion to general-purpose technology)

An examination of hardware technology trends in information and communication technology products reveals that functions heretofore implemented using specialized equipment for telecom carriers are now being achieved using general-purpose devices at an accelerating rate. In particular, high-performance general-purpose processors are enabling functions traditionally processed by hardware to be done by software, and at the same time, hardware and software are becoming increasingly separated through virtualization, enabling functions to be implemented with an even higher degree of freedom. In the datacenter industry, there are many open source software (OSS) packages that can be openly used on a licensing basis. At NTT, we are actively using and contributing to OSS developed within the NTT Group while playing a core role in the global OSS community. The use of OSS makes it possible to achieve reliability and long-term stability through inspection of code in open forums and to achieve a high level of flexibility by responding to diverse user needs. It therefore promotes greater flexibility and speed in software development.

1.2 Change in trends of Japanese/overseas telecom carriers and vendors

Compared to the situation in the datacenter industry, equipment development in the telecom-carrier network field has traditionally been slow, and it has been costly to achieve large-scale, high-reliability, and high-performance networks.

However, OTT (over-the-top) service providers and the so-called *hyper giants* in particular have adopted open product architecture to create an extensive product market whose application scope is rapidly expanding from cloud systems to enterprise and network systems. In line with this movement, telecom-equipment vendors have begun to use such open functions when implementing products. Some telecom carriers in Europe and the United States, moreover, have begun to open up their own products and hold community-based implementation-promotion



DPDK: Data Plane Development Kit
KVM: Kernel-based Virtual Machine
OvS: Open vSwitch

Fig. 1. Revolution in network-system development.

activities with the aim of improving their products and applying them to telecom carrier networks. As a result, it appears that the trend toward system development that assumes the embedding of OSS will accelerate all the more in the field of telecom carrier networks.

In addition, we can expect the proactive participation of telecom carriers in the OSS community through contributions and other activities to speed up the adoption of requirements in the field of telecom carrier networks. Such activities can enhance a telecom carrier's visibility among customers, investors, and business partners, improve corporate value, and create new business opportunities.

1.3 Change in business structure

At NTT, the transition from a B2C (business-to-consumer) to a B2B2X (business-to-business-to-X) model is accelerating, and as a result, there is a growing need to provide prompt and flexible network functions tailored to the needs of the second *B* (business partners). Consequently, there is also a need in the field of telecom carrier networks to achieve functions that meet the needs of customers in a more flexible, cheaper, and faster manner.

2. Revolutionizing network-system development using OSS

In light of the above changes in the business environment, NTT is revolutionizing its network-system development techniques to accelerate the modularization and combination of network functions. The overall goal is to create a flexible network that can give the service menu more degrees of freedom and facilitate the speedy provision of services. At NTT, we seek to accelerate such modular-type development by making a transition from the conventional in-house development and procurement method to a method that uses OSS and general-purpose hardware components and that works to incorporate telecom-carrier requirements in the open-source community for implementation in OSS (**Fig. 1**).

The following two issues must be addressed in the

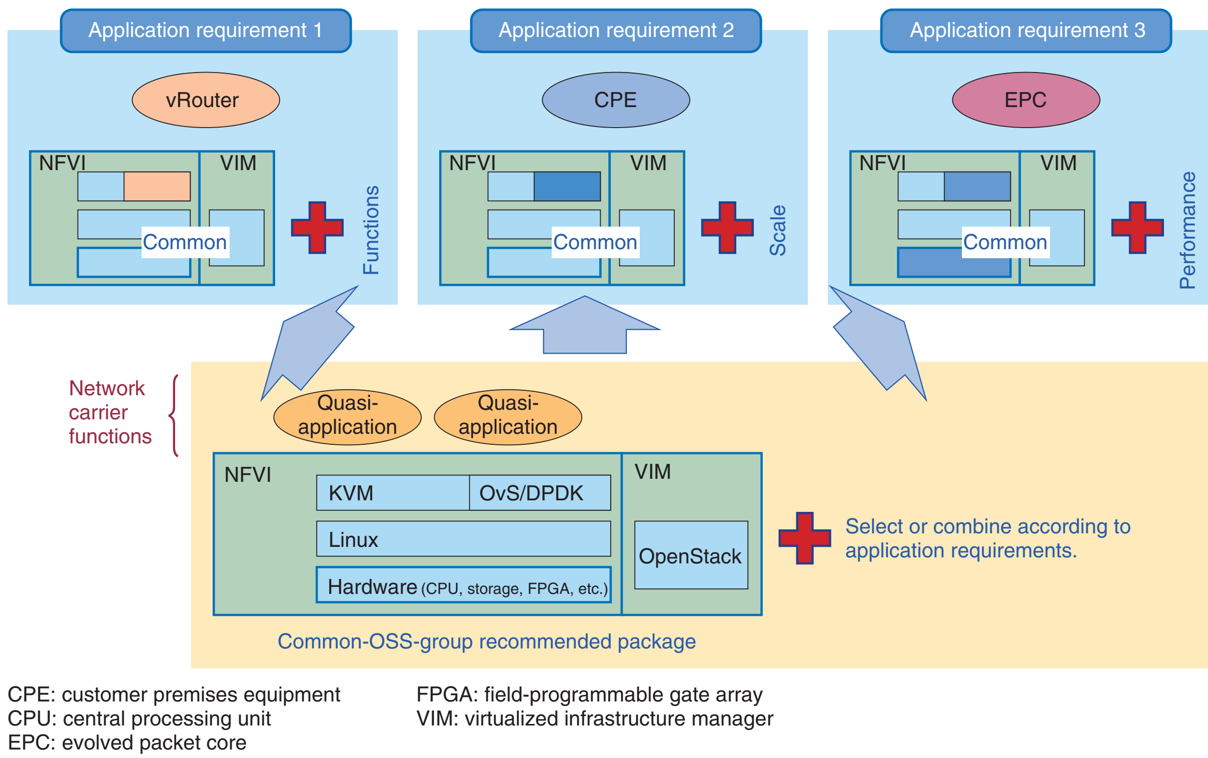


Fig. 2. Building function groups.

use of OSS:

(1) Accumulating know-how in building functions consisting of OSS components conforming to standard architecture

(2) Finding methods of dealing immediately with missing OSS functions or software bugs

To resolve these issues, we are building function groups and taking part in open-source community activities as described below.

2.1 Building of function groups

System implementation in the case of a telecom carrier network requires the provision of functions that combine a wide variety of hardware and software, products from various companies, and OSS as well as those in many variations including different software versions. A telecom carrier network, in particular, requires that an optimal combination of functions be selected to satisfy its functional and nonfunctional requirements. As a means of meeting this need, we are providing a common-OSS-group recommended package that compiles functions that can be used in common while having a business partner such as a vendor decide on a recommended pattern according to application requirements and provide the associated software.

We consider, for example, cases of building function groups conforming to network functions virtualization (NFV) architecture now being standardized at the European Telecommunications Standards Institute (ETSI) [1]. Here, a virtual network function (VNF) consisting of diverse network functions runs above the network functions virtualization infrastructure (NFVI) and management and orchestration (MANO) sections. However, while NFVI and MANO are affected by VNF requirements, they are not dependent on specific network functions, so they can be assembled as common functions (**Fig. 2**).

The main features of this common function group composed of OSS are listed below.

- A platform that satisfies diverse VNF requirements
- Proactive use of OSS and general-purpose hardware
- An architecture that partially uses required functions
- Use of tools from the datacenter field
- Application of knowledge and know-how related

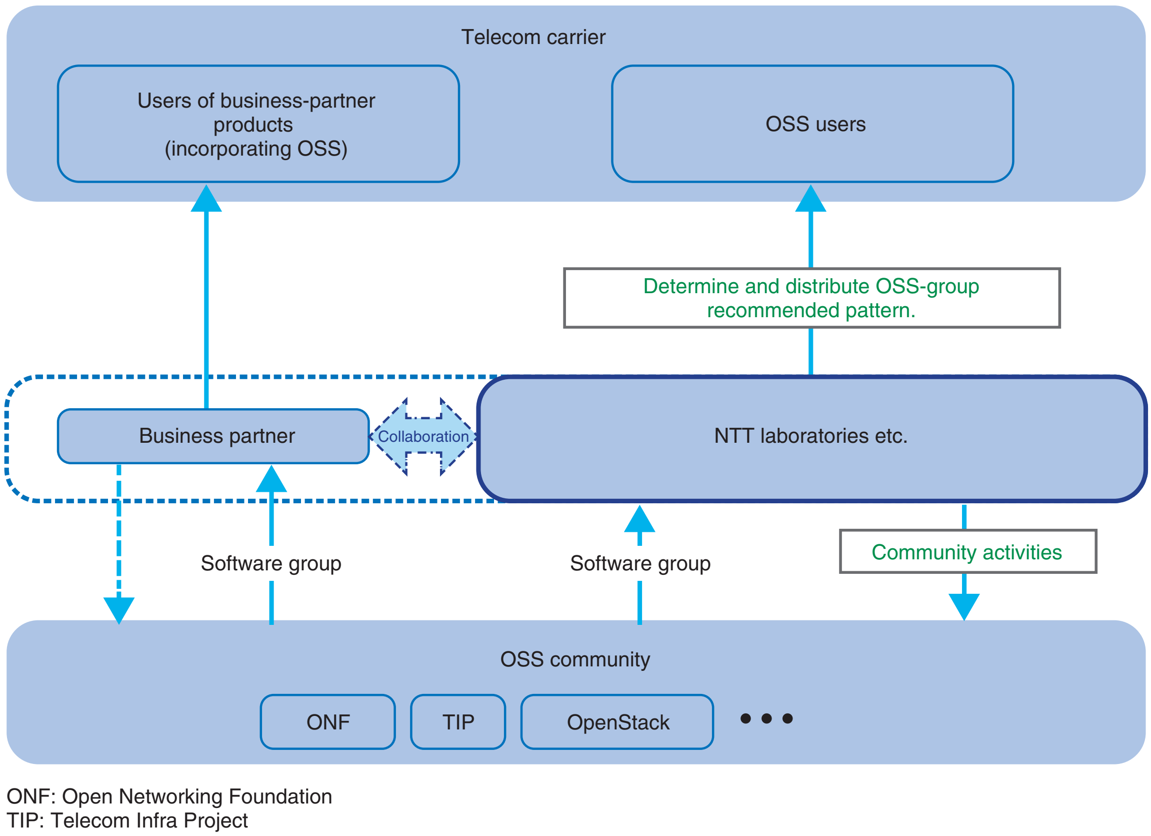


Fig. 3. Function-group building cycle.

to quality/maintenance management cultivated at NTT laboratories

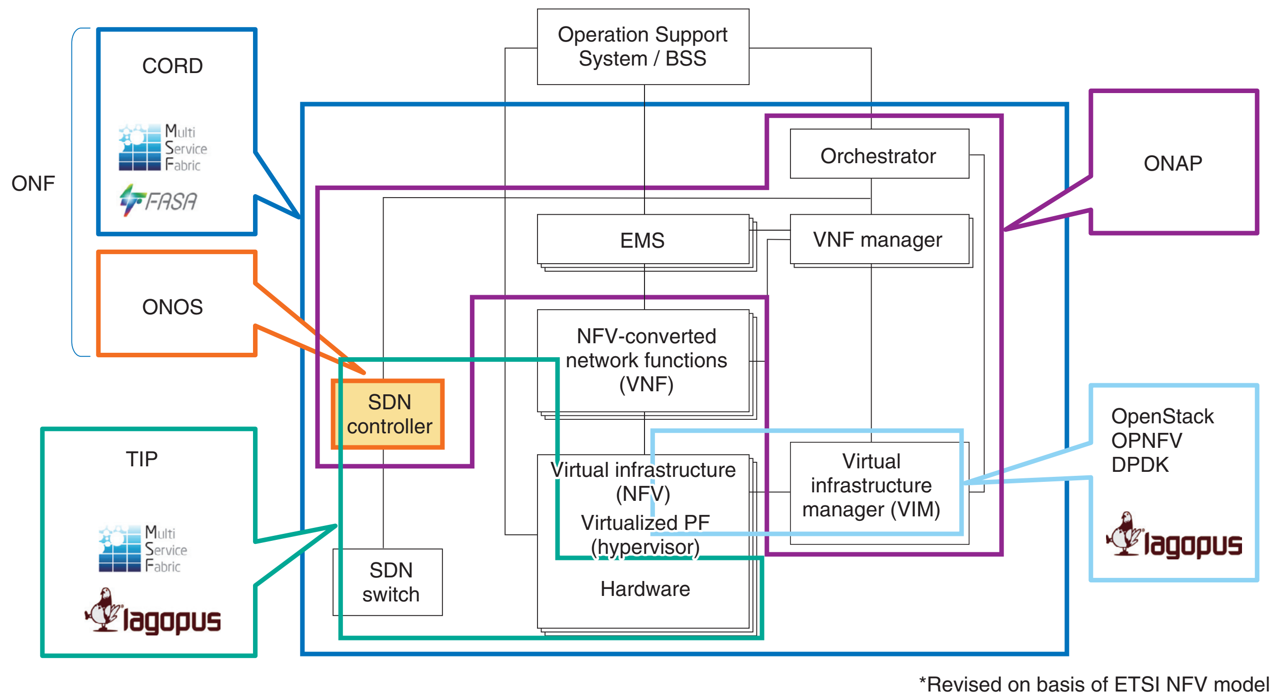
- Guarantee of connectivity to equipment from diverse vendors

This common function group can now be provided with software from a business partner who has determined a recommended pattern according to application requirements. This makes it possible to provide an operability-confirmed recommended package that extends as far as the application itself. This can simplify troubleshooting in the event of a problem and thereby reduce any system downtime (**Fig. 3**). Going forward, we will continue our efforts in resolving technical issues and easing requirements with the aim of expanding the use of this common function group.

2.2 Community activities

In system applications to a telecom carrier network, there will be times when an immediate response is needed in order to deal with missing OSS functions or software bugs. We can therefore envision cases in which missing functions are temporarily created, but continuing to respond in this manner can result in a dramatic increase in individual functions. Within the OSS community, however, publically released OSS may be objectively used and tested by engineers in various companies who may then point out software bugs or functional deficiencies. We can therefore expect software functions and quality corresponding to common requirements of telecom carriers to improve via the OSS community.

With this in mind, we are promoting community activities from the viewpoints of opening up NTT research and development products and conveying requirements to the OSS community. Here, we are examining existing OSS in terms of compatibility with telecom-carrier development strategies, degree of community activity, degree of software completion, and application fields and talking to specific communities that have a high affinity with our own products and a high OSS usage effect. Additionally, with respect to functions that we judge to be insufficient, we are conveying telecom-carrier requirements to the OSS community. The communities that we are



BSS: business support system
CORD: Central Office Re-architected as a Datacenter
EMS: element management system
ONAP: Open Network Automation Platform
ONOS: Open Networking Operating System
OPNFV: Open Platform for NFV
PF: platform
SDN: software-defined networking

Fig. 4. Targeted communities.

currently targeting based on this policy are shown in **Fig. 4**.

In the area of software-defined networking (SDN) switches and controllers, we are promoting Multi-Service Fabric (MSF) [2] technology developed by the NTT laboratories as part of our activities in the Telecom Infra Project (TIP) [3], which aims to standardize the next-generation SDN controller satisfying telecom carrier requirements. Similarly, with the aim of popularizing the Lagopus [4] switch developed by NTT laboratories within TIP, we are working toward a proof of concept demonstration. In Open Networking Foundation (ONF) activities [5], our contributions include feeding back to the community the results of an evaluation conducted by the NTT laboratories on CORD (Central Office Re-architected as a Datacenter)-3.0 from the viewpoint of a telecom carrier. Additionally, in the area of virtual infrastructure and virtual infrastructure management, we are making contributions to OpenStack [6], Open Platform for NFV (OPNFV) [7], and the Data Plane Development Kit (DPDK) [8]. At OPNFV, we are following up our activities in resource reservation technology in the Promise project with upstream activities in the OpenStack Blazar project.

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Masafumi Shimizu

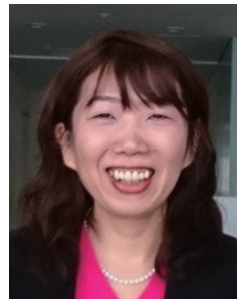
Senior Research Engineer, Network Systems Planning & Innovation Project, NTT Network Service Systems Laboratories.

He received a B.E. and M.E. in electrical engineering from Tokyo Institute of Technology in 1999 and 2001. He joined NTT Network Service Systems Laboratories in 2001 and studied IP/MPLS (Internet protocol/multiprotocol label switching) network system architecture. He was then engaged in developing IP network management systems of the Next Generation Network (NGN). During 2013–2017, he was with the R&D Vision Group, R&D Planning Department. His current interests include network virtualization technologies such as SDN and NFV, and OSS strategies. He received the Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Information and Communication Management research award in 2012.

Yasuyuki Matsuoka

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

He received a B.S. and M.S. in physics from the University of Tokyo in 1998 and 2000. He joined NTT Network Service Systems Laboratories in 2000, where he was involved in network design and systems development to launch the NGN. His current research is focused on virtualized networking and distributed computing technologies. He is a member of IEICE.



Junko Sasaki

Director, Network Systems Planning & Innovation Project, NTT Network Service Systems Laboratories.

She received a B.E. and M.E. in engineering from Osaka University in 1990 and 1992. She joined NTT in 1992 and moved to NTT Network Service Systems Laboratories in 2007. Her current interests include network virtualization technologies such as SDN and NFV, and OSS strategies.

Creating New Value by Leveraging Network-AI Technology in Service Operations

Keishiro Watanabe, Yasuhiro Ikeda, Yuusuke Nakano, Keisuke Ishibashi, Ryoichi Kawahara, and Satoshi Suzuki

Abstract

We present in this article an overview of recent research and development done at the NTT laboratories on artificial intelligence technology for networks (Network-AI) that enables proactive maintenance and operations of network services. We also describe some of the key technologies constituting Network-AI and review verification trials of these technologies conducted at an NTT operating company.

Keywords: Network-AI, proactive maintenance and operations, automation

1. Introduction

In order to forge ahead with the development of services while sustaining the services currently available in the face of social changes such as a declining population and ever more diversified communication services, we must have the ability to accurately assess the operational status of services and be able to upgrade and enhance services once they are up and running. The NTT laboratories strive to make service operations more efficient and to enhance service value and are therefore working to implement an autonomous control loop that cycles through the three phases of (1) gathering various types of information, (2) analyzing the collected information, and finally, (3) issuing accurate instructions and controls based on the analytical results in the planning, design, construction, maintenance, and operation of networks. By leveraging artificial intelligence technology for networks (Network-AI)*, we are now making good progress in developing more sophisticated operations and support systems.

Various Network-AI related initiatives are now under consideration. One such initiative is *resources-on-demand*, which automatically suggests and allocates optimal resources required by service providers. Another is *scheduled maintenance*, which eliminates the need for urgent maintenance once a network problem has already occurred. This will give us the ability to autonomously control the entire sequence of service events, from provisioning of services to maintenance and operations, and the entire NTT laboratory community is working toward this objective. This article focuses on key initiatives now underway with the goal of implementing scheduled maintenance.

2. Initiatives enabling scheduled maintenance

Two key capabilities are needed to make scheduled maintenance a practical reality. First, this would require a shift from reactive maintenance and operations that deals with faults and operational problems that have already occurred to proactive maintenance

* Network-AI: The NTT Group has adopted the brand name *corevo* for all its artificial intelligence (AI)-related research and development initiatives. Network-AI is one of the key elements of corevo.

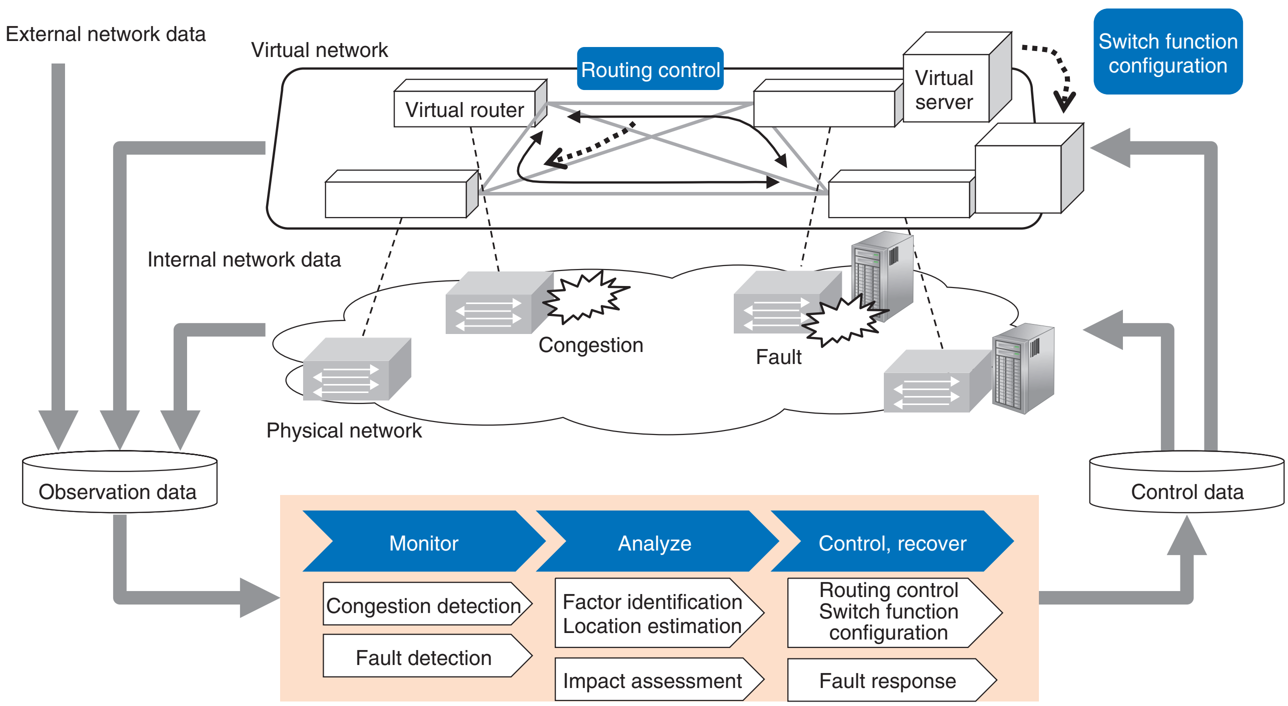


Fig. 1. Proactive controlled network [1].

and operations that focuses on preventing problems before they occur. Second, it requires systematic automated maintenance and operations that fully supports virtualization. The NTT laboratories have come up with the proactive controlled network concept as a way of implementing proactive maintenance and operations combined with automation. The idea behind a proactive controlled network is to anticipate potential performance degradation risks (e.g., outages, failures, and congestion) before they occur, to anticipate foreseeable changes in demand early on, and to achieve proactive control and early automatic recovery.

The proactive controlled network involves a sequence of typical operational phases for dealing with each type of risk: (1) monitor, (2) analyze, and (3) control and recover, as illustrated in **Fig. 1** [1], and we are developing key Network-AI technologies for each phase with the following objectives:

(1) Achieve proactive early detection of changes in network conditions due to degraded performance (congestion, equipment failure, etc.).

(2) Estimate degraded location and likely cause of the changes in network conditions.

(3) Take control to circumvent performance degradation, and implement early recovery.

Some of the core technologies being applied to implement these operational phases are indicated in **Fig. 2**.

We focus here on two of these technologies—*network anomaly detection*, a monitoring technology developed for early detection of anomalous events (e.g., silent failures), and *automatic failure points estimation*, an analysis technology. We also review the status of ongoing verification trials of the network anomaly detection technology that has been deployed and is now being evaluated at an NTT operating company.

3. Network anomaly detection technology

NTT Network Technology Laboratories is making headway in the development of an autoencoder (AE)-based network anomaly detection system designed to achieve early detection of changes in network conditions [2–4]. An AE is a kind of neural network capable of unsupervised learning of the intrinsic complex structure of data and is currently drawing a great deal of interest for anomaly detection applications.

We have utilized AE characteristics such that by setting the number of neurons in the hidden layer of the AE at less than those in the input layer, a data

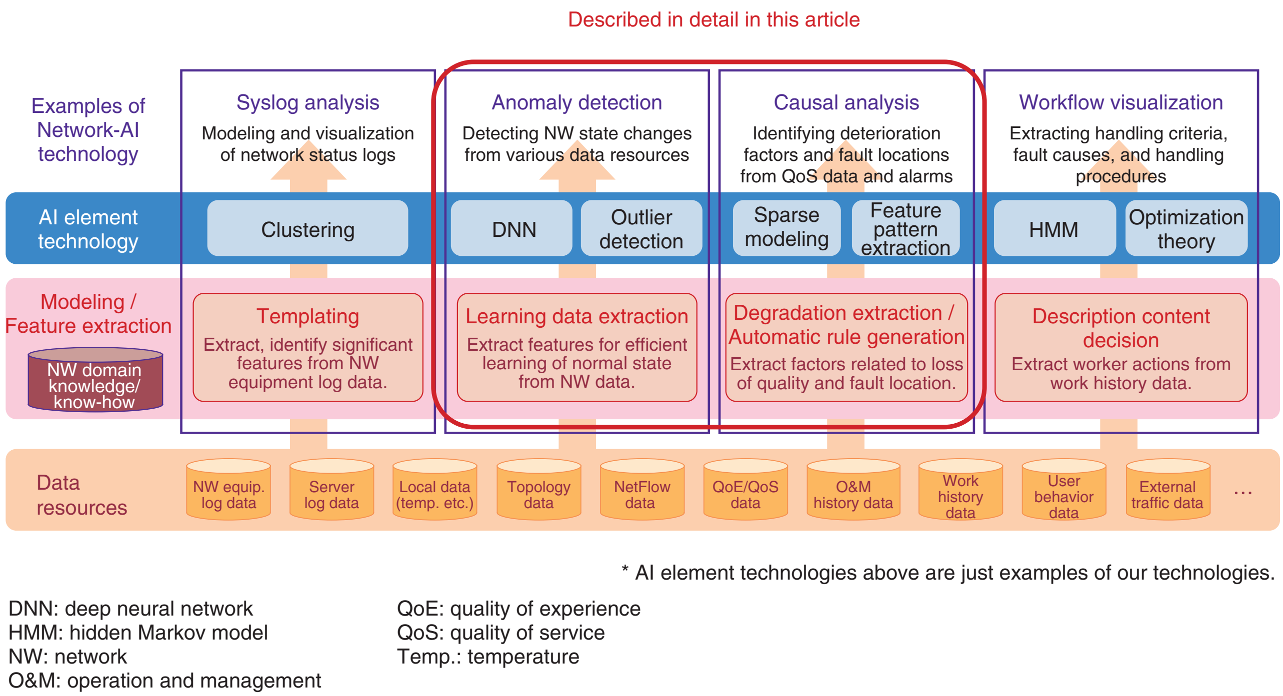


Fig. 2. Core technologies for achieving proactive controlled network.

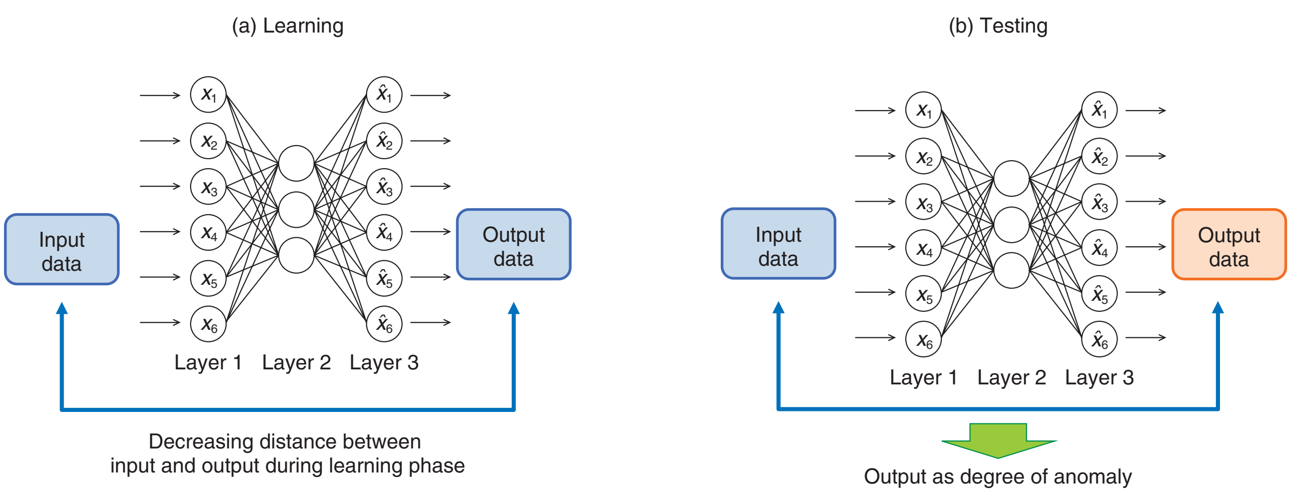


Fig. 3. AE-based anomaly detection.

dimension reduction occurs in the hidden layer by learning parameters to reconstruct the input layer data at the output layer. AE-based anomaly detection is based on the assumption that a normal data distribution is concentrated near a low-dimensional manifold in the input data space. During the learning phase shown in **Fig. 3(a)**, the normal state is learned by observing various types of data during normal operation of the network, while in the test or anomaly detection phase shown in **Fig. 3(b)**, current data are input to the AE learned as described above, and the distance between input and output layer vectors is output as the degree of anomaly. If the degree of anomaly exceeds a certain threshold, it is considered

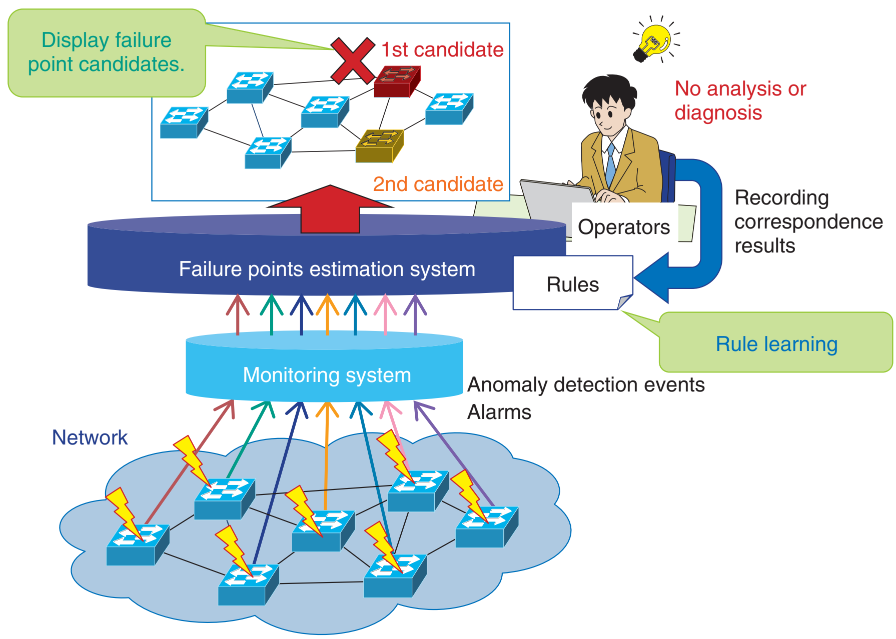


Fig. 4. Automatic failure points estimation system.

anomalous.

For our purposes, the network data that are input include numerical data such as resource/traffic data based on Simple Network Management Protocol and Management Information Base (SNMP/MIB) and flow data based on NetFlow as well as detailed text logs such as syslog data from routers and servers. To input syslog data to AE, we employ syslog analysis [5] to generate identifiers (IDs) from each syslog line, and text data are converted to numerical data based on message ID frequency analysis.

In addition to anomaly detection, efforts are also underway to identify the outlier factor when an anomaly is detected [6]. For example, if an anomaly is detected by AE, we estimate which input dimension is responsible for increasing the degree of anomaly by using a sparse-optimization technique. Calculating the contribution of each input dimension to the anomaly should make it much easier to isolate the problem after an anomaly is detected.

4. Automatic failure points estimation technology

Meanwhile, NTT Access Network Service Systems Laboratories is working on a related analytical scheme for locating network anomalies [7], as illustrated in **Fig. 4**. This system is designed to autonomously derive causal links between failure causes and alarms, or *rules*, from network information and alarms emitted by equipment that approximately locate the point of the failure. When a network anomaly is detected as described in the previous section, a detection event and proximate alarms generate a rule, which accurately predicts the points of the failure. This information is then used to send a command to circumvent the trouble and thus avoid a performance slowdown and/or commence rapid recovery of the service. Moreover, because new rules created to deal with new anomalies and failures are saved, the predictive accuracy of the system should improve over time.

5. Verification trials of network anomaly detection

We are now in the process of evaluating the network anomaly detection technology using real operational data from a testbed and actual services in collaboration with NTT operating companies. This will help us assess the effectiveness of our proposal and identify challenges that still need to be addressed. The trials now being conducted in collaboration with NTT Communications are described in this section.

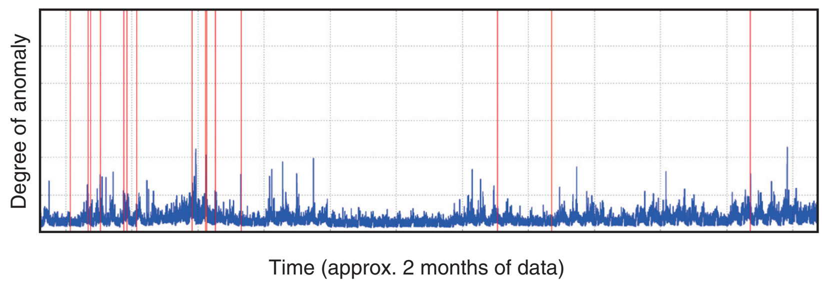


Fig. 5. Results of trial conducted with the Technology Development Department.

5.1 Collaboration with Technology Development Department

The Technology Development Department of NTT Communications operates a testbed that has been made available to NTT Communications for the development of their services. The department is also developing the Data Science Lab (DSL) on the testbed, which is a big-data analysis platform initiative to collect and analyze various types of service and infrastructure data with the idea of exploiting the data to create new service strategies and implement anomaly detection.

For this work, we evaluated the network anomaly detection technology developed by NTT Network Technology Laboratories on a range of typical operational data gathered on the DSL—SNMP/MIB, NetFlow, syslogs, trouble tickets, and the like—to assess the technology's practical performance and problems.

The basic architecture of the DSL is that of a reproducible analysis/research platform, which can reproduce analytical results and infrastructure as code. NTT Network Technology Laboratories' anomaly detection technology is currently containerized, and we are now working to integrate it on the DSL infrastructure.

In **Fig. 5**, we show anomaly data measured over a two-month time frame, with the degree of anomaly (blue line) on the vertical axis versus time on the horizontal axis. The vertical red lines indicate problems identified from trouble tickets issued during the testbed trials. The trouble tickets identify a range of problems—a server breakdown, a bug, a denial-of-service attack, and so on—and they agree remarkably well with the serious anomaly time slots shown on the graph.

However, there were other serious anomaly time slots detected with the anomaly detection technology that were not caught by the trouble tickets, so we are working to verify the effectiveness of the technology while trying to match up the detection results against actual incidents and events that occurred. In addition, there are a number of practical issues that must be resolved if we are to continually operate the anomaly detection technology on a real-time basis, and we are now addressing these issues.

5.2 Collaboration with Network Services Department

The Network Services Department of NTT Communications is currently trying to exploit AI to upgrade the service operations of a whole range of existing network services. For example, the MVNO (mobile virtual network operator) service that has attracted considerable interest and become immensely popular is a case in point, as the department seeks to exploit AI to implement anomaly detection in this service. More specifically, we have been experimenting with applying network anomaly detection to various types of resource data (utilization of central processing unit (CPU), memory, disk input/output, and so on.) on NTT Communications' virtualized service platform to see if we can detect singular events and shifts in the degree of anomaly during normal operation.

As a result, we found that it was possible to detect singular events from the degree of anomaly by AE and from the contribution of the input dimension (various kinds of time series numerical data) to the anomaly. We also observed a tendency for the anomaly degree to persist and to gradually change over longer time spans, and we were able to capture changes in system behavior manifested as changes in the degree of abnormality. In addition, we identified the specific input dimension causing the change in behavior by calculating to what degree the AE input dimension contributes to the anomaly.

From these analyses, we recognized the need for a mechanism that tracks system configuration changes (switching between act and standby, ID changes of the CPU used, and so on) and system behavior changes (changes in CPU, memory, traffic, and other patterns). Therefore, we are developing a statistical, quantitative, and relearning technology to implement such a mechanism. We also found that the new technology is capable of visualizing a range of before-and-after system state changes by clearly showing monitoring parameter trend changes when the system is upgraded.

We learned a great deal from carrying out this assessment. Work in the months ahead will focus on practically assessing anomaly detection using greater amounts of data, enhancing our interpretive capabilities after an anomaly has been detected, further testing and assessing the technology, and making efforts to build a more user-friendly implementation of the technology suitable for business environments.

6. Future development

We presented a broad overview of some of NTT laboratories' latest initiatives in the area of Network-AI, focusing on two key technologies—network anomaly detection and automatic failure points estimation—and briefly described verification trials of the network anomaly detection technology done in collaboration with an NTT operating company.

Network-AI clearly has enormous potential, and we are committed to following through with more research and development in this area. With regard to network anomaly detection in particular, we will continue to refine and upgrade this technology, conduct further verification trials in cooperation with NTT operating companies, lay the groundwork for prototypes, and eventually implement services using the technology. Network anomaly detection still faces a number of hurdles before it is ready for actual deployment. Most notably, we must improve our ability to interpret the factors involved when an anomaly is detected, and we must adapt the technology for use in different environments. Needless to say, we are hard at work in resolving these issues.

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Keishiro Watanabe
Senior Research Engineer, Traffic Engineering Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.
He received a B.E. and M.E. in satellite communications from Kyushu University in 2002 and 2004. After joining NTT, he conducted research on network management and QoE issues. He was with NTT Communications from 2012 to 2015. He is now working on the development of sophisticated operations of network systems by using AI. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Yasuhiro Ikeda
Researcher, Traffic Engineering Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.
He received a B.E. in applied physics and physico-informatics and an M.E. in applied physics from Keio University, Tokyo, in 2008 and 2010. Since joining NTT in 2010, he has been researching traffic analysis techniques for telecommunication networks. He received the IEICE Information Network Research Award in 2012. He is a member of IEICE.

Yuusuke Nakano
Research Engineer, Traffic Engineering Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.
He received an M.E. in system engineering from Wakayama University in 2005 and a Ph.D. in information science and technology from Osaka University in 2011. He joined NTT Network Service Systems Laboratories in 2005. He is currently with NTT Network Technology Laboratories. His research interests include network anomaly detection and web performance measurement and acceleration. He is a member of IEICE and the Information Processing Society of Japan.

Keisuke Ishibashi
Senior Research Engineer, Supervisor, NTT Network Technology Laboratories.
He received a B.S. and M.S. in mathematics from Tohoku University, Miyagi, in 1993 and 1995 and a Ph.D. in information science and technology from the University of Tokyo in 2005. Since joining NTT in 1995, he has been engaged in research on traffic issues in computer communication networks. He received the Information Network Research Award in 2002. Since 2017, he has also been a visiting professor at Osaka University. He is a member of the Institute of Electrical and Electronics Engineers (IEEE), IEICE, and the Operations Research Society of Japan (ORSJ).

Ryoichi Kawahara
Senior Research Engineer, Supervisor, Group Leader, Traffic Engineering Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories*.
He received an M.E. in automatic control and a Ph.D. in telecommunication engineering from Waseda University, Tokyo, in 1992 and 2001. Since joining NTT in 1992, he has been conducting research on traffic control for telecommunication networks, traffic measurement and analysis for Internet protocol networks, and network management. He received the Telecom System Technology Award from the Telecommunications Advancement Foundation in 2010, and Best Paper Awards from IEICE in 2003 and 2009. He is a member of IEICE, IEEE, and ORSJ.
*He left NTT at the end of March 2018.

Satoshi Suzuki
Senior Research Engineer, Access Network Operation Project, NTT Access Network Service Systems Laboratories.
He received an M.E. in global environmental engineering from Kyoto University in 1995. Since joining NTT in 1995, he has mainly been researching and developing network operation support systems in access and wide area Ethernet networks. He is a member of IEICE.

Initiatives toward Access Network Technology for the Beyond-5G Era

Hiroyuki Furukawa, Takahito Kirihara, Satoshi Narikawa, Katsuya Minami, Kenji Horikawa, Satoshi Ikeda, and Takeshi Arai

Abstract

We have been researching future end-user lifestyles and business transformations for carriers and other telecommunications providers that will be driven by changes in social contexts, particularly by changes in mobile, video, and Internet of Things related markets. From these changes, we identified necessary technologies to provide information and communication technology services that are expected to proliferate in the future. We present in this article our findings that examine future directions in the development of access network technology designed to realize the next-generation social infrastructure.

Keywords: access networks, future vision, advanced functionality

1. Social context changes driving lifestyle transformations

Numerous changes are occurring in society as technology advances, and they are leading to various transformations in lifestyles. In this section, we explore the background and expected outcome of these changes.

1.1 Background

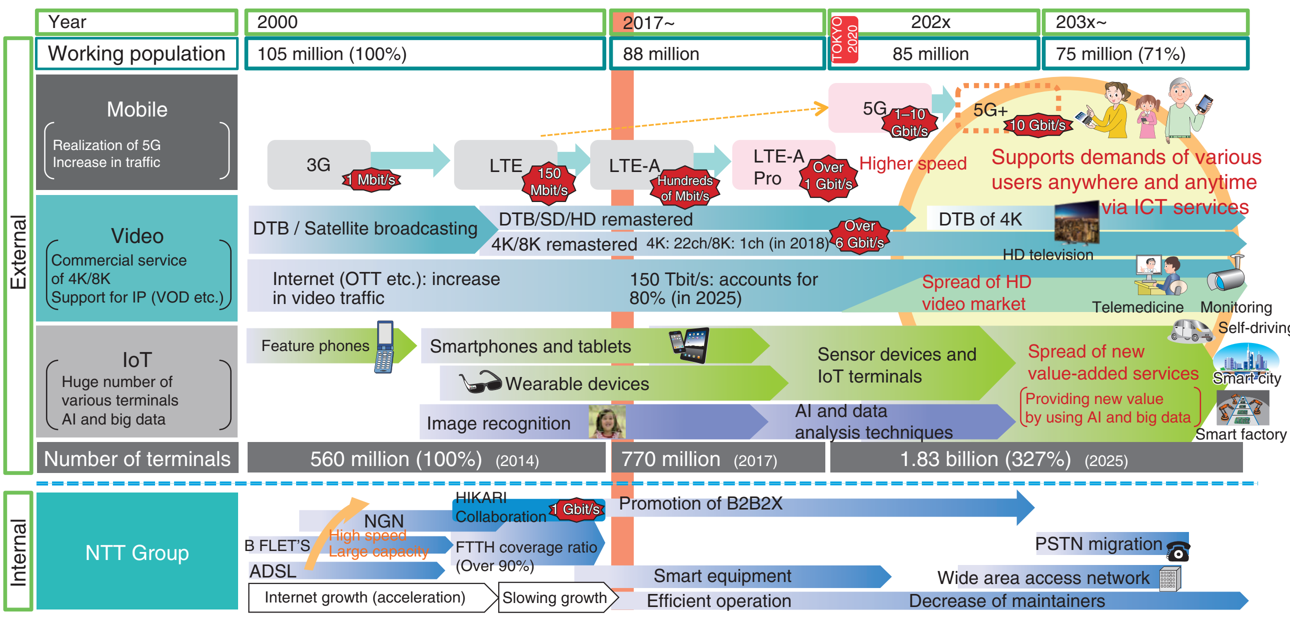
Technological advances and changes in the social context that have occurred and are expected to occur between 2000 and 203x are illustrated in **Fig. 1**. The time period from 2000 to the present has been the Internet technology growth period, as the number of Internet users increased with the introduction of high-speed and large-capacity services. The fifth-generation (5G) service is anticipated to arrive in the mobile market by 2020, which will boost transmission speeds a hundred-fold. By 202x, the 5G service area will have expanded, making 5G the foundational platform for information and communication technology (ICT) applications.

In the video content market, progress in practical 4K/8K applications is expected to heat up demand for retransmission of 4K/8K video over Internet protocol (IP) networks. In the worldwide Internet of Things (IoT) market, smartphones and tablets are the current growth drivers, but in the coming years, various types of IoT devices will be deployed such as smartwatches, smart glasses, and other wearables, as well as numerous types of sensors and imaging devices such as live cameras.

By 203x, we foresee enhanced broadband mobile communications with an expanding coverage area and the increasing use of multiple services. Additionally, the scope of the video content market will be expanded to not only broadcast and video content but also monitoring, remote medicine diagnosis, and other high-definition video applications. Furthermore, big data and artificial intelligence (AI) technologies will evolve and be used in more real-world applications. This is expected to transform lifestyles so that ICT services with multiple quality levels will be accessible everywhere in the form of advanced urban functions, which includes infrastructure, energy, traffic, and other areas.

1.2 Future ICT usage scenarios

Three ICT usage scenarios envisioned for 203x are



5G: fifth-generation
AI: artificial intelligence
ADSL: asymmetric digital subscriber line
B2B2X: business to business to X
DTB: digital terrestrial broadcasting
FTTH: fiber to the home
HD: high definition
HIKARI Collaboration: NTT's initiative for wholesale of fiber-optic services
ICT: information and communication technology
IoT: Internet of Things
IP: Internet protocol
LTE: Long-Term Evolution
LTE-A: LTE-Advanced
NGN: Next Generation Network
OTT: over-the-top
PSTN: public switched telephone network
SD: standard definition
VOD: video on demand

Fig. 1. Direction of ICT progress toward an abundant future society.

depicted in **Fig. 2**.

(1) Seamless connectivity

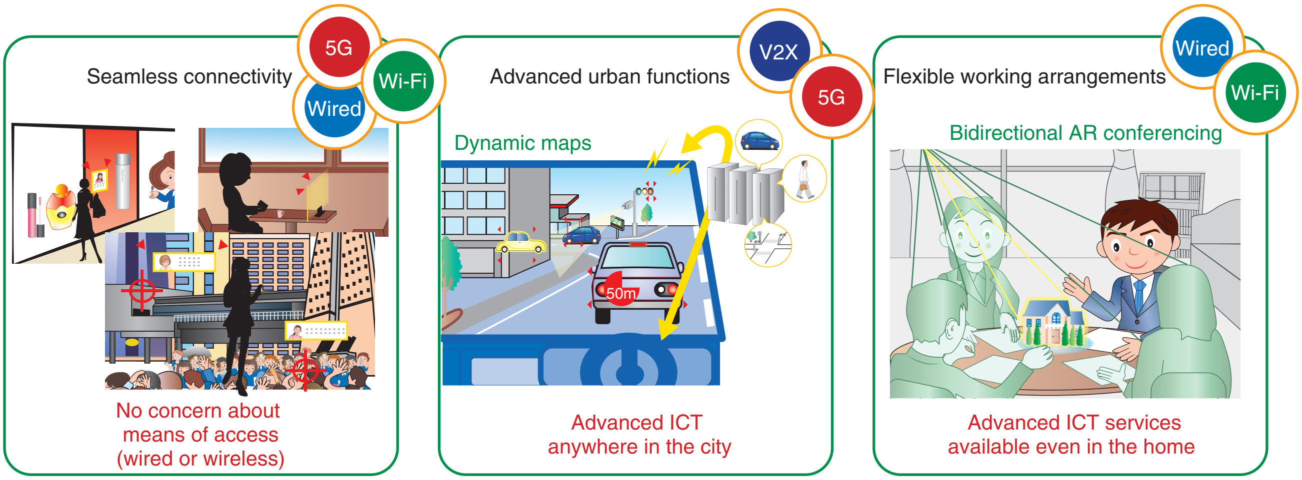
In the first scenario, users will be able to enjoy ICT services at all kinds of locations without needing to think about the access connection or device. As one possible service in this scenario, a person talking on the phone while walking down the street might decide to enter a coffee shop, where the call can be seamlessly continued as a video call on a display in the shop. Realizing this usage scenario will require the functionality to continue communications seamlessly even when the network connection points or devices change, as well as the functionality to guarantee end-to-end communication quality, which will maintain the high-level user experience, from the server providing the service to the user's device independent of the transmission media (e.g., wireless or wired) or the method of network connection.

(2) Advanced urban functions

In the second scenario, ICT will advance as urban functions providing greater added value. One possible example is the use of dynamic maps, which will be generated on servers based on a multitude of information sources from intelligent transport systems such as sensors, video or camera images, and traffic lights deployed throughout a city. The dynamic map information will then be sent to cars and other vehicles to provide advanced onboard functions such as hazard prediction. Implementing this usage scenario will require the functionality to collect a lot of data from many sources in real time and calculate useful information using networked computing resources, and the functionality to distribute this information from networked computing resources to large numbers of devices (cars) simultaneously and with low latency.

(3) Flexible working arrangements

In the third scenario, we expect to see a need for advanced ICT services to facilitate remote access working environments and flexible working arrangements, enabling people to work from home or from a shared office, for example. One possible working arrangement involves colleagues in remote locations carrying out group work via augmented reality conferencing available in each person's home. This working arrangement necessitates the assurance of low-latency broadband communication paths between multiple locations for the duration of the conference,



AR: augmented reality
V2X: vehicle-to-everything

Fig. 2. Usage scenarios for high added-value public ICT services.

as well as advanced network authentication functionality that determines whether to permit the connection between multiple sites.

1.3 Trends for telecommunications carriers

We believe the telecommunications carriers of the future will have to provide flexible network services to both users and service operators. Flexible network services involve three things: (1) customization that permits users and applications to use only the bandwidth, latency, computing resources, and other resources they need just when they need them; (2) instantaneous configurations and connections to enable instant real-time service usage; and (3) automatic selection of the optimum network without the user having to choose one. Furthermore, to enable users to conveniently access the services they subscribe to anywhere at any time, the capability for telecommunications carriers to perform centralized, end-to-end management is needed. Additionally, to provide these services inexpensively and continuously, we believe further work-process automation and reduction will be necessary through extensive application of AI and robotic technologies in operations, administration, and maintenance. Automation and reduction of work processes will also offset the future decline in maintenance personnel precipitated by a reduction in the working population in Japan.

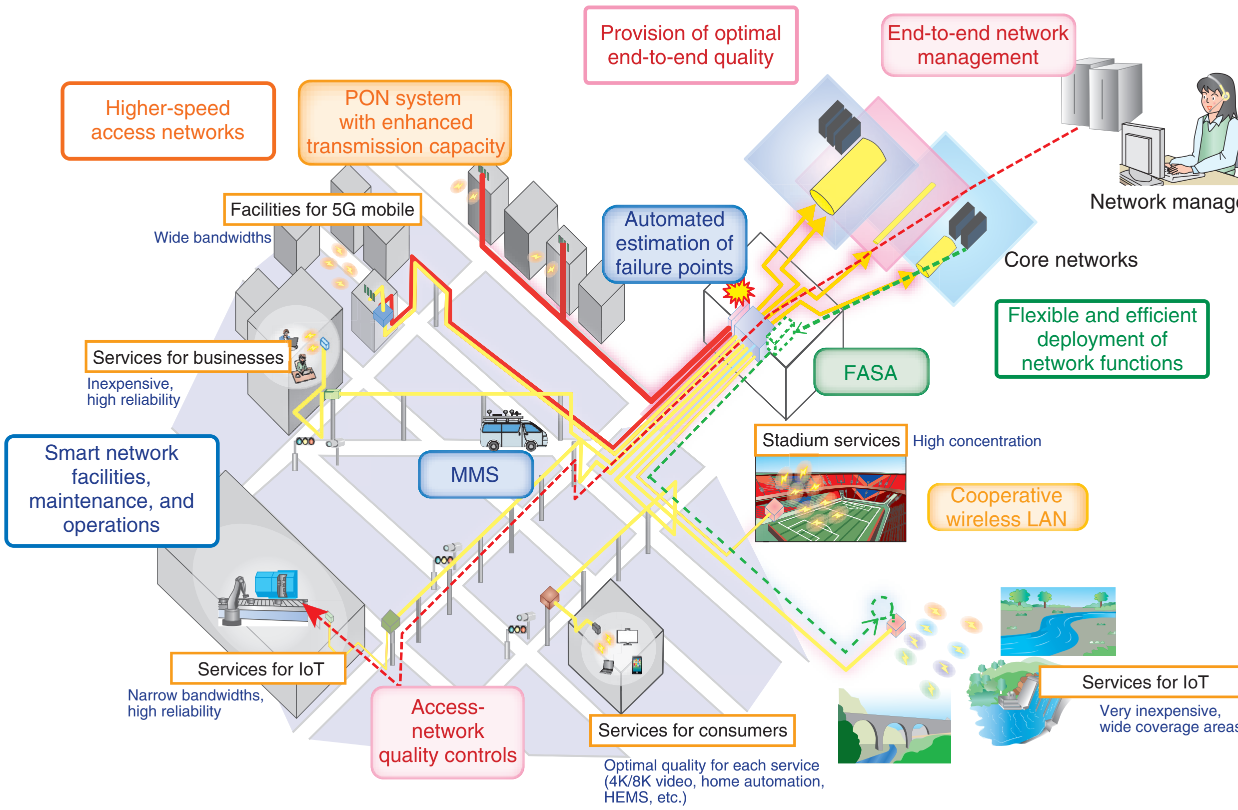
2. Access network systems technologies for the era of 5G deployment

To realize the future vision described above, NTT Access Network Service Systems Laboratories (AS Labs) aims to advance access network functionality with four research and development (R&D) initiatives, as shown in **Fig. 3**. In addition to continuing initiatives toward (1) realization of higher-speed access networks, and (2) smart network facilities, maintenance, and operations that utilize existing facilities, we are pursuing R&D projects focusing on (3) the provision of optimal end-to-end quality that goes beyond the scope of conventional quality management and also on (4) flexible and efficient deployment of network functions to address a variety of communication quality requirements. These initiatives are outlined in the following subsections.

2.1 Realization of higher-speed access network

Our R&D efforts in the area of passive optical network (PON) architectures for the construction of low-cost optical access services have furthered the development of broadband-PON (B-PON) and gigabit Ethernet-PON (GE-PON). We have also contributed to the standardization of ITU-T[*1] G.983 (2003) and IEEE[*2] 802.3ah (2004), which are for B-PON and

*1 ITU-T: International Telecommunication Union - Telecommunication Standardization Sector
*2 IEEE: Institute of Electrical and Electronics Engineers



FASA: Flexible Access System Architecture
HEMS: home energy management systems
MMS: mobile mapping system

Fig. 3. Image of future access networks.

GE-PON, respectively. In addition, we promoted the development of faster technologies that led first to the standardization of 10-Gbit/s-capable Ethernet PON (10G-EPON, IEEE 802.3av, 2009) and later, of 40-Gbit/s-capable Next Generation-PON2 (NG-PON2, ITU-T G.989, 2015) [1], which expanded transmission capacities and improved extensibility based on 10-Gbit/s-capable PON systems. These high-speed access technologies are expected to be crucial for the accommodation of mobile base stations for 5G and beyond, and for 4K/8K video content distribution. Current standardization efforts in PON systems are focused on even higher speeds, and a standard for 100-Gbit/s-capable 100G-EPON [2] is expected to be completed in 2019.

In the wireless access field, wireless local area networks (LANs) have achieved widespread proliferation, but the underlying standard, IEEE 802.11, was first established back in 1997 when the maximum transmission speed was just 2 Mbit/s. Demand for higher wireless LAN speeds has continued to grow since this time, with the spread of laptops, tablets, and other wireless devices. To address this demand, R&D progress has been made in orthogonal frequency division multiplexing and multiple-input and multiple-output technologies, paving the way for the most recent iteration of the standard, IEEE 802.11ac, which realizes physical speeds up to 6.9 Gbit/s. With this new standard, transmission speeds have now increased more than 1000 times in less than 20 years.

Further diversification of wireless devices is expected to bring even better wireless environments. One problem, however, is reduced throughput due to radio interference in highly concentrated usage environments such as sports stadiums. Standardization efforts to improve throughput in such conditions are now underway as IEEE 802.11ax. AS Labs is also studying cooperative wireless LAN technology [3] that will improve frequency usage efficiency and achieve higher speeds.

2.2 Smart network facilities, maintenance, and operations for access networks

To date, the main focus in access networks has been on deploying network equipment and optical fiber efficiently in order to deliver the optical fiber network to homes. In the future, however, access network facilities will have to cope with many diverse requirements to support the 5G and IoT telecommunications infrastructures. For example, they will have to efficiently accommodate the increasing number of mobile base stations or IoT devices over wide coverage areas. Consequently, we are looking into how to optimize the deployment of access network facilities while maximizing the use of existing ones.

Another area of focus involves achieving smarter maintenance and operations for access networks. The number of workers involved in maintenance and operation of the network is expected to decrease in the future. Therefore, it is necessary to be able to operate and maintain the network with a smaller number of workers by achieving smarter maintenance and operations. For example, we are working to improve the efficiency of equipment inspections by utilizing a mobile mapping system [4] and to reduce the burden of routine work in network operations or service reception tasks and to simplify tasks that require advanced skills by utilizing navigation technologies [5]. We are also striving to make network-fault detection operations more advanced and efficient using automatic failure points estimation technology [6] and to enable comprehensive management and operation of diverse networks through the use of network resource management technology [7].

In the coming years, we will pursue R&D of advanced automation of network operations by AI and machine learning and remote maintenance using sensors, robots, and other devices, while aggressively systemizing routine operation tasks.

2.3 Provision of optimal end-to-end quality

Future networks will have to provide services with optimal end-to-end communication quality from the service provider network to the end user devices. Networks will need the functionality to automatically guarantee required bandwidth for consumers just for the duration a video service is used, for example, as well as to permanently allocate a narrow bandwidth for IoT devices. Access networks to date have generally provided best-effort transmission. However, we are researching functions that will recognize the services users are accessing and provide quality accordingly. As mentioned previously, communications do not exclusively use NTT networks but pass through the networks of other communication carriers and ultimately traverse the user's own network. A requirement in providing end-to-end quality, then, is to coordinate our networks with these other networks. Consequently, we are studying network technologies and operation systems technologies that enable quality coordination and cooperation between networks.

2.4 Flexible and efficient deployment of network functions

Network functions virtualization, a network architecture concept involving the virtualization of many different network node functions in core networks, is gradually being rolled out. In contrast, access network systems development has been conducted separately for each provided service and function, which has stymied the deployment of generic network functions.

AS Labs, therefore, is engaged in researching Flexible Access System Architecture (FASA) [8], which segments the functions provided by access networks into components and allows the flexible combination of those components. For example, FASA turns bandwidth management functions, maintenance functions, and multicast processing functions into (software) components, making it possible to add on functions just for users that need that function or combination of functions. This, in turn, is anticipated to facilitate not only rapid provision of a variety of services but also reductions in capital expenditures through the use of general-purpose hardware, reductions in operating expenses by communalizing maintenance operations, and service continuity assurance by eliminating equipment end-of-life issues with the use of general-purpose hardware.

AS Labs has issued a FASA white paper describing a common application programming interface enabling the addition and replacement of software components and has proposed its standardization at the Broadband Forum (BBF). We are also active in the open implementation of the FASA platform in cooperation with the Open Networking Foundation (ONF) and other open-source software communities.

3. Future development

In addition to our previous studies on technology for high-speed and high-capacity networks, AS Labs is pushing forward with R&D in advanced access network functionality. We are also studying how to provide optimal end-to-end quality and flexible deployment of network functions, as well as investigating efficient base-station accommodation and new cabling applications.

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Hiroyuki Furukawa

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

He received a B.E. in electrical and electronic engineering and an M.E. in information engineering from Nagoya University in 1997 and 1999. He joined NTT in 1999. He is currently engaged in R&D focused on creating novel access network services.

Kenji Horikawa

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

He received a B.E. and M.E. in electrical and electronic engineering from Tokyo Institute of Technology in 1992 and 1994. He joined NTT in 1994, where he has been engaged in R&D of computer networks. He is a member of IEICE.

Takahito Kirihara

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

He received a B.E. in electronic engineering and an M.E. in information science and technology from Hokkaido University in 2004 and 2006. He joined NTT Access Network Service Systems Laboratories in 2006, where he has been researching innovative network technologies for access applications. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Satoshi Ikeda

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

He received a B.E. and M.E. in electrical communications engineering from Tohoku University, Miyagi, in 1993 and 1995. He joined NTT in 1995 and began researching multi-channel video signal transmission systems for FTTH (fiber-to-the-home). He is currently engaged in R&D of novel access network services. He is a member of IEICE.

Satoshi Narikawa

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

He received a B.E., M.E., and Ph.D. in electrical and electronic engineering from Tokyo Institute of Technology in 2001, 2003, and 2012. He joined NTT Access Network Service Systems Laboratories in 2003, where he has been researching innovative network technologies for access applications. He received the Young Engineer's Award from IEICE in 2007 and the Best Paper Award from IEICE in 2008. He is a member of IEICE.

Takeshi Arai

General Manager, Access Network Service Systems Project, NTT Access Network Service Systems Laboratories.

He received a B.E. and M.E. in instrumentation engineering from Keio University, Kanagawa, in 1991 and 1993. He joined NTT in 1993. He is currently engaged in R&D focused on the creation of novel access network services.

Katsuya Minami

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

He received a B.E., M.E., and Ph.D. in information systems engineering from Osaka University in 1998, 2000, and 2003. He joined NTT in 2003. He is currently researching and developing novel access network services. He is a member of IEICE.

Research toward Realizing a Future Network Architecture

Seisho Yasukawa, Hiroaki Sato, Takeshi Hirota, Takuya Tojo, Ken-ichi Endo, Yasunobu Kasahara, and Hiroshi Suzuki

Abstract

In the 5G (fifth-generation mobile communications) and Internet of Things era, trends such as work on social infrastructure services, the explosive increase in the number of terminals and the amount of network traffic, and the use of artificial intelligence for smart devices and services will have a huge impact on networks, thereby increasing the need for new network architectures. This article analyzes the impact of these trends, examines network requirements, and introduces initiatives to develop the necessary architectures and key technological elements verified by proof of concept.

Keywords: network architecture, 5G, PoC

1. Five elemental technologies

The NTT laboratories are studying network infrastructure architectures and practical elemental technologies that will provide B2B2X (business-to-business-to-X) model business and other societal infrastructures in the future as we fully enter the fifth-generation mobile communications and Internet of Things (5G/IoT) era.

This article reports on the following five elemental technologies.

(1) Network slice technology, which provides 5G transport able to accommodate multiple societal infrastructures such as self-driving and remote factory control and new digital services such as IoT. It can isolate multiple logical service networks for operators with different characteristics.

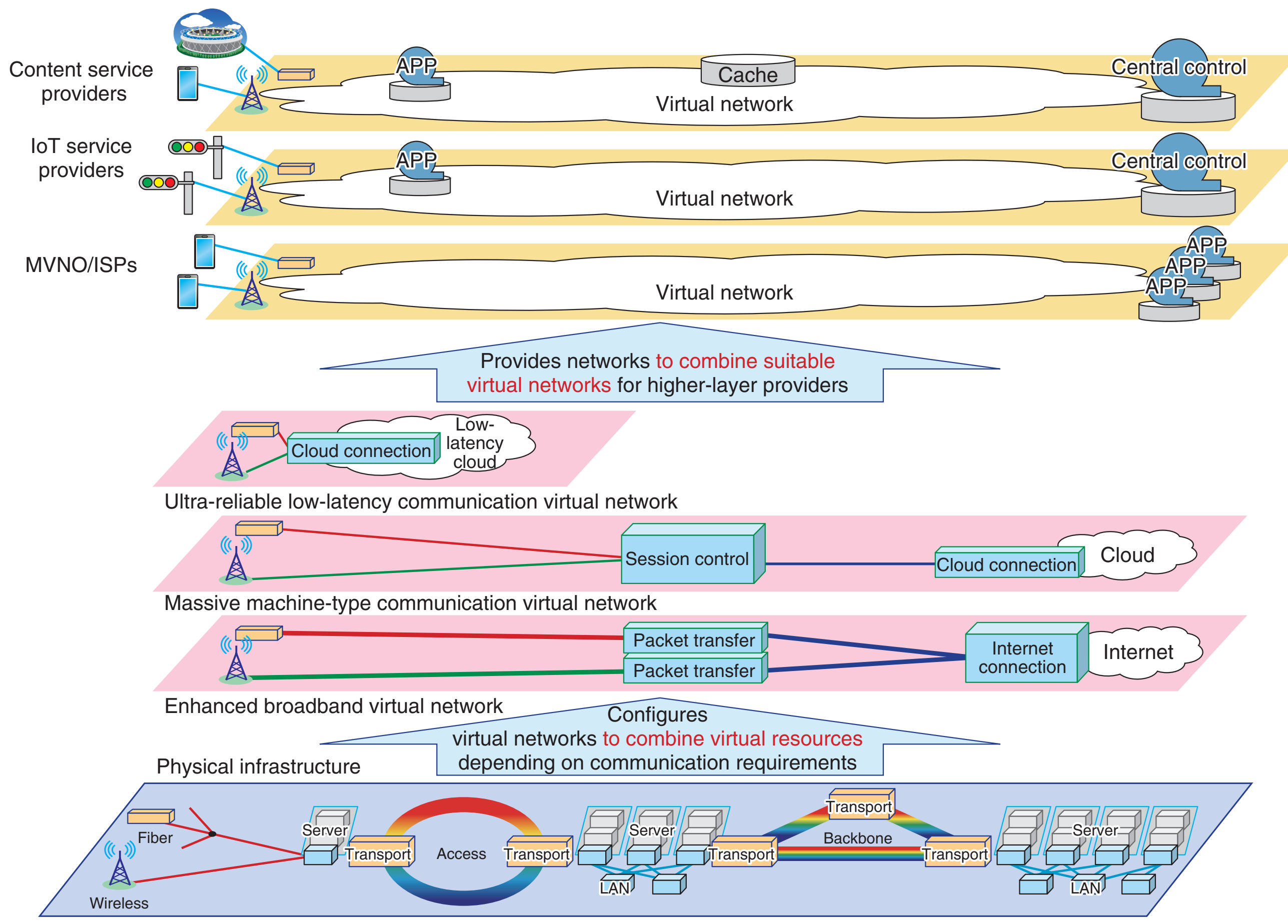
(2) Cloud native software-defined anything (SDx)* control technology, which enables cloud operators to create their own services by tuning and linking cloud applications and network applications from a simple catalog of applications on a self-service basis.

(3) Multi-layer software-defined networking (SDN) control technology, which provides integrated control of Internet protocol (IP) and transport layers using an SDN controller, for rapid service provision and resource optimization over the entire network.

(4) Content delivery network (CDN) technology, which is important for realizing 5G transport and will provide economical, high-quality distribution of high-definition, realistic video content including 4K/8K, augmented reality (AR), and virtual reality (VR) content.

(5) Inter-network cooperative mechanisms for protecting systems against massive cyberattacks. The mechanisms deal with increasingly large-scale and diverse distributed denial of service (DDoS) attacks by obtaining and spreading security threat information among network operators beforehand as a preventive defense against attacks. These mechanisms also link multiple network security functions to implement stronger detection and prevention functions.

* SDx: A general term for technology to control information technology infrastructure resources (servers, storage, networks, etc.) via software.



APP: application
ISP: Internet service provider
LAN: local area network
MVNO: mobile virtual network operator

Fig. 1. Network slice concept.

2. Network slice technology

Network slicing is a major new and innovative 5G era network technology, along with high-capacity packet transport and low-latency datacenter connection technologies. Network slicing involves managing physical equipment (physical resources) such as servers and routers as resources that can be partitioned virtually (virtual servers, virtual links, virtual network functions, etc.). This technology makes it possible to configure virtual networks (slices) by combining these virtual resources on the shared physical equipment (**Fig. 1**). A strength of network slicing, unlike conventional virtual private networks (VPN) and virtual routers, is that programmably controlled end-to-end networks can be configured immediately, like a cloud service, by flexibly combining virtual lines, virtual servers, virtual network functions, virtual high-order application functions, and virtual operations support systems and business support systems (OSS/BSS). The slice user is able to freely select network functions and control protocols and to control routes without being restricted by physical network functions, hierarchical structures, or operational rules.

As extreme examples, an IoT service provider could operate a network without using Ethernet or IP, or a content service provider could use its own routing control protocols and its own quality of service (QoS) policies that do not conform to international standards.

Network slicing is useful, for example, for achieving a variety of communication conditions on the same physical equipment, as with 5G networks, or for providing program-controllable virtual resources to higher-layer service providers.

The international standards for 5G cover three communication modes for implementing various communication conditions: high-capacity broadband communication (e.g., 4K/8K video distribution), massive machine-type (many session/connection) communication (e.g., IoT), and ultra-reliable low-latency communication (e.g., for AR, self-driving cars); and we are studying ways to configure virtual networks that realize each of these (Fig. 1).

For example, most of the traffic in a high-capacity broadband communications network would be transferred via the Internet, so deploying a packet transport function with a tree structure and the Internet connection as the root would be efficient. For a many session/connection communication network, it would be effective to deploy many session/connection functions at the location where the sessions are needed. For an ultra-reliable low-latency communication network, deploying an ultralow-latency cloud near the access location would be effective for connecting to a datacenter within a range that meets latency requirements.

Three types of services for providing virtual resources to higher-layer service providers are being considered. They are: network slicing as a service (NSaaS), which provides an end-to-end virtual network with a full set of functions that can be oriented, for example, to Internet service providers (ISPs) and mobile virtual network operators (MVNO); network slicing platform as a service (NPaaS), which provides virtual network platforms that can be combined and customized by higher-layer service providers; and network slicing infrastructure as a service (NIaaS), which provides individual components such as virtual servers and virtual links.

For example, an MVNO or ISP could use NSaaS to procure a full set of virtual communications-operator facilities, including virtual OSS and BSS, and then conduct business using only its own subscriber web user interface. Or, as live events are held in cities like Tokyo, Nagoya, and Sapporo on a daily or weekly basis, a content provider could use NPaaS to move its own live video processing and distribution functions to buildings near the venues and configure virtual CDNs on a daily or weekly basis to satisfy latency requirements. The NTT laboratories are working on international standardization and research and development (R&D) on network slicing technologies including slice management, slice gateways, slice isolation, and telemetry, aiming for commercial implementations in 202x.

2.1 Slice management technology

Slice management technology is being modeled in three layers, for the infrastructure provider, slice provider, and slice operator (higher-layer service provider), and application programming interfaces (APIs) between these layers are being studied (**Fig. 2**).

The infrastructure provider owns the network and datacenter facilities and manages them as pools of resources such as virtual links (bandwidth) and virtual servers (central processing unit (CPU) capacity). A slice provider procures virtual resources from the infrastructure provider through an API and configures slices. In practical operation, this three-layer model is not limited to simple, horizontal specialization, and APIs are created taking all kinds of real configurations into consideration. For example, a slice operator might combine virtual resources from its own facilities with virtual resources from other facilities and control programs centrally without regard for whose facility is being used.

We are also studying ways to apply telemetry technology to programmable slice monitoring, control, and collection of analysis data, in units of slices, from APIs for slice operators.

2.2 Slice gateway technology

Slice gateway technology is used for connecting slices among slice providers and for connecting subslices within a slice provider. We are studying technologies to link slice management functionality with slice access authentication functionality and packet transport functions, to allow packets to be transported to appropriate slices (or subslices) based on slice connection policies. It also provides the edge functionality for slice isolation, as described next.

2.3 Slice isolation technology

Slice isolation involves isolating end-to-end traffic flow among slices, over link segments, including traffic within physical servers. The future goal is to achieve complete noninterference among slices so they will not affect each other, regardless of traffic congestion, functional faults, or software bugs. However, this is difficult to achieve with the current virtualization technology, so we are studying implementations ranging from loose isolation, on the level of controlling QoS priorities, to strict isolation, which

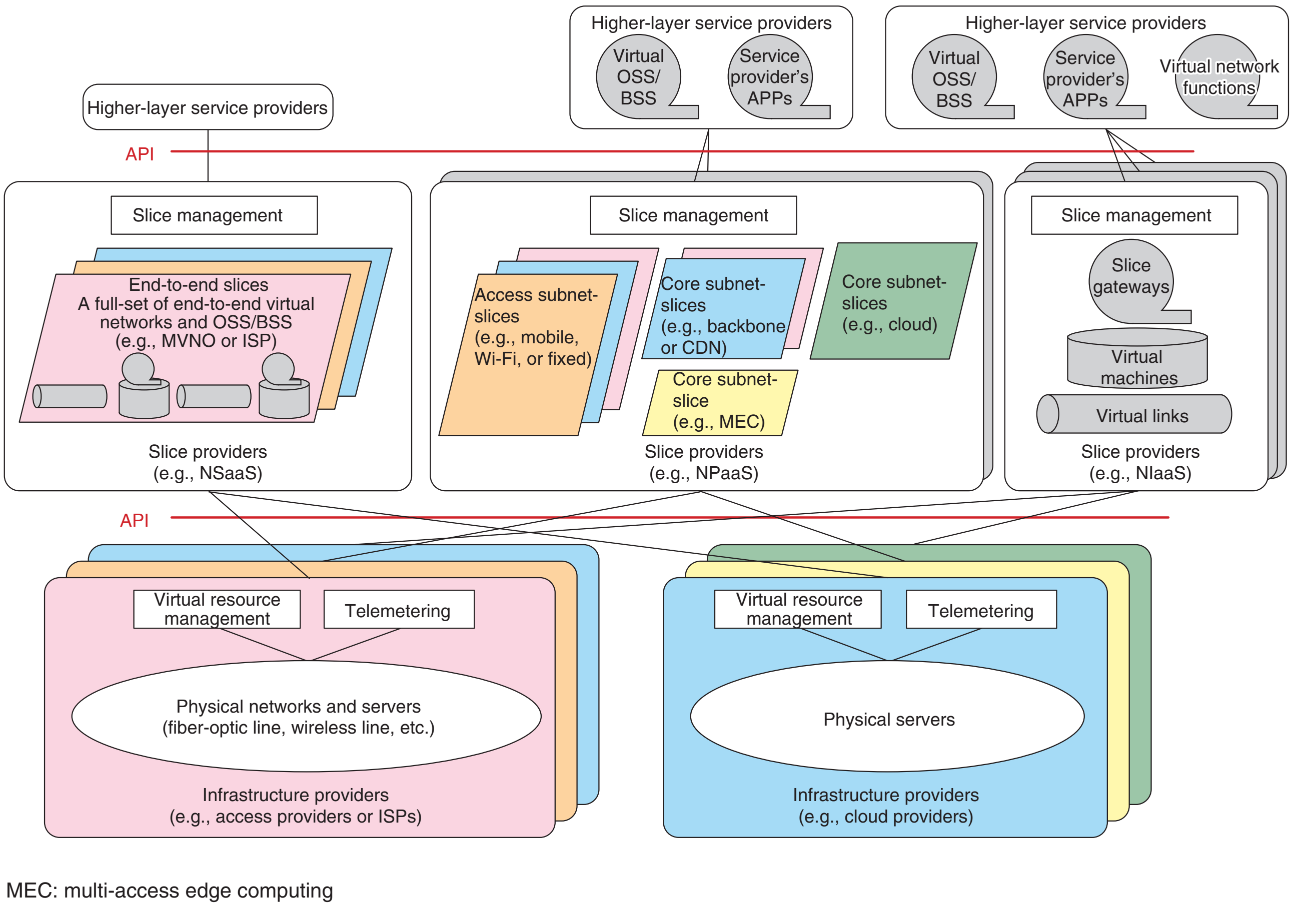


Fig. 2. Network slice model.

maintains a higher degree of noninterference by securing resources such as virtual link bandwidth and virtual server CPU. For virtual link protocols in particular, there are international standard protocols that can separate multiple flows, for example, VXLAN (Virtual eXtensible Local Area Network), MPLS (Multi-Protocol Label Switching), and segment routing (SR). The NTT laboratories are working to augment these protocols to incorporate requirements for isolation and create new international standards.

3. Cloud native SDx control technology

Cloud native SDx control provides services easily and rapidly using automatic end-to-end control for network and cloud environments. It also offers the applications needed to provide services, rather than just providing individual network services (**Fig. 3**).

Conventional network services were simply functions that connect service users and service providers. Service providers are now providing diverse services on cloud environments, but the inability of cloud platforms to coordinate with networks is an obstacle to providing services quickly. As such, we aim to achieve rapid provision of services by collectively controlling networks, cloud environments used by service providers, and even applications. Implementing this concept requires mechanisms to automatically configure resources for providing services (networks, cloud resources, etc.), and to manage the information needed to support the resources.

We are studying ways to provide these automated mechanisms as user-friendly service configuration patterns that service providers can customize according to their own services, based on various technologies such as cloud environment workflows, cloud environment control, and network control. Automatic control of these various resources also requires appropriate management of information, such as what resources are being controlled, the state of each

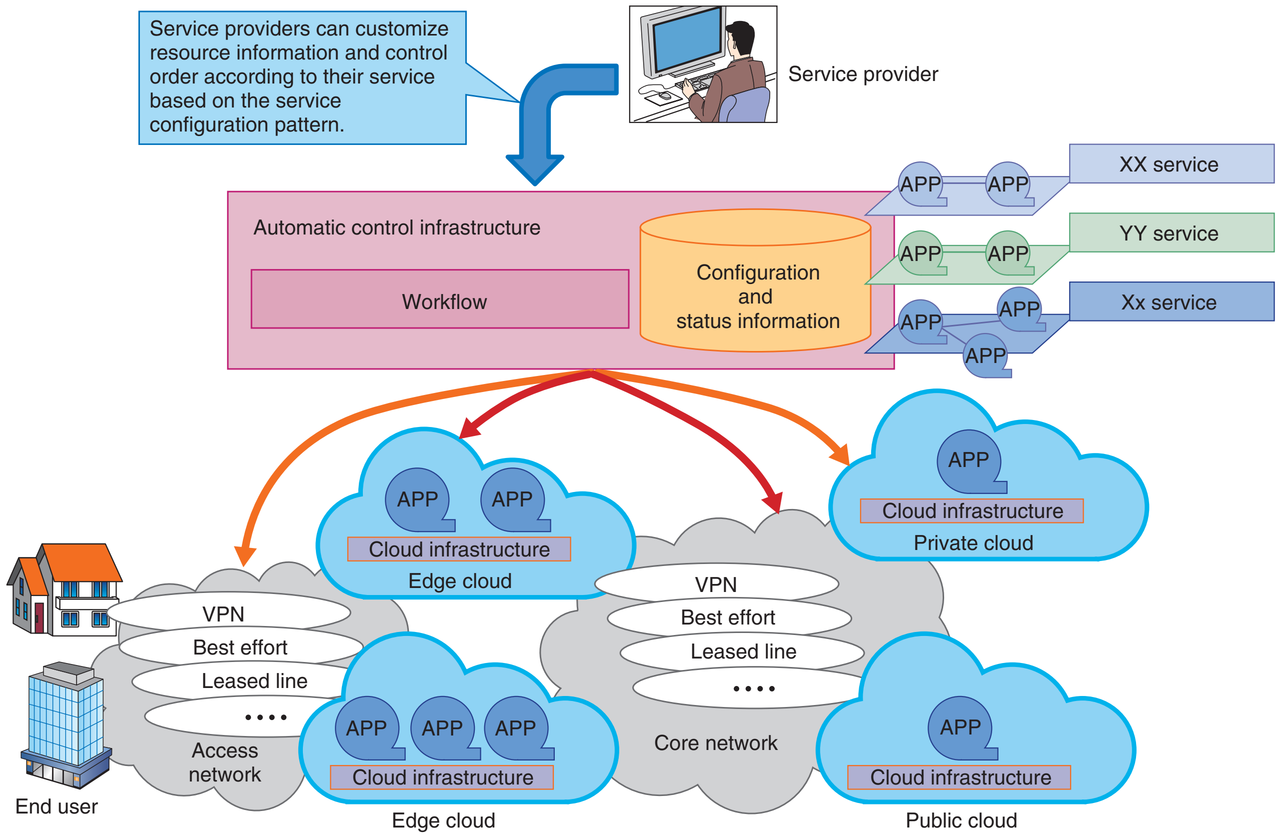


Fig. 3. Cloud native SDx control technology.

resource, and in what order settings need to be applied. Consequently, we have been studying models for entities being controlled and ways to manage overall configuration and state information, so that the various entities being controlled can be handled uniformly, rather than being dependent on particular services or physical equipment.

By establishing methods for the modeling and configuration management that we are currently studying, and building them into an automated control mechanism, we will realize a control platform able to centrally manage the resources needed for services and to control them automatically.

4. Multi-layer SDN control technology

We are studying multi-layer SDN control technology in order to achieve rapid service provision and overall optimization of network resources. Multi-layer SDN control integrates the control of IP and transport layers from the SDN controller, enabling the settings needed in routers and transport equipment to be done simultaneously, so that paths for different types of services such as IP-VPN or dedicated Ethernet lines can be provided on-demand from the SDN controller (**Fig. 4**). In addition to working to achieve rapid provision of services in this way, we are also studying ways to provide various grades of quality and reliability, in anticipation of the various levels of service that will be required in the 5G era [1].

Specifically, we are studying (1) implementation of routing control and protection in the IP layer with SR suitable for SDN control, (2) implementation of routing control and restoration in the transport layer with optical wavelength switching, (3) real-time monitoring of the network state using streaming telemetry technology, and (4) optical wavelength defragmentation to reorganize fragmented optical wavelengths (**Fig. 5**). By combining these elemental technologies, we aim to achieve graded quality and reliability, an SDN controller that can control IP and transport layers autonomously according to network conditions, and new network operations that will maximize the utilization of all network resources. We are currently

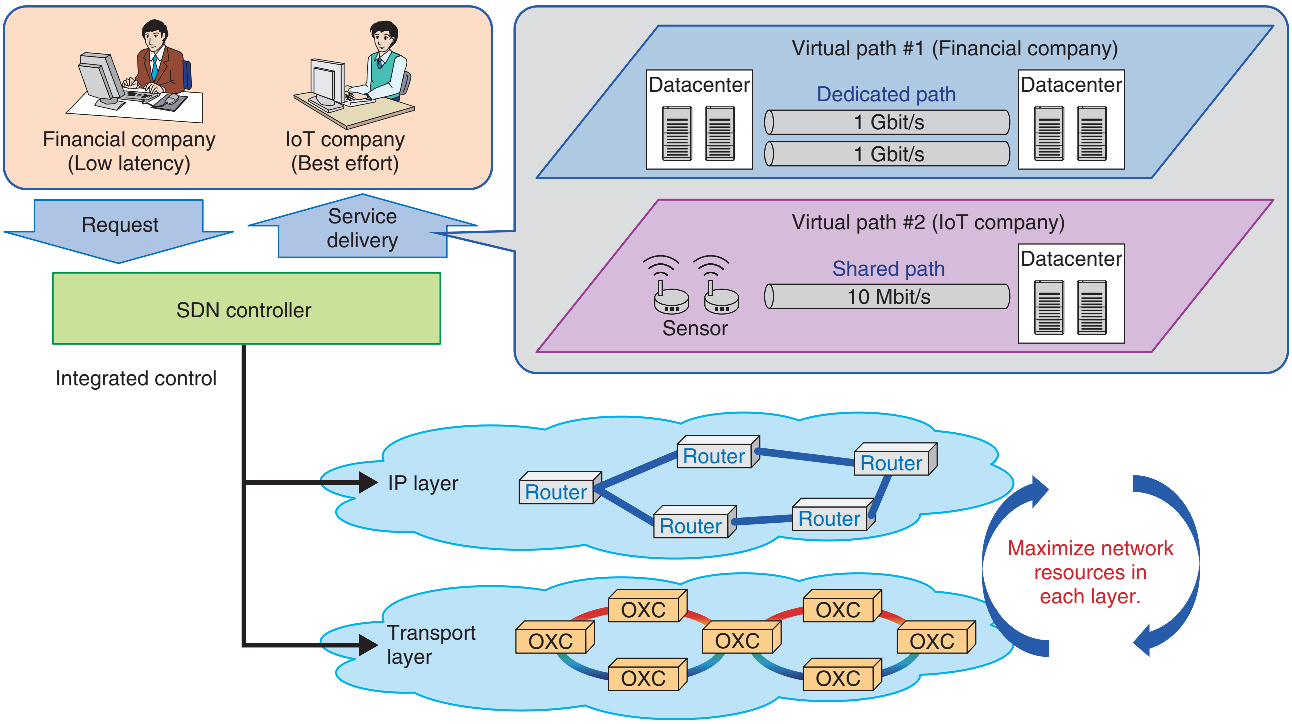


Fig. 4. Multi-layer SDN control technology.

implementing prototypes of the controller functions shown in Fig. 5, based on an open-source SDN controller called ONOS (Open Network Operating System) and verifying the technology as we work to establish multi-layer control technology.

5. CDN technology

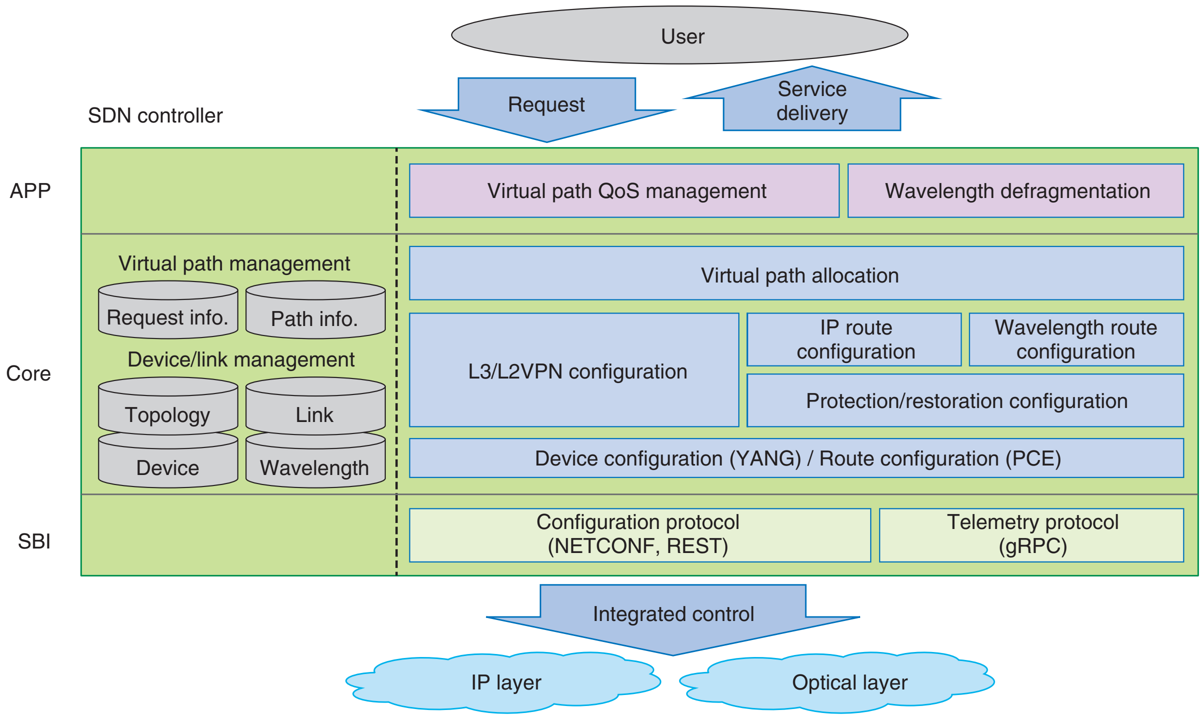
We are studying CDN technologies for high quality, economical distribution of high-definition, highly realistic next-generation video content, including 4K/8K and AR/VR (**Fig. 6**). CDN is based on three key technologies: video quality of experience (QoE) control and distribution design technology, real-time high-capacity distribution technology, and state visualization technology.

5.1 Video QoE control and distribution design technology

Video QoE control and distribution design technology is designed to implement video content distribution economically, based on QoE. It will be able to preserve QoE while achieving efficient utilization of facilities by optimizing the balance between QoE and facility resources. It will use information measured from the various equipment, applications, and terminals on the network to estimate QoE, viewing conditions, and the states of servers, networks, and other resources. It will select distribution servers and routes (server/content navigation) to control traffic according to factors such as the viewer's subscribed services, and perform content cache placement linked with this control.

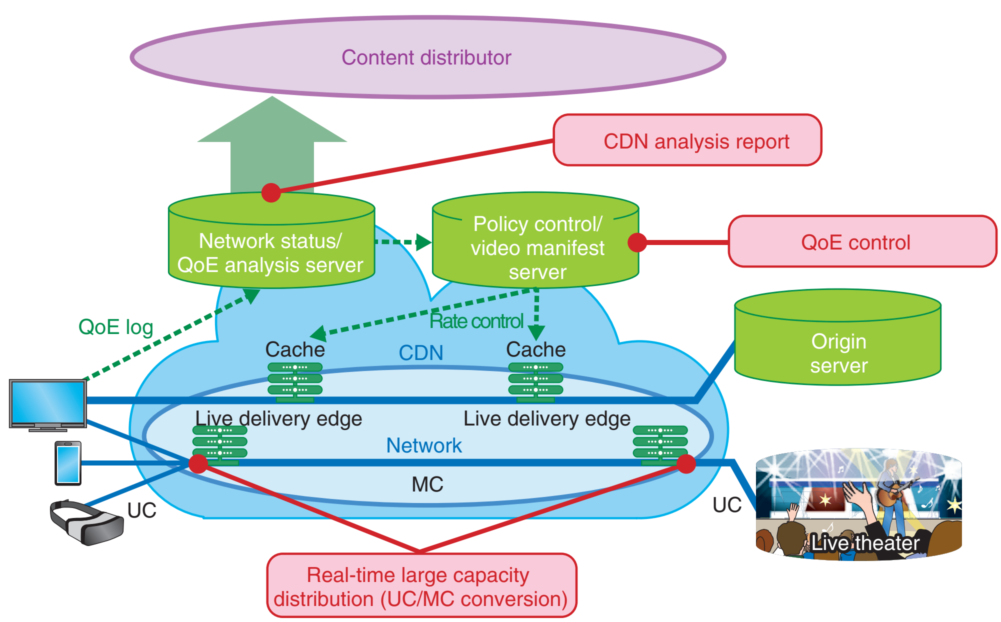
5.2 Real-time high-capacity distribution technology

Real-time high-capacity distribution technology realizes efficient and stable, high-capacity live video distribution. Normally, HTTP (Hypertext Transfer Protocol) based unicast communication is used between distribution servers and terminals, so when viewer demand increases due to events such as live coverage, the load on distribution servers and the network increases greatly. Converting distribution over the network segments to multicast and leaving distribution server and terminal communication as unicast (unicast/multicast conversion) makes it possible to avoid multiple distributions of the same live



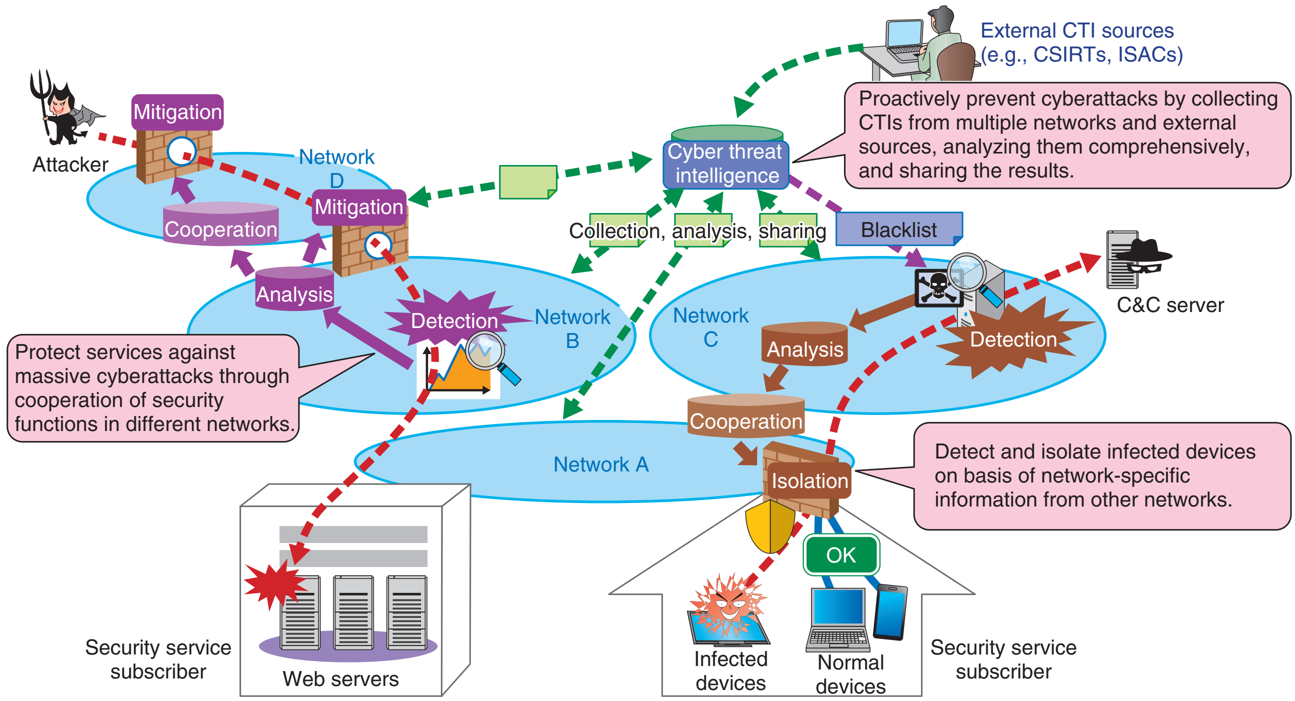
gRPC: An open source remote procedure call (RPC) system.
NETCONF: Network Configuration Protocol
PCE: Path Computation Element
REST: Representational State Transfer
SBI: southbound interface
YANG: Yet Another Next Generation

Fig. 5. Elements of multi-layer SDN control technology.



QoE: quality of experience
UC/MC: unicast/multicast

Fig. 6. CDN technology.



C&C: command and control
CSIRTs: computer security incident response teams
CTI: cyber threat intelligence
ISAC: Information Sharing and Analysis Center

Fig. 7. Cooperative mechanisms for protecting systems against massive cyberattacks.

video and also increases the utilization efficiency of distributor servers and other facilities, while still achieving stable distribution.

5.3 State visualization technology

State visualization technology is designed to estimate and visualize metrics such as distribution conditions, QoE, and viewing behavior (playback, pause, seek, termination of video) from information measured and accumulated from devices, applications, and terminals on the network, and to provide this information to content distributors. This enables content distributors to understand the characteristics of content viewing by viewers, helping them to improve efficiency.

We hope to implement a high-performance, economical CDN platform using these technologies, carrier network platforms, and the accompanying management information.

6. Cooperative mechanisms for protecting against massive cyberattacks

With recent increases in the scale of DDoS attacks and diversification in the types of malware, it is becoming difficult for individual networks to deal with such attacks efficiently in terms of performance and functionality. To overcome this, it is important to strengthen detection and protection functions by obtaining and sharing security threat information among network operators as preventative attack countermeasures and to link the security functions among multiple networks. Therefore, efforts are underway to realize advanced preventative defense capabilities, increased capacity of DDoS attack defenses, and advanced detection and prevention mechanisms for malware infection (**Fig. 7**).

6.1 Advanced proactive defense

For advanced proactive defense, we are studying mechanisms that generate and share network-aided cyber threat intelligence (CTI) faster and more accurately through comprehensive analysis of network flows and other network-specific information between multiple networks as well as collecting CTI from external sources. These mechanisms will contribute to advancing proactive defense techniques such as expanding domain name system (DNS) blacklist information.

6.2 Increased capacity of DDoS attack defenses

To increase the capacity of DDoS attack defenses, we are studying a mechanism to distribute DDoS attack traffic to the defense functions of networks on the attack route while considering the defense capacity of each network. This is expected to achieve appropriate cooperation of defense functions.

This mechanism has enabled us to defend against attacks of dramatically higher bandwidth than single-network countermeasures.

6.3 Advanced detection and prevention mechanisms for malware infection

To achieve more advanced malware infection detection and prevention mechanisms, infected devices must be rapidly and accurately detected and isolated to prevent information leaks and other consequences. However, it is difficult to isolate only the infected devices on each network when the DNS server that can detect the typical behavior of malware (i.e., a C&C (command and control) server) and the devices are on different networks. Therefore, we are studying a mechanism to link the detection information in the DNS server and the device information, in order to quickly and accurately isolate the infected devices.

This initiative aims to achieve a mechanism to detect and protect against cyberattacks by linking functions and information of multiple networks. In the future, we plan to evaluate the technology on commercial networks, identify issues toward practical implementation, and promote system implementation.

7. Future prospects

We have described the results of studying future network technologies, including network slicing, cloud-native SDx, multi-layer SDN control, CDN, and inter-network cooperative mechanisms for protecting systems against the expanding and diversifying cyberattacks. We will continue to demonstrate technologies with proof of concept systems, move elemental technologies toward completeness, and refine the overall architectures.

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Seisho Yasukawa
Group Leader, Senior Research Engineer, NTT Network Technology Laboratories.

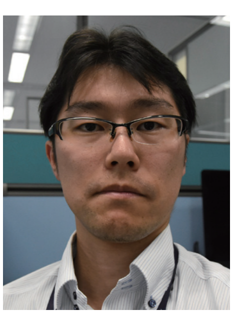
He received a B.E. and M.E. in applied physics from the University of Tokyo in 1993 and 1995. Since joining NTT in 1995, he has conducted R&D of asynchronous transfer mode (ATM) based multimedia switching and NGN (Next Generation Network) architecture. He has also been engaged in standardization activities related to P2MP (Point-to-Multipoint)-MPLS. His current research involves 5G transport technology.

Hiroaki Sato
Senior Research Engineer, NTT Network Service Systems Laboratories.

He joined NTT in 1992 after receiving a master's degree from Tokyo Institute of Technology. He developed asynchronous transfer mode passive optical network (ATM-PON) systems, IP multicast CDN systems, and IPv6 backbone systems for Internet access. He specified the video streaming guideline on LTE (Long Term Evolution) for content providers and developed SDN-LAN to connect network functions virtualization systems including vEPC (virtual evolved packet core) in NTT DOCOMO. Since returning to NTT, he has been investigating vCPE (virtual customer premises equipment) using open source software and 5G transport with network slicing.

Takeshi Hirota
Senior Research Engineer, Network Architecture Innovation Project, NTT Network Technology Laboratories.

He has worked on the development of a network management system for synchronous digital hierarchy, ATM, and packet transport technology. He is currently researching automatic unified control from networks to cloud environments. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).



Takuya Tojo
Senior Research Engineer, Network Architecture Innovation Project, NTT Network Technology Laboratories.

He received a B.E. and M.S. in computers and systems engineering in 2002 and 2004, and a Ph.D. in advanced science and technology in 2007 from Tokyo Denki University. He joined NTT Service Integration Laboratories in 2004. From 2012 to 2014, he was with NTT DOCOMO. He is a member of IEICE.

Ken-ichi Endo
Senior Research Engineer, Network Architecture Innovation Project, NTT Network Technology Laboratories.

He received a B.E. and M.S. in electronic engineering in 1984 and 1986. He joined NTT LSI Laboratories in 1986. He has been with NTT Network Technology Laboratories since 2012, where he is studying distribution of next-generation video content.

Yasunobu Kasahara
Senior Research Engineer, Access Network Service Innovation Group, Access Network Service Systems Project, NTT Access Network Service Systems Laboratories.

He received a B.E. and M.E. in electronic engineering from Nihon University, Chiba, in 1996 and 1998. He joined NTT in 1998 and worked on the development of optical access systems such as ATM systems, passive optical networks, and layer 2 switches. He is currently engaged in R&D of content distribution technologies for emerging services. He is a member of IEICE.

Hiroshi Suzuki
Researcher, Transport Service Systems Development Project, NTT Network Service Systems Laboratories.

He received a B.E. and M.E. from Shizuoka University in 2008 and 2011. He joined the NTT Group in 2011. His recent research involves cooperative mechanisms for protecting against massive cyberattacks.

MOOSIA: Technology for One-stop Operation

Takaaki Moriya, Atsushi Yoshida, Yoshihiko Ito, Masahiro Kobayashi, Shigeaki Harada, and Shingo Horiuchi

Abstract

This article introduces MOOSIA (Multi-Orchestrator for One-Stop operation with Innovative Aggregation of services), NTT's orchestrator that enables service providers to combine, operate, and maintain network, cloud, and application services in a unified manner.

Keywords: B2B2X, service collaboration, operation

1. Introduction

The flourishing application programming interface (API) economy and the *cloud-first* movement motivated us to research and develop capabilities for one-stop operation that will enable service providers to combine and operate networks, clouds, and applications provided by multiple operators, in a unified manner. We have also put forward the concept of MOOSIA™*1 that is aimed at achieving a world that makes it easier to put exciting ideas into practice, that is, a world that makes it easier than ever to create, provide, and operate services proposed or planned by enterprises or individuals.

In the business-to-business-to-X (B2B2X) model, companies representing the second B (i.e., service providers) can freely and flexibly combine wholesale services such as networks, clouds, and applications, which are provided by first-B companies (i.e., carriers) in order to provide a collaborative service (referred to from here on simply as *service* unless otherwise specified) to end users (the 'X' in B2B2X) as shown in **Fig. 1**.

In this article, we describe (1) zero-touch network operation and closed-loop technology that evolves operations mainly within first-B companies, (2) application of artificial intelligence (AI) technologies to closed loops, (3) the API orchestrator that is the core of service creation by second-B companies, (4) technology for enhancing the API orchestrator, (5) the API framework that functions as a general system for API specifications, and (6) the future evolution of MOOSIA.

2. Zero-touch network operation and closed-loop technology

Current first-B operators such as large-scale network operators are feeling the pressure of a large workload and heavy use of human resources just to keep their networks functioning 24 hours a day, 365 days a year. It is crucial to reduce the operational workload and shift the work done at night and on weekends to daytime, weekday work in order to reduce operating expenses. Networks are currently operated manually, with some minimal help provided by operations support systems. Skilled engineers are required for decision making and network control to implement recovery when failures occur, and therefore, 24/7 emergency response teams are required, further increasing operation expenses.

Zero-touch network operation is aimed at solving

*1 MOOSIA: An acronym for Multi-Orchestrator for One-Stop operation with Innovative Aggregation of services. It is a trademark of NTT.

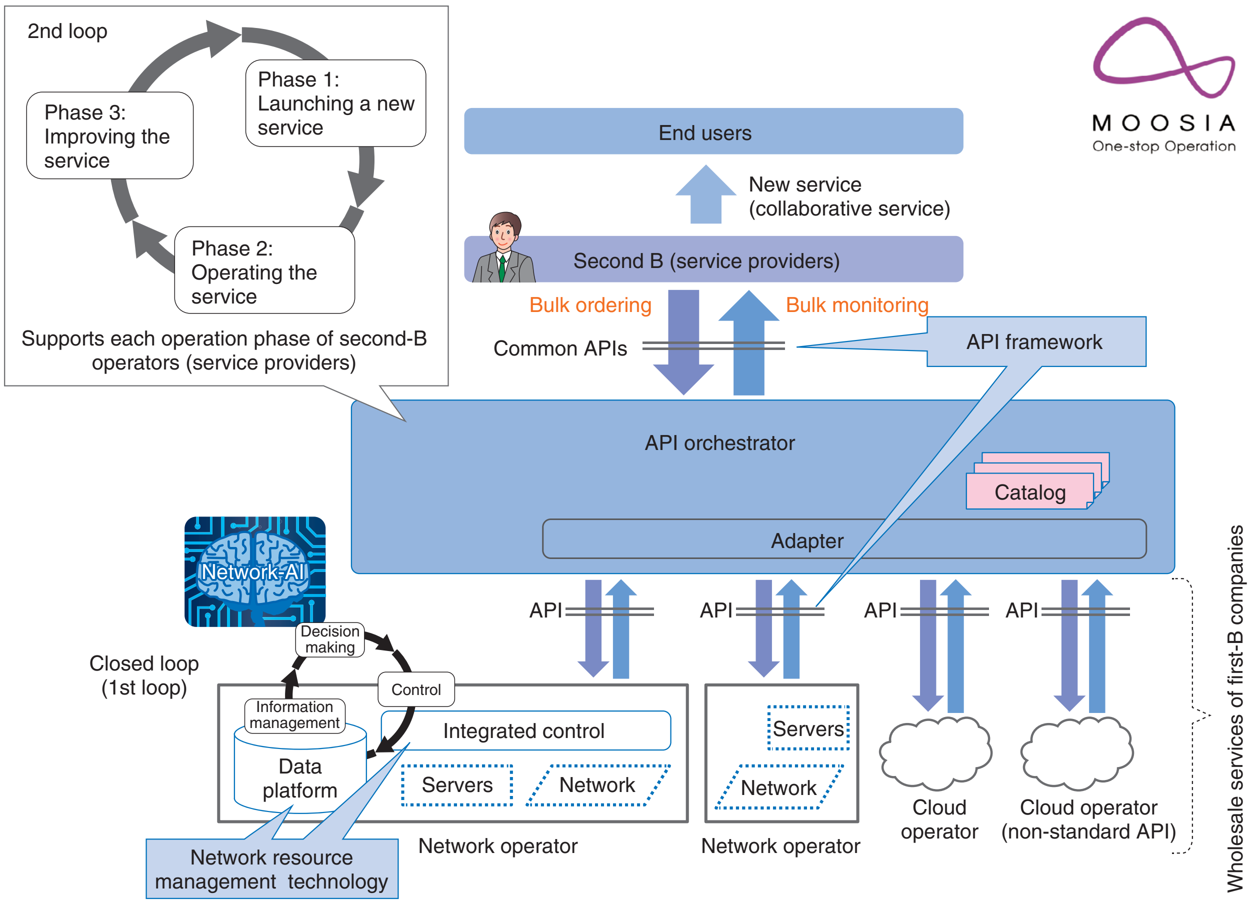


Fig. 1. Overview of MOOSIA in B2B2X model.

this problem by automating network control. Autonomous network operation, along with the control loop that enables it, is important in achieving this goal, as shown at the bottom left of Fig. 1. This loop involves the following sequence of steps: (1) collect and manage information on the operation status of wholesale services, → (2) analyze the collected information and make decisions, → (3) control wholesale services, → return to (1) and repeat. This process is called a closed loop as defined by TM Forum[*2] (TMF), which is a standardization association related to network operations.

Achieving such a closed loop requires unified network resource information between the collection, decision making, and controlling processes. We have proposed network resource management technology for this purpose. This technology is equipped with configuration and management functions based on generic management targets called *entities*. In addition, this technology provides an external mechanism for prescribing the characteristics of individual units of equipment and communication protocols as a *specification*, which is separate from the programs making up the operations support system. This technology also features functions for specifying inter-layer relationships together with these specifications to achieve integrated network management [1].

We are applying this network resource management technology to develop a data collection and usage platform that unifies network configuration data based on a uniform model. This platform collects and stores in common a wide range of data such as network configuration data, alarms, and logs from

*2 TM Forum (formerly known as the TeleManagement Forum): A global standardization association in the telecommunications industry that discusses and specifies management technologies and standardization in relation to communications of the future.

individual pieces of equipment. The platform transfers the data to Network-AI (NTT's AI for networks). In addition, integrated control within a first-B operator consists of technology that enables unified management of the virtual and non-virtual network. With integrated control, the above network resource management technology is used to manage network resources and enable uniform orchestration of the existing non-virtual network and the virtualized network (i.e., software-defined networking).

3. Application of AI technologies to MOOSIA

To implement a closed loop, an advanced intelligent process consisting of analysis, prediction, and decision-making must be incorporated into the system. Incorporating the AI technologies described in the article "Creating New Value by Leveraging Network-AI Technology in Service Operations" [2] enables MOOSIA to analyze the massive amount of information accumulated in the data collection and usage platform in order to promptly detect risks such as equipment failure and traffic congestion that might affect service quality. Similarly, when building a service for a second-B company or changing its configuration after a service launch, or when carrying out a primary response to an equipment failure or traffic congestion, MOOSIA immediately computes an optimal plan for reconfiguring the service among the huge number of combinations available based on network configuration and resource conditions. This optimal plan guarantees performance while minimizing cost. Then MOOSIA forwards the plan to the integrated control mechanism.

As the first step in applying AI technologies to MOOSIA, we are holding a closed-loop trial applying optimal resource allocation technology that considers future demand in virtual networks [3].

4. API orchestrator

The technologies described above pertain mainly to the evolution of wholesale services within a network operator. The following issues arise when multiple wholesale services of various first-B companies are combined to enable second-B companies to provide new collaborative services in an end-to-end fashion: (1) compatibility between different wholesale services must be taken into account when combining them; (2) the cause of a fault in a collaborative service must be searched out by carrying out troubleshooting that spans multiple wholesale services; and (3) automating the process of combining wholesale services is difficult because the format of a wholesale service API is different among first-B companies [4].

The core function that resolves these issues is the API orchestrator in MOOSIA. For a second-B company that wishes to launch a new collaborative service, the API orchestrator facilitates the use of wholesale services instead of developing the entire service from scratch. This approach can drastically speed up service development by a second-B company. Specifically, it can accelerate the cycle shown at the upper left of Fig. 1 that consists of three phases: combining wholesale services and launching a new service (phase 1), operating the newly provided service as desired (phase 2), and improving the provided service (phase 3). Since the closed loop described earlier is called the 1st loop, we call this cycle the 2nd loop.

The API orchestrator defines the specifications of a publicly available wholesale service as a catalog. It defines the specifications of a collaborative service by creating a federated catalog that combines multiple catalogs of publicly available wholesale services (**Fig. 2**) [5]. In this catalog-driven manner, the API orchestrator generically executes multiple services.

Here, we describe each function of the API orchestrator in Fig. 2. First, the REST (Representational State Transfer) API sending/receiving section receives TMF-compliant APIs (such as an order for a collaborative service). The catalog/resource management section, meanwhile, manages TMF-compliant catalogs (refer, create, update, and delete). Next, the scenario execution/management section inputs the requested order and executes (create, update, delete, etc.) the associated wholesale services according to a scenario based on the corresponding federated catalog. In addition, the API adapter section absorbs the differences between TMF APIs, to which the API orchestrator conforms, and APIs provided by wholesale services. Then, that section executes the wholesale services.

This kind of architecture provides loose coupling between the API adapter and scenario execution/management section. It is beneficial because we can flexibly add new services or APIs by simply adding new catalogs and API adapters. The lifecycle management section, moreover, manages the lifecycles of assembled resources after building a service, while it also performs monitoring and fault detection. For second-B companies, the above functions and features simplify the combination of multiple wholesale services and the creation/management of collaborative services, thereby achieving phases 1–3 in the 2nd

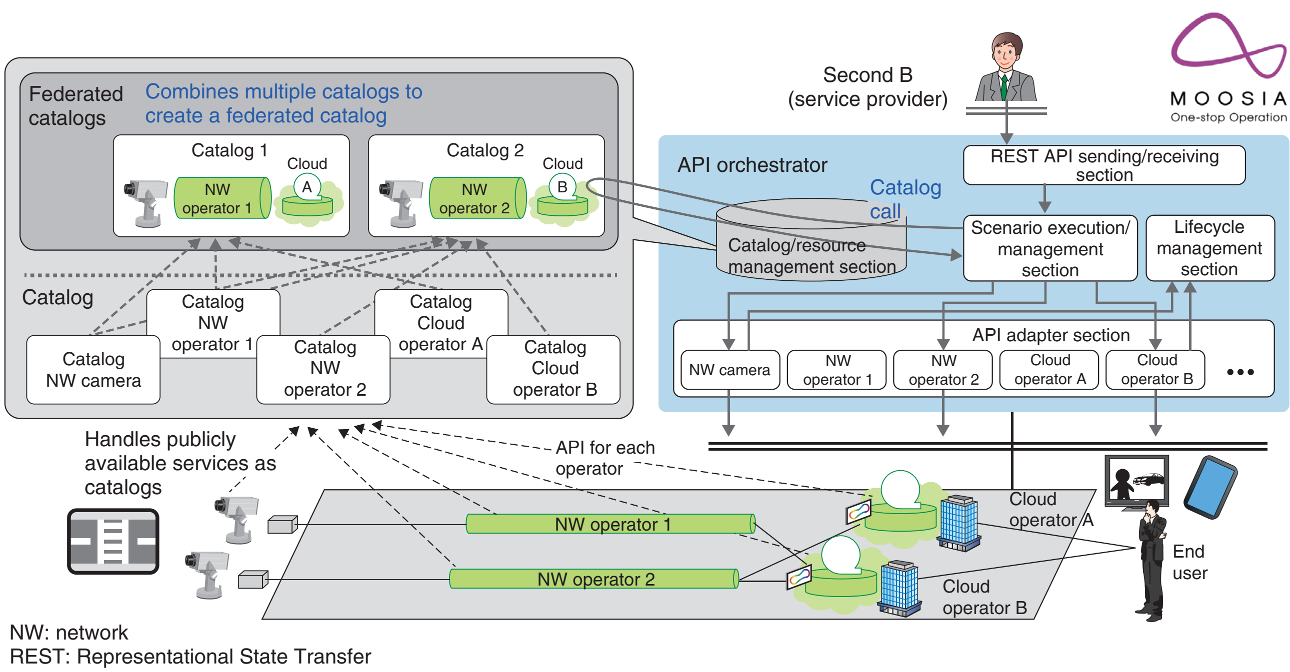


Fig. 2. Overview of API orchestrator.

loop shown in Fig. 1.

5. Technologies for enhancing service assurance and fulfillment in MOOSIA

We introduce here two technologies that respectively enhance phases 2 and 3 in the 2nd loop.

The technology for phase 2 measures the end-to-end quality of service. Although the operation APIs of a first-B company's wholesale services provide monitoring, detection, troubleshooting, or other functions, they are often limited to guaranteeing the service level agreement (SLA) within only a wholesale service. That means functions have not been sufficiently prepared for securing end-to-end quality in a collaborative service provided by a second-B company to end users. This technology therefore deploys a quality-collection agent on the U-plane (user plane), such as on a cloud, to determine/control the quality experienced by an end user on an end-to-end level.

The technology for phase 3 makes recommendations on service configuration. A wholesale service includes many configuration parameters, and therefore, establishing the settings when initially building the service is not a simple task. Consequently, having second-B companies provide answers to some simple questions makes it possible for this technology to present potential network/cloud service configurations and parameter settings. The technology can also predict performance based on configuration information and current operating conditions after the service launch and can also present an optimal reconfiguration and resetting plan whenever performance is out of bounds. This approach helps to guarantee performance, minimize costs, and thereby improve the service overall.

6. API framework

We refer here again to the issue described in section 4 (issue 3), which is the difficulty of automating the process of combining wholesale services due to different formats in the wholesale service APIs among first-B companies. One possible solution to this issue is to provide common API specifications in order to simplify a first-B company's task of designing the API. Additionally, for a second-B company, we can expect common operations regardless of the service being used thanks to the standardized common API specifications (as prescribed by TMF). For example, the business process involved in ordering a service does not depend on the service being provided, so we consider that API specifications corresponding to that process can be standardized in a service-independent manner.

To establish API specifications for an operation, we have been establishing (1) a target business process, (2) a data model for the data to be used in the process of step (1), and (3) the functions for achieving the process in step (1) using the data of step (2) and a means of deploying those functions in the operation system. In actuality, though, API specifications can be defined as a method of data distribution between the functions established in (3) based on the data model in (2) with respect to the business process in (1). We call a general system for establishing such API specifications an API framework. In addition, we are studying an API framework focusing, for example, on specific API specifications such as an API for checking the resource inventory of first-B companies and on functions for bundling multiple APIs such as to coordinate the authentication functions of a second-B company and a first-B company. In relation to the above, TMF is working to establish operation reference models that include common APIs, so we plan to upstream the results of our studies [6].

7. Future evolution of MOOSIA

In fiscal year 2016, we teamed up with a partner service provider to conduct trials that combined commercial service APIs provided by both an NTT Group company and a non-NTT company. The results of this trial showed that we successfully established catalog-based API orchestrator technology. This API orchestrator is now reaching a practical level of implementation.

Going forward, we will continue to research and develop MOOSIA technologies to enable customers to create new services as needed by combining individual services. We will also enable customers to operate and expand such services with the aim of making it easier to create, operate, and improve services.

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Takaaki Moriya

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

He received a B.E., M.Sc., and Ph.D. in engineering from the University of Tokyo in 2001, 2003, and 2011. He joined NTT Network Service Systems Laboratories in 2003, where he studied IPv6 mobility, web-telco collaboration, and other topics. He also worked on commercial service development of Internet protocol interconnection between international carriers (e.g., Long Term Evolution (LTE) roaming). He is currently studying operation technologies including MOOSIA. He received the Young Researcher's Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in fiscal year 2009.

Atsushi Yoshida

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

He received a Bachelor of Science and Engineering from Ritsumeikan University, Kyoto, in 2003, and a Master of Information Science and Technology from the University of Tokyo in 2005. He joined NTT Network Service Systems Laboratories in 2005. He is currently studying operation technologies including MOOSIA.

Yoshihiko Ito

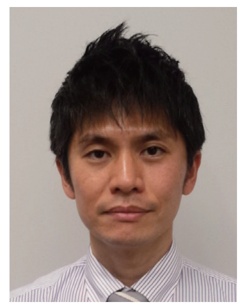
Researcher, Operation Innovation Project, NTT Network Service Systems Laboratories.

He received a B.E. and M.E. in informatics from Kyoto University in 2009 and 2011. In 2011, he joined NTT Network Service Systems Laboratories. He is currently studying operation technologies including MOOSIA. He is a member of IEICE.

Masahiro Kobayashi

Research Engineer, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.

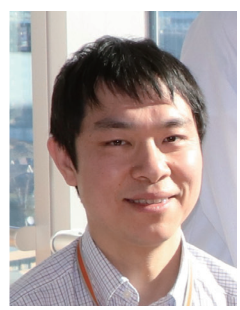
He received a B.S. and M.S. in information science from Tohoku University, Miyagi, in 2007 and 2009. He joined NTT in 2009. He is currently studying optimal resource control in the virtualized communication network at NTT Network Technology Laboratories. He is a member of IEICE.



Shigeaki Harada

Senior Research Engineer, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.

He received a B.S., M.S., and Ph.D. in information science from Tohoku University, Miyagi, in 2001, 2003, and 2006. Since joining NTT Network Technology Laboratories (formerly NTT Service Integration Laboratories) in 2006, he has been researching traffic analysis and traffic control in IP networks. He is a member of IEICE.



Shingo Horiuchi

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

He received a B.E. and M.E. in engineering from the University of Tokyo in 1999 and 2001. He joined NTT Access Network Service Systems Laboratories in 2001, where he has been researching and developing access network operation systems. He has also been engaged in standardization work for operations support systems in TM Forum as a member of the Zero-touch Orchestration, Operations & Management (ZOOM) Project since 2014. He is a member of IEICE.

Global Collaboration Initiatives Revolutionizing Research and Development of Network Technologies

Takeshi Kuwahara, Hitoshi Irino, and Ken-Ichi Suzuki

Abstract

To transform the network into a new social infrastructure, it is essential that the research and development (R&D) scheme for network systems be revolutionized not only by promoting more tie-ups than ever before with diverse business partners but also by collaborating with global partners in various phases of the R&D process. This article presents examples of these activities focusing on the APAC (Asia-Pacific) Telecom Innovation Initiative (ATII) now in progress and collaborative efforts with carriers and other partners based outside of Japan.

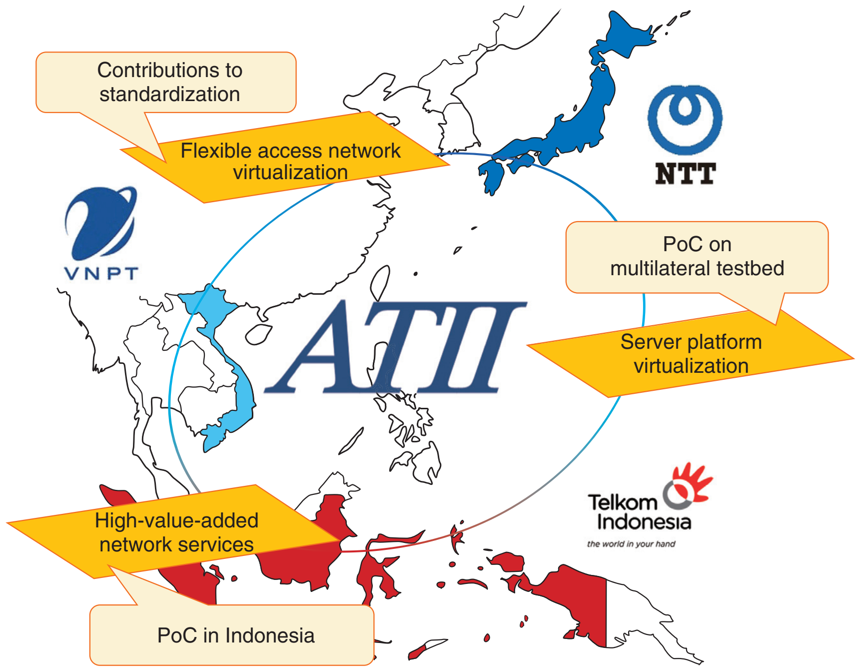
Keywords: network R&D, open innovation, global expansion

1. Global collaboration in network research and development (R&D)

At the NTT laboratories, we have been working to expand NTT technology globally through standardization activities and other efforts and have therefore formed collaborative tie-ups with carriers and business partners such as vendors outside Japan. Now, with the aim of transforming the network into a new social infrastructure, we plan to form collaborative tie-ups with global partners at various R&D phases driven through open innovation, and to promote more tie-ups than ever before with diverse business partners. These efforts reflect the importance of forming a new *ecosystem* while revolutionizing the R&D scheme and promoting accelerated R&D.

To be more specific, we are beginning to engage with Asia-Pacific (APAC) carriers in addition to carrying out our traditional activities with European and American carriers through standards developing organizations (SDOs). Our approach here is to undertake joint studies from the early stages of R&D on use cases, technology applicability, and common carrier requirements. APAC has high growth potential as a telecommunications market compared with Europe and the United States, and future investment in new technologies and services for the telecommunications infrastructure can be expected. APAC also includes many countries having diverse regional characteristics, and this is expected to lead to the development of new services based on diverse needs in the telecommunications market and information and communication technology (ICT) industry. Collaborating with a variety of players in the APAC region should stimulate innovation in the use of ICT and contribute to the creation and expansion of a productive and affluent society in the APAC region. Our aim here is to use this engagement with APAC as an opportunity to transform the entire global industry.

In this article, we introduce the APAC Telecom Innovation Initiative (ATII) now in progress and collaborative efforts with carriers and other partners outside Japan as specific examples of our new approach to network R&D.



PoC: proof of concept

Fig. 1. Overview of ATII.

2. ATII R&D initiative and global dissemination from the APAC region

In April 2017, NTT and PT Telkomunikasi Indonesia (Persero) Tbk (hereinafter, TELKOM), Indonesia's leading telecommunications provider, established ATII as an R&D initiative targeting virtual infrastructure technologies with the aim of improving communication services and creating new network services in the APAC region [1]. The Vietnam Posts and Telecommunications Group (VNPT) joined ATII in September 2017, and at present, the initiative participants are actively working to disseminate information from the APAC region on a global scale (**Fig. 1**). Joint studies are being conducted in the ATII toward the creation of new network services with a view to 2020 and beyond. Moreover, with the aim of solving common problems in the APAC region, joint technical studies and proofs of concept (PoCs) are being carried out on "Flexible and Smart Network" technologies with a focus on virtual infrastructure technologies. Three work projects (WPs) have so far been launched to conduct joint studies and PoCs.

(1) WP1: High Value-added Network Services

We conducted a joint PoC with TELKOM on smart building services applying Data Stream Assist technology [2] at a TELKOM building in Bandung, Indonesia (**Fig. 2**). From here on, we plan to conduct more studies toward field trials of such services.

(2) WP2: Server Platform Virtualization

We conducted a joint PoC based on a virtual customer premises equipment (vCPE) use case. The demonstration involved controlling a TELKOM virtual firewall (vFW) by using NTT virtual machine manager technology [3] via an interconnection between TELKOM (Bandung) and NTT (Tokyo – Kuala Lumpur) test beds (**Fig. 3**). With the knowledge gained here, we are improving elemental technologies and planning to popularize and expand this scheme by contributing it to open source software (OSS) communities.

(3) WP3: Flexible Access Network Virtualization

We conducted a joint study on access network virtualization based on Flexible Access System Architecture (FASA) [4, 5] and undertook the drafting of common specifications by extracting common requirements from use cases brought to the study. We released the results of this study as a white paper and are now promoting standardization activities with TELKOM and other European and American carriers at the Broadband Forum (BBF).

At ATII, we plan to make proposals and suggestions

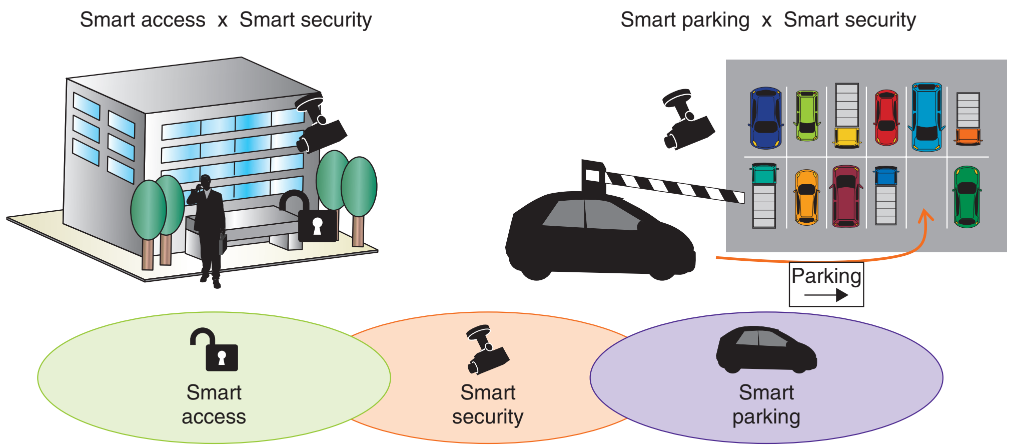
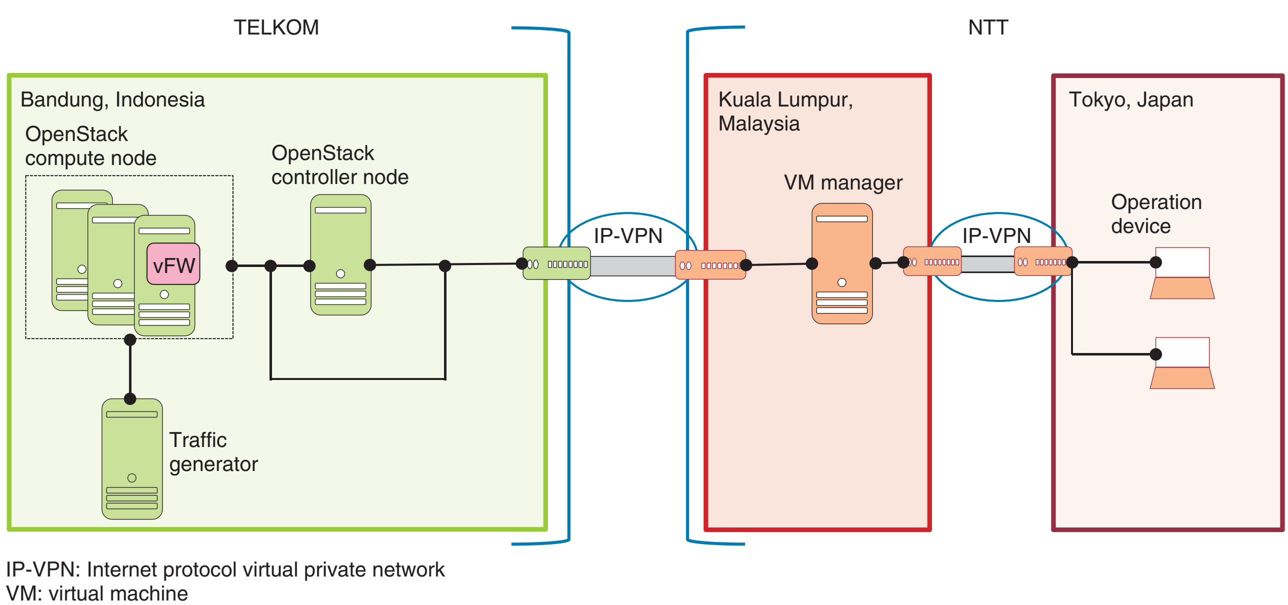


Fig. 2. Example of high-value-added network services.



IP-VPN: Internet protocol virtual private network
VM: virtual machine

Fig. 3. Joint PoC on multi-country test beds.

to SDOs and industry alliances by pursuing more joint studies and PoCs as we go forward. We also seek to expand this initiative by encouraging the participation of more service providers and partners.

3. Activities regarding access network virtualization (FASA) with an eye to global expansion

FASA was proposed in February 2016 by the NTT laboratories as a concept related to the development of future access network technology. We explain the latest activities involving FASA in this section.

3.1 FASA activities to date

The aim with FASA is to enable end users to access diverse services in a quick and low-cost manner and to enable service providers (the second 'B' in the B2B2X (business-to-business-to-X) model) to provide services promptly. To realize the FASA concept, we released a FASA application programming interface (API) in phases as white papers in May 2016 and

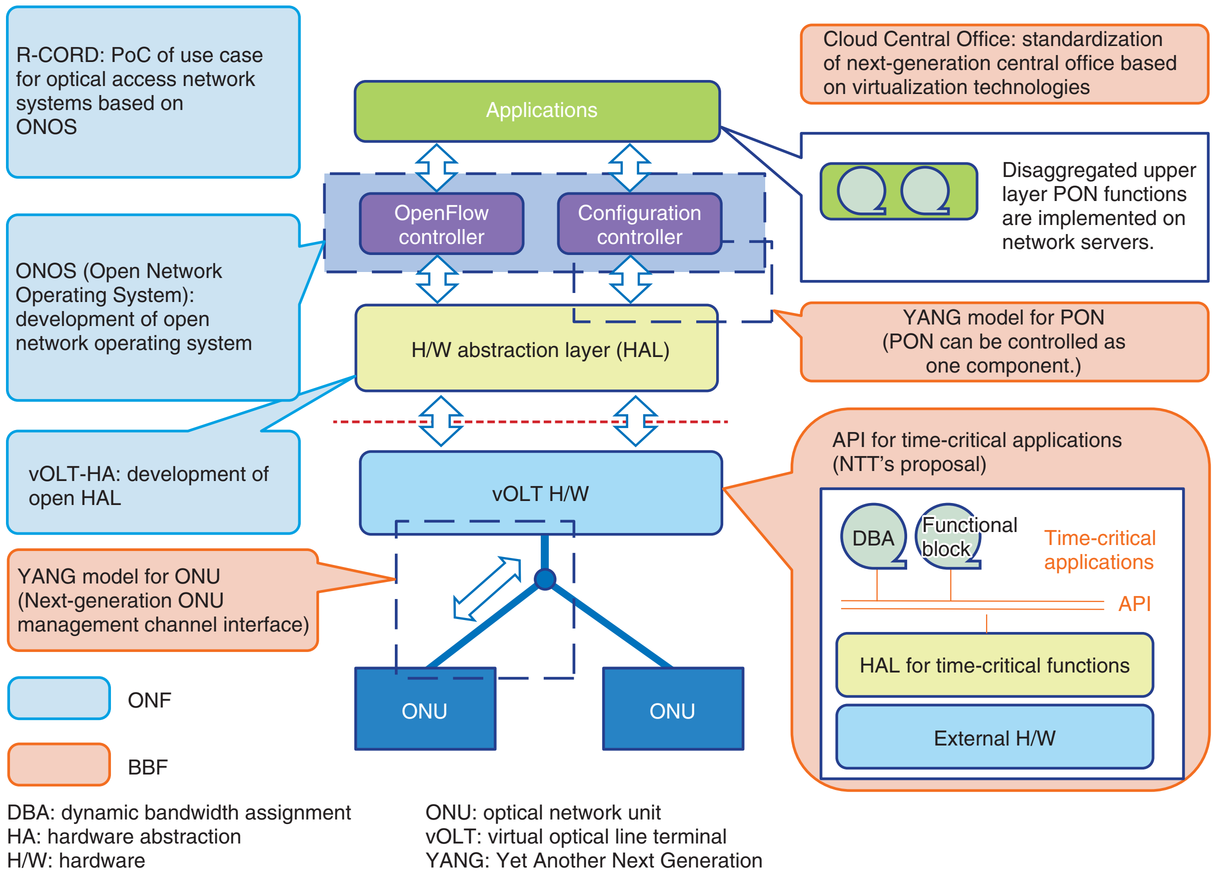


Fig. 4. FASA R&D based on cooperation between organizations in standardization projects and the use of open source software.

February 2017, promoting it as a commonly usable API.

3.2 Collaboration with other organizations on access network virtualization

The Central Office Re-architected as a Datacenter (CORD) project for virtualizing and reconfiguring a telecom carrier's central office in the same way as a datacenter is being moved forward in the Open Networking Foundation (ONF). In particular, studies on passive optical network (PON) virtualization are being conducted in the R-CORD (Residential CORD) project targeting subscribers (access the network). In this project, we are realizing FASA through verification experiments on use cases based on FASA (**Fig. 4**).

The BBF, moreover, has launched the standardization of Cloud Central Office corresponding to CORD in ONF, and in terms of access, it is standardizing specifications for architecture targeting software-defined networking (SDN) access nodes and for YANG (Yet Another Next Generation) data modules for use in configuring and managing access network equipment. The abstraction layers of the virtual OLT (optical line terminal) are being investigated to communalize the equipment interface that is dependent on hardware.

There are many areas in which these standardization activities overlap with FASA, so we are cooperating with other organizations to reflect FASA requirements and specifications in those areas and accelerate research on FASA. Furthermore, as part of the FASA activities, we have proposed a new standardization project at BBF on the virtualization of time-critical applications such as DBA (dynamic bandwidth assignment) and have commenced related standardization activities [6].

Additionally, as part of our access virtualization efforts in ATII WP3 described above, we are extracting common requirements among APAC carriers and incorporating them into FASA to communalize FASA technology. In short, we aim to globalize FASA and related technologies by studying FASA use cases using OSS, standardizing technologies that reflect FASA requirements, and communalizing FASA technologies among carriers.

4. Joint experiment with Chunghwa Telecom using white-box switches

In this section, we report on a joint experiment conducted with Chunghwa Telecom of Taiwan in 2017.

4.1 Carrier collaboration with Chunghwa Telecom

Telecom carriers have not only sought to lower costs in recent years but have also expressed a growing need to have networks that can respond quickly and flexibly to dramatic increases in traffic and diverse usage scenarios. To this end, it is becoming increasingly important to use globally common and general-purpose technologies and products instead of conventional carrier-dedicated network products.

The NTT laboratories have begun collaborating with Chunghwa Telecom on the application of common and general-purpose technologies and products to various areas of a carrier network (network edge, core backbone network, and datacenter network). Activities such as these are helping to form stronger inter-APAC-carrier ties. In this collaboration, a memorandum of understanding on joint research and joint experiments was signed in February 2017, and a joint experiment was successfully conducted at Chunghwa Telecom Laboratories in Taoyuan City, Taiwan, from November 20 to December 1, 2017 [7].

4.2 Verification of virtual-network configuration and control technologies

The NTT laboratories have been developing Multi-Service Fabric (MSF) technology as part of their R&D efforts in configuring a network with general-purpose equipment [8]. MSF is technology for configuring a highly reliable network using simple general-purpose equipment while also being an SDN architecture supporting multi-vendor network equipment. This technology was first released as OSS in October 2017 [9]. In this architecture, the MSF controller interacts with upper-level systems using REST (Representational State Transfer) and controls target switches using a configuration and control protocol such as NETCONF (Network Configuration Protocol). Additionally, with the assumed use of a Clos* network topology consisting of switches incorporating a general-purpose data-transfer ASIC (application specific integrated circuit) such as white-box switches, MSF can achieve virtual networks such as a Virtual eXtensible Local Area Network (VXLAN) or layer-3 virtual private network (VPN) using MPLS (Multi-Protocol Label Switching).

Chunghwa Telecom, meanwhile, has proposed a uniform control method for multiple SDN architectures using a GUI (graphical user interface) and has developed an orchestrator called Network Adapter with Programmability and Automation (NAPA) that can easily grasp network conditions. NTT and Chunghwa Telecom conducted a joint experiment on linking NAPA and MSF to verify virtual-network configuration and control technologies using an Ethernet VPN VXLAN running on an operating system for white-box switches (**Fig. 5**). In addition to verifying the interoperability of both companies' technologies, this joint experiment simulated faults that can occur in carrier network operation in order to verify a level of reliability that ensures service continuity can be provided. For example, the experiment verified that redundancy measures at the time of a fault in the MSF controller and automatic switching of communication paths at the time of a fault in white-box switches were functioning adequately.

NTT and Chunghwa Telecom plan to use the knowledge gained in this joint experiment to conduct more detailed technical studies and tests toward the use of general-purpose products such as white-box switches in commercial services. Moreover, at NTT, we will disseminate these experimental results and the knowledge gained from this collaboration in open communities such as Telecom Infra Project and ONF with the aim of gaining more advocates of this technology on a global basis.

5. Future development

The NTT laboratories will continue to collaborate with diverse global partners and promote accelerated R&D for network technologies driven by open innovation with the aim of achieving a network that creates new value for its users.

* Clos: A network connection format in which all lower-tier network devices (leaves) are connected to all upper-tier network devices (spine) with no network devices on the same tier (fellow leaf devices or fellow spine devices) connected to each other.

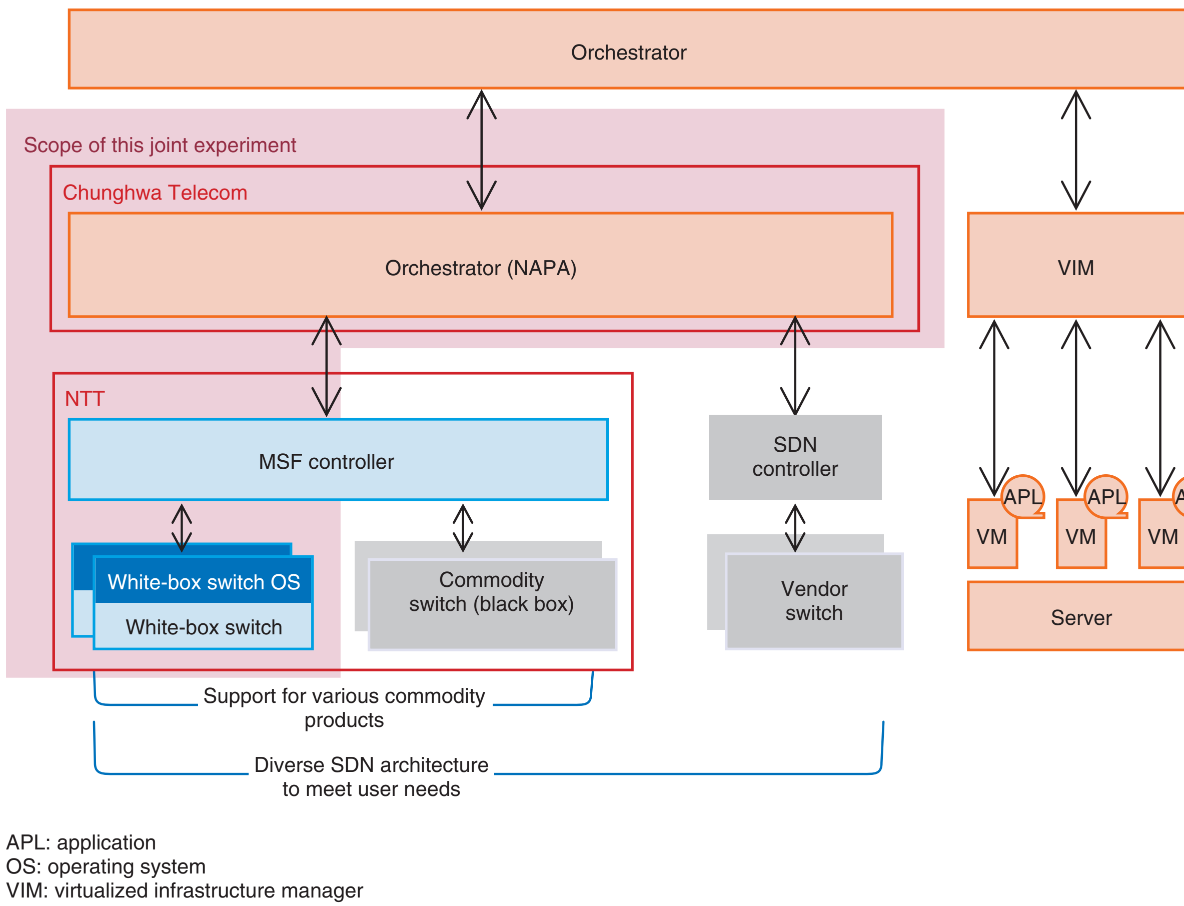


Fig. 5. Joint experiment with Chunghwa Telecom using white-box switches.

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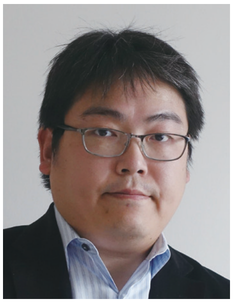


Takeshi Kuwahara
Senior Research Engineer, Supervisor, Group Leader, Innovative Network Technology and Collaboration Group, NTT Network Technology Laboratories.

He received a B.E. and M.E. from Waseda University, Tokyo, in 1995 and 1997. Since joining NTT in 1997, he has been engaged in R&D of ATM networks, IP-VPNs, cloud systems, network security, and edge computing technologies. He was in charge of telecom carrier relations regarding network R&D while based in Washington, D.C., USA, and led the establishment of ATII (APAC Telecom Innovation Initiative) while in his current position. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

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

He received a B.A. in environmental information and an M.A. in media and governance (I.T.) from Keio University in 2003 and 2005. He joined NTT Network Service Systems Laboratories in 2005. He researched traffic analysis technologies using flow information such as NetFlow/IPFIX (IP Flow Information Export) and proposed drafts about IPFIX in the Internet Engineering Task Force as part of standardization efforts. He has been one of the original architects of NTT's SDN technology for Multi-Service Fabric (MSF) since July 2014. He also initiated a project to construct an original networking OS called "Beluganos" using OSS and OpenFlow on merchant silicon-based switches. He is a member of IEICE.

Ken-Ichi Suzuki
Senior Research Engineer, Supervisor, NTT Access Network Service Systems Laboratories.

He received a B.E. and M.E. in electronic engineering from Utsunomiya University, Tochigi, in 1988 and 1990, and a Ph.D. in information science and technology from Hokkaido University in 2009. He joined NTT in 1990, where he has been engaged in R&D of optical communications systems. He is currently working on the FASA project and has also been involved in R&D of optical access related systems/technologies including next-generation optical access systems and long-reach PON systems based on burst-mode optical-amplifier and digital coherent technologies. He has served as Vice Chair of the IEEE (Institute of Electrical and Electronics Engineers) 1904 Access Networks Working Group, Chair of the Optical Access Test Implementation Liaison Committee in HATS (Harmonization of Advanced Telecommunication Systems) Conference of Japan, and Chair of WP3, the Project for Flexible Access System Virtualization, of ATII. Dr. Suzuki is a member of OSA (The Optical Society), IEEE, and IEICE.

Traffic Prediction and Quality Evaluation for Improving Communication Quality during Major Events

Daisuke Ikegami and Jun Okamoto

Abstract

NTT Network Technology Laboratories is studying event-traffic prediction and quality evaluation for preventing deterioration in communication quality due to a sudden increase in traffic during major events. In this study, we model user movement and communication behavior and predict traffic volumes and communication quality on the day of an event by prior simulation.

Keywords: traffic prediction, multi agent simulation, communication behavior

1. Countermeasures to traffic during major events

Recent years have seen explosive growth in the use of mobile terminals such as smartphones and tablets and the emergence of diverse media services. As a result, the communication applications for mobile users have become increasingly diverse, and data-intensive communications as in video viewing and image sharing on social networking services have become an everyday activity. This means that major events such as fireworks displays and festivals—that is, events where more than ten times the usual number of people can come together at a specific time within a specific space—can potentially generate large volumes of mobile traffic that existing facilities and resources cannot easily accommodate. Consequently, the problem arises as to how to estimate the communication resources needed and implement appropriate countermeasures such as adding more facilities and resources in order to carry such a large volume of traffic and prevent deterioration in communication quality.

In general, past traffic data and actions implemented by operators can be stored for events that are held regularly, and such knowledge can be used when necessary to mount countermeasures to heavy traffic. With this approach, however, it must be kept in mind that the timetable and venue can change even for the same event, resulting in temporal and spatial changes in traffic. In addition, first-time events have no past traffic data, which makes accurate estimation of traffic volumes difficult.

2. Event-traffic prediction

NTT Network Technology Laboratories has proposed a method for predicting event traffic in the area surrounding the event venue by using simulation that inputs behavior rules of mobile terminal users based on two key assumptions: (a) the behavior of people at an event can be consolidated into typical behavior according to event content, and (b) typical user behavior for even a new event is equivalent to that of a similar past event (**Fig. 1**). With the proposed method, parameters such as map data and number of users are input into the user behavior model (behavior rules), and traffic volumes generated by simulation in certain temporal and spatial granularities are output. Here, the user behavior model consists of (1) a

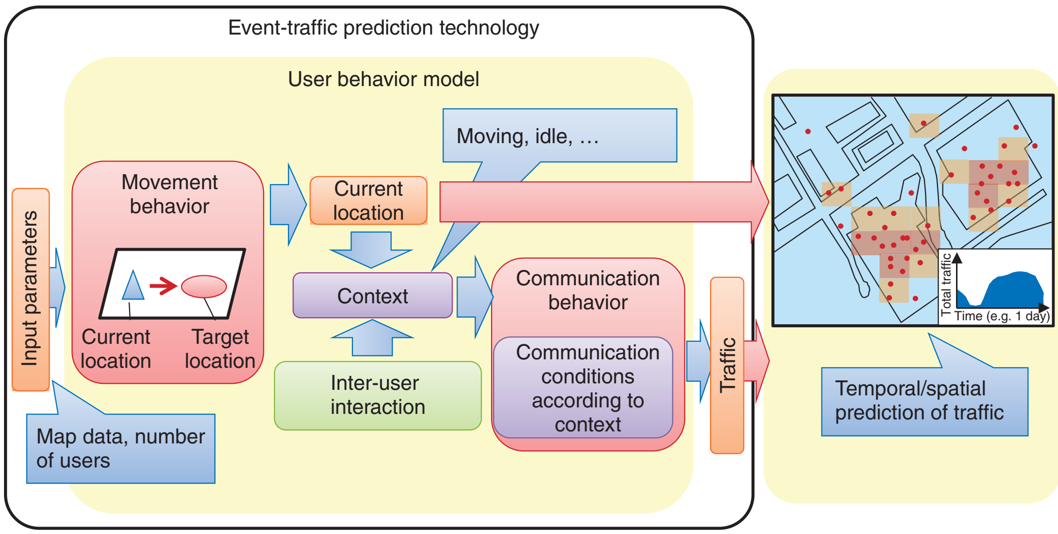


Fig. 1. Event-traffic prediction method.

movement behavior model describing user movement, and (2) a communication behavior model describing communication behavior, as summarized below:

(1) The movement behavior model consists of spatial movement rules in an event venue space. It determines a user's destination and route of movement within the time period simulated.

(2) The communication behavior model consists of traffic generation rules of a mobile terminal carried by a user. It determines the presence/absence of traffic and the traffic volume depending on the time, place, and surrounding area.

In this study, we consider that user communication behavior has a strong dependence on user context, and we model this feature accordingly. For example, we expect a user to communicate infrequently while in motion and frequently while waiting in line.

3. Event-time communication-quality evaluation

To accurately estimate the communication resources needed at the time of an event, we need to estimate the communication quality for the predicted flow of event traffic and specify the locations and times corresponding to a drop in communication quality. Techniques for estimating the quality of mobile communications have been proposed in the past. These techniques are used to estimate communication quality at any measurement point based on radio parameters such as interference and terminal receive strength. However, since many people can be expected to assemble at the same time during an event, resulting in communication conditions that are vastly different from normal times, estimating radio parameters for an event day beforehand has been difficult. This, in turn, has made it difficult to estimate communication quality.

In this study, we are focusing on the fact that the results of user behavior will affect radio parameters on event day and therefore estimate communication quality at event time accordingly. Specifically, based on traffic prediction results and a communication resource deployment plan envisioned for an event, we estimate communication quality on event day by inputting venue congestion and traffic flowing through each resource—which relate to radio receive strength and interference—into a mathematical model (**Fig. 2**).

4. Toward further improvements in communication quality

In this article, we introduced a study on methods of event traffic prediction and communication quality evaluation for dealing with sudden jumps in traffic associated with major events. These methods involve conducting prior simulations to predict mobile-user behavior that affects mobile traffic on event day and to estimate communication quality at event time.

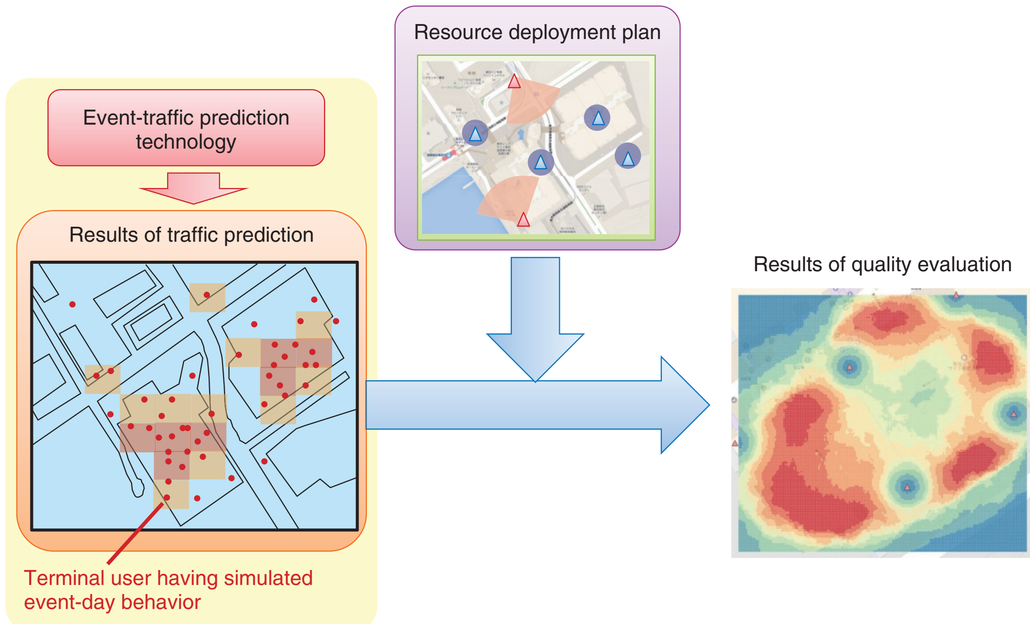
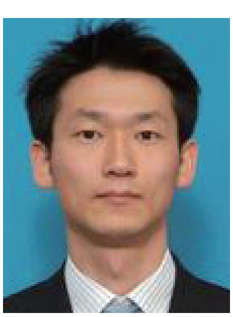


Fig. 2. Overview of quality evaluation technique based on event traffic.

These methods can be applied to facility design, as in deriving optimal locations for deploying communication resources. In the future, we expect that these methods will be applied in estimating and improving communication quality during the international sports event happening in Tokyo in 2020 and during other major events held throughout Japan.

However, from the viewpoint of monitoring and control, it is necessary to deal with changes in mobile-user behavior due to scheduling delays on event day and the holding of special events. Given the possibility of real-time and detailed network control by 5G (fifth-generation mobile communications systems) in the future, we plan to study the application of this technology to real-time control based on observed traffic and communication quality data in addition to prior facility design as described in this article.



Daisuke Ikegami
Associate Manager, NTT Network Technology Laboratories.

He received a B.E., M.E., and Ph.D. from Waseda University, Tokyo, in 2002, 2004, and 2007. Since joining NTT Service Integration Laboratories in 2007, he has been researching IP (Internet protocol) service network engineering. He also carried out promotional activities related to research and development technologies at NTT Beijing Representative Office from 2012 to 2015. He received the Young Engineer Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 2010. He is a member of IEICE.

Jun Okamoto
Senior Research Engineer, Supervisor, Service Assessment Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.

He received a B.S. and M.S. in electrical engineering from the Tokyo University of Science in 1994 and 1996. He joined NTT in 1996 and has been engaged in the quality assessment of visual communication services. He is currently working on developing subjective and objective methods to assess audio/visual communication services. He has been contributing to VQEG (Video Quality Experts Group) since 2004. He received the Telecommunications Advancement Foundation Award in 2009 and the International Telecommunication Union Encouragement Award in Japan in 2010.

Investigating Countermeasures against High-altitude Electromagnetic Pulse (HEMP)

Masato Maruyama, Ken Okamoto, Yuichiro Okugawa, and Jun Kato

Abstract
The threat of attack by a nuclear explosion triggering a high-altitude electromagnetic pulse (HEMP) has become an actuality. HEMP has the capacity to destroy a wide range of electric and electronic equipment. We report here on initiatives being studied to reduce the damage caused by a breakdown of communications and to restore communications promptly.

Keywords: HEMP, pulse, nuclear

1. Introduction

The recent deterioration in the international situation means that an attack by high-altitude electromagnetic pulse (HEMP) is becoming a more realistic threat. HEMP is a very powerful electromagnetic wave generated when a nuclear explosion occurs at an altitude of 30–400 km (**Fig. 1**). Heat rays, blasts, and radiation caused by a nuclear explosion would not reach the ground because of the very high detonation altitude. However, strong electromagnetic waves would be radiated over a wide area (radius of 1000 km) at ground level.

HEMP is capable of destroying a wide variety of electric and electronic equipment. As a result, all systems including electricity, gas, water and sewage, transportation, broadcasting, and communication would be deprived of control functions and possibly break down and stop functioning over a wide geographical area [1]. In particular, disruption or severing of communications would be a major barrier to restoration and further exacerbate the initial damage. Therefore, the most important task is to devise countermeasures to HEMP in order to protect communication equipment.

One effective countermeasure would be to protect key facilities by installing electromagnetic-wave shielding and noise filters in equipment. However, from a cost perspective, it is impossible to protect every piece of equipment. Therefore, in the first instance, it is essential to clarify the possible flow-on effects of disruption to communication equipment caused by HEMP and to consider appropriate (necessary and sufficient) protective measures. Specifically, we first have to know the maximum intensity of HEMP that equipment might be exposed to (the required proof stress for the equipment), and the intensity of electromagnetic waves that the equipment can withstand without failing (the actual proof stress of the equipment). Then, if the actual proof stress of the device is below what is required, necessary measures to compensate for the shortfall revealed by the proof stress test will have to be taken.

2. Countermeasures against HEMP to protect telecom equipment

Here, we explain the issue of required proof stress and actual proof stress of equipment.

2.1 Required proof stress of equipment

HEMP has been discussed at various academic

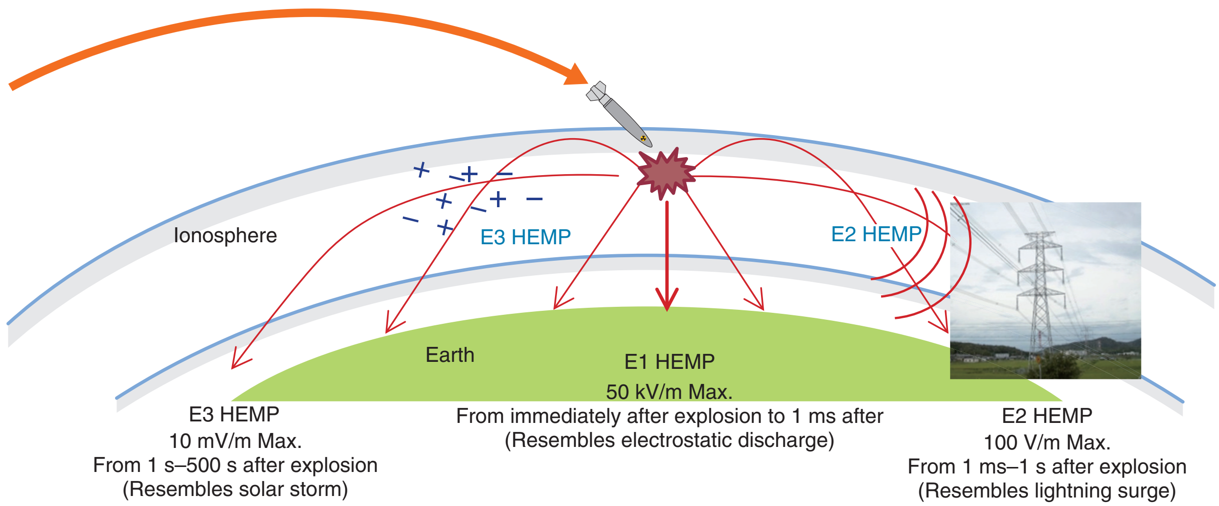


Fig. 1. Depiction of HEMP attack.

conferences and standardization meetings since the 1990s, and in 2009, Recommendation ITU-T K.78 "High altitude electromagnetic pulse immunity guide for telecommunication centres" was approved by the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 5 [2]. This standard describes the proof stress requirement for telecom and power equipment for each way (seven ways in total) in which HEMP can affect them. However, the proof stress required for the equipment depends on the environment in which the equipment is installed (such as the building structure and the presence or absence of countermeasures against lightning strikes). Therefore, we are evaluating the equipment installation environment based on the NTT Standard Operation Procedure and past electromagnetic wave measurement results.

2.2 Actual proof stress of equipment

To measure the proof stress of equipment, it is necessary to expose the equipment to an electromagnetic pulse imitating HEMP. However, the electromagnetic pulse created by HEMP is extremely strong and has a very steep rise characteristic, so determining how to generate the pulse and expose the equipment to it is a challenging task.

3. Future plans

We are currently evaluating the communication device installation environment, examining the electromagnetic pulse application test method, and building a test environment in cooperation with the NTT EAST Technical Assistance and Support Center. Going forward, we plan to collaborate with the Disaster Prevention Planning Office of each of the NTT operating companies and carry out proof stress tests on various kinds of equipment.

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Masato Maruyama

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

He received a B.E. and M.E. in electronics engineering from the University of Electro-Communications, Tokyo, in 2001 and 2003. He joined NTT Energy and Environment Systems Laboratories in 2003 and engaged in studies on stabilization of direct current power supply systems and optimization of air conditioning for telecom equipment rooms. He has been with NTT Network Technology Laboratories since 2015. His current research interest is electromagnetic compatibility for telecommunication systems.

Ken Okamoto

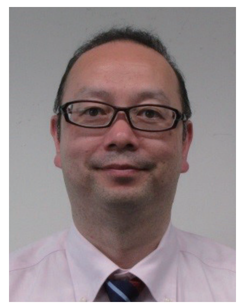
Senior Research Engineer, EMC Technology Group, Environmental Technology and Management Project, NTT Network Technology Laboratories.

He received a B.E. and M.E. in science from Nagoya University in 2004 and 2006. He joined NTT Energy and Environment Systems Laboratories in 2006 and engaged in studies on spatio-temporal image analysis in video monitoring of slope failure to detect a sign of the disaster. He is currently studying the electromagnetic compatibility (EMC) technology for telecommunications.

Yuichiro Okugawa

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

He received a B.E. and M.E. in electrical engineering from Tokyo University of Science in 2002 and 2004. He joined NTT Energy and Environment Systems Laboratories in 2004 and studied the EMC technology for telecommunications. He has been engaged in quantitative evaluation using electromagnetic simulation about the influence of electromagnetic field on communication equipment by HEMP. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).



Jun Kato

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

He received a B.E. from Shizuoka University in 1992. He joined NTT Telecommunication Networks Laboratory in 1992, and has been engaged in research and development of EMC for telecommunication systems. He is currently a supervisor of EMC Group at NTT Network Technology Laboratories.

Automotive Edge Computing Consortium—a Global Effort to Develop a Connected Car Platform

Koya Mori

Abstract

NTT launched the Automotive Edge Computing Consortium with various global partners, namely, DENSO Corporation, Ericsson, Intel Corporation, NTT DOCOMO, Toyota InfoTechnology Center Co., Ltd., and Toyota Motor Corporation, in order to develop technologies for connected cars using automotive big data. The objective of the consortium is to form an ecosystem for connected cars to support emerging services such as intelligent driving, the creation of maps with real-time data, and driving assistance based on cloud computing.

Keywords: edge computing, connected car, automotive big data

1. Introduction

Safer driving, minimized traffic delay, effective resource consumption, and a lower level of air pollution are some of the demands of the future society where a profound increase in mobile telecommunication usage for connected cars is expected. In advanced automotive services such as intelligent driving, data generation for real-time maps, and cloud-assisted driving, it is expected that a huge number of data transfers between connected cars and the cloud will be inevitable. By 2025, it is predicted that the amount of data exchanged between connected cars and the cloud will reach 10 exabytes per month [1]. This is 10,000 times the amount of data exchanged today. Thus, technologies such as distributed networking and system architectures with computing resources that can accommodate the processing of a huge amount of data are needed.

To enable the fulfillment of these demands and to promote the widespread use of the new technology, NTT, alongside DENSO Corporation, Ericsson, Intel Corporation, NTT DOCOMO, Toyota InfoTechnology Center, and Toyota Motor Corporation, established the Automotive Edge Computing Consortium (AECC) [2].

2. Issues in developing connected car platform

A capacity issue arises with the current mobile network and cloud computing system in accommodating a large number of connected cars effectively. In a network topology expressed in a tree form as the basic architecture of a mobile network, traffic on such a network converges at the narrow top end, and this causes a huge concentration of data from/to connected cars. Moreover, data concentration is an even more serious issue because the current cloud computing is also located at converged datacenters. These heavy concentrations of data cause a slow response time and long processing time between connected cars and the cloud system and are an obstacle to implement a platform to serve a large number of connected cars.

Therefore, the purpose of the AECC is to design a system architecture for a connected car platform to convey and process a huge amount of data with an appropriate network and assignment of computing resources (**Fig. 1**).

3. Concept of AECC

One solution to the aforementioned issue is to

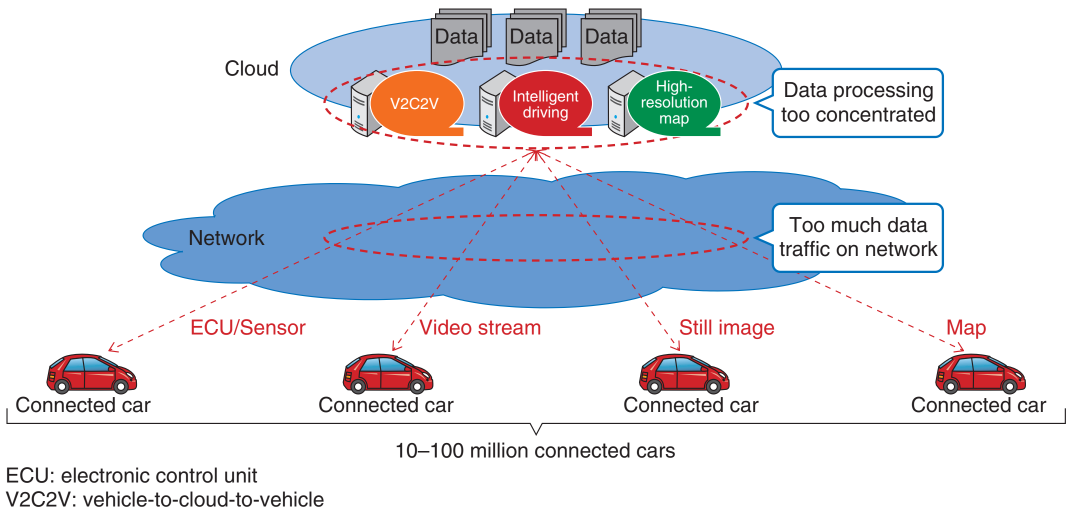


Fig. 1. Issues of current mobile network architecture [1].

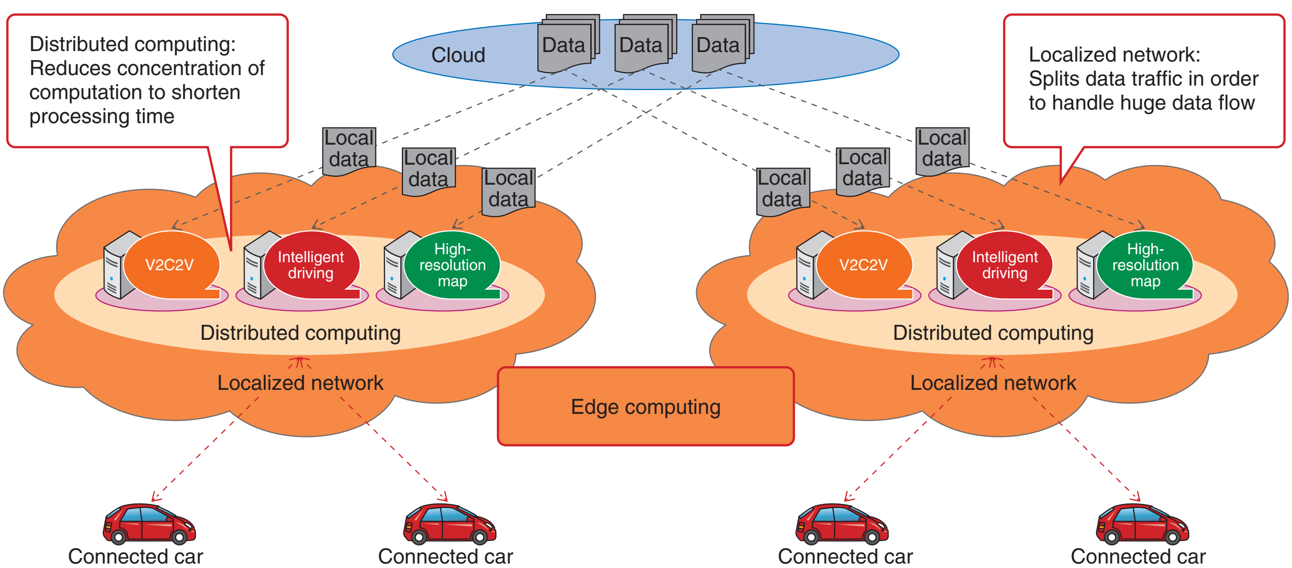


Fig. 2. Utilization of edge computing [1].

distribute computing resources on a localized network. When computing and network resources are distributed locally, each local system can handle a small amount of data traffic and implement timely responses to connected cars.

The distributed network and computation features of edge computing make it a promising technology that could be adopted to realize this concept. The network is designed to split data traffic into several localities that cover reasonable numbers of connected cars. The computation resources are hierarchically distributed and layered in a topology-aware fashion to accommodate localized data and to allow large volumes of data to be processed in a timely manner (**Fig. 2**).

Edge computing technology will thus provide an end-to-end system architecture framework used to distribute computation processes to localized networks. Therefore, the AECC will focus on increasing capacity to accommodate automotive big data in a

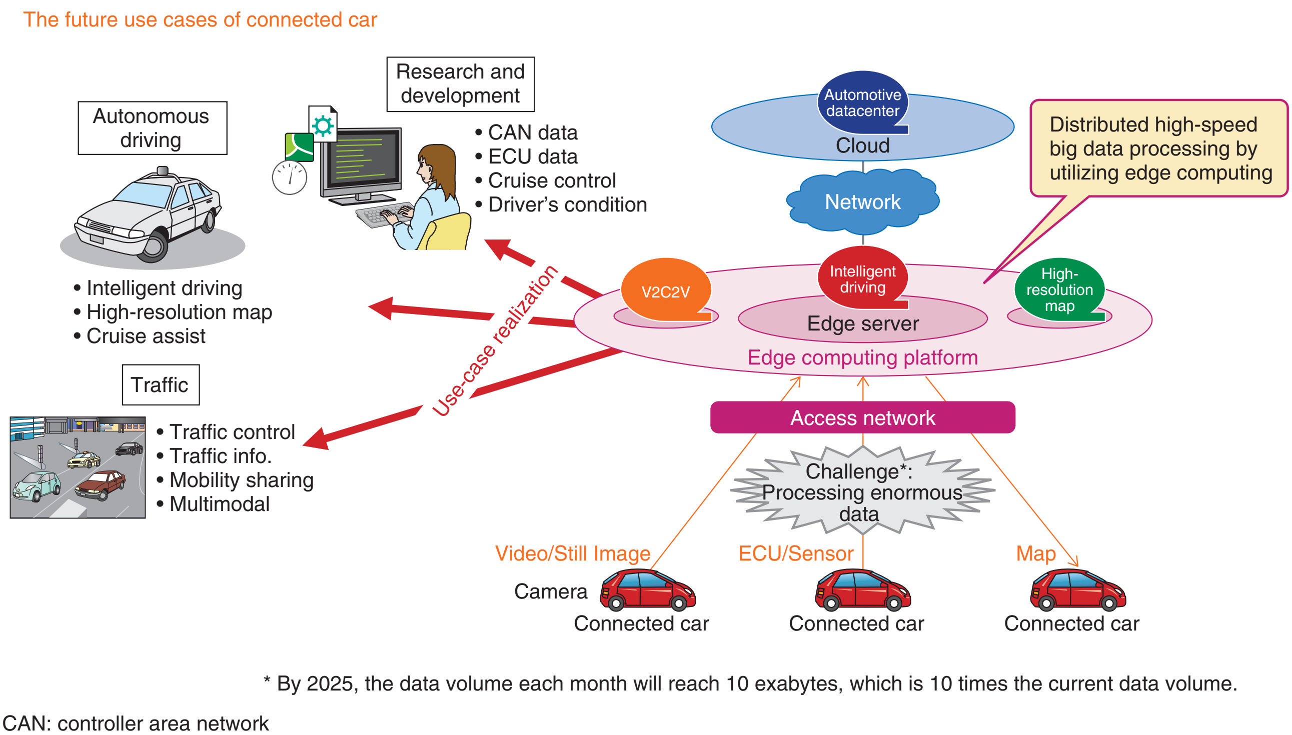


Fig. 3. Concept of AECC.

reasonable fashion between vehicles and the cloud by means of edge computing technology and more efficient network designs. The consortium will define requirements and develop use cases for emerging mobile services, with a particular focus on the automotive industry (**Fig. 3**).

4. Global spread of technology

There are important steps needed to realize AECC's vision, starting with developing and implementing technologies surrounding connected cars on a global scale, fostering the global acceptance of a common system architecture, and involving related industries in the construction of the architecture. To achieve this mission, we brought together partners from different fields of industry including automotive, telecommunications, and information technology to establish the AECC. With a strong global partnership, we want to push our requirements as an input to standards developing organizations and industry bodies to achieve global standards. In concrete form, we want to endorse the aforementioned edge computing, networks, and architecture to accommodate huge volumes of traffic and the creation of corresponding analysis tools for data processing to realize intelligent driving, data generation for real-time maps, and cloud-assisted driving. For that reason, we will continue our efforts in defining the requirements for the system architecture and creating the necessary platform that will enable future automotive services.

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[2] Website of AECC, https://aecc.org/

Koya Mori

Senior Research Engineer, NTT Network Innovation Laboratories.

After joining NTT in 2004, he researched and developed an Internet of Things application based on software technologies such as the OSGi (Open Services Gateway Initiative), OpenStack, and edge computing. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Investigation of Unintentional One-ring Outgoing Calls

Abstract

This article describes an actual problem case involving unintentional one-ring outgoing calls. The Network Interface Engineering Group investigated the mechanism of the problem and devised some solutions to prevent a recurrence. This is the forty-sixth article in a series on telecommunication technologies. This contribution is from the Network Interface Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: PBX, IP phone, IP packet capture

1. Introduction

The Network Interface Engineering Group conducts investigations and provides technical support to solve highly technical problems that occur in Internet protocol (IP) network services such as FLET'S HIKARI NEXT. In the investigations, we often capture and analyze IP packets to find out the root causes of the problem and then present practical solutions to enable continuous use of the services by our customers. However, IP network services accommodate not only an Ethernet-based device but also a VoIP (voice over Internet protocol) gateway, which converts IP signals to non-IP signals such as analog or integrated services digital network (ISDN) signals. Therefore, it is necessary to choose proper measurement devices such as oscilloscopes, protocol analyzers, or other terminal-specific measurement devices to collect and analyze data when we face technical problems.

In this article, we introduce a case involving unintentional one-ring calls that occurred in a business phone system using extension phones. The details of the problem and our analysis method are also presented in the following sections.

2. Problem overview and investigation method

A customer (User A) recognized that the one-ring calls were happening several times a day and therefore contacted the maintenance provider of their private branch exchange (PBX). By checking the call logs of the PBX, the maintenance provider found that the one-ring calls were coming from one particular number. Therefore, User A also contacted the caller suspected of making the one-ring phone calls so as to solve the problem. The caller (User B) was using the optical IP telephone service called HIKARI DENWA OFFICE A (ACE) with the Netcommunity SYSTEM αNX II type-L (NXIIL) phone system. The NXIIL system data indicated that the telephone number of User A was registered in the phonebook of the NXIIL system. We checked the call history data saved on all of the phones deployed in User B's system and determined that only one particular phone was used to call User A. However, the user of the phone claimed that he had not make the phone calls. Suspecting a device failure, the field maintenance personnel performed the usual maintenance procedures such as turning the power of the NXIIL main equipment off/on and replacing the central control unit (CCU)[*1]. These procedures did not solve the problem, however, so the Technical Assistance and Support Center conducted an investigation of the matter.

The configuration of the user networks and data collection points is shown in **Fig. 1**. We collected: (1)

*1 CCU: A circuit board unit that performs IP packet routing and call processing of the system.

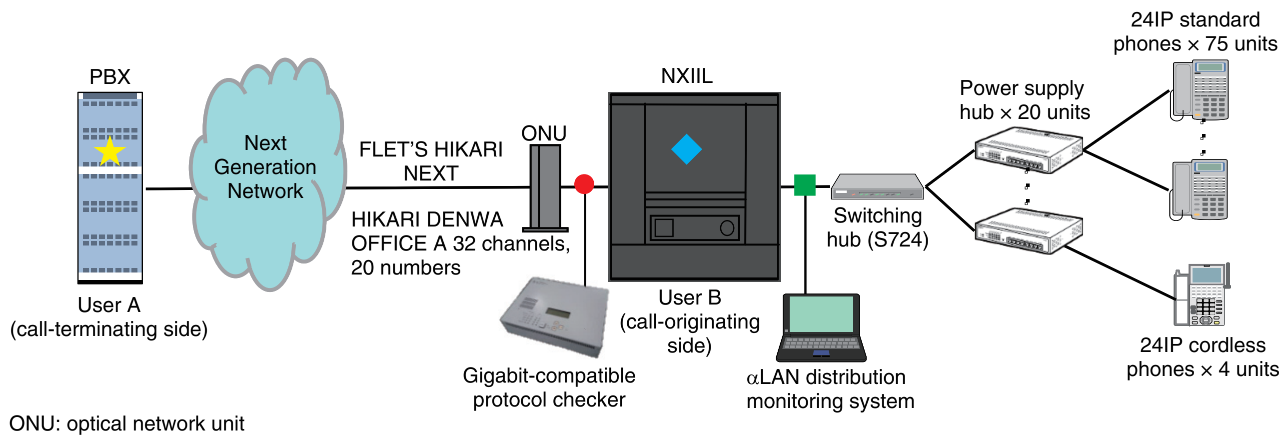


Fig. 1. Connection configuration and data collection points.

incoming call logs of the PBX at the call-terminating side (★), (2) IP packets on the Ethernet section with a packet capture device (●), (3) IP extension phone operation commands with an αLAN distribution monitoring system[*2] (■), and (4) system data on the NXIIL system (◆). By collecting and analyzing such data, we can determine where the problem originated.

3. Analysis of collected data

We describe in this section how we analyzed the data to detect the root of the problem.

3.1 Incoming call log of PBX

The incoming call log on the User A side PBX showed that extremely short calls (less than one second from receipt to disconnection of call) occurred four times during the investigation. Moreover, all of the calls had the same identification number registered in the NXIIL system.

3.2 IP packet capture data

We analyzed the captured IP packet data and found that INVITE signals (request signals to establish calls in the session initiation protocol (SIP)[*3]) were sent from User B to User A. Note that the sending time of the INVITE signals all agreed with the recorded time of the one-ring calls in the PBX logs described above. Furthermore, CANCEL request signals (shutdown signals of the ongoing session in SIP) were also sent from the User B side. Therefore, the calls were terminated by the reception of 487 Request Terminated (termination of request signals in SIP) messages sent from the User A side (**Fig. 2**).

3.3 αLAN distribution monitoring system log

The actual user operations of the IP extension phone on the User B side were revealed by analyzing the data collected by the αLAN distribution monitoring system. The estimated user operations were as follows; first, the phonebook button was pushed twice. Then an off-hook/on-hook operation was done. Note that these were done within approximately one second (see **Table 1**).

3.4 NXIIL main equipment system data

Upon checking the common phonebook data, we found that the telephone number of User A was registered as a first entry when the user selects a *furigana* (Japanese syllabary character) search function.

4. Mechanism of unintentional one-ring calls

We found that User B used the off-hook external line capture function in the NXIIL system. This enables the user to make an outgoing call only by an off-hook operation—without pushing any number buttons—when an arbitrary number registered in the phonebook function is selected (i.e., when the number is displayed on the telephone's liquid crystal display (LCD) panel).

*2 αLAN distribution monitoring system: A local area network distribution monitoring system compatible with α series business phones. (Other monitoring systems are for bus distribution or star distribution.)

*3 SIP: A control protocol used in HIKARI DENWA and many IP phones to perform various procedures pertaining to calls, including calling of the other party, notifying the caller that the other party is being called, and managing route information of the called party.

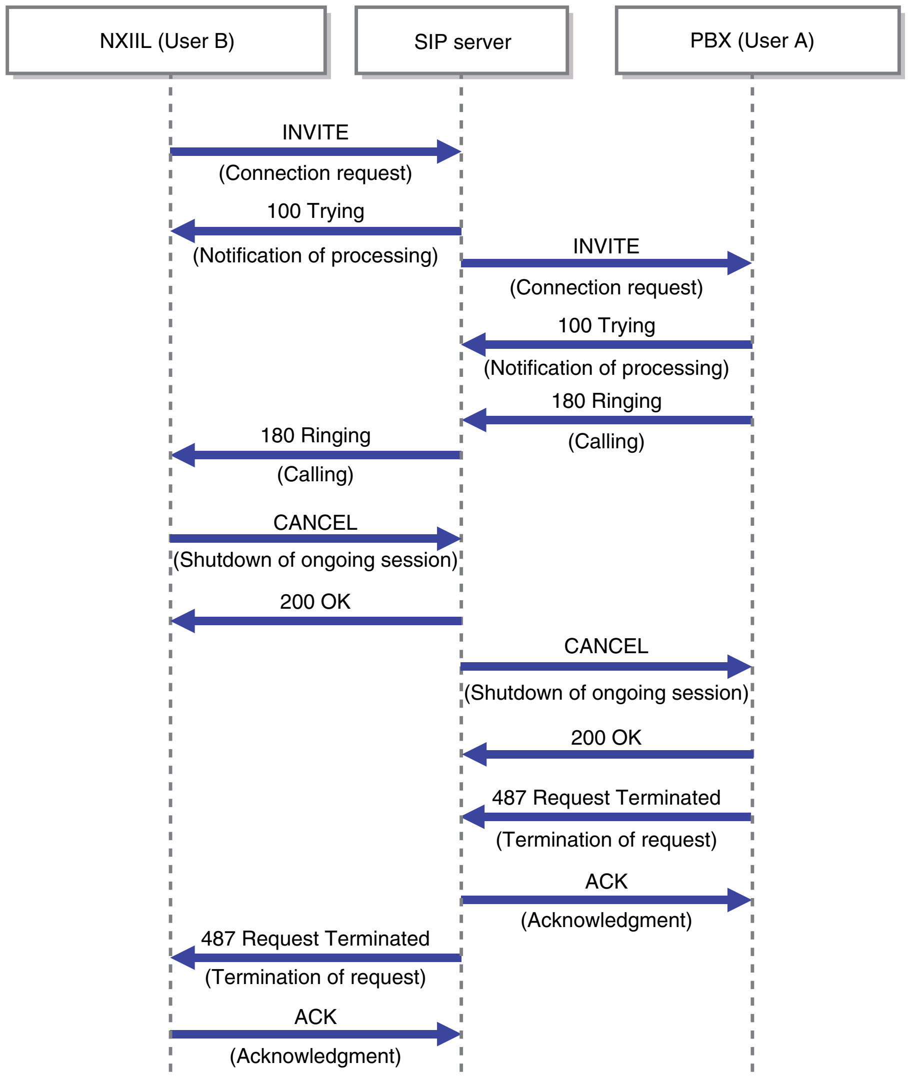


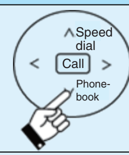
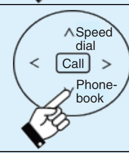
Fig. 2. SIP sequence.

Table 1. IP extension outgoing call operations (excerpt).

Time	Status display	Explanation
17:40:12	Phonebook	Phonebook button pressed
17:40:13	Phonebook	Phonebook button pressed
17:40:13	Off-hook	Receiver picked up
17:40:14	LK7 private-use	Line key 7 captured
17:40:14	On-hook	Receiver put down

When a business phone is connected to a HIKARI DENWA line or an ISDN line, the call session is established in the first few milliseconds. Therefore, the outgoing signal is delivered to the other party even when an on-hook operation is performed right after the off-hook. As a result, the call appears as a one-ring call on the User A side (**Table 2**). Note that the one-ring call does not occur when a business

Table 2. Mechanism for occurrence of unintentional one-ring calls.

Operation sequence	Telephone operation	LCD panel	Status
1		Furigana search	Furigana search function in phonebook selected
2		Relevant phonebook registration name ○○○○ ××××	Phonebook registration name of the relevant number selected
3	Off-hook	Relevant telephone number	Available external line captured and outgoing call to the relevant number made
4	On-hook	Time/Day/Day of the week/Month Extension number/ Extension name	Line disconnected

phone is connected to an analog line.

5. Inference of cause

From the captured data described in the previous section, we speculated the sequence of events as follows. First, the user (User B) pushed the phonebook button in order to use the "a-ka-sa-ta-na" (A-B-C-D-E) line search function of the phonebook. However, the user accidentally pressed the phonebook button twice. Then the user tried to clear the display by doing off-hook/on-hook operations since the first telephone number entry in the phonebook (wrong destination number) was displayed on the LCD. As a result, the call appeared as a one-ring call on the User A side. In general, pushing a *clear* button on the telephone is recommended to cancel the operation instead of using the off-hook/on-hook operation.

6. Countermeasures

We proposed the following three countermeasures to prevent unintentional calls to a particular telephone number.

(1) Users should be sure to use the *clear* button rather than performing off-hook/on-hook operations to clear the telephone number shown on the LCD.

(2) Register a dummy telephone number (e.g., an unused, short-digit number) as the first entry in the phonebook to avoid making an unintentional call, If the user prefers to use off-hook/on-hook operations instead of the clear button to cancel the operation, no call will go through to the dummy number.

(3) Disable the off-hook external line capture function of the business phone to prevent automatic external line capture when performing off-hook operations.

The customer of the call-originating side (User B) decided to perform countermeasures (1) and (2). As a result, no unintentional one-ring outgoing calls have subsequently occurred.

7. Conclusion

In this article, we introduced a problem case involving unintentional one-ring calls in a business phone system using extension phones. The problem was solved by analyzing captured Ethernet IP packets and controlling signals between the main business phone equipment (NXIIL) and the IP extension phone. The Technical Assistance and Support Center works diligently to solve such troublesome problems and ensure continuous service for our customers.

Successful Joint Test of Next-generation Onboard IoT Platform

1. Introduction

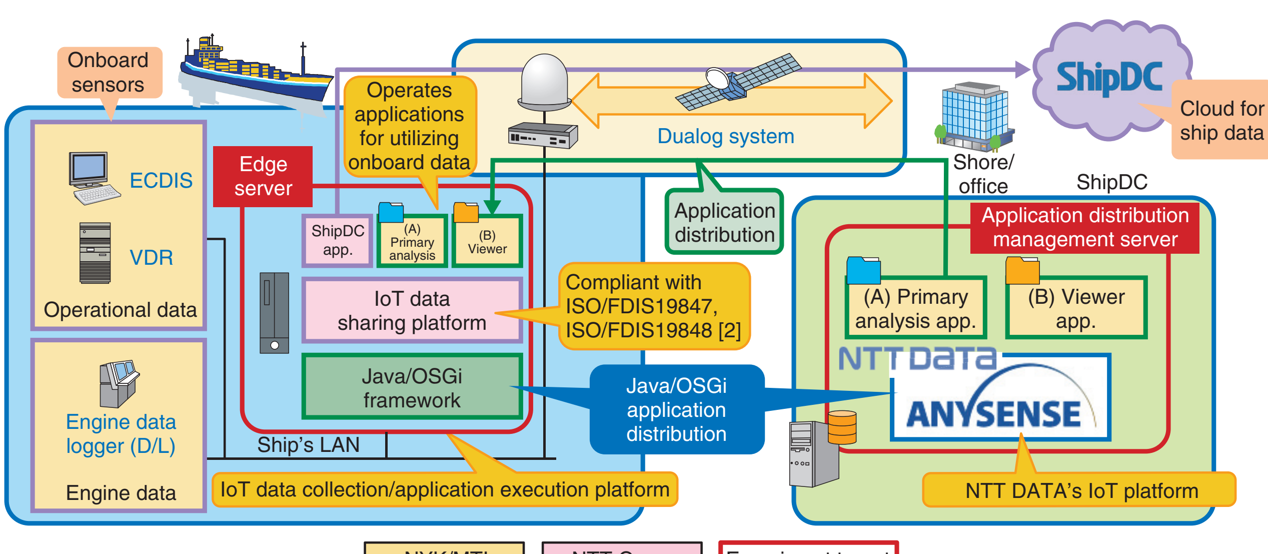
The NYK Group (Nippon Yusen Kabushiki Kaisha and MTI Co., Ltd.) and the NTT Group (NTT and NTT DATA) have successfully conducted a proof-of-concept experiment for a next-generation onboard Internet of Things (IoT) platform. The test was conducted aboard Hidaka, a domestic coastal vessel owned and operated by Kinkai Yusen Kaisha Ltd. of the NYK Group.

2. Background and details of experiment

The NYK Group previously developed a ship information management system (SIMS) that enables the gathering, monitoring, and sharing of detailed data between ship and shore, with the aim of promoting safe and efficient operations. The data include information on the operational condition and performance of oceangoing vessels.

In September 2017, the four companies began collaborating to make use of NTT's edge computing technology in order to develop a next-generation onboard IoT platform by adding to SIMS a new system that would enable the remote distribution and management of onboard applications from land offices [1]. This experiment was conducted using NTT DATA's ANYSENSE IoT platform and the communication company's expertise in developing infrastructure that makes use of IoT solutions (**Fig. 1**).

This platform is also compliant with onboard IoT international standardization being devised by the



ECDIS: electronic chart display and information system
ISO/FDIS: final draft International Standard of the International Standards Organization.
LAN: local area network
OSGi: Open Services Gateway Initiative
VDR: voyage data recorder

Fig. 1. Next-generation onboard IoT platform.

Japan Ship Machinery and Equipment Association and under development by the International Standards Organization (ISO) [2]. In addition, the gathered data can be utilized not only on board but also from an IoT open platform ShipDC, a ship datacenter established by Nippon Kaiji Kyokai (Class NK).

3. Future prospects

The four companies performing this test will next conduct a proof-of-concept experiment on an ocean-going vessel operated by the NYK Group. They will also continue to strive for innovation in the maritime industry in order to improve the safety and efficiency of vessel operations, and will promote environmental initiatives and global competitiveness.

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http://www.ntt.co.jp/news2017/1709e/170919a.html

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For Inquiries

Research and Development Planning Department, NTT

http://www.ntt.co.jp/news2018/1802e/180215a.html

External Awards

Encouraging Award
Winner: Daisuke Hisano, NTT Access Network Service Systems Laboratories
Date: July 27, 2017
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Communication Systems

For "Evaluation of TDM-PON System Aggregating TDD-based Mobile Fronthaul and Secondary Services."
Published as: D. Hisano, T. Shimada, H. Ou, T. Kobayashi, Y. Nakayama, J. Terada, and A. Otaka, "Evaluation of TDM-PON System Aggregating TDD-based Mobile Fronthaul and Secondary Services," IEICE Tech. Rep., Vol. 116, No. 401, CS2016-66, pp. 13–18, 2017.

Encouraging Award
Winner: Takahiro Suzuki, NTT Access Network Service Systems Laboratories
Date: July 27, 2017
Organization: IEICE Technical Committee on Communication Systems

For "Parallel Implementation of Cipher on CPU/GPU for Programmable Optical Access Equipment."
Published as: T. Suzuki, S. Kim, J. Kani, K. Suzuki, and A. Otaka, "Parallel Implementation of Cipher on CPU/GPU for Programmable Optical Access Equipment," IEICE Tech. Rep., Vol. 116, No. 9, CS2016-1, pp. 1–6, 2016.

2018 OSA Fellow Member
Winner: Takashi Saida, NTT Device Innovation Center
Date: January 1, 2018
Organization: The Optical Society (OSA)

For his seminal contribution to advances in waveguide-type polarization devices for coherent optical networks.

Female Researcher Encouragement Award
Winner: Yoko Ono, NTT Device Technology Laboratories
Date: March 10, 2018
Organization: The Electrochemical Society of Japan

For her research and development of photocatalytic and battery electrode materials for energy-generation and energy-storage technologies.

Young Scientist Presentation Award
Winner: Tetsuhiko Teshima, NTT Basic Research Laboratories
Date: March 17, 2018
Organization: The Japan Society of Applied Physics (JSAP)

For "Reconstruction of Micro-scale Tissues in Self-folded Microrolls."
Published as: T. Teshima, H. Nakashima, Y. Ueno, S. Sasaki, C. Henderson, and S. Tsukada, "Reconstruction of Micro-scale Tissues in Self-folded Micro-rolls," The 78th JSAP Autumn Meeting, Fukuoka, Japan, Sept. 2017.

OFT Young Researcher's Award
Winner: Shingo Ohno, NTT Access Network Service Systems Laboratories
Date: March 21, 2018
Organization: IEICE Technical Committee on Optical Fiber Technologies (OFT)

For "Distributed Spatial Mode Dispersion Measurement along Strongly Coupled Multicore Fiber Using Rayleigh Backscattering Interference Pattern."
Published as: S. Ohno, K. Toge, D. Iida, and T. Manabe, "Distributed Spatial Mode Dispersion Measurement along Strongly Coupled Multicore Fiber Using Rayleigh Backscattering Interference Pattern," IEICE Tech. Rep., Vol. 117, No. 323, OFT2017-48, pp. 23–28, 2017.

Young Researcher's Award
Winner: Atsushi Nakamura, NTT Access Network Service Systems Laboratories
Date: March 22, 2018
Organization: IEICE

For his research on applications of highly sensitive microbending detection using a 1-μm-band mode-detection optical time domain reflectometer (OTDR) and on a long-range 1-μm-band mode-detection OTDR and its field test.

Young Researcher's Award
Winner: Kenji Miyamoto, NTT Access Network Service Systems Laboratories
Date: March 22, 2018
Organization: IEICE

For "Experimental Evaluation of Mobile Fronthaul Optical Bandwidth and Wireless Transmission Performance for Base Station Architecture Splitting LTE PHY Layer Functions in Downlink" (in Japanese) and "Proposal of Low Latency Symbol Level Transmission Scheme in Intra PHY Split Base Station" (in Japanese).
Published as: K. Miyamoto, T. Shimizu, J. Terada, and A. Otaka, "Experimental Evaluation of Mobile Fronthaul Optical Bandwidth and Wireless Transmission Performance for Base Station Architecture Splitting LTE PHY Layer Functions in Downlink, " Proc. of the IEICE General Conference 2017, B-8-44, Nagoya, Japan, Mar. 2017.
K. Miyamoto, T. Shimizu, J. Terada, and A. Otaka, "Proposal of Low Latency Symbol Level Transmission Scheme in Intra PHY Split Base Station," Proc. of the IEICE Society Conference 2017, B-5-42, Tokyo, Japan, Sept. 2017.

Young Researcher's Award
Winner: Saki Nozoe, NTT Access Network Service Systems Laboratories
Date: March 22, 2018
Organization: IEICE

For "Low Crosstalk 125 μm-cladding 2LP-mode 4-core Fiber with Air-hole Structure."
Published as: S. Nozoe, T. Sakamoto, T. Matsui, Y. Amma, K. Takenaga, Y. Abe, K. Tsujikawa, S. Aozasa, K. Aikawa, and K. Nakajima, "Low Crosstalk 125 μm-cladding 2LP-mode 4-core Fiber with Air-hole Structure," IEICE Tech. Rep., Vol. 117, No. 323, OFT2017-54,

pp. 67–70, 2017.

Young Researcher's Award
Winner: Junki Ichikawa, NTT Network Innovation Laboratories
Date: March 22, 2018
Organization: IEICE

For "A Context Generation Method for Utilization of IoT-resources."
Published as: J. Ichikawa, Y. Minami, J. Yamamoto, and K. Shimano, "A Context Generation Method for Utilization of IoT-resources," Proc. of the IEICE General Conference 2017, B-18-28, Nagoya, Japan, Mar. 2017.

Young Researcher's Award
Winner: Hirofumi Sasaki, NTT Network Innovation Laboratories
Date: March 22, 2018
Organization: IEICE

For "An Analysis of Gaussian Beam Propagation for Orbital Angular Momentum (OAM) Multiplexing" and "An Experimental Evaluation of Gaussian Beam Propagation with Multiple Uniform Circular Array in 28 GHz Band."
Published as: H. Sasaki, D. Lee, H. Fukumoto, T. Nakagawa, and H. Shiba, "An Analysis of Gaussian Beam Propagation for Orbital Angular Momentum (OAM) Multiplexing," Proc. of the IEICE General Conference 2017, B-17-4, Nagoya, Japan, Mar. 2017.
H. Sasaki, D. Lee, H. Fukumoto, and H. Shiba, "An Experimental Evaluation of Gaussian Beam Propagation with Multiple Uniform Circular Array in 28 GHz Band," Proc. of the IEICE Society Conference 2017, B-17-29, Tokyo, Japan, Sept. 2017.

Young Researcher's Award
Winner: Takuro Fujii, NTT Device Technology Laboratories
Date: March 22, 2018
Organization: IEICE

For "1.3-μm InGaAlAs-based Directly Modulated Membrane Distributed Reflector Laser Array" (in Japanese).
Published as: T. Fujii, H. Nishi, K. Takeda, E. Kanno, K. Hasebe, T. Kakitsuka, T. Tsuchizawa, and S. Matsuo, "1.3-μm InGaAlAs-based Directly Modulated Membrane Distributed Reflector Laser Array," Proc. of the IEICE General Conference 2017, C-3-21, Nagoya, Japan, Mar. 2017.

SASIMI Young Researcher Award
Winner: Saki Hatta, NTT Device Innovation Center
Date: March 26, 2018
Organization: The Institute of Electrical and Electronics Engineers (IEEE) Council on Electronic Design Automation

For "Area-efficient Programmable Finite-state Machine Toward Next Generation Access Network SoC."
Published as: S. Hatta, N. Tanaka, and T. Sakamoto, "Area-efficient Programmable Finite-state Machine Toward Next Generation Access Network SoC," Proc. of the 21st Workshop on Synthesis and System Integration of Mixed Information Technologies (SASIMI 2018), Matsue, Japan, Mar. 2018.

Maejima Hisoka Award
Winner: Ken Nakamura and Takayuki Onishi, NTT Media Intelligence Laboratories; Koyo Nitta, NTT Device Innovation Center
Date: April 10, 2018
Organization: Tsushinbunka Association

For their development of H.265 video encoding compatible large-scale integrated circuit called NARA and the encoder incorporating NARA, as well as contribution to practical implementation of H.265 coding.

IPSJ Best Paper Award
Winner: Akihiro Miyata, Nihon University; Takashi Isezaki, Masanao Nakano, Tatsuya Ishihara, Reiko Aruga, NTT Service Evolution Laboratories; Takayoshi Mochizuki, NTT Research and Development Planning Department; Tomoki Watanabe, NTT Service Evolution Laboratories; Osamu Mizuno, NTT Intellectual Property Center
Date: June 6, 2018
Organization: Information Processing Society of Japan (IPSJ)

For "A Wheelchair Motion Estimation Model Using the Recent Control Ability."
Published as: A. Miyata, T. Isezaki, M. Nakano, T. Ishihara, R. Aruga, T. Mochizuki, T. Watanabe, and O. Mizuno, "A Wheelchair Motion Estimation Model Using the Recent Control Ability," IPSJ Journal, Vol. 57, No. 10, pp. 2316–2326, 2016.

Papers Published in Technical Journals and Conference Proceedings

Network Resource Management Architecture with Unified Information Models

S. Horiuchi, K. Akashi, M. Sato, and T. Kotani

Proc. of the 19th Asia-Pacific Network Operations and Management Symposium (APNOMS), Seoul, Korea, Sept. 2017.

With a view to the coming era of network virtualization, NTT is working on network operations that can flexibly manage diverse types of networks including those currently in operation. This article introduces network resource management technology for comprehensively operating a wide range of networks by expressing management specifications based on a uniform information model.

Power of Uninitialized Qubits in Shallow Quantum Circuits

Y. Takahashi and S. Tani

Proc. of the 35th Symposium on Theoretical Aspects of Computer Science (STACS 2018), Article no. 57, Caen, France, Feb./Mar. 2018.

We study the computational power of shallow quantum circuits with $O(\log n)$ initialized and $n^{O(1)}$ uninitialized ancillary qubits, where n is the input length, and the initial state of the uninitialized ancillary qubits is arbitrary. First, we show that such a circuit can compute any symmetric function on n bits that is classically computable in polynomial time. Then, we regard such a circuit as an oracle and show that a polynomial-time classical algorithm with the oracle can estimate the elements of any unitary matrix corresponding to a constant-depth quantum circuit on n qubits. Since it seems unlikely that these tasks can be done with only $O(\log n)$ initialized ancillary qubits, our results give evidence that adding uninitialized ancillary qubits increases the computational power of shallow quantum circuits with only $O(\log n)$ initialized ancillary qubits. Lastly, to understand the limitations of uninitialized ancillary qubits, we focus on near-logarithmic-depth quantum circuits with them and show the impossibility of computing the parity function on n bits.

Batteryless Bicycle Speed Recorder with Hub Dynamo and FM/AM Radio as Time Stamp Function

A. Tanaka, T. Nishihashi, H. Sakamoto, R. Suematsu, T. Kawanishi, and T. Douseki

IEEJ Transactions on Sensors and Micromachines, Vol. 138, No. 3, pp. 79–86, March 2018.

A batteryless bicycle speed recorder with a hub dynamo and FM/AM radio has been developed. The hub dynamo functions as both a power source and a speed sensor. It produces a voltage waveform with fourteen AC cycles per rotation of the bicycle wheel, which enables precise determination of speed and acceleration. Sound data of radio broadcasting was also used as a time stamp function. The data is stored in a magnetoresistive random-access memory (MRAM). A road test showed that a fabricated speed recorder mounted on a bicycle stored and reproduced accurate values of a large acceleration and its duration when the brakes were suddenly applied while the bicycle was being ridden.

Integer Nesting/Splitting for Golomb-Rice Coding of Generalized Gaussian Sources

R. Sugiura, Y. Kamamoto, and T. Moriya

Proc. of 2018 Data Compression Conference, p. 427, Snowbird, UT, USA, March 2018.

This paper presents a qualitative approach of combining *Golomb-Rice (GR) code* with algebraic bijective mappings which losslessly convert between arbitrary positive integers of different dimension and shape the distribution of generalized Gaussian sources. The mappings and integer nesting and splitting enable GR encoding, with a little additional computation, to compress more efficiently sources based on wider classes of distributions than Laplacian. Simulations showed, especially for some Gaussian sources, that almost optimal average code length is achievable by performing integer nesting before GR encoding the integers. This scheme will be useful for applications dealing with various types of sources and requiring low computational costs.

Piecewise Linear Predictive Coding for Nonlinear Signal Analysis and Automatic Trend Extraction

F. Ishiyama

The IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. J101-A, No. 4, pp. 36–45, April 2018 (in Japanese).

Linear predictive coding (LPC) is a widely used method of time series analysis, and Yule-Walker equation is used for the analysis. However, as Yule-Walker equation replaces given time series with a periodic time series, it is not suitable for transient analysis. Therefore, we introduced a method of LPC without the replacement. In addition, we consider a short enough time width, apply our LPC within the width, and obtain instantaneous characteristics such as frequencies and decay rates within the width. We can find nonlinear characteristics of a given time series by applying the above analysis piecewisely and by comparing the neighboring pieces.

Access System Virtualization for Sustainable and Agile Development

A. Otaka

IEICE Transactions on Communications, Vol. E101-B, No. 4, pp. 961–965, April 2018.

This paper describes why we require access system virtualization. The purpose of access system virtualization is different from that of core network virtualization. Therefore, a specific approach should be considered such as the separation of software and hardware, interface standardization, or deep softwarization.

Optimal Golomb-Rice Code Extension for Lossless Coding of Low-entropy Exponentially-distributed Sources

R. Sugiura, Y. Kamamoto, N. Harada, and T. Moriya

IEEE Transactions on Information Theory, Vol. 64, No. 4, pp. 3153–3161, April 2018.

This paper presents an extension of Golomb-Rice (GR) code for coding low-entropy sources, in which the gap between their entropy and the conventional GR code length gets larger. We mention here the following four facts related to the proposed code, extended-domain GR (XDGR) code: it is represented by multiple code trees based on the idea of almost instantaneous fixed-to-variable length codes, with its algorithm being a generalization of unary coding; its structure naturally contains run-length coding; the gap between the entropy and its average code length is theoretically guaranteed to be asymptotically negligible as the entropy of the exponentially distributed sources tends to zero; and its coding parameter, corresponding to the negative-domain Rice parameter of GR code, can be estimated from the input source-symbol sequence. Experimental evaluations are also presented supporting the theorems. The proposed XDGR code, having a simple algorithm and high compression performance, is expected to be used for many coding applications that deal with exponentially distributed sources at low bit rates.
