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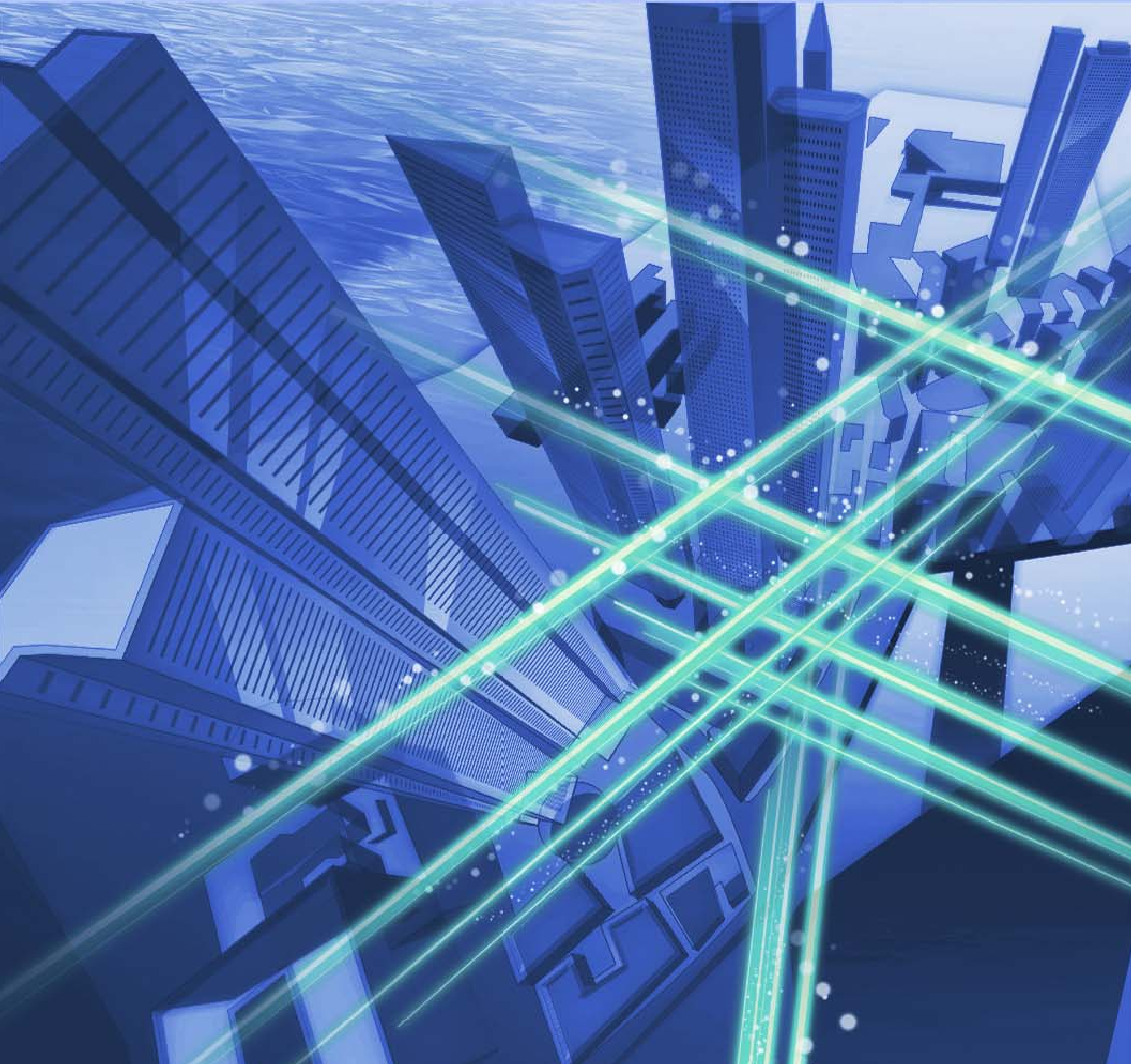

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Network Technology Development for Digital Society of the Future

Yukari Tsuji, Shinya Tachimoto, and Masaki Kobayashi

Abstract

As society moves toward digitization, the network supporting a digital society must likewise evolve. NTT has taken up the research and development (R&D) of a network infrastructure called Cognitive Foundation® in order to solve a wide variety of problems in our digital society. This article introduces specific R&D achievements based on the following R&D directions of network technology for the future digital society: (1) R&D of competitive network infrastructure technologies, (2) advanced and smart network operation supporting digital transformation of the NTT Group, and (3) global environmental protection and optimal use of energy.

Keywords: digital transformation, cognitive foundation, network technology

1. Network technology required for digital transformation

The Internet of Things (IoT) is advancing rapidly, resulting in numerous benefits. In addition to enabling all sorts of things to be connected to the network and massive quantities of digital data (big data) to be efficiently gathered and stored, the IoT is making it possible to improve business efficiency and productivity through analysis and forecasting using artificial intelligence (AI). At the same time, Japan is faced with serious social problems such as an aging population with a declining birthrate and a shrinking labor force and the need to be continually prepared for natural disasters that can cause massive damage. As a result, expectations are rising for a *digital transformation* (DX) that can solve such social problems by distributing data across the boundaries separating diverse industries while bringing about important changes in society.

As a social infrastructure, the network must be able to quickly and stably provide an optimized network configuration to meet the diverse needs of service operators that manage social systems with a limited amount of information and communication technology (ICT) resources. NTT's Cognitive Foundation® (**Fig. 1**) is an overlay networking technology to meet these demands and one of the solutions to achieve DX. This technology covers the network from the cloud to edge computers as virtualized ICT resource groups. It features a multi-orchestration function that acts as a hub for optimally integrating and uniformly managing and operating multiple resources on different layers.

Furthermore, with the progress of DX, it is becoming increasingly necessary for the network to support new digital services such as smart cities, MaaS (Mobility as a Service), and FinTech (financial technology) in addition to the current network services. NTT has established a new research and development (R&D) project to promote the study of a new network infrastructure supporting DX and has begun to discuss use cases with the aim of creating new markets.

2. Three R&D directions

In this article, we introduce specific achievements of the following R&D directions of network technology for the future digital society: (1) R&D of competitive network infrastructure technologies, (2) advanced and smart network operation supporting the DX of the NTT Group, and (3) global environmental protection and optimal use of energy.

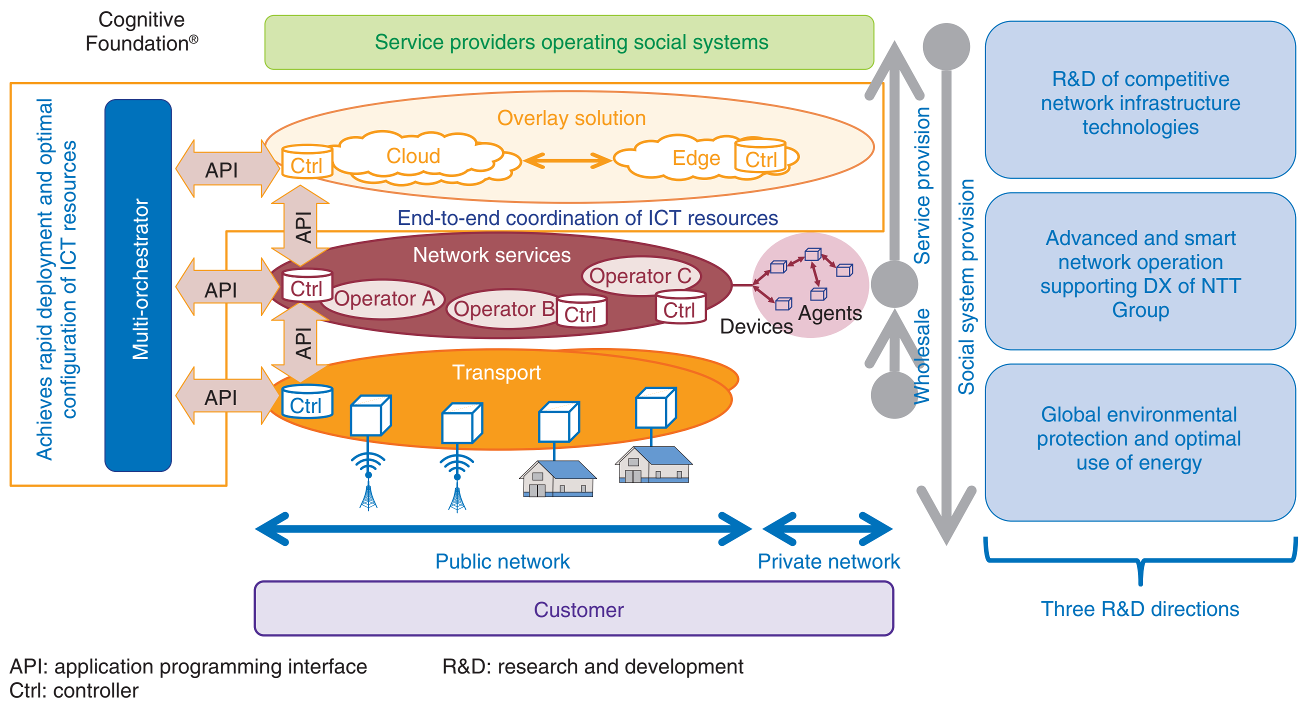

Fig. 1. Overview of Cognitive Foundation®.

2.1 R&D of competitive network infrastructure technologies

The first R&D direction is to establish new network infrastructure technologies for increasing communications speed and capacity, expanding connectivity, and lowering costs. The goal is to provide an attractive network for both service providers and service users by increasing the value of our network. These technologies include FASA®* (Flexible Access System Architecture), which converts a portion of the optical access equipment to software in order to switch between a variety of applications including the 5G (fifth-generation mobile communication network) mobile communications standard, and GNSS (global navigation satellite systems), a positioning technology that can greatly improve the accuracy of positioning measurements in unfavorable satellite-signal reception environments such as urban areas while having the potential for use in diverse application services.

2.2 Advanced and smart network operation supporting DX of NTT Group

The second R&D direction is to establish the automatic network operation technologies in order to respond rapidly to service diversification with as little manual intervention as possible. These technologies can be applied to promote the NTT Group's DX and to improve the maintenance of social infrastructures. In this way, NTT seeks to contribute to the provision of a network that can respond rapidly to the diverse service demands of various industries through a variety of network operation technologies, including those for achieving sophisticated and efficient operations through the use of AI. These include technology for coordinating services, ICT resources, and network resources across the boundaries between various operators and industries and technology for fault detection, analysis, and recovery to enable rapid restoration of facilities in the event of a problem in the optical transport network.

2.3 Global environmental protection and optimal use of energy

The third R&D direction is to establish resilient network infrastructure technologies that take the global environment into account, including decarbonization, with the aim of achieving the United Nations SDGs (Sustainable Development Goals).

* FASA is a registered trademark of Nippon Telegraph and Telephone Corporation in Japan.

Table 1. Three R&D directions and specific technologies.

Three R&D directions	Specific technologies
R&D of competitive network infrastructure technologies (introduced in Feature Articles in this issue)	FASA®: New Access System Architecture [2]
	Positional Information Service with High Added Value Based on Cooperation between GNSS and Networks [3]
	Carrier Edge Computing Infrastructure Technology for High-presence Virtual Reality Services [4]
	Service-partner-oriented Network Slicing [5]
	Guaranteed Transmission within Maximum Allowable Network Latency for Enhanced User Experience in Two-way Communication Applications [6]
	Optimal Design and Control of Network Resources [7]
	Video Delivery Technology with QoE Control [8]
	Data Stream Assist Technology Supporting Video Transfer [9]
	Per-device Policy Control Technology Using Artificial Intelligence [10]
	Privilege Sharing and Transfer Based on Passwordless Authentication [11]
	Optical Fiber and Optical Device Technology for Innovative Manufacturing [12]
	Wildlife Detection System Using Wireless LAN Signals [13]
Advanced and smart network operation supporting DX of NTT Group (will be introduced in Feature Articles in July 2019 issue)	Technology for Smart Coordination of ICT/Network Resources and Services
	Failure Point Estimation Using Rule-based Learning
	Deep Learning Based Anomaly Detection Technology for ICT Services —DeAnoS: Deep Anomaly Surveillance
	Automatic Generation of Recovery-command Sequences
	Failure Localization in Optical Transmission Networks
	Business Navigation Technology
Global environmental protection and optimal use of energy (will be introduced in Feature Articles in July 2019 issue)	Environmental Optimization Technology for Telecom Centers

NTT is contributing to building a decarbonized society and creating a novel energy distribution business by achieving autonomous energy control centered on drastic energy savings in a cloud-native network and virtualization of the power-supply network. To begin with, we aim to achieve significant energy savings through such initiatives as optimal design of equipment layout in machine rooms.

Specific technologies that NTT is pursuing as part of these three R&D directions are listed in **Table 1**. Some of these technologies are introduced in detail in this issue.

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FASA®: New Access System Architecture

Takamitsu Tochino, Keita Nishimoto, Tomoya Hatano, Kota Asaka, Jun-ichi Kani, and Jun Terada

Abstract

NTT Access Network Service Systems Laboratories has been promoting new access system architecture called FASA® (Flexible Access System Architecture), and researching and developing the modularization of functions making up the access system. This article introduces the technology behind the software modularization of the dynamic bandwidth allocation function, which was announced in a press release in November 2018 and demonstrated for the first time at NTT R&D Forum 2018 Autumn.

Keywords: FASA, access system, DBA

1. Introduction

NTT Access Network Service Systems Laboratories has been researching and developing FASA®[*1] (Flexible Access System Architecture) as the optical access system of the future since it announced the concept in February 2016 [1, 2]. FASA reflects the research and development (R&D) of competitive network infrastructure technologies that enable the functions making up the access system to be extensively modularized and combined as needed. The aim here is to achieve an optical access system that can replace functions in a flexible and rapid manner according to service requirements.

The access system in widely used passive optical network (PON) systems has a point-to-multipoint network configuration on which users share a single optical fiber and bandwidth via fiber splitters. Here, the function that governs the performance of a PON system is dynamic bandwidth allocation (DBA), which, as the name implies, allocates bandwidth dynamically according to user bandwidth requirements.

At NTT Access Network Service Systems Laboratories, we considered that the optical access system could be applied to a wide array of services if the DBA function in a PON system could be replaced as needed. With this in mind, we conducted R&D and established software modularization technology for the DBA function, proposed two optical line terminal (OLT) models capable of incorporating the function, and enabled both OLT models to accommodate the softwarized DBA function (**Fig. 1**).

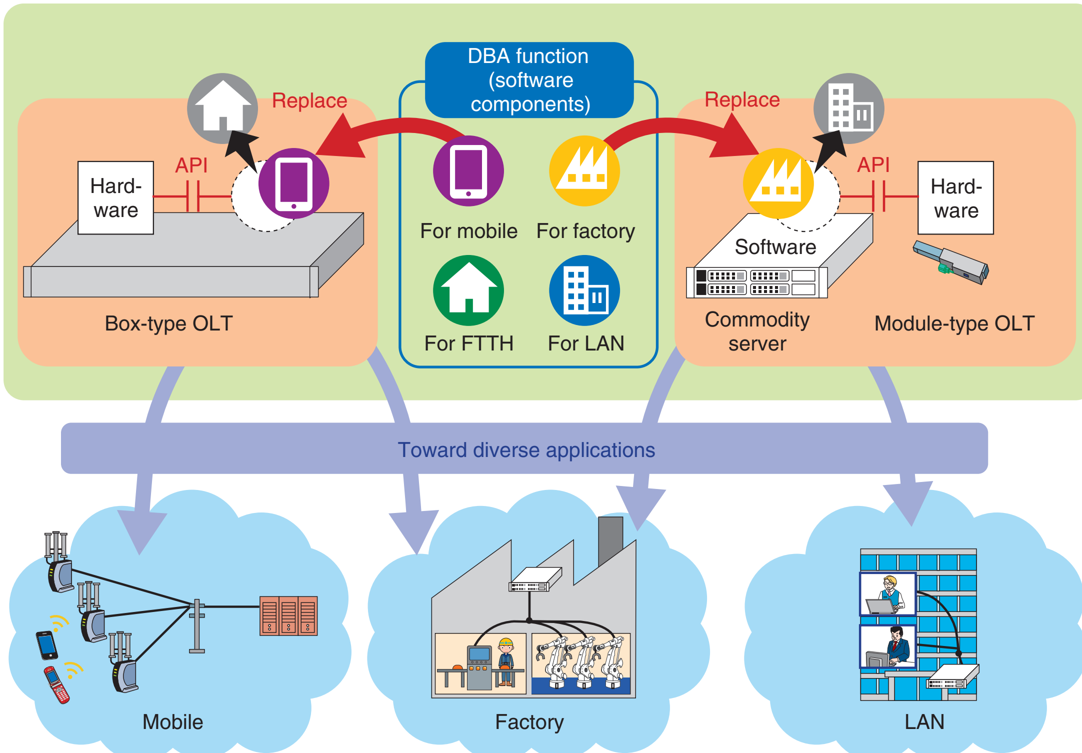
2. Software modularization technology for DBA function

The DBA function must be capable of high-speed processing on the sub-millisecond order to allocate bandwidth to each user according to fluctuating bandwidth requirements. To enable function replacement as needed while maintaining high-speed processing, we modularized the DBA function into a high-speed processing section and an algorithm whose specifications would differ for each service and implemented the former as hardware and the latter as software. We also defined the interface between the software and hardware components as an application programming interface (API)[*2] and promoted its standardization at the Broadband Forum industry organization, which completed the process in 2018.

As a result, the DBA function can be replaced as

*1 FASA is a registered trademark of Nippon Telegraph and Telephone Corporation in Japan.

*2 API: Interface specifications for exchanging information between two components.



API: application programming interface
FTTH: fiber to the home
LAN: local area network

Fig. 1. Replacement of softwarized DBA function to meet service requirements.

needed according to service requirements while achieving high-speed processing.

3. Two OLT models and API implementation

We defined two OLT models to enable a PON system to be used in a variety of applications and developed a prototype OLT of each model for evaluation.

The first model is a box-type OLT for use in environments such as a telecommunication carrier's exchange office. We expect it to be applied to future mobile systems in addition to existing FTTH (fiber-to-the-home) services. The second model is a module-type OLT, which is implemented only for OLT functions that must be processed by hardware in a compact module in combination with a commodity server that stores the OLT functions modularized in software. We expect this type of OLT to be applied to factories and local area networks on university campuses, and in office buildings and other such settings.

In either of these OLT models, the incorporation of an API enables the DBA function to be replaced with another one according to the application. This scheme eliminates the need for extensive equipment upgrading at the hardware level according to service requirements and enables the application range of optical access systems to be expanded.

4. Future plan

Going forward, the team at NTT Access Network Service Systems Laboratories plans to pursue software modularization for functions other than the DBA function in cooperation with carrier system vendors, standardization bodies, and open source software organizations throughout the world. The goal here is to enable the optical access system to be applied to a wide variety of services.

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Positional Information Service with High Added Value Based on Cooperation between GNSS and Networks

Seiji Yoshida, Takahito Kirihara, Shunichi Tsuboi, Tsuyoshi Toyono, and Takeshi Kuwahara

Abstract

At NTT Network Technology Laboratories, with a view to implementing a *smart* world that accelerates digital transformations, we are developing technology that improves the precision of positioning measurements made using GPS (Global Positioning System) and other forms of GNSS (global navigation satellite systems) in urban canyon environments with many high-rise buildings. We are also developing technology that can dramatically improve the positioning measurements by doing some of the positioning calculations on cloud edge nodes, resulting in services with new added value.

Keywords: GNSS, GPS, positioning

1. Introduction

The Global Positioning System (GPS) has been used for car navigation and other consumer applications since the 1990s, and nowadays, global navigation satellite systems (GNSS) are used in a wide range of applications including smartphones. In Japan, the Quasi-Zenith Satellite System (the *Japanese GPS*) went into full-scale operation in November 2018 and has attracted great interest due to its ability to achieve highly accurate positioning using augmentation signals.

At NTT Network Technology Laboratories, we are conducting research and development aimed at using GNSS and network/cloud synergy to create new added value in the field of positioning measurements in order to achieve a smart world where digital transformations are accelerated.

Although navigation satellite signals ideally enable positions to be measured with high precision anywhere on Earth, the actual positioning accuracy is greatly affected by the satellite signal reception environment. Previous efforts to address this issue have mostly involved attempts to improve the performance of GNSS receivers. However, as we move towards the realization of the Internet of Things, where all devices are connected to the network, our aim is to provide a groundbreaking solution to this issue by delegating part of the GNSS positioning calculations to cloud edge nodes and to provide new added value in positioning information.

2. Diversification of GNSS positioning function deployment, and a cloud-based GNSS positioning architecture

As shown in **Fig. 1**, GNSS positioning is used in various applications. While fast-moving objects such as autonomous vehicles require high-frequency positioning information, other applications such as surveying require highly accurate positioning information for static locations. Smartphones and car navigation

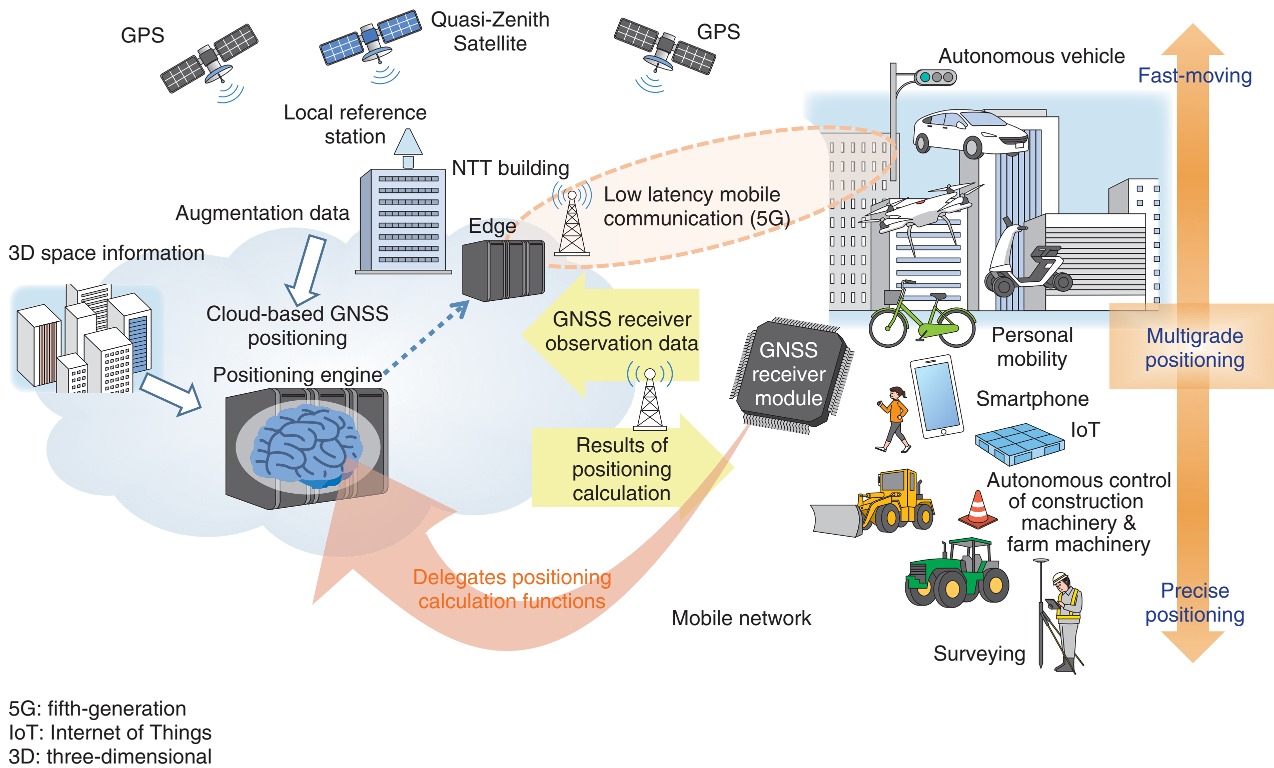

Fig. 1. Overview of cloud-based GNSS positioning architecture.

systems use a method called code-based positioning[*1] that can achieve a positioning accuracy of a few meters, while surveying uses a method called carrier-phase based positioning[*2] that is capable of measuring positions to within a matter of centimeters.

In carrier-phase based positioning, sophisticated arithmetic processing is needed to solve the problem of wavenumber ambiguity.[*3] These needs have hitherto been met by general-purpose GNSS receiver products compatible with code-based positioning and high-end GNSS receiver products for special applications compatible with carrier-phase based positioning, which have been used according to the requirements of each application. The high cost of receiver products that support carrier-phase based positioning is one factor that has hindered the growth of such applications. Furthermore, different applications have diverse requirements in terms of factors including the accuracy and frequency of positioning measurements and the cost and power consumption of equipment, and it is becoming difficult to cover these requirements with a receiver chip (hardware).

A cloud-based GNSS positioning architecture enables inexpensive general-purpose GNSS receivers to be used at positioning locations by delegating part of the positioning calculations to the cloud. In this way, differences in positioning methods and their performance requirements for specific applications can be absorbed into the processing performed in the cloud. Specifically, we have come up with a new GNSS positioning architecture whereby a single receiver can be used to provide multigrade positioning capabilities (Fig. 1). Ultimately, the positioning calculations are performed not inside the GNSS receiver at the positioning point but in the cloud based on observation data[*4] transferred from the receiver. The results of these positioning calculations (coordinate

*1 Code-based positioning: The normal GNSS positioning method whereby satellite-specific code signals are used to measure the arrival times of signals from navigation satellites at the receiving position.

*2 Carrier-phase based positioning: A more accurate positioning method where carrier wave phase information is used in addition to the code signals transmitted by navigation satellites. In favorable conditions, this method can achieve precise positioning with an accuracy of 1 cm or less.

*3 Wavenumber ambiguity: The ambiguity that arises from not knowing the number of waves in the carrier signal propagated from a navigation satellite to the receiving position.

values) are sent back to the positioning point.

This architecture uses computing resources based on CPUs (central processing units) and GPUs (graphics processing units) that are abundant on cloud edge nodes, and these perform advanced positioning processing including satellite selection processing. Carrier-phase based positioning not only greatly reduces the time required for initial positioning calculations, but also has the advantage of being able to seamlessly select diverse augmentation signals, including the NTT building's local reference station.

Other innovative approaches may also be considered, including the use of artificial intelligence, machine learning, or geospatial information such as two-dimensional (2D) maps and 3D building data to process GNSS positioning. It is also possible to consider advanced collaboration with various cloud-based applications that utilize location information.

The number of general-purpose GNSS receiver products that support the output of observation data has been increasing recently, and some products support multiple frequency bands (multiband). In addition, with smartphones, some terminals running Android version 7 and above are able to acquire observation data of the built-in GNSS receiver via APIs (application programming interfaces), and it is expected that the number of such terminals will increase greatly in the future.

A-GNSS (Assisted GNSS)*5 has been introduced in cellphones and smartphones to exploit the synergy between GNSS and networks, but a cloud-based GNSS positioning architecture can be regarded as a more advanced form of synergy. GNSS positioning calculations have hitherto been performed inside the GNSS receiver chipset. However, the functional deployment of these calculations is expected to become more diverse in the future, with calculations performed not only in the cloud, but also in smartphone apps, in-vehicle processors, and so on. Our aim is to provide the flexibility that allows functions to be deployed optimally for each application while keeping up with future trends.

3. Case study: smart mobility

In this section, we describe how positioning measurements can be implemented in moving vehicles as an example of the application of cloud-based GNSS positioning architecture to smart mobility.

In an urban canyon reception environment consisting of high-rise buildings with a grid-like system of roads, there are few open spaces where satellite signals can be received as direct line-of-sight signals. Instead, these signals are reflected and refracted by buildings, resulting in multipath signals that greatly diminish the accuracy of positioning calculations. We show in **Fig. 2** the results of performing code-based positioning calculations by post-processing using signals from GPS and the Quasi-Zenith Satellite System collected by a general-purpose single-band GNSS receiver as used by car navigation systems and the like while traveling on an ordinary road in Tokyo's Marunouchi district. By applying our Smart Satellite Selection*6 algorithm, which screens the received satellite signals for candidate signals that are suitable for positioning calculations, we confirmed that it is possible to greatly improve the positioning accuracy even at points that were estimated to be far from the road when using conventional technology [1]. This satellite selection step only took about 5 ms per positioning point in the environment used for this verification experiment.

The control of autonomous vehicles is expected to be a complex process involving the use of lasers, lidar, odometry, gyroscopes, accelerometers, dynamic maps, and in-vehicle cameras, but GNSS positioning requires measurements that are accurate enough to determine which lane a vehicle is traveling in. Using observation data from GPS satellites collected by the above-mentioned single-band GNSS receiver along the Inner Circular Route (Shuto Expressway), we confirmed that the application of our satellite selection algorithm to the results of carrier-phase based positioning (VRS-RTK: virtual reference station real-time kinematic) calculations performed by post-processing can deliver convergent (fix) solutions more of the time (i.e., a higher fix rate).

Since a fix solution is assumed to provide positioning results that are accurate to within a few tens of centimeters, they can be used to estimate not only the lane in which a vehicle is traveling, but also the position of the vehicle within the lane. The initial positioning calculation time that is required to re-establish a fix solution after GNSS satellite signals have been temporarily lost (e.g., while passing through tunnels

*4 Observation data: Information about the results of pseudo-range and carrier phase measurements in positioning calculations performed by a GNSS receiver. Also called "raw data."

*5 A-GNSS (Assisted GNSS): A fast method for distributing information about the orbits of navigation satellites via mobile communications networks.

*6 Smart Satellite Selection: NTT's proprietary GNSS satellite signal selection algorithm, which selectively rejects multipath signals from invisible (non-line-of-sight) satellites with large latency.

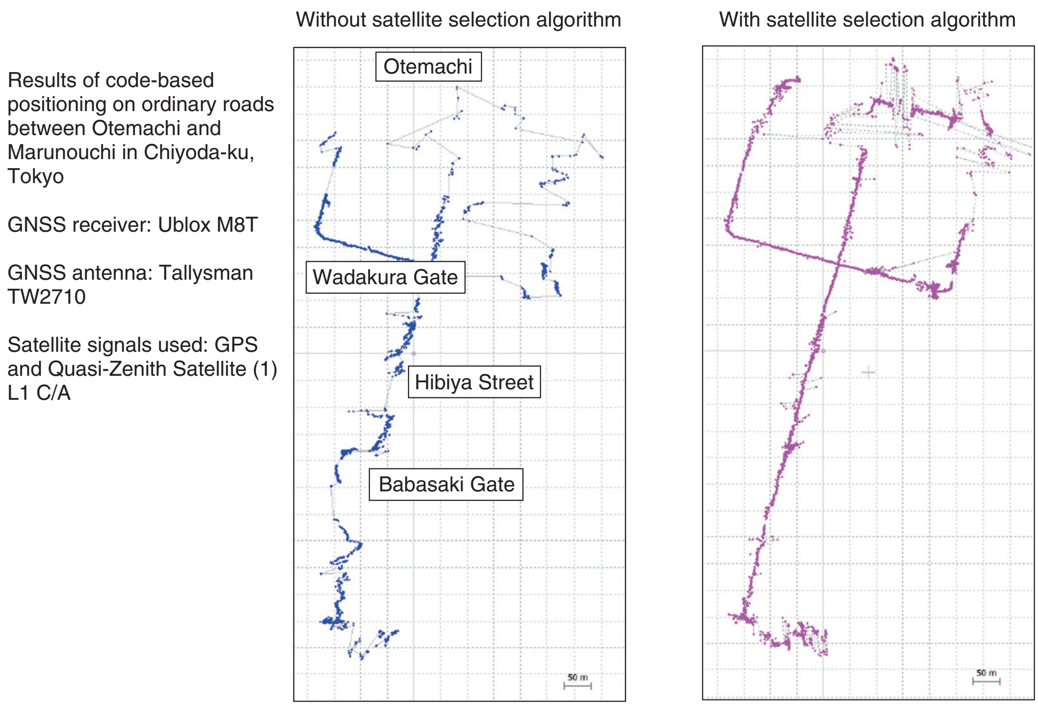

Fig. 2. Effect of applying a satellite selection algorithm (code positioning).

or under bridges) is also less than 10 s and is expected to become even shorter when using a multiband GNSS receiver. When positioning calculations have to be performed at a high frequency of about 10 times per second, a positioning engine could conceivably be installed at a cloud edge node as shown in Fig. 1 and accessed via 5G (fifth-generation) low latency mobile communications modes such as URLLC (ultra-reliable and low latency communications). This architecture also helps to reduce the cost of in-vehicle equipment, which presents a barrier to the spread of automatic driving.

4. Future prospects

In the field of smart mobility, connected cars equipped with communication means such as C-V2X (cellular-vehicle to everything) will become widespread, and it may become possible to implement low latency broadband communications from one vehicle to another (V2V: vehicle to vehicle) and between vehicles and roads (V2I: vehicle to infrastructure). This technology comprehensively ascertains the positions of people and vehicles and is therefore expected to be applied to a wide range of fields, including ascertaining the positions of pedestrians and cyclists at junctions with poor visibility, ascertaining the positions of passengers in vehicle allocation services, increasing the efficiency of bus services, and creating barrier-free maps. It may also have applications in large-scale events and the management of transportation in disaster situations. We will study ways in which high-precision positioning technology can be applied to positional information services of this sort, including the use of advanced cooperation.

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Carrier Edge Computing Infrastructure Technology for High-presence Virtual Reality Services

Hiroki Iwasawa, Yusuke Urata, Shinya Tamaki, Kenta Kawakami, Yuuki Nakahara, Kotaro Ono, Ryota Ishibashi, and Takeshi Kuwahara

Abstract

Technical studies are underway at NTT Network Technology Laboratories on edge computing that uses computing resources in carrier facilities. This article introduces a technical demonstration of a use case providing a virtual reality application via an edge computing infrastructure performed in collaboration with Toppan Printing Co., Ltd.

Keywords: edge computing, virtual reality, Akraino

1. Introduction

Cloud computing is widely used for executing applications on the cloud and providing a variety of services. Cloud computing benefits the user by making it unnecessary to manage computing resources such as servers. However, various networks may exist between the user and the cloud, and as a result, the distance to cloud servers and the effects of limitations and quality fluctuations in the communications bandwidth of each network can make it difficult to provide low-latency, broadband services in a stable manner.

In response to this problem, attention is being focused on edge computing as a means of providing services by deploying computing resources such as servers at locations near users [1]. Within this field of edge computing, NTT Network Technology Laboratories is conducting technical studies on a system for installing computing resources in carrier facilities (telecommunications buildings etc.) near users. The aim here is to provide new services having low-latency and broadband capabilities that have traditionally been difficult to achieve on the cloud.

This article introduces a technical demonstration performed in collaboration with Toppan Printing Co., Ltd. on a virtual reality (VR) application requiring low-latency communications as a promising use case for edge computing.

2. Edge computing infrastructure technology for high-presence VR services

VR applications can be broadly divided into two types: the viewing of previously generated video (such as 360-degree video), and real-time generation of three-dimensional (3D) video according to user viewpoint movement and operation.

The former type using previously generated video places constraints on the user such as the inability to move about freely in virtual space or to move objects.

In contrast, the latter type using real-time 3D video makes it possible to move about freely in virtual space and to manipulate objects by generating the video according to sensor information such as the position and orientation of a head mounted display (HMD) using a graphics processing unit (GPU) or other type of processor in real time. It is thought that this type of VR, especially that having high-quality

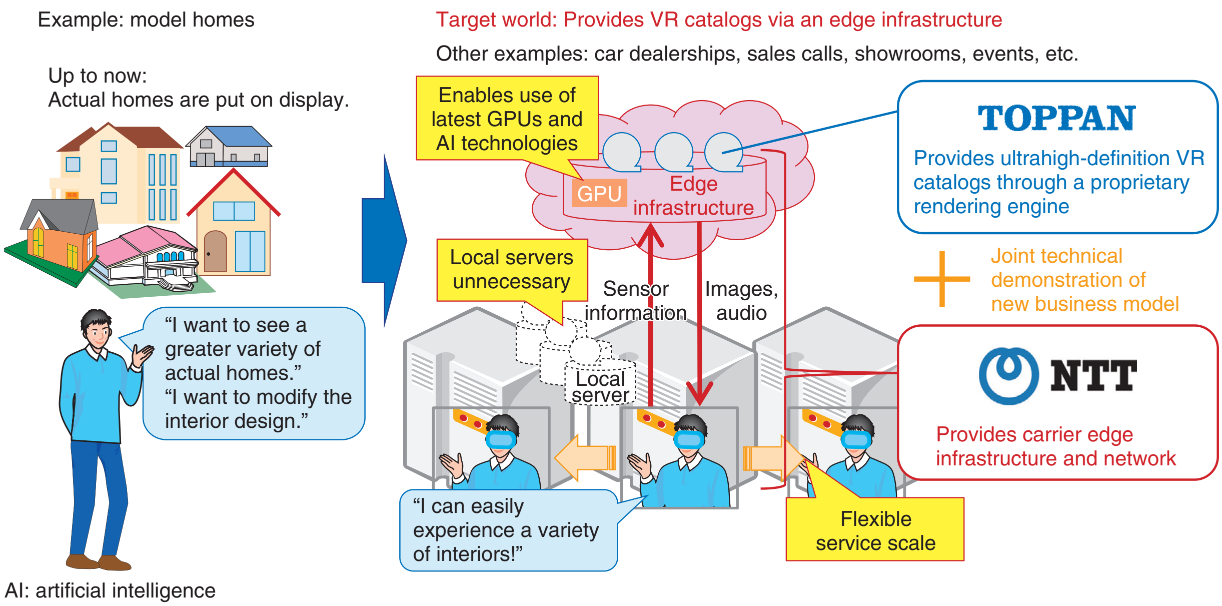

Fig. 1.   VR digital catalog application via edge computing infrastructure.

characteristics (high definition, high frame rate), has the potential to be applied to digital catalogs. A digital catalog using VR would enable the user to vary the components, colors, and patterns of a product in virtual space at car dealerships, home builder offices, and all types of showrooms. We focus in this article on high-quality VR with an emphasis on digital catalogs.

To prevent VR sickness in VR applications that generate 3D video in real time, the sequence of processes from a user terminal operation to the display of 3D video on the terminal screen must be completed in an extremely short period of time (such as several tens of milliseconds) [2]. It is for this reason that this type of VR application has usually been provided using local terminals without a network connection. However, it is difficult to achieve high-quality VR with stand-alone HMDs or smartphones, and a specialized personal computer mounting a high-performance GPU can be costly in terms of equipment and operation. In the face of such problems, we considered the possibility of using edge computing to provide low-latency, high-quality VR even in a remote manner, thereby eliminating the need for individual users to manage high-performance specialized computers.

In the joint experiment presented here, we ran a VR application from Toppan Printing for display of model homes on NTT's edge computing test bed, generated video in real time on this edge computing infrastructure based on sensor information from a smartphone terminal, and tested the delivery of that video data on the terminal. The results of this demonstration confirmed that a high-quality VR-supporting digital catalog application from Toppan Printing could be provided via a remote edge computing infrastructure on the network (**Fig. 1**).

We also tested proprietary technology for achieving high-quality services such as the suppression of delay jitter in traffic control oriented to VR video.

3. Research and development (R&D) of edge computing infrastructures

In addition to work on edge computing applications including VR, R&D is underway at NTT Network Technology Laboratories on edge computing infrastructures to support efficient facility construction and scaling and high operability at low cost. As part of this effort, we are participating in Akraino Edge Stack, an open source software (OSS) project under the Linux Foundation [3, 4].

The Akraino project is aimed at achieving edge computing not only for telecommunications carriers but also for various types of enterprises and industries by combining OSS technologies reflecting industry best practices according to requirements and restrictions of each edge-specific use case. Our aim here is to collaborate with global partners through an open community to promote fast-paced and efficient R&D of edge computing and create a global ecosystem in this field.

4. Future outlook

We will continue our collaborative efforts with Toppan Printing to achieve an edge computing infrastructure that can provide ultralow-latency and high-quality VR services in a flexible manner.

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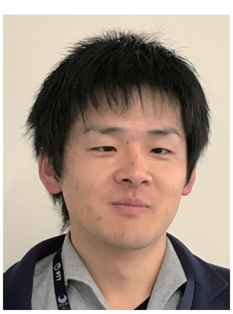
Trademark notes



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Service-partner-oriented Network Slicing

Takuya Sato, Tomohiro Okada, Shunsuke Homma, and Hidetaka Nishihara

Abstract

In the coming 5G (fifth-generation mobile communications) era, it will be necessary to create diverse services using networks with high-performance characteristics such as large-capacity broadband, massive session connectivity, and ultralow-latency and high-quality communications. This article introduces network slicing technology for rapidly constructing and providing virtual networks corresponding to such diverse service requirements, and slice gateway technology for achieving end-to-end slices that can maintain a fixed level of communications quality on an end-to-end basis.

Keywords: network slicing, 5G, end-to-end slice

1. Introduction

In the fifth-generation mobile communications (5G) era, it is expected that various new services will be created by taking advantage of the features of 5G such as high-capacity broadband, massive session connectivity, and ultralow-latency and high-quality communications. To realize these new services, a variety of networks will be required to meet various service requirements. The challenge is to provide networks quickly and flexibly in response to such demands.

2. Network slicing technology

Network slicing technology enables the simultaneous construction and operation of multiple virtual networks called *slices* having different requirements on a common physical infrastructure. Physical facilities are managed as resources that can be virtually partitioned, and these resources can be freely combined to create the virtual network needed. Conventional communications networks use expensive specialized equipment that takes time to build. In contrast, with slices, various services can be promptly provided by switching settings using general purpose equipment that is relatively inexpensive. This technology is expected to support networks of the 5G era. At NTT, our aim is to use this technology to quickly provide our service partners with the networks they need.

3. Slice gateway technology

The provision of networks for service partners with diverse requirements requires end-to-end slices, each of which can maintain a fixed level of communications quality on an end-to-end basis. One problem here is the construction and operation of end-to-end slices that straddle multiple provider networks managed under various rules. To solve this problem, NTT is proposing an architecture that deploys slice gateways (SLGs) at connection points between provider networks (**Fig. 1**). An SLG provides functions needed on a slice data plane such as protocol conversion, traffic allocation, and inter-slice isolation. The SLG deployed at the connection point between the networks can operate the slice across multiple networks with different specifications by performing appropriate conversion according to the specifications of each network.

We are currently installing SLGs using open source software (OSS) on the NetroSpherePIT [1] test platform and conducting trials. A slice can be constructed

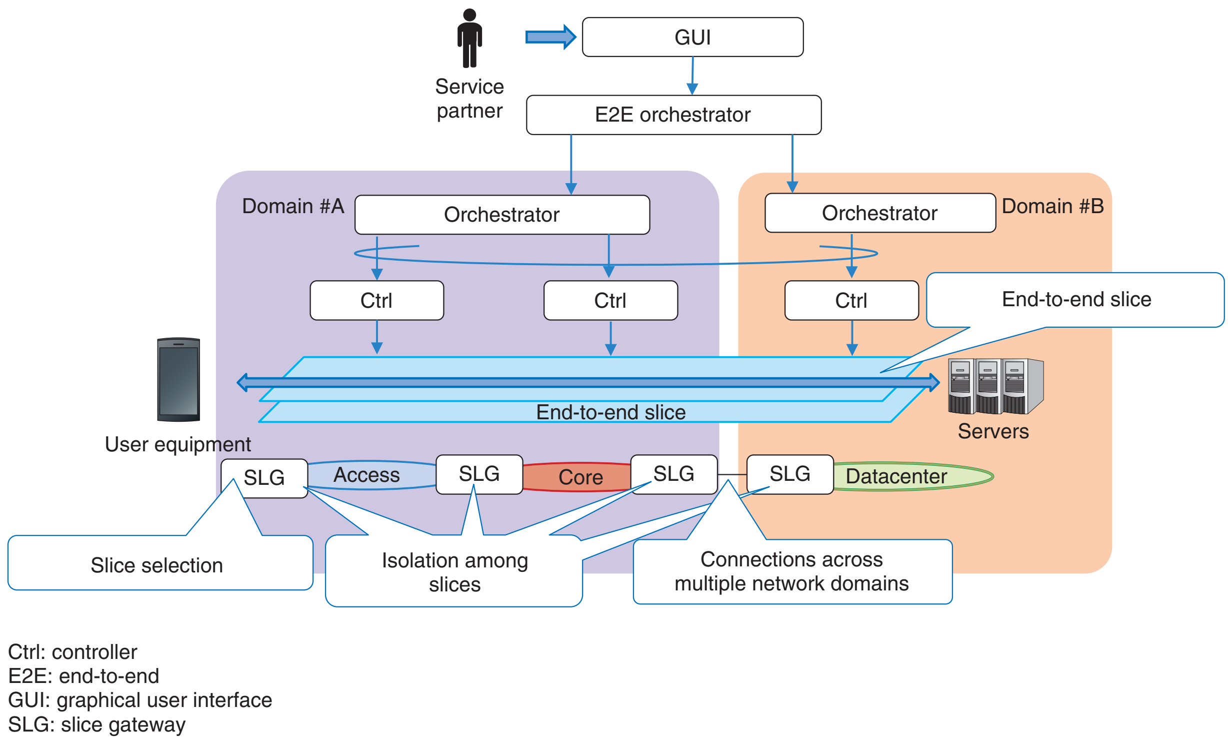

Fig. 1. Overview of proposed architecture.

using any protocol compatible with the specifications of the infrastructure network. We are investigating the construction of slices using the new technology SRv6 (Segment Routing Internet Protocol version 6). We are also constructing and evaluating end-to-end slices with latency guarantee [2] as an added function with the aim of providing an even better user experience. Finally, we have also developed a prototype GUI (graphical user interface) for constructing and switching slices and displaying slice operation status through telemetry technology. The research and development (R&D) results described above were presented at NTT R&D Forum 2018 Autumn held in November 2018. At this exhibit, service partners were able to experience slice control for themselves.

4. Future outlook

NTT is moving forward on refining network slicing and SLG technologies through test bed trials with an eye to commercialization. We are currently promoting global standardization with the aim of including these technologies in commercial products and de facto OSS.

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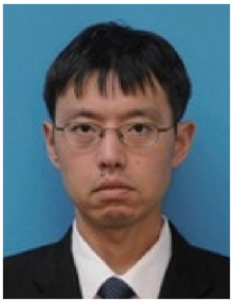

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Guaranteed Transmission within Maximum Allowable Network Latency for Enhanced User Experience in Two-way Communication Applications

Tatsuya Fukui, Yuki Sakaue, and Katsuya Minami

Abstract

Keeping network latency below a certain level in two-way communication applications or systems enhances the user operating experience. However, the bandwidth-based shaping method commonly used in bandwidth guarantee services can generate large network latency due to burst-traffic leveling, thereby degrading the operating experience. We propose here a new shaping technique that takes required latency into account to guarantee the flow of traffic without exceeding maximum network latency.

Keywords: latency guarantee, two-way communication applications, QoE (quality of experience)

1. Introduction

The use of two-way communication applications/systems has been expanding in recent years. A typical example is a system for remotely operating heavy equipment in construction work. In this type of system, an operator sends an operating signal to a remotely located piece of equipment over the network to operate that equipment in a certain way. At this time, the operator can receive and view video taken by a camera installed on the equipment to confirm that the equipment responded as instructed. The time from operation input by the operator to confirming the operation by camera video is considered to greatly affect the user operating experience. In the case of remote operation, network communication latency is a major factor in the degradation of this experience.

Reducing this network latency to a low level improves the operating experience, but requirements in terms of allowable latency exist. In this regard, the occurrence of latency within one frame period of camera video will not affect the display of that video. In fact, based on the authors' experience, there are times when latency even within two frame periods is not noticeable by the user, resulting in no degradation of the operating experience. In this way, there are many cases even in two-way communication applications in which low latency is not necessarily achieved but in which a certain amount of latency tolerance exists. Other examples of two-way communication applications are virtual reality, eSports, and remote desktop operation.

2. Network latency guarantee technique

In light of the above, we propose here a technique for transmitting network traffic that while not necessarily having low latency does not exceed the amount of allowable latency. Conventionally, when communication signals of the type described above are transmitted on a best-effort basis, the effects of other types of traffic might generate network latency above the level allowed, resulting in a greatly degraded operating

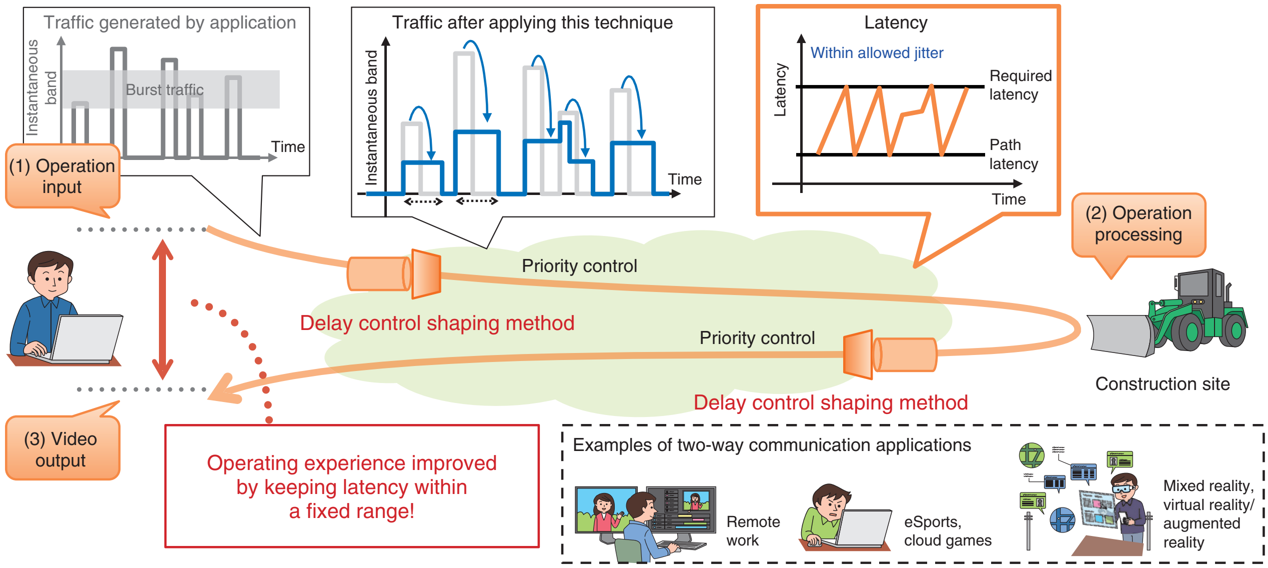

Fig. 1. Overview of network latency guarantee technique.

experience. Furthermore, while a method that treats certain types of communications as priority traffic unaffected by other types of traffic can be considered, such priority traffic may be transmitted at a level of latency lower than necessary, and since video traffic is often transmitted in bursts as mentioned above, the load on the network can be large.

If, in an effort to solve these problems, the conventional bandwidth-based shaping method used in bandwidth guarantee services is applied, large latency would occur even for a bandwidth setting larger than the average video rate, resulting in major degradation of the operating experience. This is because the burst transmission of video traffic results in a flow of traffic that instantly exceeds the set bandwidth, and shaping this traffic to fall within a certain bandwidth increases the time that signal data are stored in a buffer on network equipment. The end result is large latency.

In response to this issue, the proposed technique guarantees transmission within a certain amount of latency even for burst traffic as in video applications and suppresses the load on the network to the maximum extent possible (**Fig. 1**). For NTT, this technique contributes to the deployment of a competitive network infrastructure. The specific scheme behind this technique is as follows. When traffic flows into the network, the amount of arriving traffic is continuously measured, and the amount of traffic to be sent into the network is calculated in real time based on a previously established amount of allowable latency and the minimally generated amount of end-to-end path latency within the network. In a relay network, prioritizing this traffic over best-effort traffic enables transmission within a certain amount of latency. In addition, shaping the traffic to the allowable latency according to the calculated amount of traffic can reduce the load on the network. We implemented a prototype of this function and evaluated its performance using a two-way communication application, and we found it to be effective in improving the user operating experience.

3. Future outlook

The application scope of the technique presented in this article is not one-way communications as in video delivery services but rather two-way communications in which processing is performed at a remote location according to an operating signal received from an operator. Going forward, we plan to perform surveys and trials of a wide range of applications and systems whose operating experiences can be improved by this technique with the aim of providing this feature as a network service.

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Optimal Design and Control of Network Resources

Kenzo Okuda, Takeshi Hirota, Mika Ishizuka, Yasuharu Kaneko, and Seisho Yasukawa

Abstract

NTT Network Technology Laboratories is researching and developing technologies for flexibly tracking network changes on various timescales with the aim of achieving a network with high facility usage efficiency and enhanced convenience of use. This article introduces optimal network design technology and cloud native SDx (software-defined-anything) control technology as specific examples of technologies under study.

Keywords: optimization, optical network, SDx control

1. Introduction

With the coming of a full-scale fifth-generation mobile communications (5G)/Internet of Things (IoT) era, studies are underway at the NTT laboratories on architecture that can respond flexibly to changes occurring in the various stages of network operation. This article reports on the following technologies.

(1) Optimal network design technology

To deal with long-term changes in demand, this technology visualizes the cost effectiveness of facility investment based on actual data and supports the formulation of optimal facility investment planning.

(2) Cloud native software-defined-anything (SDx) control technology

This technology optimally allocates the resources needed for providing services such as networks and cloud environments in response to short-term changes in demand and automatically configures settings for a wide variety of patterns through workflow control.

2. Optimal network design technology

Optimal network design technology is applied in order to conduct studies on optimal facility investment, equipment deployment policies, and network topology in response to long-term (several months to several years) changes in the state of the network due, for example, to increases in communications demand. The conventional approach has been to rely on highly skilled and experienced operators to conduct these studies. However, to provide a flexible network in a sustainable manner in the face of a declining population and changes in society, the need has arisen to carry out even more advanced studies without the need for skilled personnel through data analysis technologies such as artificial intelligence (AI).

To solve this problem, the NTT laboratories are using actual facility data to 1) visualize and predict changes in facility usage conditions, 2) analyze ways of improving facility usage efficiency, and 3) enhance the optimization of network-configuration and facility-deployment proposals without skilled personnel.

At the latest NTT R&D Forum held in November 2018, we presented the concept of optimal design technology targeting the transport network, the visualization and forecasting of changes in facility usage conditions, and analysis of areas of improvement in facility usage efficiency (**Fig. 1**).

3. Cloud native SDx control technology

The idea behind cloud native SDx control technology

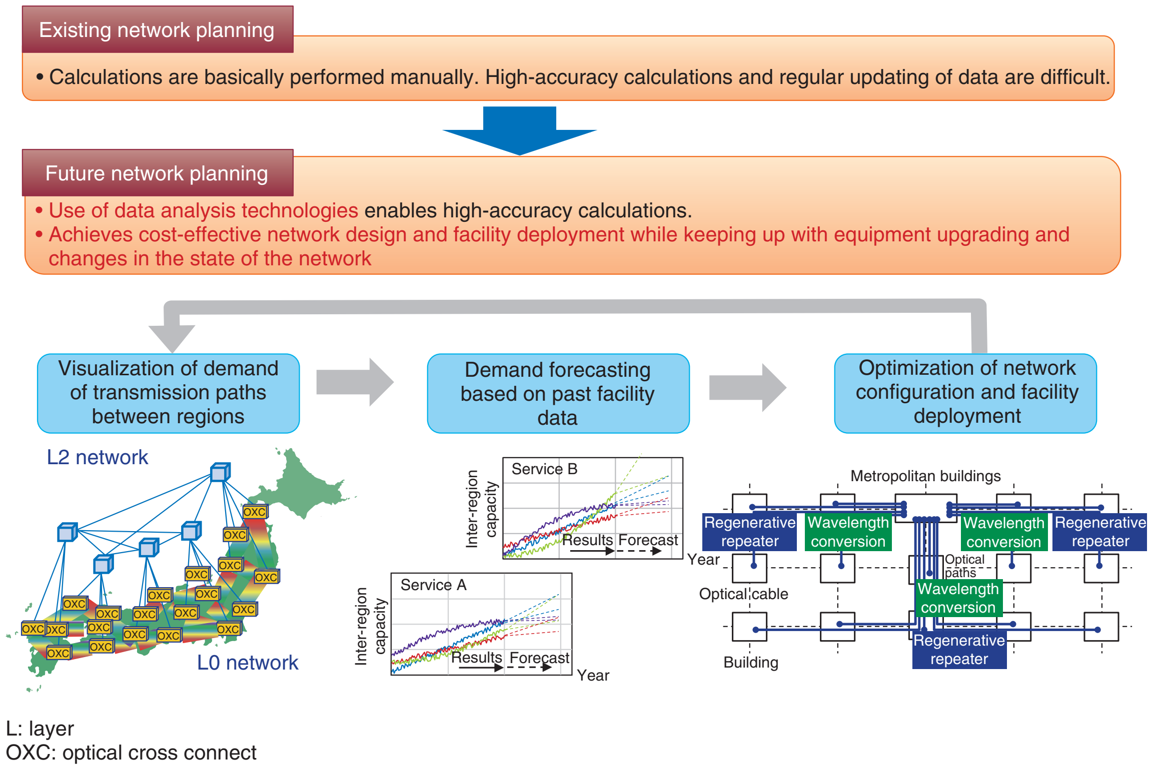


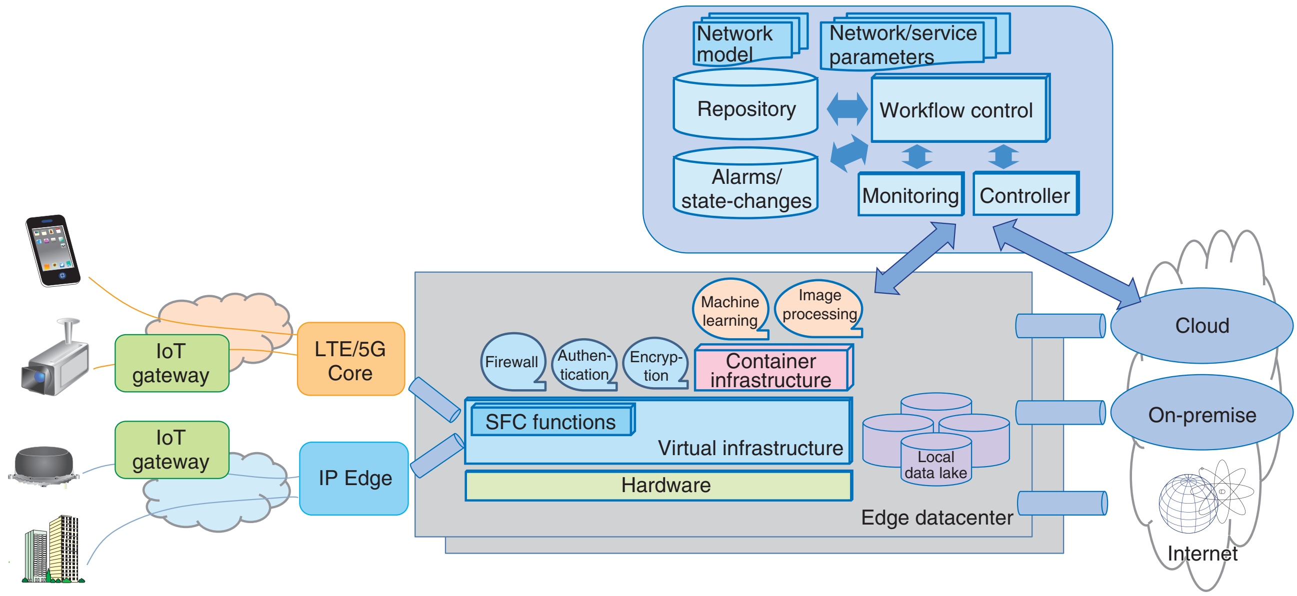
Fig. 1. Optimal network design technology.

is to automate the immediate provision and maintenance/operation of services spanning the cloud and network. We are studying in particular the following topics: 1) a mechanism for automatically controlling the resources needed for service provision (network/cloud resources, etc.), and 2) the need for a method of appropriately managing resource information, the target of control. With respect to the first topic above, we are studying a mechanism for handling the network and cloud environment and even applications for providing services through a sequence of operations by combining such technologies as network functions virtualization and software-defined networking. This mechanism will be based on technologies already being used on the cloud under the assumption that they can also be used to control the network. In addition, the resources needed to provide services, which may be of a physical type (computers, network devices, etc.) or a virtual type (virtual computers, software-defined network functions, etc.), need to be linked and controlled. To this end, we are studying means of modeling these target resources so that they can be handled in a general-purpose manner. In this way, we aim to provide flexible support for a wide range of services (**Fig. 2**).

At the NTT R&D Forum held in November 2018, we presented a scheme for achieving efficient operations when providing a new service or responding to a fault in the system. This scheme combines an automatic-control mechanism and optimal resource allocation function to perform optimal resource allocation based on information on the resources needed for responding to such an event and on the state of resources at the time of the event, and performs automatic control based on the results of that allocation.

4. Future outlook

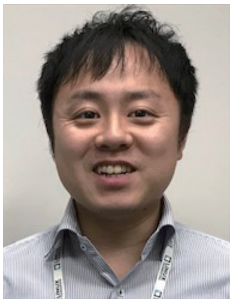
In this article, we introduced optimal network design technology and cloud native SDx control technology, which will be applied to support the network infrastructure that is slated to become the social infrastructure of the future. These technologies will promote the digital transformation of network design and control through AI and will facilitate investment that keeps up with changes in the state of the network and in path design without the need for skilled personnel. Going forward, our plan is to perfect this



IP: Internet protocol
LTE: Long-Term Evolution
SFC: service function chaining

Fig. 2. Cloud native SDx control architecture.

technology through verification experiments with an eye to becoming the infrastructure technology of the full-scale 5G/IoT era.



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Video Delivery Technology with QoE Control

Takafumi Okuyama, Hiroyuki Kitada, Arifumi Matsumoto, Toshihito Fujiwara, Daisuke Kobayashi, Hiroshi Inoue, Ken-ichi Endo, Yasunobu Kasahara, and Ken Nakamura

Abstract

The amount of high-definition content has been increasing significantly lately, and there is also growing demand for video delivery services. This article introduces technology intended to address these issues. It achieves this by delivering high-definition and high-presence video content with high quality in an economical manner by optimizing the server deployment and communication network of content delivery providers and communication providers and by implementing new delivery control techniques.

Keywords: CDN, QoE control, multicast conversion

1. Introduction

To enable a large number of customers to enjoy high-definition video over the network, it is essential that no phenomena occur that can degrade quality within the communication network, or more specifically, that can lower the customer's quality of experience (QoE). To this end, we propose video delivery technology consisting of two component technologies—technology for controlling QoE and technology for efficiently delivering video data—that are implemented in an end-to-end manner from the video delivery server to the viewing terminal (**Fig. 1**).

2. Technology for controlling QoE

The technology for controlling QoE consists of three phases: namely, information collection/analysis, policy determination, and delivery control, as summarized below.

The information collection/analysis phase uses network/QoE visualization technology to determine whether it is possible to provide QoE that satisfies the customer, and if not, to clarify the phenomena such as network congestion that prevents this. This is accomplished by collecting and analyzing network conditions and server load status from the network as well as information related to customer viewing quality and content from the customer's viewing terminal.

The policy determination phase determines the delivery policy governing the delivery server and content delivery network (CDN) to be selected, the resolution that can be provided, advertising content, and other data in order to provide the appropriate QoE for each customer and gain the customer's satisfaction. This policy can be set according to the customer's service, the viewing location, or other factors.

The delivery control phase uses the policy established in the policy determination phase to decide on specific delivery conditions such as video resolution and bandwidth that can satisfy the QoE, advertising content, and other information, and which delivery server to use and to perform manifest control for notification to the viewing terminal.

Executing these three phases in a linked manner enables the provision of good quality video while avoiding congestion in the network.

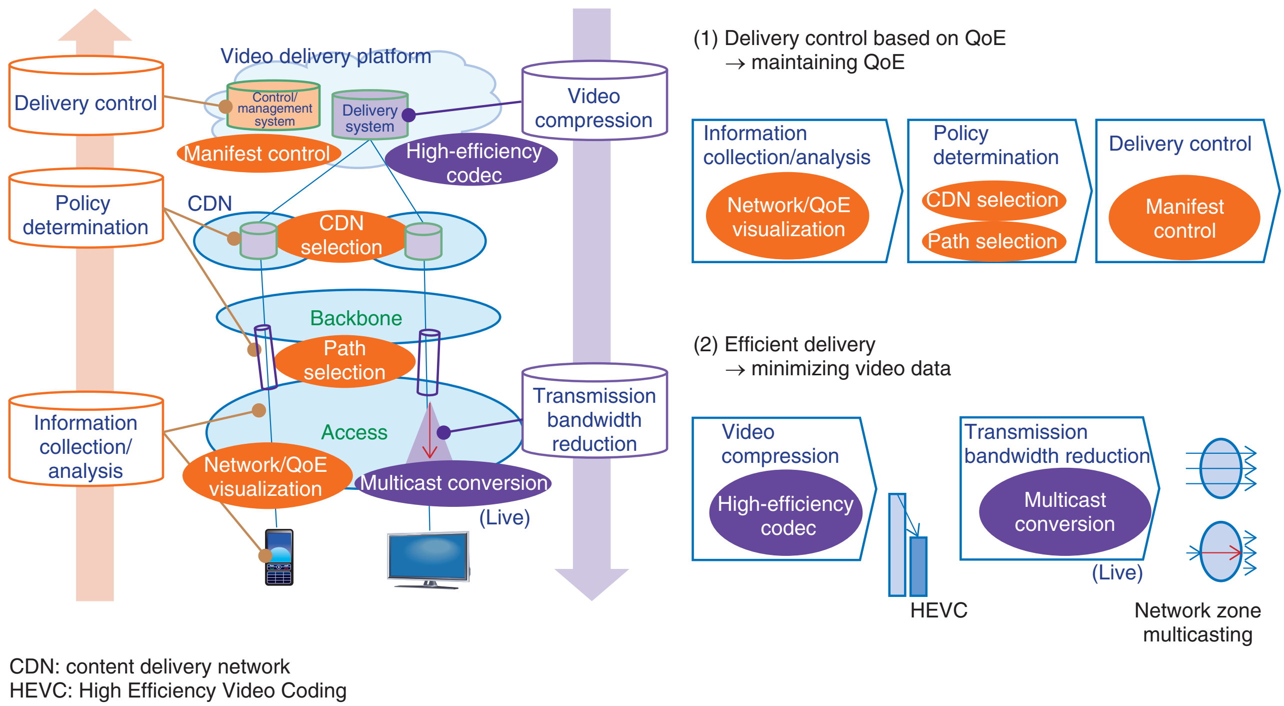


Fig. 1. Video delivery technology for controlling QoE.

This technology for controlling QoE was demonstrated at the NTT R&D Forum held in November 2018 in the form of a delivery experiment that connected a server group on the NTT laboratories' network with a test bed at NTT Communications over the Internet.

3. Technology for efficiently delivering video data

The technology for efficiently delivering video data encompasses two independent technologies. One is high-efficiency codec technology, which encodes high-definition 4K video in real time based on the HEVC (High Efficiency Video Coding) standard. Its proprietary variable-bit-rate control technology can compress video to an amount less than half that of conventional H.264 encoding technology.

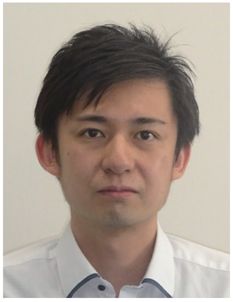
The other is multicast conversion technology, which converts traffic from unicast to multicast within the network zone while having the delivery provider and viewer use a general-purpose web interface (HTTP (Hypertext Transfer Protocol)-based unicast) device. This scheme makes it possible for a delivery provider or network provider to reduce the facility resources needed for data transfer of one item of content by a factor equal to the number of simultaneous viewers. It also enables stable delivery to an individual viewer regardless of the number of simultaneous viewers.

In short, the application of these technologies enables the delivery of video at a level of quality that can satisfy many viewers.

This technology for efficiently delivering video data was demonstrated at the NTT R&D Forum.

4. Future work

In addition to enhancing the video delivery function in the access network, we plan to develop the all-in-one system architecture from the streaming platform to the viewing terminal for the video distribution business.



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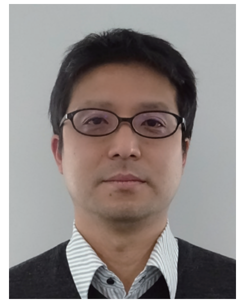

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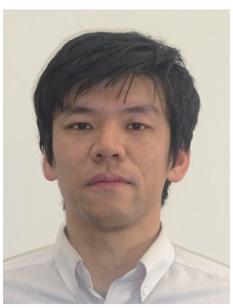

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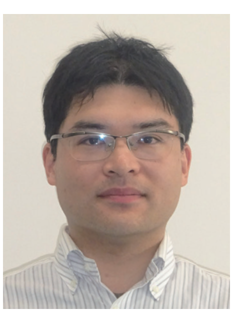

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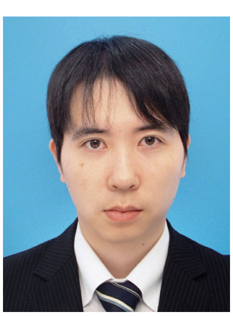

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Data Stream Assist Technology Supporting Video Transfer

Naoki Higo, Takuma Tsubaki, Kohjun Koshiji, Toshimitsu Tsubaki, and Takeshi Kuwahara

Abstract

Research and development is underway at NTT Network Technology Laboratories on data stream assist technology deployable in a lightweight and flexible manner to provide a network that can support complex services using high-functionality and high-performance Internet of Things (IoT) devices. As a specific use case, this article introduces technology that can vary communication protocol, timing, and volume to accommodate diverse types and uses of camera video and raise network usage efficiency while improving the convenience of use for IoT service providers.

Keywords: edge computing, IoT services, video surveillance

1. Introduction

The Internet of Things (IoT) has been spreading in recent years thanks to advances in video analysis using artificial intelligence and the expansion of broadband and high-speed communication circuits [1].

While security services for crime prevention and surveillance are typical video applications using cameras, increasing attention is coming to be focused on the use of video in differing applications such as in marketing for understanding customer purchasing behavior and in manufacturing for inspecting product appearance. In short, the purposes of using video are diversifying.

2. Difficulty of varying configuration of video IoT systems

When a video IoT system is implemented, it is common to construct such systems on the user's premises. Doing so, however, makes it necessary to deploy dedicated equipment such as a media server, which makes it difficult to modify the system configuration whenever changes in the video application occur. The barrier to introducing video IoT is consequently high.

Depending on the application, it may not be necessary to obtain camera video at all times. For example, there are few cases in which video needs to be continuously watched during uneventful periods but many cases in which it needs to be watched in the event of an abnormal occurrence such as an undesirable incident or accident in order to understand the situation. In such a scenario, obtaining video on a continuous basis may result in congestion on the user's local area network. It may also cause congestion on the telecom carrier's network in the case of remote viewing or analysis. There is therefore a need for dynamically changing to a configuration that obtains video only when needed.

3. Data stream assist technology

Data stream assist technology is intended to solve the above problem by achieving network functions that can contribute to video IoT managed services.

As shown in **Fig. 1**, this technology consists of two types of functions: a transfer function for transferring video streams and a linking control function for managing the transfer function [2]. These functions must follow design guidelines for lightweight software that can be combined with an existing video IoT system and deployed in a distributed manner. For this reason,

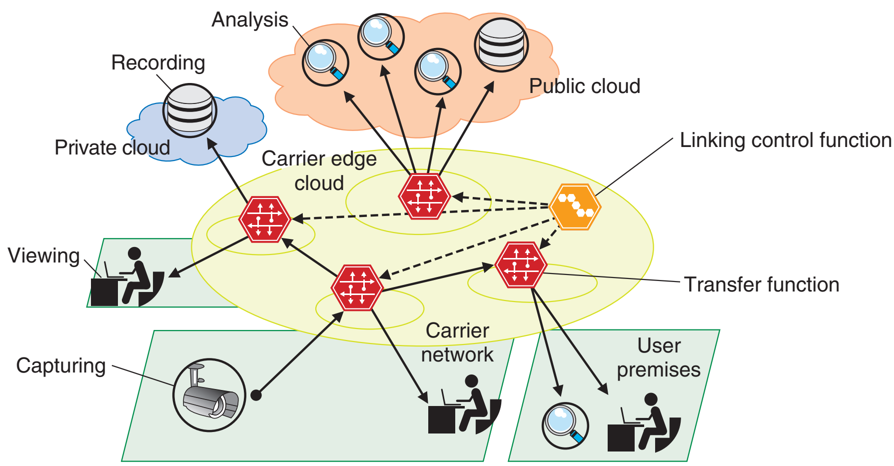

Fig. 1. Configuration of data stream assist technology.

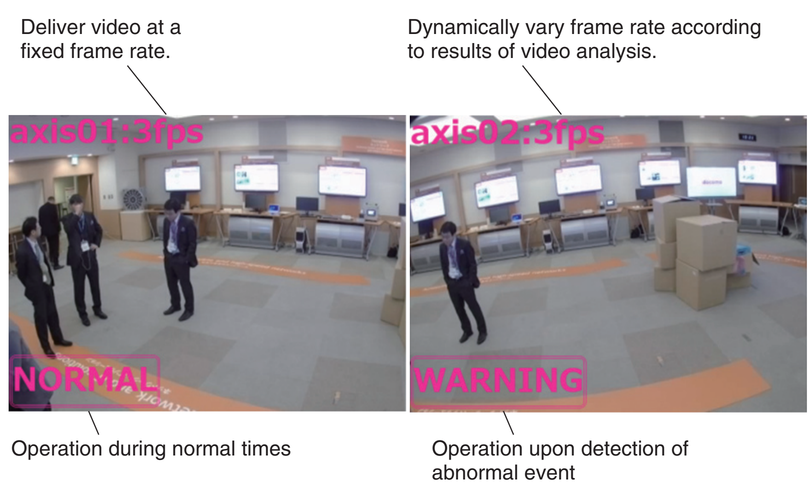

Fig. 2. Demonstration using prototype system.

we adopted Docker [3] as an environment for running function processes and Kubernetes [4] as a container orchestrator in a prototype system (**Fig. 2**) that we constructed. When a video stream is registered, the physical machines and areas to be used are declared so that containers in a standby state are deployed on each machine and stream management functions are launched for obtaining and transferring video media information. This is followed by actual delivery of video streams upon request from viewing devices as delivery destinations. In this way, it becomes possible to dynamically deploy necessary functions and to obtain only the video needed when certain types of events occur. This enables the flexible construction of a system even in an environment with limited network and computing resources.

4. Future outlook

We consider data stream assist technology to have high affinity with a multi-cloud environment that combines a carrier edge cloud* with public and private clouds. Our aim is to achieve rapid rollout of video IoT and high scalability by dynamically deploying network functions for efficient and safe

* Carrier edge cloud: A cloud infrastructure constructed by a telecom carrier within the carrier's network and provided to users.

delivery of video according to the video application.

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[3] Docker, https://www.docker.com/
[4] Kubernetes, https://kubernetes.io/

Trademark notes

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Per-device Policy Control Technology Using Artificial Intelligence

Hidetaka Nishihara, Hiroki Iwahashi, Kaori Kurita, Kazuhiro Matsuo, Hirofumi Noguchi, Takuma Isoda, Misao Kataoka, and Yoji Yamato

Abstract

The number and variety of Internet of Things (IoT) devices such as network cameras and televisions connecting to networks has been increasing recently, and the network requirements for each of these devices are also diversifying. This article introduces policy control technology for controlling networks in the IoT era that is optimized for each device by automatically identifying the type and/or model of each device from its communication behavior.

Keywords: IoT, policy control, device identification

1. Introduction

The development of the Internet of Things (IoT) is continuing, with all kinds of objects connecting and communicating with networks. As this development progresses and 4K/8K video gains popularity, new usage scenarios and applications are emerging, and the devices being used are becoming increasingly diverse. The quality requirements and communication characteristics are also becoming more diverse, for example, high-speed and high-capacity transmission, or low-capacity but capable of transmitting many sessions.

NTT Network Service Systems Laboratories is conducting research and development on a policy control technology for the IoT era for implementing network control optimized to the type and characteristics of each device connected to the network that flexibly handles the network requirements as devices increase in capacity and diversity. We introduce here the overall system and two of its component technologies.

2. Policy control technology

The policy control technology identifies the traffic from an application or particular user and controls traffic according to individual control rules (policies) based on the results, to provide flexible, value added services that meet the diverse needs of users. Examples of types of control include filtering, quality of service, and bandwidth control.

The policy control technology is implemented by two main functions called the Policy and Charging Enforcement Function (PCEF) and the Policy and Charging Rules Function (PCRF), and these are located within the carrier network. The PCRF decides which policies to apply based on the user or application, and the PCEF executes control instructions. The PCEF identifies input traffic and applies appropriate control according to instructions from the PCRF.

3. Automatic device behavior analysis

We have been developing a means of automatic device behavior analysis. It identifies the type and model of a device based on communication data. For example, it can identify network cameras and displays on a home or office network.

Identifying the type of a device makes it possible to optimally operate networks and efficiently manage huge numbers of devices. The automatic device

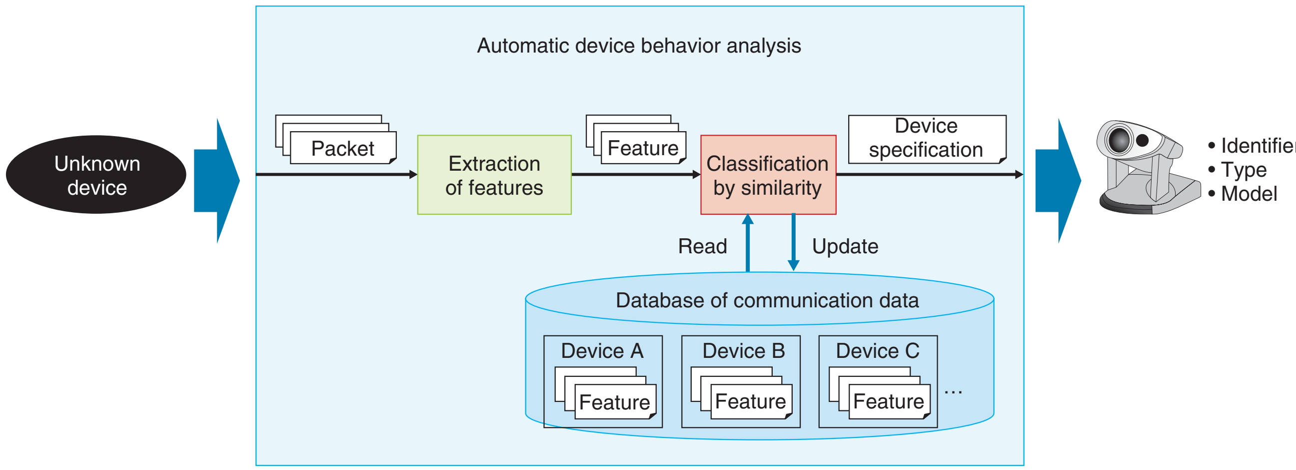


Fig. 1. Overview of device identification.

behavior analysis does not require high performance computers or special software because it only uses ordinary communication data from devices. The technology performs two stages of processing (**Fig. 1**): extraction of features from communication data, and classification based on the similarity of features.

In the first process—extraction of features—the system collects packets from a device at regular time intervals and creates abstracted data from it using information such as the packet length and the number of packets. The abstracted data are used as device feature data in the next process.

In the second process—classification based on similarity of features—the system compares feature data prepared for each device type and model with the feature data from devices to be identified, to determine which is most similar. This process uses machine learning to derive similarity of devices from large volumes of feature data.

This processing enables the system to identify the type and model of devices.

4. Overall system

With conventional policy control technologies, control is performed at the level of subscriber lines. For this reason, individual devices cannot be identified from the network side if a subscriber line accommodates multiple devices. Therefore, we added a way for the PCRF to automatically analyze behavior and select policies for each device from the device identification results. The overall architecture of this system is shown in **Fig. 2**. Specifically, an artificial intelligence (AI) component with the automatic device behavior analysis is placed on the carrier network, mirrored packets are input to the AI, and (1) device types and models are identified by the automatic device behavior analysis. After the identification by the AI is completed, the PCRF is notified of the subscriber line information (source IP (Internet protocol) address etc.) and corresponding results, and (2) the PCRF uses this information to automatically select optimal policies from per-device policies associated with the subscriber line prepared beforehand. The PCRF then instructs the PCEF to apply the relevant policies to communication from each of the devices.

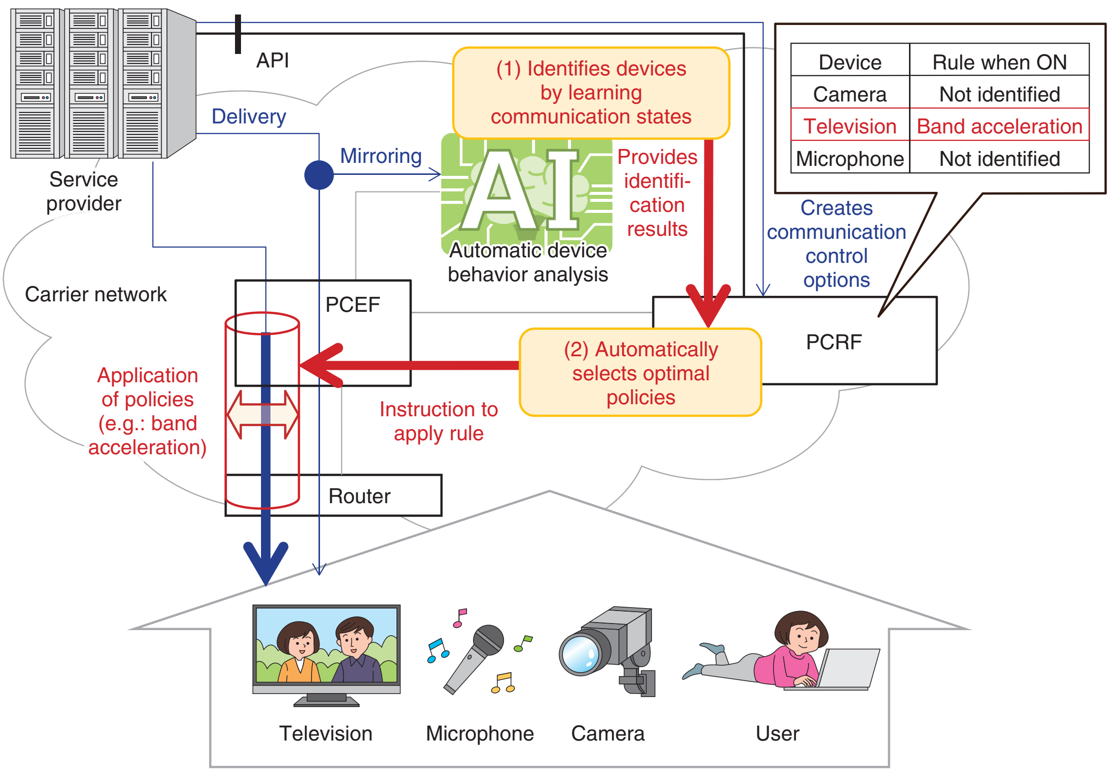
Use of this technology allows individual devices on a subscriber line to be identified, and network control that is optimized for each device to be implemented.

5. Future prospects

With the increasing number and diversity of devices connected to networks, we have introduced automatic device behavior analysis, which identifies the types and models of devices from their communication behavior, and policy control technology, which implements network control optimized to each device, based on this information.

Various methods are possible for creating feature values from communication data and for determining similarity in the automatic device behavior analysis, so we will continue working to improve the technology and create services, keeping in mind the networks to which it will be applied.

For the policy control technology, service providers



AI: artificial intelligence
API: application programming interface

Fig. 2. IoT era policy control system architecture.

providing services to users will continue to study design and configuration of new per-device policies, and we are studying an application programming interface that will enable flexible provision of services.

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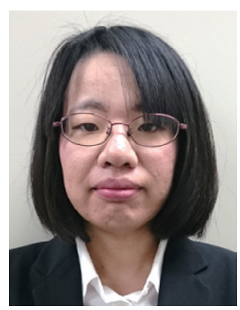

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Privilege Sharing and Transfer Based on Passwordless Authentication

Yasuhiko Yoshimura, Yurika Suga, Yoshihiko Omori, Takao Yamashita, and Akira Shibata

Abstract

Research is underway at the NTT laboratories on an authentication platform that provides both security and convenience. This article describes secure and passwordless authentication platform technology for application to a variety of services that use smartphones and other mobile devices that have grown in popularity. This technology is expected to be applied to a wide array of services to improve their convenience of use.

Keywords: authentication, passwordless, FIDO

1. Introduction

The explosive increase in the use of mobile devices such as smartphones has been accompanied by the ability to use all sorts of online services regardless of location. Although the method of authentication using an identifier (ID) and password has become commonplace when using individual services, it requires the user to remember and input a different password for each service. This presents a problem in terms of convenience. There is also concern about spoofing (impersonation) due to leaked IDs and passwords. In response to these problems, we have been studying technologies with the aim of achieving secure and convenient authentication.

2. FIDO-related technology

The FIDO (Fast IDentity Online) Alliance proposes an authentication method using public key encryption technology to achieve secure and convenient authentication (**Fig. 1**) [1]. One set of FIDO specifications presents the Universal Authentication Framework (UAF) protocol that assumes the use of mobile devices such as smartphones. The UAF protocol stores a private key for authentication in a secure area of the mobile device (such as a secure element (SE) or trusted execution environment (TEE)) and uses the mobile device as an authentication token. Using public key encryption technology at the time of authentication provides a high level of security without the need for secret information (such as a password) shared by the server and device. Passwordless authentication can also be achieved using some means of personal confirmation such as biometric authentication that mobile devices are beginning to provide as standard.

3. Overview of convenience-enhancing technology

Various service providers have begun to introduce FIDO-certified authentication ecosystems reflecting the ongoing spread of FIDO technology. We at the NTT laboratories seek to make people's lives more convenient by enabling users to share privileges to use products and services provided by the application with FIDO technology.

When using public key encryption technology that is used in secure authentication methods such as FIDO UAF, as many keys as the number of services being used will be registered in the mobile device, but when using a new device such as when upgrading to a new model, a user has to re-register those keys. The proposed convenience-enhancing technology would ease the burden of such re-registration by providing a

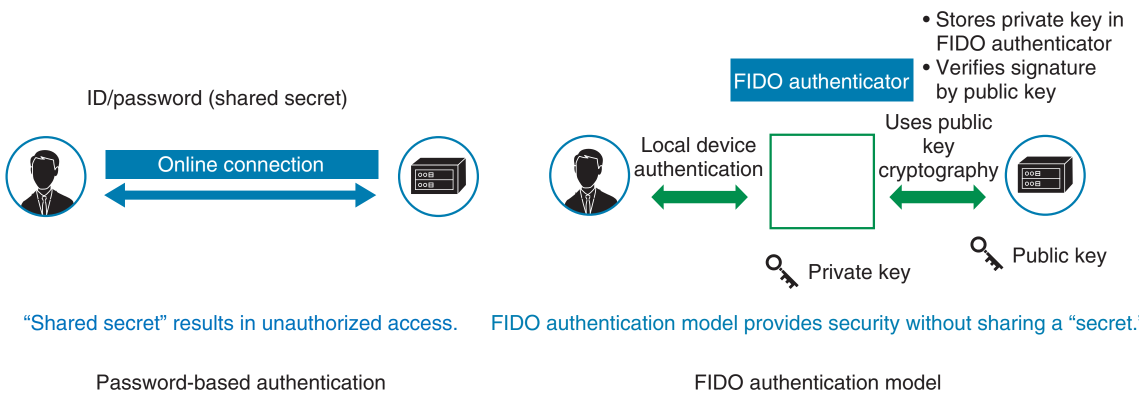

Fig. 1. Features of FIDO authentication.

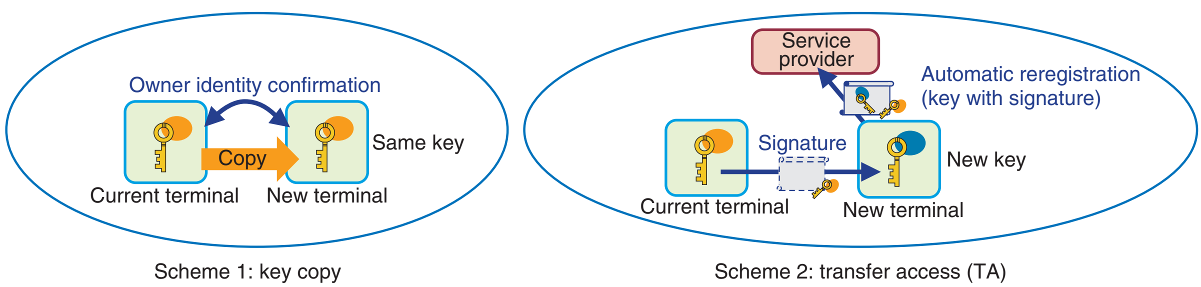

Fig. 2. Overview of key-sharing (transfer) schemes.

mechanism for securely and easily sharing keys among multiple devices.

An overview of key-sharing (transfer) schemes at the core of this convenience-enhancing technology is shown in **Fig. 2**. Scheme 1 is a key-copy scheme that duplicates a private key stored in the SE/TEE area of a device in a new device. To ensure security, this scheme incorporates various methods to verify the user of a device such as biometric authentication and identity confirmation using a digital certificate, and it uses proximity communication methods to eliminate communications over the Internet such as near-field communication or Bluetooth [2]. In addition, key sharing between two devices can be achieved by a simple device operation using biometric authentication and device-pairing via device-to-device contact.

Scheme 2 is a transfer access (TA) [3] scheme developed by researchers at the University of Washington in Seattle, USA. In this scheme, a new device notifies the server (service provider) that the user of a new device is the same as a user whose private key has already been registered by sending a digital signature calculated using the private key. This scheme is effective when a service provider needs to detect the addition of a device by a user, though it requires the modification of an authentication server.

4. Application of convenience-enhancing technology

We are researching methods to achieve privilege sharing (transfer) to use services and resources by using mechanisms such as those for sharing private keys among devices used in convenience-enhancing technology [4]. Enabling the current device and a new one in the TA scheme in Fig. 2 to correspond to user A and user B, respectively, public key registration by user B will mean, from the viewpoint of the service provider, that user A who already has the privilege to use a service has passed it to user B. This technology can be applied not only to sharing privileges to use services between devices but also to various types of services by using it to grant certain privileges from one user to another (**Fig. 3**).

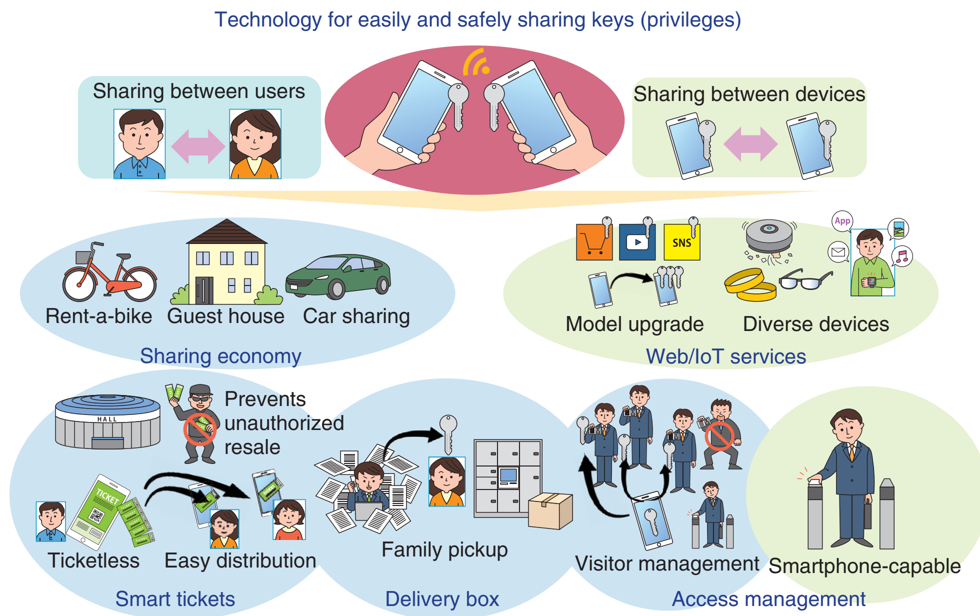

Fig. 3. Application of convenience-enhancing technology.

5. Future outlook

We described a secure and convenient method for sharing and transferring privileges to use services without the need for passwords. Looking to the future, we plan to study specific systems for applying this method to a variety of services as shown in **Fig. 3** to achieve a general-purpose and sophisticated authentication platform and add value to related services.

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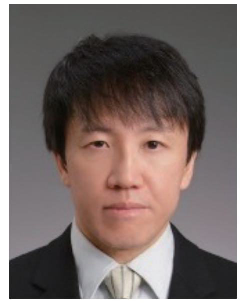

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Optical Fiber and Optical Device Technology for Innovative Manufacturing

Takashi Matsui, Kyozo Tsujikawa, Tadayuki Imai, Yuichi Akage, Takashi Sakamoto, Nobutomo Hanzawa, Yuto Sagae, Kazuhide Nakajima, and Hiroki Morimura

Abstract

Long-distance transmission of high-quality and high-power laser optics has been achieved for the first time in the world by combining the advanced optical fiber and optical device technologies developed by NTT in the optical communications field with the high-power laser processing technology of Mitsubishi Heavy Industries, Ltd. The use of laser processing technology is spreading rapidly at manufacturing sites in the automobile, aircraft, and other industries. The results of this joint research are expected to be the first step in revolutionizing the concept of manufacturing for a variety of social infrastructures through B2B2X (business-to-business-to-X) initiatives.

Keywords: laser processing, optical fiber, optical device

1. Introduction

Laser processing technology such as for metal cutting and welding is finding widespread use these days at manufacturing sites in the automobile, aircraft, and other industries. The laser beams used in laser processing can be generally divided into single mode and multi-mode[*1] in terms of properties (**Fig. 1**). A single-mode laser beam features high directivity. The beam emitted from the optical fiber can be easily focused on a single point, making for high-precision laser processing. The output from the latest single-mode laser oscillators extends to 10 kW (about 10,000 times the optical intensity used in optical communications), which enables high-precision laser processing with good efficiency. However, the transmission distance of a single-mode laser with conventional optical fiber is limited to only a few meters.

In contrast, a multi-mode laser beam can propagate for more than several tens of meters with existing optical fiber technology, but the wide angle of this type of laser beam emitted from the optical fiber limits its processing precision. Consequently, if a 10-kW-class single-mode laser beam can be propagated over distances greater than several tens of meters while maintaining processing quality, it should be possible to greatly ease restrictions on processing location or scale of the processing target at the processing site. Furthermore, if the direction and shape of a single-mode, high-output laser beam can be freely controlled, it should be possible to control the shape in cutting and hole forming and achieve efficient overlay processing[*2] (**Fig. 2**).

*1 Single-mode laser, multi-mode laser: In a single-mode laser, one mode of light with high directivity propagates within the optical fiber. In a multi-mode laser, in contrast, multiple modes of light propagate along various paths, which means that the laser beam emitted from the optical fiber cannot focus on a single point.

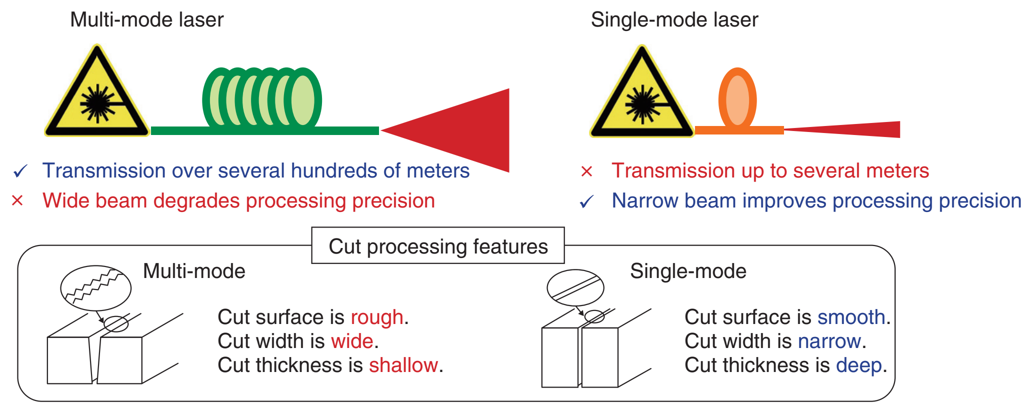
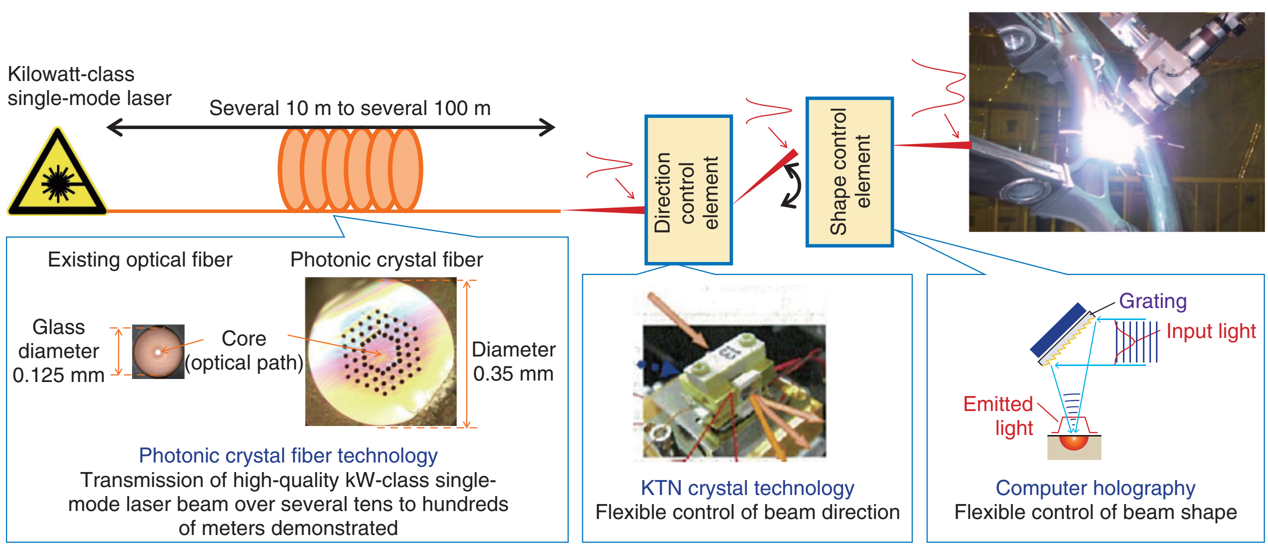


Fig. 1. Existing laser processing technology and multi-mode/single-mode features.



KTN: $KTa_{1-x}Nb_xO_3$ (potassium tantalate niobate)

Fig. 2. New laser processing technology leveraging NTT technology.

2. Optical fiber and optical device technology for high-power transmission

We have succeeded in transmitting a 10-kW high-quality laser beam over a distance of 30 m by optimizing photonic crystal fiber previously developed as a low-loss, high-capacity transmission medium by NTT as a high-power transmission medium [1]. Photonic crystal fiber is optical fiber that transmits light by confining it within an area surrounded by countless air holes. Precise control of the diameter and pitch of these air holes makes it possible to maintain a single mode for application to laser processing even for high power input on the order of 10 kW [2]. This joint research also involved a study on the application of potassium tantalate niobate ($KTa_{1-x}Nb_xO_3$: KTN) crystal [3], which was developed by NTT for possible

*2 Overlay processing: This is technology for improving the heat-resistance and corrosion properties of a material by welding metallic powder having desired properties on the surface of a substrate. If the shape of the laser beam used in overlay processing can be controlled to be flat and broad, the area subjected to overlay processing with one application of laser beam irradiation can be expanded.

application to optical switches and optical memory, and computer holography [4] to laser processing. The use of KTN crystal and computer holography here enables flexible control of the laser beam direction and shape. We expect the combination of these three technologies—photonic crystal optical fiber, KTN crystal, and computer holography—to enable 10-kW-class laser beams to be delivered to any processing site for performing flexible, high-quality, and high-efficiency laser processing.

3. Future outlook

The initiative described here is aimed at creating new added value by combining the results of research and development of competitive network infrastructure technology with technology from another industry. Going forward, we expect trials that demonstrate the potential of this technology in actual laser processing to drive its growth as a technology that can revolutionize the manufacturing sites of a variety of social infrastructures.

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Wildlife Detection System Using Wireless LAN Signals

Tomoki Murakami, Shinya Otsuki, Takafumi Hayashi, Yasushi Takatori, and Kazuo Kitamura

Abstract

The NTT Group considers the primary industry of agriculture an important field and is promoting development of innovative technologies that integrate agriculture with information and communication technology. This article introduces initiatives related to a wildlife detection system that are part of this work. The system can accurately detect wildlife that enters agricultural land over a wide area, using only fluctuations in wireless local area network radio signals.

Keywords: wireless LAN, sensing, machine learning

1. Introduction

Damage to agricultural produce by wildlife totals around 20 billion yen per year in Japan, with damage from wild boar and deer accounting for approximately 80% of this (**Fig. 1**). This damage also contributes to secondary damage such as a declining desire to continue farming, and unutilized arable land, resulting in deeper social issues than are represented by these numbers. Many institutions are actively studying measures to counter such wildlife damage using information and communication technology to detect intrusions, prevent intrusions, capture, or chase away the wildlife. The NTT laboratories are focusing on sensing technologies for detecting intrusions using radio waves.

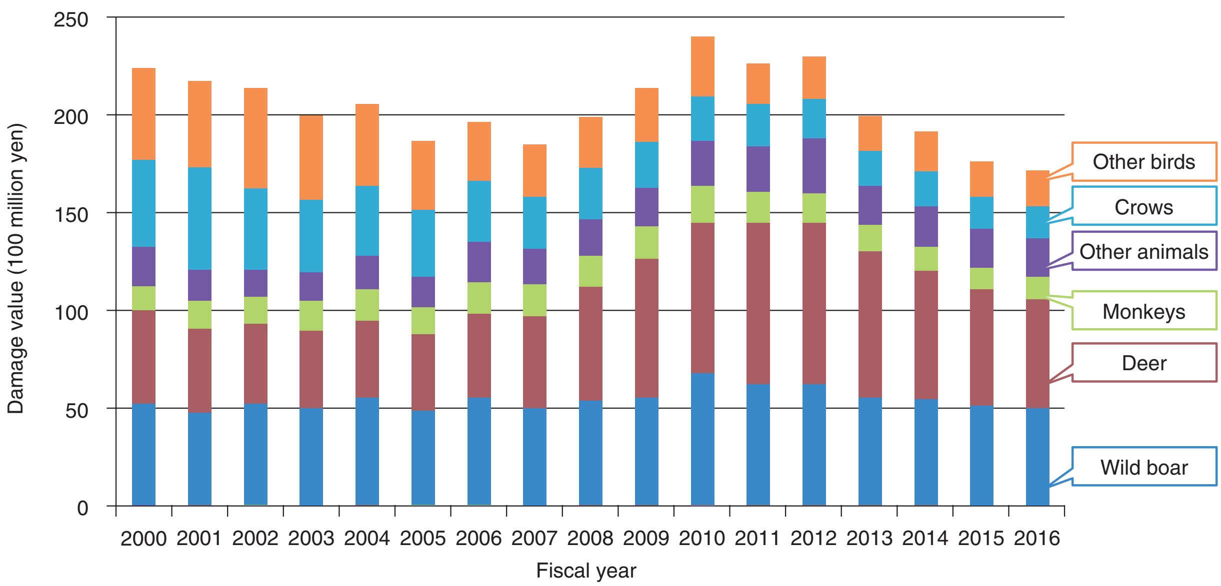
2. Trends in sensing technologies using radio waves

Radio waves are used as a communication medium by mobile terminals such as smartphones and are widely used in mobile communications and wireless local area network (LAN) systems. They are also used for non-communications applications such as sensing, microwave ovens, GPS (Global Positioning System), and wireless power transmission, making them essential for everyday life. Sensing technologies have attracted particular attention recently, and application domains have been expanding, from detecting people and animals (a domain already in use) to object and behavior recognition (a new domain).

Sensing technologies utilizing radio waves can be categorized by whether the object being detected has a radio device or not. We refer to the latter as device-free sensing. Generally, device-free sensing is done using various types of radio waves such as microwaves, millimeter waves, infrared rays, and visible light. In this study we focus on microwaves, which are very good compared to other radio waves in terms of detection range, detection of obstructed objects, and detection at night (**Table 1**). Moreover, if wireless LAN microwave frequencies are used, some existing wireless LAN devices can be reused, reducing the cost of deploying the system.

3. Wildlife detection system using wireless LAN radio waves

For the proposed system, an IEEE (Institute of Electrical and Electronics Engineers) 802.11ac [1] wireless LAN access point and several terminals are deployed in the sensing area, and fluctuations in the radio waves between them are analyzed to detect wildlife in the area (**Fig. 2**). Specifically, a separate



Note: The above graph is based on data in "Trends in Damage to Agricultural Production Due to Wildlife," published by the Ministry of Agriculture, Forestry and Fisheries.

Fig. 1. Trends in value of agricultural damage due to wildlife.

Table 1. Device-free sensing characteristics.

		Microwaves	Millimeter waves	Infrared light	Visible light (camera)
Frequency		300 MHz–30 GHz	30 GHz–300 GHz	Tens of terahertz	Hundreds of terahertz
Detection range	Distance	Up to 100 m	Up to 10 m	Up to 10 m	Up to 10 m
	Direction	No dependency on direction	Specific direction	Specific direction	Specific direction
Night-time detection		✓	✓	✓	×
Obscured object detection		✓	×	×	×
Deployment cost		Low	High	Moderate	Moderate

collection device deployed in the area collects the radio packets for Channel State Information (CSI)* notifications, which are periodically exchanged between the access point and terminals and are necessary for transmission beam forming. The data are collected into a database on the network, and machine learning is applied to detect wildlife [2]. The proposed system enables CSI to be collected easily, which could previously only be done using specialized equipment, and it enables existing wireless LAN systems to be repurposed, greatly reducing the cost of deployment. A dynamic demonstration of the system was conducted at the NTT R&D Forum 2018 Autumn, in which a wild boar stuffed animal and a plastic bottle representing a person were recognized, demonstrating the feasibility of the system (**Fig. 3**).

4. Future prospects

Many of the visitors to the NTT R&D Forum 2018 Autumn were troubled by the agricultural damage caused by wildlife, so we intend to use the proposed

* CSI: Information regarding the propagation path between transmitter and receiver antennas, including amplitude and phase information for each subcarrier when using orthogonal frequency division multiplexing.

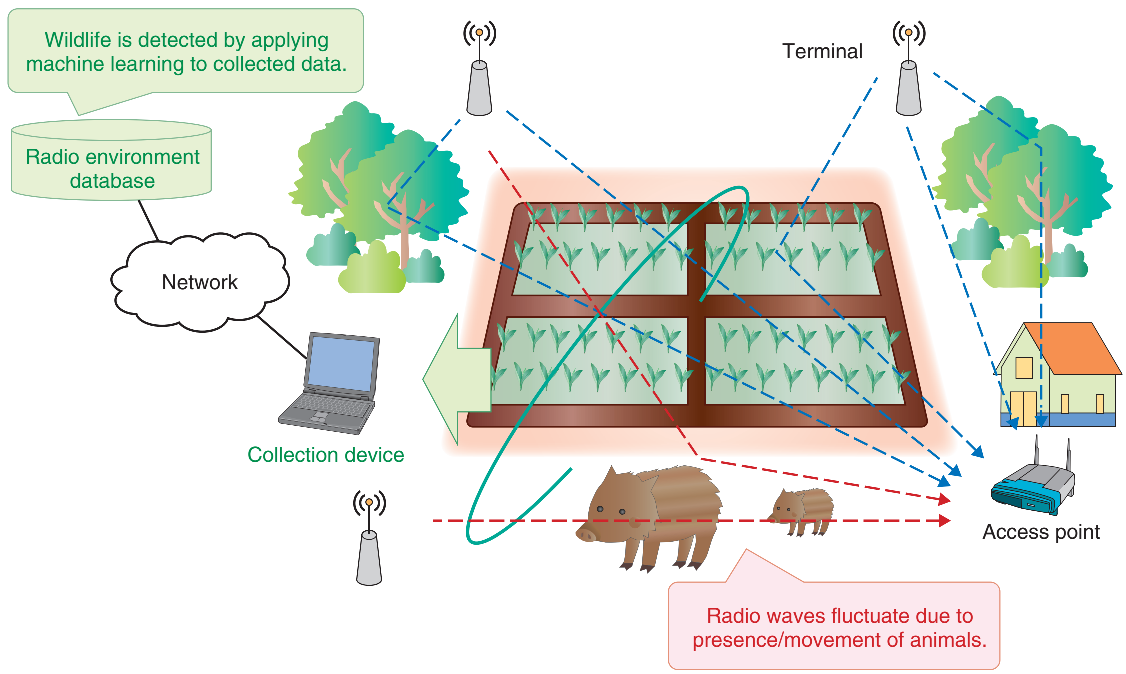
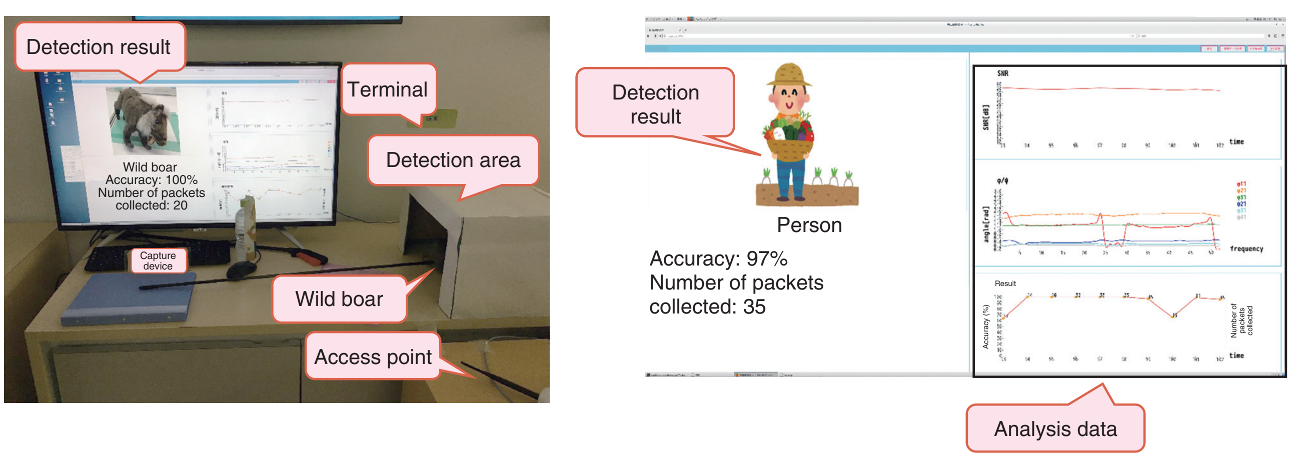


Fig. 2. Overview of wildlife detection system.



(a) Detection of a stuffed toy (simulated wild boar)

(b) Detection of a plastic bottle (simulated person)

Fig. 3. Demonstration of proposed system.

system to establish technology to counter wildlife damage and also to expand the range of applications beyond wildlife, to detecting intrusions by people and objects as well.

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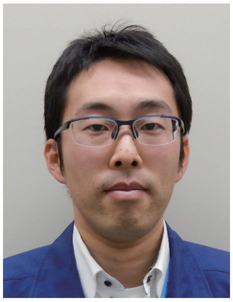

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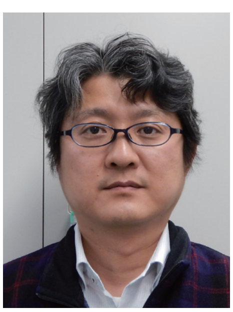

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Versatile Video Coding: a Next-generation Video Coding Standard

Seishi Takamura

Abstract

The scope of Subcommittee (SC) 29 of ISO/IEC (International Organization for Standardization/International Electrotechnical Commission) Joint Technical Committee 1 is coding of audio, picture, multimedia, and hypermedia information. Working Group (WG) 11, part of SC 29, is standardizing video coding, media transmission, streaming, audio coding, image/video retrieval, and genomic information coding. In April 2018, WG 11 initiated standardization of next-generation video coding called Versatile Video Coding (VVC), which is aimed at achieving higher compression, in conjunction with ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) Study Group 19. This article introduces the background, target, and recent development status of VVC.

Keywords: ISO/IEC JTC 1/SC 29/WG 11, MPEG, Versatile Video Coding

1. Introduction

Subcommittee (SC) 29 (Coding of audio, picture, multimedia, and hypermedia information) is a subcommittee of the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC), an international standardization body, Joint Technical Committee (JTC) 1, and it has been the hub of standardization activities related to the coding of multimedia information technology [1, 2]. There are two Working Groups (WGs), WG 1 and WG 11, under the auspices of SC 29. WG 11 is known as the Moving Picture Experts Group (MPEG), and it develops the standards for technologies such as video and audio coding, multiplexing/synchronizing audio and visual streams, high efficiency coding, three-dimensional video coding, and image/video retrieval. These standards are known as MPEG series standards.

The amount of Internet protocol (IP) traffic is increasing rapidly worldwide. It was reported that in 2017, the annual run rate for global IP traffic was 122 EB (exa (10^{18}) bytes) per month [3]. IP traffic is predicted to grow at a compound annual growth rate of 26% from 2017 to 2022, and to increase threefold (387 EB per month) by 2022. IP video traffic accounted for 75% of all IP traffic in 2017, which is forecast to be 82% by 2022. Such video traffic content is already compressed (mainly by MPEG coding standards) down to a few hundredths of the original size. Thus, it is clear that not only video-based services but also network services as a whole would collapse without video coding standards. Also, with the trend for rapid growth of video traffic, more and more powerful compression techniques are necessary.

2. Latest video coding standard

Development of the most recent international video coding standard to date, H.265/MPEG-H HEVC (High Efficiency Video Coding), began in 2010 by the Joint Collaborative Team on Video Coding (JCT-VC) consisting of WG 11 and the International Telecommunication Union - Telecommunication Standardization Sector Study Group 16 (ITU-T SG16) Working Party 3, Question 6 (VCEG: Video Coding Experts Group). The initial version of the Final Draft International Standard (FDIS) was completed in January 2013. It is used in 4K/8K broadcasting and video transmission. More than 2 billion HEVC-compliant devices have been shipped worldwide.

Since the initial version of HEVC, various extensions and amendments have been published [4].

HEVC effectively achieves compression performance twice that or more than any of the previous standards. However, due to the strong demand for higher compression, in 2014 MPEG began working on achieving an even better video coding standard, aiming at a next-generation video coding standard named Future Video Coding (FVC) at that time.

At a meeting in Strasbourg, France, in October 2014, a brainstorming session was held inviting engineers from the communications, network service, and hardware fields as speakers. At that meeting, the requirements for FVC were discussed and defined as broadcasting, IP television, contribution quality video transmission, digital cinema, surveillance, mobile viewing, and virtual reality (VR), among others. In February 2015, JCT-VC began developing reference software for next-generation video coding called Key Technical Area (KTA).

At a meeting in Geneva, Switzerland, in October 2015, the Joint Video Exploration Team (JVET) between ISO/IEC and ITU-T was created, and this team subsequently inherited KTA and used it to develop reference software called Joint Exploration Model (JEM). MPEG issued the requirements for the functionalities and performance of FVC in June 2016 [5]. In January 2017, JEM was confirmed to have achieved a significant performance gain compared to the HEVC test model (HM) [6]. In April 2017, a Call for Evidence was issued [7].

In October 2017, a Call for Proposal (CfP) was issued [8]. At the same time, the team was renamed the Joint Video *Experts* Team (keeping the same abbreviation JVET). After the meeting, 26 CfP responses from 21 organizations were submitted. All the proposals were carefully compared via a subjective viewing test, and the results were compiled and reported at a meeting in San Diego, USA, in April 2018. The new standard is named ISO/IEC 23090 MPEG-I Part 3 Versatile Video Coding (VVC). The "I" in MPEG-I stands for Immersive Media. Based on the subjective results and proposed technological details, a technical description document (Working Draft 1: WD1) and reference software (VVC Test Model 1: VTM1) were created as a starting point.

3. Current standardization status of VVC and future development plan

VVC will support three types of video: Standard Dynamic Range (SDR), High Dynamic Range (HDR), and 360° (VR-oriented, omnidirectional view). Various technologies are being proposed and evaluated in JVET's exploration process. The target compression performance is a 30–50% bit-rate reduction compared to H.265/HEVC at the same subjective video quality.

JVET holds standardization meetings four times a year. At each meeting, proposed coding tools are intensively reviewed from subjective/objective aspects. Decisions are made on which tools will be adopted, and the WD is updated based on the consensus of attendees with various backgrounds. At the same time, implementation of adopted tools, encoding optimization (outside the scope of standardization) and performance enhancement, and bug fixes are carried out on the reference software VTM using an open/public repository.

Numerous contribution documents have been submitted so far, with 118 in April 2018 (beginning of standardization), 559 in July 2018, 690 in October 2018, 897 in January 2019, and 858 in March 2019. This is far more than the total submitted at the first five meetings on HEVC standardization.

After the March 2019 meeting, meetings will be held in Gothenburg, Sweden, (September 2019), Geneva (October 2019), Brussels, Belgium, (January 2020), Alpbach, Austria, (April 2020), and Geneva (June–July 2020), as well as a meeting in Rennes, France, (October 2020) to reach the FDIS stage.

The most recent reference software for VVC, VTM5.0, achieves a 33.14% bit-rate reduction (luminance (Y) Bjøntegaard Delta rate (BD-rate)), an encoding runtime of 6.71 times, and a decoding runtime of 1.03 times compared to HEVC reference software HM16.19, under the random access coding structure. More details are given in **Table 1**. Faster coding tools with more coding gain are demanded.

Some of the principal tools adopted in VVC so far are listed in **Table 2**. Among them, CST (chroma separate tree), CCLM (cross-component linear model), ALF (adaptive loop filter), AFF (affine motion compensation), MTS (multiple transform set), and DQ (dependent quantization) contribute to improving coding performance more than others. Many proposals, including those on neural network technologies, are intensively evaluated and selected at each meeting.

4. Future exploration of WG 11

This article has overviewed the background of VVC standardization, the latest trends, and future

Table 1. Coding performance of current VVC (VTM5.0) against HEVC (HM16.19).

Coding structure	Y BD-rate	Encoding runtime	Decoding runtime
All intra	–23.14%	22.46	1.04
Random access	–33.14%	6.71	1.03
Low delay B	–24.69%	4.82	0.89
Low delay P	–28.15%	4.39	0.92

Table 2. Principal tools adopted in HEVC and current VVC.

Category	H.265/HEVC	MPEG-I VVC (WD4) [9]
Partition structure	Maximum size of 64 x 64, quad-tree	Maximum size of 28 x 128, quad-/ternary-/binary-tree, **CST (chroma separate tree)**
Intra prediction	Direct current (DC) + Planar + 33 directional prediction, reference/boundary pixel filter	DC + Planar + 65 directional prediction + 28 wide angle + 3 **CCLM (cross-component linear model)**, PDPC (position dependent prediction combination), MLIP (multi-line intra prediction), CPR (current picture referencing)
Inter prediction	Skip, merge, weighted prediction	**AFF (affine motion compensation)**, CIIP (combined intra/inter prediction), triangular, BWA (bi-directional weighted average), decoder-side motion refinement (BDOF (bi-directional optical flow), DMVR (decoder-side motion vector refinement)), MV prediction (ATMVP (alternative temporal motion vector prediction), HMVP (history-based motion vector prediction)), AMVR (adaptive motion vector difference), PMC (pairwise merge candidate), MMVD (merge with motion vector difference)
Transform	Square transform (up to 32 x 32 size), fixed transform bases (discrete cosine transform (DCT)2, discrete sine transform (DST)7)	Square and rectangular transforms (up to 64 x 64 size), shape adaptive transform, **MTS (multiple transform set)** (DCT2, DST7, DCT8)
In-loop filter	Deblocking filter (DF), sample adaptive offset (SAO)	**ALF (adaptive loop filter)**, large-block adaptive DF, LADF (luma-adaptive DF), SAO
Quantization, entropy coding	Fixed quantization, position context	**DQ (dependent quantization)**, template context

plans. Other than VVC, current MPEG standardization efforts continue on video retrieval standard ISO/IEC 15938 MPEG-7 Part 15: Compact Descriptors for Video Analysis (CDVA), neural network coding, and genomic information coding standard ISO/IEC 23092 MPEG-G.

As for point cloud compression (PCC) standards, Video-based PCC (V-PCC) of MPEG-I Part 5 is scheduled to reach the FDIS stage in January 2020, and Geometry-based PCC (G-PCC) of MPEG-I Part 9 is scheduled to reach the FDIS stage in April 2020. Additionally, work is underway on high-density light field video coding, 6DoF (degree of freedom) video coding with which the user walks a few steps away from a central position in a scene, and 3DoF+ video coding, with which the user does not walk in the scene (e.g., sitting on a chair) [10].

For 3DoF+, a CfP was issued at the meeting in Marrakech, Morocco, in January 2019 [11], and it is scheduled to reach the FDIS stage of MPEG-I Part 7 in July 2020. Moreover, standardization of Low Complexity Video Coding Enhancements, which enables two-layered spatial scalability [12], and Essential Video Coding (ISO/IEC 23094 MPEG-5 Part 1) [13] are under development. MPEG's coverage and activity is ever increasing.

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He received a B.E., M.E., and Ph.D. from the Department of Electronic Engineering, Faculty of Engineering, the University of Tokyo in 1991, 1993, and 1996. His current research interests include efficient video coding and ultrahigh-quality video processing. He has fulfilled various duties in the research and academic community in current and prior roles, including serving as Associate Editor of the Institute of Electrical and Electronics Engineers (IEEE) Transactions on Circuits and Systems for Video Technology (2006–2014), Editor-in-Chief of the Institute of Image Information and Television Engineers (ITE), Executive Committee Member of the IEEE Region 10 and Japan Council, and Director-General Affairs of ITE. He has also served as Chair of ISO/IEC JTC 1/SC 29 Japan National Body, Japan Head of Delegation of ISO/IEC JTC 1/SC 29, and as an International Steering Committee Member of the Picture Coding Symposium. From 2005 to 2006, he was a visiting scientist at Stanford University, CA, USA.

He has received 46 academic awards including ITE Niwa-Takayanagi Awards (Best Paper in 2002, Achievement in 2017), the Information Processing Society of Japan (IPSJ) Nagao Special Researcher Award in 2006, PCSJ (Picture Coding Symposium of Japan) Frontier Awards in 2004, 2008, 2015, and 2018, the ITE Fujio Frontier Award in 2014, and TAF (Telecommunications Advancement Foundation) Telecom System Technology Awards in 2004 and 2008, and in 2015 with highest honors, the Institute of Electronics, Information and Communication Engineers (IEICE) 100-Year Memorial Best Paper Award in 2017, and the Kenjiro Takayanagi Achievement Award in 2019.

He is a Fellow of IEEE, a senior member of IEICE and IPSJ, and a member of Japan Mensa, the Society for Information Display, the Asia-Pacific Signal and Information Processing Association, and ITE.

Examples of Wireless LAN Problems Caused by IP Packets and Wireless Encryption Scheme

Technical Assistance and Support Center, NTT EAST

Abstract

As wireless local area network (LAN) communication becomes more popular, the number of failures is increasing and the causes of failure are becoming more diverse. This article introduces two cases concerning problems with wireless LAN caused by IP (Internet protocol) packets and a wireless encryption scheme. This is the fifty-second article in a series on telecommunication technologies.

Keywords: wireless LAN, IP packets, WPA encryption

1. Introduction

The spread of mobile terminals (smartphones, laptop computers, tablets, etc.) equipped with a wireless local area network (LAN) function has led to the installation of wireless LAN access points (APs) in various locations regardless of whether the AP is indoors or outdoors. Thus, an environment in which various locations can be connected to the Internet is being established. NTT EAST also offers a public wireless LAN environment as a solution called Town Wi-Fi [1]. As the Internet-connection environment is improved, wireless LANs are also adopting standards for higher communication speeds. The IEEE* 802.11ax standard—for communication speeds of up to 9.6 Gbit/s—is currently being formulated.

Moreover, a multitude of vendors sell smartphones and tablet devices that support wireless LAN communication. In addition to the conventional Internet communication using a personal computer, the usage patterns of users, such as making calls with a smartphone via a wireless LAN, are becoming more diverse.

Under these circumstances, as wireless LAN communication becomes more diversified, the number of failures is increasing—not only failures caused by radio waves (such as insufficient received signal strength) but also those caused by Internet protocol (IP) packets and wireless encryption schemes. Accordingly, it is necessary to establish measures for multifaceted failure response and prompt recovery.

In this report, two cases are introduced concerning problems with wireless LAN caused by IP packets and a wireless encryption scheme that were handled by the Technical Assistance and Support Center.

2. Case 1

This case involved an investigation of the cause of call disconnections and the failure of Wi-Fi systems connected to a FLET'S Hikari optical line.

2.1 Overview

We were notified that calls on specific terminals were constantly being disconnected at a customer's site. The site was configured with a Session Initiation Protocol (SIP) server, Wi-Fi routers, and other devices connected to a FLET'S Hikari optical line in a manner enabling communication by smartphones via

* IEEE: Institute of Electrical and Electronics Engineers

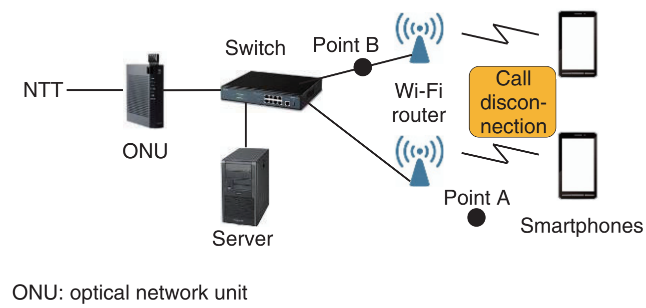

Fig. 1. Configuration of equipment.

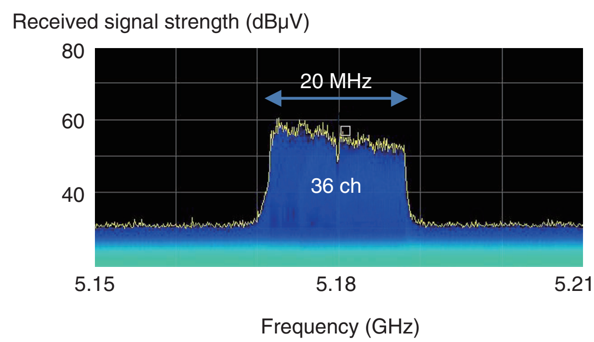

Fig. 2. Results of radio-wave environment test.

Wi-Fi (**Fig. 1**).

Our field maintenance department tested the optical line to confirm it was operating normally and replaced the Wi-Fi router. The call disconnections were not resolved, however, so the Technical Assistance and Support Center was asked to investigate the cause of the failure.

2.2 Investigation of cause and results of investigation

First, a call test was conducted using two terminals: one made by company A (vendor recommended) and one made by company B (not vendor recommended) that was affected by call disconnections while the customer was using it. It was confirmed that a disconnection occurred during extension calls between the company-B-made terminals. To identify the cause of the failure (disconnection), we investigated the radio-wave environment and the communication protocol between the Wi-Fi router and the SIP server.

(1) Radio-wave environment

The radio-wave environment near the AP (point A in Fig. 1) was measured using a spectrum analyzer (Tektronix RSA 6104A). The measurement results revealed that the received signal strength was sufficiently high at 60 dBμV (with the minimum reception sensitivity at 27 dBμV), and no disturbance waves or interference waves were found to be present (**Fig. 2**).

(2) Communication protocol

Using a packet capture tool (Wireshark), we captured packets between the Wi-Fi router and the server (point B in Fig. 1). The results of the packet capture test are listed in **Table 1**. If the terminal can communicate normally, the packets are sent to the server only once. On the contrary, if the terminal suffers a failure, packets are sent directly to other terminals without going through the server. The maximum packet interval was 21 ms in a normal case and 193 ms in the event of the failure. In other words, in the failure case, it exceeded 180 ms, which is the standard for guaranteeing quality.

2.3 Estimation of cause of failure and response

The results of the above-described investigation indicated that the disconnected calls occurred during extension calls using the company-B-made terminal,

Table 1. Results of packet capture test (between Wi-Fi router and server).

	Packet destination	Packet interval*
Terminal with occurring failure	172. 28. 0. 124 (terminal)	193 ms (max.)
Normal terminal	172. 28. 0. 10 (server)	21 ms (max.)

*The standard to guarantee sufficient quality specifies an interval less than 180 ms.

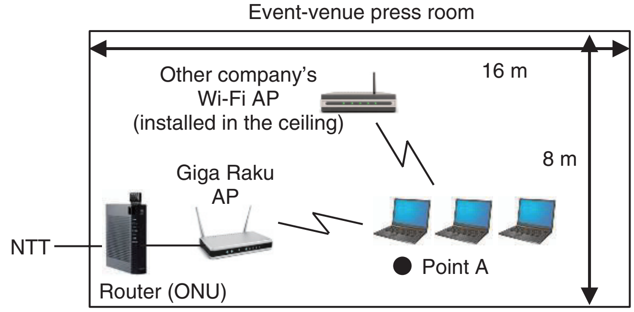

Fig. 3. Configuration of equipment.

namely, the one not recommended by the vendor. The reason for this finding is explained as follows. The SIP server has a buffer that absorbs packet-interval fluctuations, so communication via the server is normal. In the case of the terminal with the failure, packets are sent directly to the other terminal (i.e., without going through the server). We thus presumed that the failure occurred because the packet-interval fluctuation could not be absorbed. The failure can therefore be resolved by using only terminals recommended by the vendor.

3. Case 2

The next case involved an investigation into the cause of a failure in *Giga Raku Wi-Fi* communication in the press room of an event venue.

3.1 Overview

In this case, a constant communication failure (disconnection and decrease in throughput) was occurring in the Giga Raku Wi-Fi service installed in the press room at an event venue. Although the APs were rebooted and other measures were tried, the failure was not resolved; consequently, we were asked to investigate the cause of the failure and to take measures to fix it.

The customer was using laptop computers connected to a Giga Raku Wi-Fi AP (high-end-type made by company C) under an ONU (optical network unit) integrated router. Another company's Wi-Fi AP was set up in the center of the press room (**Fig. 3**).

3.2 Investigation of cause and results of investigation

First, a wireless LAN tester (a product developed by the Technical Assistance and Support Center [2]) was used to confirm the failure. After the tester with the Giga Raku Wi-Fi AP (channel 1) was connected and throughput was measured, it was confirmed that a disconnection occurred during communication. Next, we conducted investigations on the Wi-Fi radio-wave received signal strength, the radio-wave environment, and the communication protocol between APs and terminals to identify the cause of the failure.

(1) Wi-Fi radio-wave received signal strength

Received signal strength in the room was measured by using the received signal strength-distribution map-creation function of the wireless LAN tester. The results of that measurement indicated that the received signal strength was 52 dBμV (with a minimum reception sensitivity of 27 dBμV) even at the lowest location, which indicates that the received signal strength was sufficient anywhere in the room (**Fig. 4**).

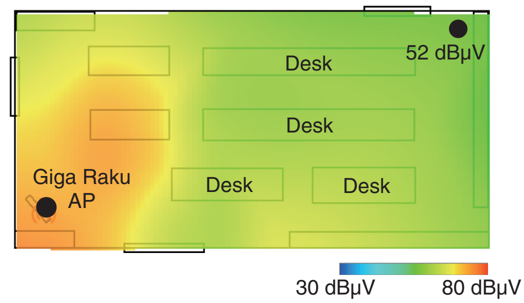

Fig. 4. Distribution map of received signal strength.

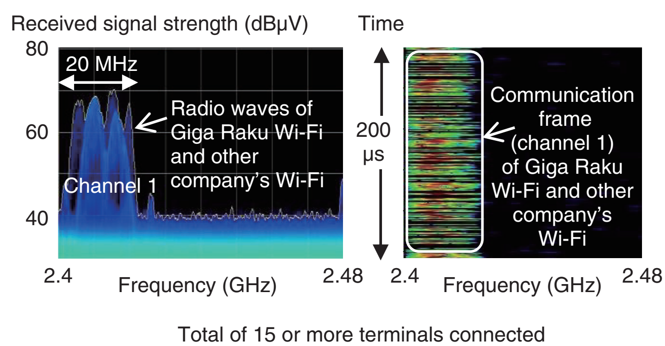

Fig. 5. Communication spectrum and communication status.

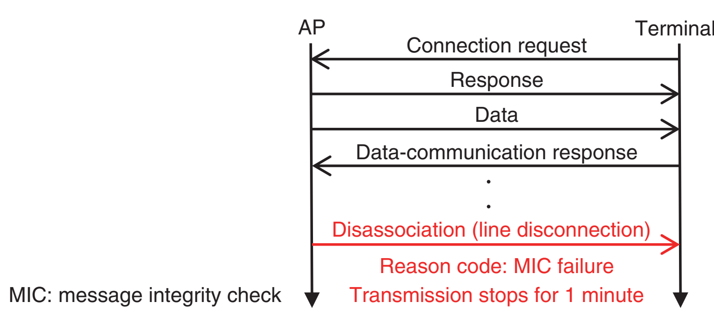

Fig. 6. Result of protocol measurement during communication.

(2) Radio-wave environment

A spectrum analyzer (Tektronix RSA6104A) was used to measure the radio-wave environment at the location of the failure (point A in Fig. 3). According to the results of that measurement, although another Wi-Fi radio wave (from the other company's Wi-Fi AP) was recognized on the same channel as the radio wave from the Giga Raku Wi-Fi AP (channel 1), no other disturbances were discovered (**Fig. 5**).

(3) Communication protocol between APs and terminals

A Wi-Fi failure-analysis tool (Air Magnet) was used to measure the protocol for communication between the APs and terminals. According to the results of that measurement, a so-called disassociation packet was sent from the AP to the terminal to confirm that a disconnection had occurred (**Fig. 6**). This disconnection was due to a message integrity check (MIC) failure. This kind of communication disconnection occurs when there is a tampering-detection-code error in the cryptographic frame used in Wi-Fi Protected Access (WPA) encryption.

3.3 Cause of failure and countermeasure

The results of these investigations suggest the cause of the disconnection and the resulting decrease in throughput were as follows.

(1) Communication disconnection

The Wi-Fi communication is disabled (stopped) for one minute on detection of an MIC failure in WPA encryption. WPA is not recommended because of its cryptographic vulnerabilities [3]. Accordingly, changing the setting to allow only WPA2 encryption is considered a potential measure to eliminate the failure.

(2) Decrease in throughput

Since both Giga Raku Wi-Fi and Wi-Fi of other companies use channel 1, throughput is reduced when many terminals communicate on channel 1. We expect that changing the channel of the Giga Raku Wi-Fi from channel 1 (automatic setting) to channel 11 (fixed setting) will improve throughput. When we actually changed the channel in that manner, we found that throughput was improved by approximately 30 Mbit/s.

4. Concluding remarks

In this report, two example cases concerning problems with wireless LAN tackled by the Technical Assistance and Support Center were introduced. These examples demonstrate that the number of failures is increasing, not only failures caused by radio waves (such as insufficient received signal strength) but also those caused by, for example, communication protocols and communication packets.

In the EMC Engineering Group of the Technical Assistance and Support Center, to quickly resolve noise problems (such as conduction and radiation) and contribute to the smooth provision of communication services, we will continue to actively engage in technical collaboration, technology development, and technology dissemination activities through technology seminars.

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Trademark notes

World's Fastest 600-Gbit/s per Lambda (λ) Optical Transmission with 587-Gbit/s Data Transfer—Prospect for Realizing 600-Gbit/s/λ Optical Network and Data Transfer Protocol

1. Introduction

The National Institute of Informatics (NII), NTT EAST, and NTT announced that they had experimentally demonstrated communications with a data transfer rate of 587 Gbit/s between general-purpose servers on a 600-Gbit/s/λ (λ: lambda, indicating wavelength) optical transmission system spanning Tokyo and Chiba.

For this experiment, we constructed the world's longest transmission link with total distances of 102 km over commercial field fiber in a 600-Gbit/s/λ transmission system. In addition, we recorded the fastest data transfer rate of 587 Gbit/s between one set of servers by applying the Massively Multi-Connection File Transfer Protocol (MMCFTP) developed by NII for data transfer. Moreover, in order to achieve a highly reliable optical network, we developed and successfully demonstrated flexible route switching with an adaptive change in the transmission rate from 600 Gbit/s to 400 Gbit/s and with optical wavelength conversion, based on the transmission distance of the optical signal.

2. Overview of achievements

For the experimental demonstration conducted in November 2018, we constructed an optical transmission system (**Fig. 1**) capable of transmitting signals at a rate of 600 Gbit/s at a single wavelength, between the NII office (Hitotsubashi, Chiyoda-ku, Tokyo) and the NTT EAST office (Kashiwa City, Chiba). We successfully demonstrated three experiments.

2.1 Experiment 1

For the 600-Gbit/s transmission system, NTT introduced an adaptive-rate transponder supporting a variety of transmission rates ranging from 100 Gbit/s to 600 Gbit/s, by implementing the world's most advanced digital signal processing technology and OTUCn* technology which enables the multiplexing of up to six 100-Gbit/s Ethernet client signals on one chip. NTT EAST constructed a network that transferred data at 600 Gbit/s and at 400 Gbit/s in experiments. We verified the full throughput on a 600-Gbit/s/λ signal using data generated by test equipment. We demonstrated for the first time in the world 600-Gbit/s transmission over commercial field fiber with total distances of 102 km.

2.2 Experiment 2

In this communication environment, MMCFTP was used to transfer data from one server to two servers and data from two servers to one server. We successfully confirmed that large capacity data of 40 terabytes were transferred at data transfer rates of 587 Gbit/s and 590 Gbit/s. For example, 40 terabytes is equivalent to 1600 ordinary 25-gigabyte Blu-ray

* OTUCn: Technology that accommodates services of over 100 Gbit/s (such as ultrahigh-speed Ethernet signaling) and reliably transmits data over optical networks.

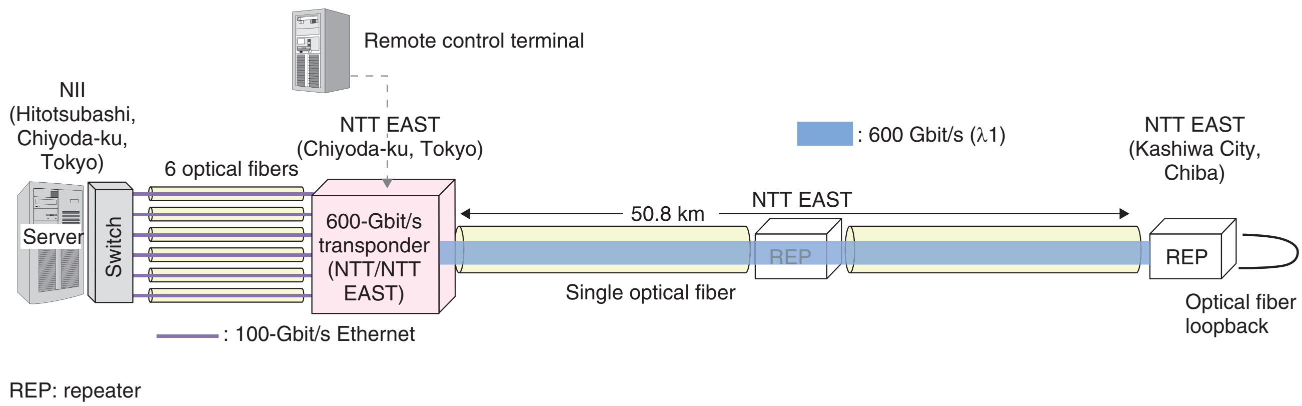

Fig. 1. Schematic of field trial network.

discs, which means that this large volume of data can be transferred in about 9 minutes, or the volume of one Blu-ray disc can be transferred in about 0.4 s. This result indicates a prospect of 587-Gbit/s data transfer between one set of servers.

2.3 Experiment 3

We successfully demonstrated a data transfer function linked with the route switching function. At that time, we confirmed that a communication link was reestablished by an adaptive change of transmission rate from 600 Gbit/s to 400 Gbit/s with the optical wavelength conversion according to the switching of the transmission route.

The transmission rate of the optical signal before transmission route switching was 600 Gbit/s, and the measured data transfer rate was 580 Gbit/s. After switching to the long distance route, the transmission rate of the optical signal was switched, and the measured data transfer rate was 393 Gbit/s.

Part of this work utilizes digital coherent optical transmission technology, which is the result obtained in the research project involving terabit optical network technologies towards the big data era supported by the Ministry of Internal Affairs and Communications.

3. Future work

In the state-of-the-art academic research, the amount of data to be handled—generated by computer simulation science, high-performance experimental apparatuses, and sensors used for Internet of Things services—has been increasing explosively. In order to transfer huge amounts of data efficiently, NII will further improve the MMCFTP software and provide it for advanced science research projects to stabilize and enhance data transfer rates.

NTT EAST and NTT will continue to promote the development of large capacity transmission technologies in order to continue meeting the demand for increases in traffic.

For inquiries:

Public Relations Office, Planning Department,
NTT Information Network Laboratory Group
http://www.ntt.co.jp/news2018/1812e/181211a.html

External Awards

DBSJ Young Researcher's Achievement and Contribution Award
Winner: Hiroyuki Toda, NTT Service Evolution Laboratories
Date: March 4, 2019
Organization: The Database Society of Japan (DBSJ)

For his contribution to the activities of DBSJ and his outstanding achievement in the research areas that DBSJ targets.

Young Scientist Presentation Award
Winner: Ryuichi Ohta, NTT Basic Research Laboratories
Date: March 9, 2019
Organization: The Japan Society of Applied Physics (JSAP)

For "Radiative Lifetime of Bound Excitons in GaAs with Vibrational Strain."
Published as: R. Ohta, H. Okamoto, T. Tawara, H. Gotoh, and H. Yamaguchi, "Radiative Lifetime of Bound Excitons in GaAs with Vibrational Strain," The 79th JSAP Autumn Meeting, 20p-211A-14, Nagoya, Aichi, Japan, Sept. 2018.

Young Researcher's Award
Winner: Erina Takeshita, NTT Access Network Service Systems Laboratories
Date: March 21, 2019
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For "DF Re-election for Reduction of BUM Traffic Loss during Link Failure between PEs in EVPN Multi-homing Network" and "Reduction of Total Maintenance End Points in End-to-end Monitor Placement on Virtual Private Network Infrastructure."
Published as: E. Takeshita, G. Yazawa, H. Kimura, A. Morita, S. Yoshihara, and A. Otaka, "DF Re-election for Reduction of BUM Traffic Loss during Link Failure between PEs in EVPN Multi-homing Network," Proc. of the 2018 IEICE General Conference, B-8-3, Tokyo, Japan, Mar. 2018 (in Japanese). E. Takeshita, G. Yazawa, H. Kimura, and A. Morita, "Reduction of Total Maintenance End Points in End-to-end Monitor Placement on Virtual Private Network Infrastructure," Proc. of the 2018 IEICE Society Conference, B-8-17, Kanazawa, Ishikawa, Japan, Sept. 2018 (in Japanese).

Young Researcher's Award
Winner: Shingo Ohno, NTT Access Network Service Systems Laboratories
Date: March 21, 2019
Organization: IEICE

For "Measurement Accuracy Improvement in Distributed Measurement of Spatial Mode Dispersion along Strongly Coupled Multicore Fiber" and "Measurement Range Improvement in Distributed Measurement of Spatial Mode Dispersion along Strongly Coupled Multicore Fiber."
Published as: S. Ohno, K. Toge, D. Iida, and T. Manabe, "Measurement Accuracy Improvement in Distributed Measurement of Spatial Mode Dispersion along Strongly Coupled Multicore Fiber," Proc. of the 2018 IEICE General Conference, B-13-19, Tokyo, Japan, Mar. 2018 (in Japanese). S. Ohno, K. Toge, and T. Manabe, "Measurement Range Improvement in Distributed Measurement of Spatial Mode Dispersion along Strongly Coupled Multicore Fiber," Proc. of the 2018 IEICE Society Conference, B-13-14, Kanazawa, Ishikawa, Japan, Sept. 2018 (in Japanese).

Young Researcher's Award
Winner: Ryota Shiina, Kazutaka Hara, and Satoshi Ikeda, NTT Access Network Service Systems Laboratories
Date: March 21, 2019
Organization: IEICE

For "Optical/RF Hybrid Wireless Systems for Realizing Stabilized Wireless Environment."
Published as: R. Shiina, K. Hara, and S. Ikeda, "Optical/RF Hybrid Wireless Systems for Realizing Stabilized Wireless Environment," Proc. of the 2018 IEICE Society Conference, B-8-2, Kanazawa, Ishikawa, Japan, Sept. 2018 (in Japanese).

Young Researcher's Award
Winner: Ryo Miyatake, NTT Network Innovation Laboratories
Date: March 21, 2019
Organization: IEICE

For "A Study on Measurement Area Reduction Method for Efficient Wireless Site Survey of LPWA."
Published as: R. Miyatake, Y. Asai, K. Suzaki, and H. Shiba, "A Study on Measurement Area Reduction Method for Efficient Wireless Site Survey of LPWA," Proc. of the 2018 IEICE Society Conference, B-17-19, Kanazawa, Ishikawa, Japan, Sept. 2018 (in Japanese).

Young Researcher's Award
Winner: Akira Masuda, NTT Network Innovation Laboratories
Date: March 21, 2019
Organization: IEICE

For "Quadrature-amplitude-coding PAM to Improve Bandwidth-limitation Tolerance" and "Achievement of 90-Gbaud PAM-4 with NL-MLS and 2.88-Tb/s O-band Transmission Using 4-λ LAN-WDM and 4-core Fiber SDM."
Published as: A. Masuda, S. Yamamoto, S. Kawai, and M. Fukutoku, "Quadrature-amplitude-coding PAM to Improve Bandwidth-limitation Tolerance," Proc. of the 2018 IEICE General Conference, B-10-11, Tokyo, Japan, Mar. 2018 (in Japanese). A. Masuda, S. Yamamoto, H. Taniguchi, and M. Fukutoku, "Achievement of 90-Gbaud PAM-4 with NL-MLS and 2.88-Tb/s O-band Transmission Using 4-λ LAN-WDM and 4-core Fiber SDM," Proc. of the 2018 IEICE Society Conference, B-10-41, Kanazawa, Ishikawa, Japan, Sept. 2018 (in Japanese).

IEEE VR Best VRSJ Demo Award
Winner: Munekazu Date, Megumi Isogai, and Hideaki Kimata, NTT Media Intelligence Laboratories
Date: March 26, 2019
Organization: The 26th IEEE (Institute of Electrical and Electronics Engineers) Conference on Virtual Reality and 3D User Interfaces (IEEE VR 2019)

For "Full Parallax Table Top 3D Display Using Visually Equivalent Light Field."
Published as: M. Date, M. Isogai, and H. Kimata, "Full Parallax Table Top 3D Display Using Visually Equivalent Light Field," IEEE VR 2019, Demo ID: D31, Osaka, Japan, Mar. 2019.

Maejima Hisoka Award
Winner: Hiroyuki Oto and Yasuyuki Uchiyama, NTT DOCOMO; Kazuaki Obana, NTT Network Innovation Laboratories
Date: April 10, 2019
Organization: Tsushinbunka Association

For the commercial deployment of network functions virtualization technology enabling multi-vendor EPC (evolved packet core) software.

Papers Published in Technical Journals and Conference Proceedings

Anomaly Detection for Mixed Transmission CAN Messages Using Quantized Intervals and Absolute Difference of Payloads

T. Koyama, T. Shibahara, K. Hasegawa, Y. Okano, M. Tanaka, and Y. Oshima

Proc. of the ACM Workshop on Automotive Cybersecurity 2019, pp. 19–24, Richardson, TX, USA, March 2019.

The control of vehicles can be taken over by injecting malicious controller area network (CAN) messages. To detect malicious messages, anomaly-detection systems based on intervals or payloads of CAN messages have been proposed. However, these systems cannot accurately detect malicious messages injected into mixed CAN messages, which include periodic and sporadic transmissions. Moreover, sophisticated systems leveraging machine learning are not deployable because the computers in vehicles have limited computational resources. Therefore, we propose a lightweight system to detect malicious messages injected into mixed CAN messages. The proposed system extracts features essential for detecting such messages from CAN messages; thus it is deployable in vehicles. Specifically, we use the quantized intervals and the absolute difference of payloads. We collected 44 hours of running data from 4 types of vehicles and injected 7788 malicious messages into 33 mixed and 8 periodic CAN messages. Our result shows that our system achieved high detection performance: a true positive rate of 97.55% and a false positive rate of 0.003%.

Resource-efficient Verification of Quantum Computing Using Serfling's Bound

Y. Takeuchi, A. Mantri, T. Morimae, A. Mizutani, and J. F. Fitzsimons

npj Quantum Information, Vol. 5, Article no. 27, April 2019.

Verifying quantum states is central to certifying the correct operation of various quantum information processing tasks. In particular, in measurement-based quantum computing, checking whether correct graph states are generated is essential for reliable quantum computing. Several verification protocols for graph states have been proposed, but none of these are particularly resource efficient: multiple copies are required to extract a single state that is guaranteed to be close to the ideal one. The best protocol currently known requires $O(n^{15})$ copies of the state, where n is the size of the graph state. In this paper, we construct a significantly more resource-efficient verification protocol for graph states that only requires $O(n^5 \log n)$ copies. The key idea is to employ Serfling's bound, which is a probability inequality in classical statistics. Utilizing Serfling's bound also enables us to generalize our protocol for qudit and continuous-variable graph states. Constructing a resource-efficient verification protocol for them is nontrivial. For example, the previous verification protocols for qubit graph states that use the quantum de Finetti theorem cannot be generalized to qudit and continuous-variable graph states without tremendously increasing the resource overhead. This is because the overhead caused by the quantum de Finetti theorem depends on the local dimension. On the other hand, in our protocol, the resource overhead is independent of the local dimension, and therefore generalizing to qudit or continuous-variable graph states does not increase the overhead. The flexibility of Serfling's bound also makes our protocol robust: our protocol accepts slightly noisy but still useful graph states.

Quantum Key Distribution with Simply Characterized Light Sources

A. Mizutani, T. Sasaki, Y. Takeuchi, K. Tamaki, and M. Koashi

arXiv:1904.02364 [quant-ph], April 2019.

To guarantee the security of quantum key distribution (QKD), several assumptions on light sources must be satisfied. For example, each random bit information is precisely encoded on an optical pulse and the photon-number probability distribution of the pulse is exactly known. Unfortunately, however, it is hard to check if all the assumptions are really met in practice, and it is preferable that we have a minimal number of device assumptions. In this paper, we adopt the differential-phase-shift (DPS) QKD protocol and drastically mitigate the requirements on light sources. Specifically, we only assume the independence among emitted pulses, the independence of the vacuum emission probability from a chosen bit, and upper bounds on the tail distribution function of the total photon number in a single block of pulses for single, two and three photons. Remarkably, no other detailed characterizations, such as the amount of phase modulation, are required. Our security proof significantly relaxes demands for light sources, which paves a route to guarantee implementation security with simple verification of the devices.

Dialogue Breakdown Detection Using BERT with Traditional Dialogue Features

H. Sugiyama

The 10th International Workshop on Spoken Dialogue Systems Technology (IWSDS 2019), Siracusa, Sicily, Italy, April 2019.

Despite the significant improvements in Natural Language Processing with neural networks such as machine reading comprehension, chat-oriented dialogue systems sometimes generate inappropriate response utterances that cause dialogue breakdown because of the difficulty of generating utterances. If we can detect such inappropriate utterances and suppress them, dialogue systems can continue the dialogue easily.

Investigating the Perceived Timing of Sensory Events Triggering Actions in Patients with Parkinson's Disease and the Effects of Dopaminergic Therapy

Y. Yabe, M. A. Goodale, and P. A. MacDonald

Cortex, Vol. 115, pp. 309–323, June 2019.

Few studies have investigated if Parkinson's disease (PD), advancing age, or exogenous dopamine therapy affect the perceived timing of past events. Here we show a phenomenon of 'temporal repulsion' of a sensory event relative to an action decision in patients with PD. In these patients, the timing of a sensory event triggering an action was perceived to have occurred earlier in time than it really did. In other words, the event appeared to be pushed away in time from the performance of the action. This finding stands in sharp contrast to the 'temporal binding' we have observed here and elsewhere (Yabe et al., 2017; Yabe & Goodale, 2015) in young healthy participants for whom the perceived onset of a sensory event triggering an action is typically delayed, as if it were pulled towards the action in time. In elderly patients, sensory events were neither repulsed nor pulled toward the action decision event. Exogenous dopamine alleviated the temporal repulsion in PD patients and normalized the temporal binding in healthy elderly controls. In contrast, dopaminergic therapy worsened temporal binding in healthy young participants. We discuss this pattern of findings, relating temporal binding processes to dopaminergic and striatal mechanisms.
