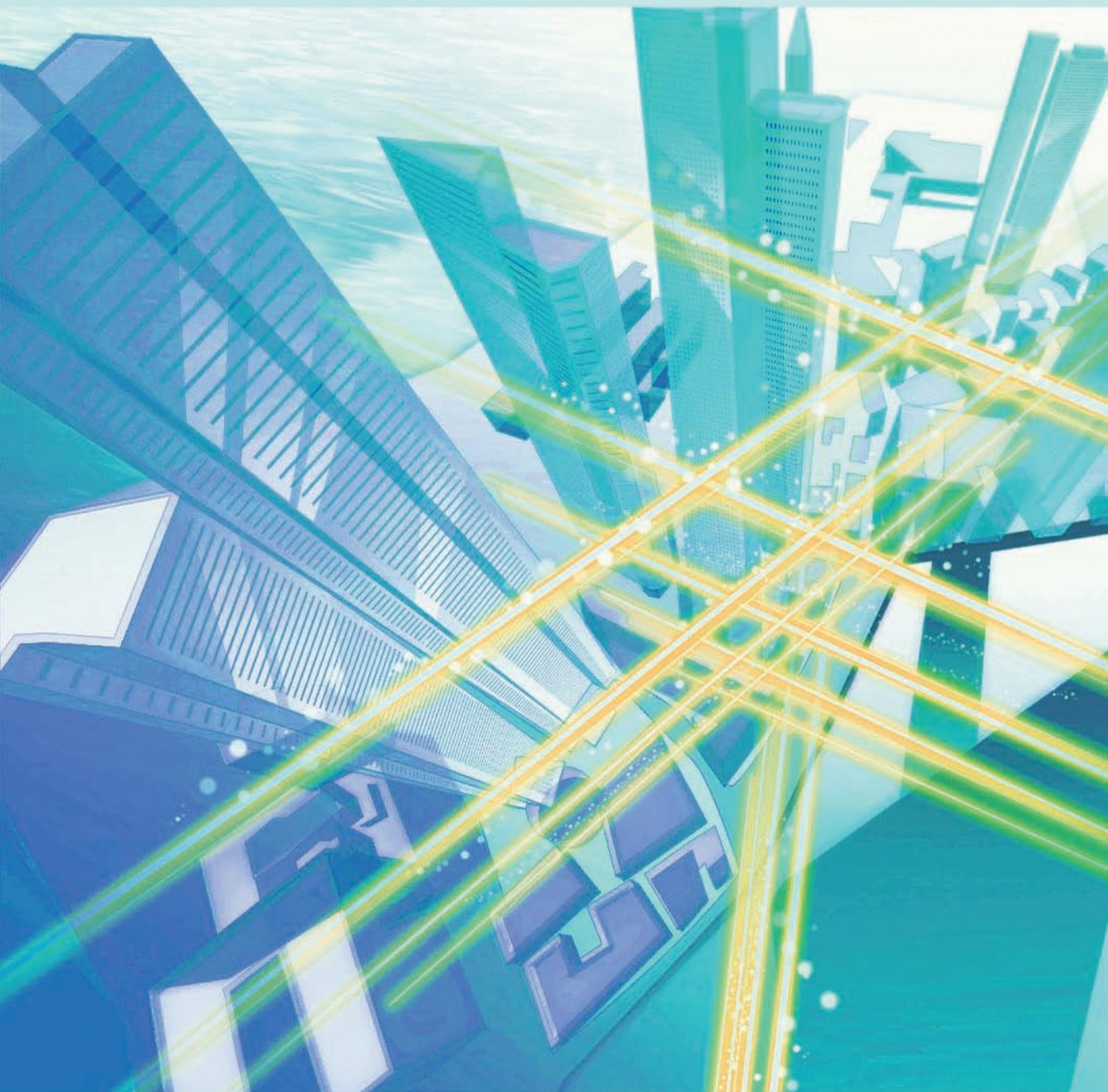


# NTT Technical Review

5

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## Feature Articles: Movable and Deployable ICT Resource Unit—Architecture for Quickly Responding to Unexpected ICT Demand

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External Awards/Papers Published in Technical Journals and Conference Proceedings

## Overview of Movable and Deployable ICT Resource Unit Architecture

*Toshikazu Sakano, Satoshi Kotabe, and Tetsuro Komukai*

### Abstract

When the Great East Japan Earthquake struck in 2011, a lot of the information and communication technology (ICT) infrastructure suffered catastrophic damage, which triggered ICT service outages in various areas for long periods of time. NTT Network Innovation Laboratories has been working to solve this problem and has developed ICT architecture called the Movable and Deployable ICT Resource Unit (MDRU). This architecture enables us to instantly deliver ICT services in damaged areas by installing a transportable ICT unit that accommodates the equipment necessary for providing ICT services. This article presents an overview of the MDRU architecture and also introduces a research and development project launched to realize it.

*Keywords: resilient ICT, Wi-Fi, IP-PBX*

### 1. Introduction

The Great East Japan Earthquake struck on March 11, 2011 and caused catastrophic damage over a wide area of northeastern Japan due not only to the large tremor but also to the devastating tsunami that it triggered. Telecommunication companies and information and communication technology (ICT) service<sup>\*1</sup> providers also suffered serious damage to their network infrastructure. Because of the damage, they had to stop delivering ICT services in quite a few areas for a long time. At the same time, people in the damaged areas urgently needed ICT services in order to confirm the safety of their loved ones such as family members, relatives, friends, and neighbors, and to collect information on what was happening and what would happen next. This resulted in an explosion in the demand for ICT services. This large supply-and-demand gap in the ICT sector strongly reminded people of the importance of the ICT infrastructure and the necessity of service continuity even under extreme disasters.

NTT Network Innovation Laboratories responded to the public's expectations by proposing the resilient ICT architecture called the Movable and Deployable ICT Resource Unit (MDRU)<sup>\*2</sup> [1]. The MDRU archi-

ture enables us to promptly reestablish ICT services in disaster-affected areas by installing transportable resource units that accommodate the functions necessary to deliver ICT services such as telephony and information sharing.

These Feature Articles report on the MDRU architecture and the research and development (R&D) activities underway in NTT Network Innovation Laboratories. This article gives an overview of the MDRU architecture and explains the R&D projects launched to realize it. Subsequent articles report the major technologies used in the architecture, including those for Wi-Fi-based network configuration [2], high-speed optical-link establishment [3], efficient media storage and transmission [4], and convenient ICT service delivery [5]. The last article reports on a feasibility study of MDRU use in an area in the Philippines, which was affected by Typhoon Haiyan in 2013, as an example of a specific activity being conducted toward MDRU commercialization [6].

<sup>\*1</sup> ICT service: General term for a service related to the information network and the Internet, which includes telephone and information services.

<sup>\*2</sup> MDRU: A transportable unit that accommodates equipment necessary to deliver ICT services. The word is also used for an ICT architecture that uses the unit for instant delivery of ICT services.

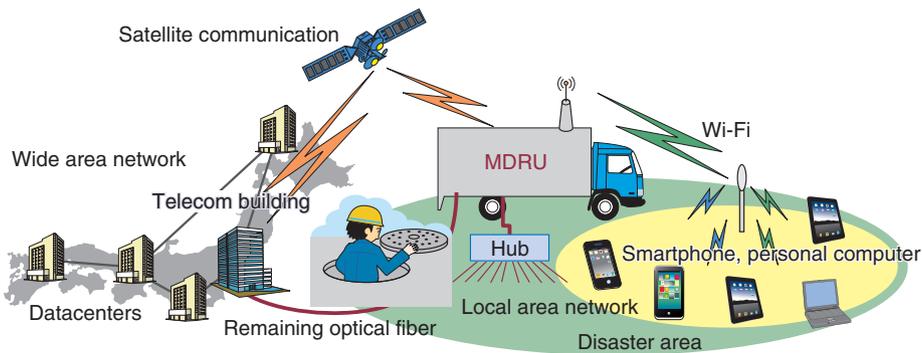


Fig. 1. Concept of MDRU architecture.

## 2. MDRU architecture

The concept of the MDRU architecture is shown in **Fig. 1**. An MDRU is a transportable unit accommodating the various resources necessary to deliver ICT services. Once a disaster occurs, one or more MDRUs are promptly transported to the disaster-affected area and set up there. Each unit then rapidly forms a Wi-Fi-based local area network (LAN) in its surrounding area and starts delivering at least basic ICT services to the people in the area. The MDRU is connected to the existing wide area network (WAN) via remaining optical fibers and/or satellite links. Once the MDRU is connected to the WAN, it acts as a local information hub.

After the earthquake struck in 2011, NTT deployed transportable systems such as switching systems, base-station systems, and satellite public telephone systems in an effort to respond to the disaster. The objective of using these systems was to repair the existing network infrastructure or to temporarily replace damaged portions of the infrastructure. Unfortunately, such systems took too long to install and activate, as a lot of work was needed such as to confirm the locations and degree of damage and to make system adjustments. The repairs were patchwork, and services lagged. It sometimes took as long as a few weeks to recover basic service. Moreover, it was not easy to flexibly respond to the unexpected demand that arose after the disaster such as when a large evacuation center was established in an unpredictable place. The MDRU architecture, on the other hand, is aimed at creating a new ICT service-delivery environment anytime, anywhere irrespective of the situation of the existing network infrastructure [7]. An MDRU forms a Wi-Fi-based LAN in its surround-

ing area and promptly delivers basic ICT services within the local area. The MDRU architecture enables us to flexibly and instantly deliver ICT services in any situation by optimizing the system configuration and by selecting the technologies that meet the current objectives.

## 3. Enabling technologies in MDRU architecture

The major enabling technologies adopted for the MDRU architecture are shown in **Fig. 2**. The MDRU actually acts as a movable telephone office and/or datacenter. It accommodates network equipment, servers, and storage devices. They are interconnected to form a LAN in the unit. The LAN is extended to the surrounding area by way of a Wi-Fi-based access network to reach customer devices such as smartphones and personal computers. In the server, application software for ICT services such as Internet protocol (IP)-based telephony is installed [8]. Several new technologies allow the MDRU to instantly respond to new demands for ICT services in the disaster-affected area. Details of the technologies are reported in the other Feature Articles in this issue.

## 4. MDRU R&D project

NTT Network Innovation Laboratories launched an R&D project aimed at realizing the MDRU architecture in collaboration with NTT Communications Corporation, Tohoku University, and Fujitsu Limited, and with the support of the Ministry of Internal Affairs and Communications of Japan. The prototype MDRUs developed in the project are shown in **Fig. 3**. Several types of MDRUs that have different sizes and resource capabilities have been developed. The

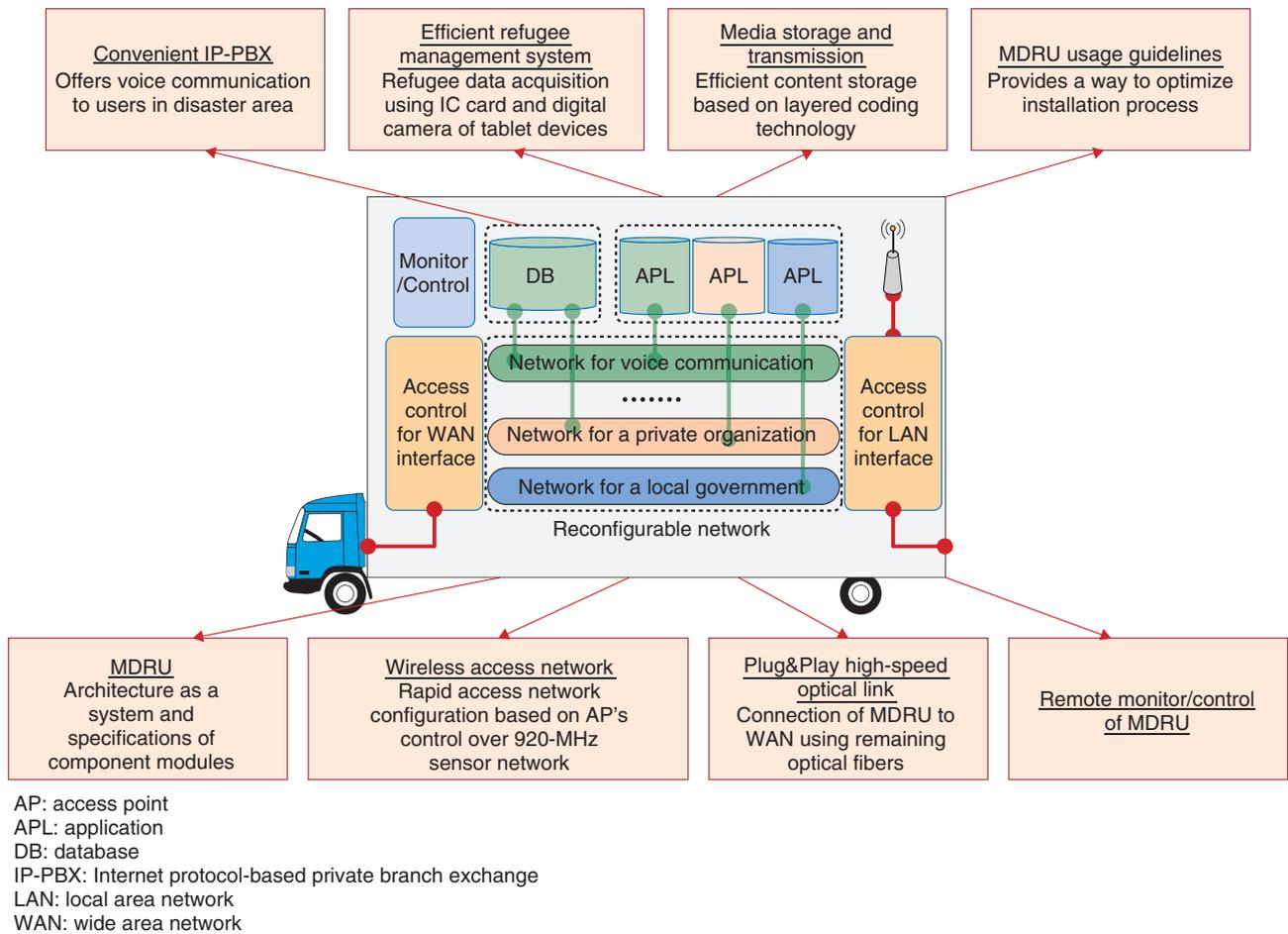


Fig. 2. Major enabling technologies applied in MDRU architecture.

MDRUs have been subjected to several feasibility studies and proof-of-concept experiments such as those to confirm the operation of major functions.

The specifications of the latest prototype MDRU, which is a vehicle called the ICT Car, are summarized in **Table 1**. The ICT Car can deliver ICT services for five consecutive days without external electric power, as it hosts an electric power system consisting of a generator and batteries and an energy-saving air conditioning system based on latent heat material. The ICT Car carries several wireless equipment modules such as Wi-Fi access point equipment and wireless transceivers for fixed point-to-point wireless links. These wireless modules are distributed in the area surrounding the ICT Car and used to form the widest possible wireless access network.

### 5. MDRU installation experiment as a proof of concept

We conducted an MDRU installation experiment using ICT Car at the University of Aizu in Fukushima Prefecture to prove our concept. Some pictures of the experiment are shown in **Fig. 4**. In Fig. 4(a), project members take the wireless modules from the ICT Car and prepare to distribute them. In Fig. 4(b), some project members are setting up a Wi-Fi access point module by connecting the module to its antenna.

The experimental results are shown in **Fig. 5**, which plots the relationship between the installation patterns of the wireless access network and the measured times necessary to start delivering a service. We experimentally confirmed that it was possible for us to start delivering ICT services within 40 minutes after the arrival of the ICT Car at the intended site. When the wireless access network was extended by a

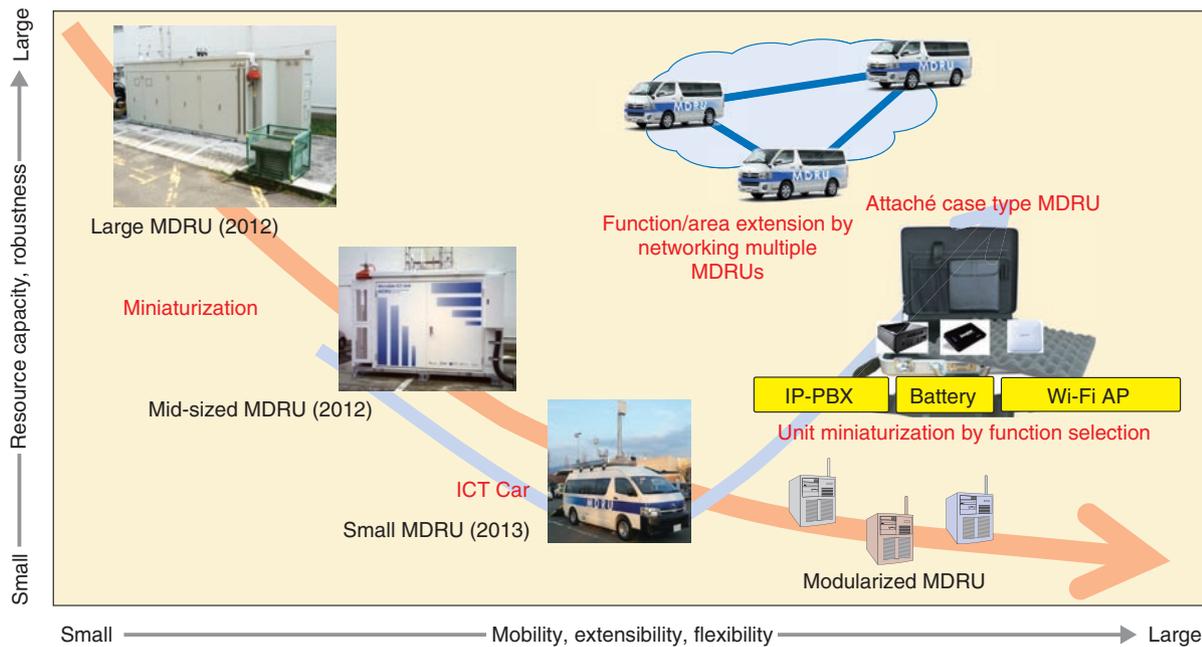


Fig. 3. Roadmap of MDRU development.

Table 1. Specifications of ICT Car.

Item	Details
Base car	Toyota Hiace (net capacity: 1 ton)
Power source	Gasoline electric generator, lithium-ion battery unit, electric power input from outside
Air conditioning	Energy-saving air conditioning system based on latent heat material
Number of racks	2 (8U 19-inch racks)
Servers	- Application server (e.g. for IP-PBX) - Server for virtual network control - Server for remote operation - Server/storage for hosting/housing
Link to WAN	1G Ethernet media converter
Access network	Wi-Fi (2.4G/5G), wired (1G/100M Ethernet), FWA (5-GHz/25-GHz band)
Network control	Wide-area ubiquitous network (920-MHz band, sensor network)

FWA: fixed wireless access

few kilometers by linking several wireless modules, it took about 140 minutes in total, regardless of the type of area extension. These times meet our MDRU requirement of delivering service within a few hours after arrival. Thus, we can conclude from the experiments and trials that the proposed MDRU architecture is highly effective.

## 6. Summary and future work

This article introduced the MDRU architecture, which was developed to resolve the critical issues appeared after the 2011 earthquake, and described several achievements of the MDRU R&D project. The feasibility of the proposed MDRU concept has

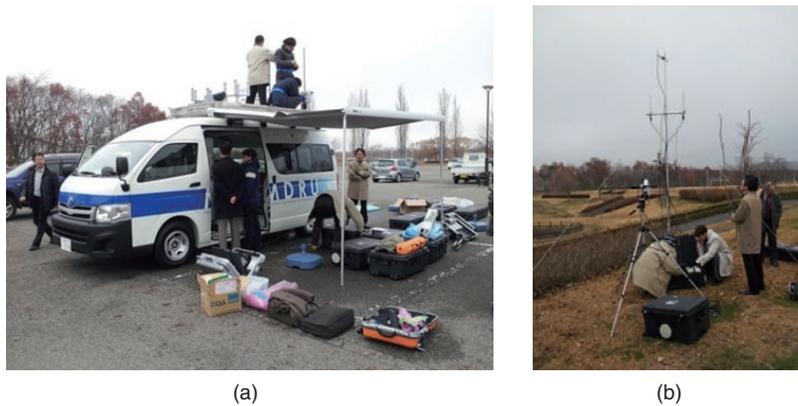


Fig. 4. MDRU installation experiment; (a) preparation for wireless module distribution, and (b) setup of Wi-Fi module.

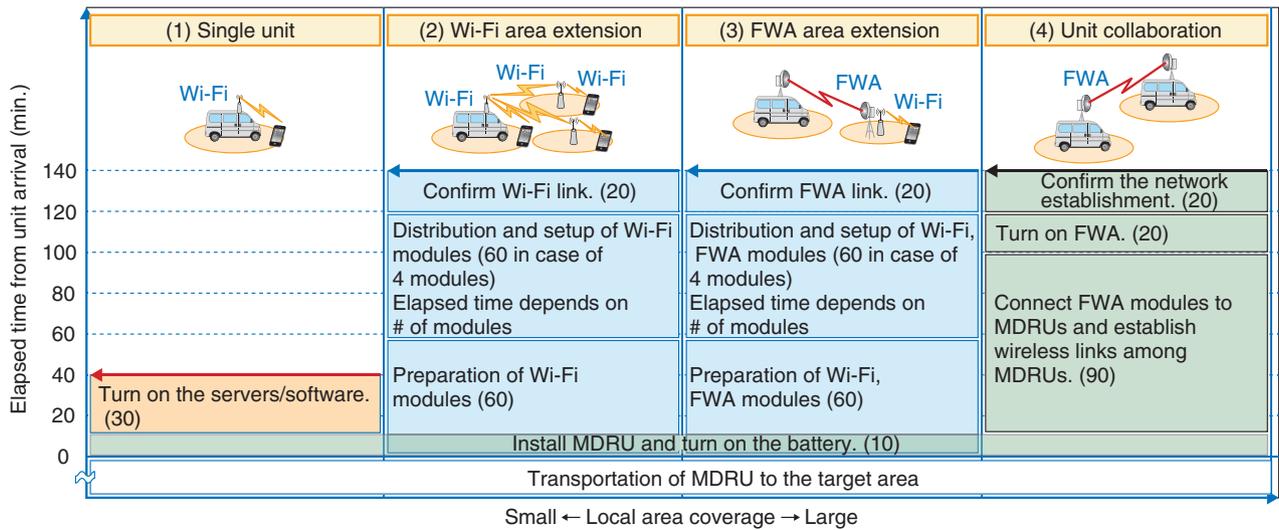


Fig. 5. Patterns of LAN extension and measured installation times.

already been confirmed, and the project is now moving toward the commercialization phase. Discussion of the global standardization of the MDRU architecture in ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) SG (Study Group) 15 started in 2014. A feasibility study of our MDRU architecture in an actual disaster area has also been conducted in the Philippines, where MDRU sets were used to provide services to people in an area affected by a typhoon.

There are other goals to be accomplished in the MDRU R&D project, so our R&D activities will continue. Our final goal is to apply MDRUs domestically as well as globally and to contribute to saving the

lives of people in disaster areas in the future.

### Acknowledgement

Part of the work in this article is being conducted under the national projects, *R&D on the reconfigurable communication resource unit for disaster recovery* and *R&D of “Movable ICT Units” for emergency transportation into disaster-affected areas and multi-unit connection*, both supported by the Ministry of Internal Affairs and Communications of Japan.

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# Wireless Access Network System Using M2M Wireless Access for MDRU

*Yoshitaka Shimizu, Yasuo Suzuki, Tomoaki Kumagai,  
and Kazuto Goto*

## Abstract

NTT Network Innovation Laboratories has been developing the Movable and Deployable ICT Resource Unit (MDRU) that enables us to quickly reestablish information and communication technology (ICT) services in disaster-stricken areas. In this article, we introduce a novel MDRU radio function that constructs a Wi-Fi access network quickly and flexibly around the MDRU by using machine-to-machine wireless access as the control link.

*Keywords: M2M wireless access, remote control, Wi-Fi network*

## 1. Introduction

Smartphones with Wi-Fi capability have rapidly come into widespread use. They enable users to access the Internet outdoors and indoors via wireless local area networks (WLANs). Consequently, the number of users who access the Internet with smartphones is increasing. We expect that there will be more and more opportunities to use Wi-Fi in the near future since a lot of Wi-Fi access points (APs) will be installed to strengthen connectivity prior to the 2020 Tokyo Olympic Games.

In view of the popularity and consequent importance of Wi-Fi, we must consider how to recreate Wi-Fi services after a disaster strikes. It is necessary to rapidly and flexibly deal with unexpected network failures such as those caused by the severing of optical fiber to Wi-Fi APs, which might occur after a disaster. For example, when several access links are broken and a network operator tries to recreate them by using Wi-Fi multi-hop connections such as wireless distribution system (WDS)<sup>\*1</sup> links, the corresponding Wi-Fi APs must be reset so as to establish multi-hop connections by linking neighboring APs to one another. Moreover, the conventional solution

demands that users and administrators reset each AP according to the surrounding radio link situation. This is not easy, and it takes too long to reestablish Wi-Fi networks. To solve this problem, NTT Network Innovation Laboratories has been developing the Movable and Deployable ICT Resource Unit (MDRU) [1], which allows information and communication technology (ICT) services to be reestablished quickly in disaster areas. As a key MDRU wireless function, we are developing a system that enables rapid construction of a wireless access network by using machine-to-machine (M2M) wireless access<sup>\*2</sup> as the control link. This will make it possible for users to access the Internet via the Wi-Fi function of their smartphone.

\*1 WDS: A wireless distribution system used to form multi-hop connections.

\*2 M2M wireless access: A machine-to-machine wireless access system that is based on the standard method used in private wireless systems but has an added function that enables it to control the APs and wireless terminals (WTs) from a network.

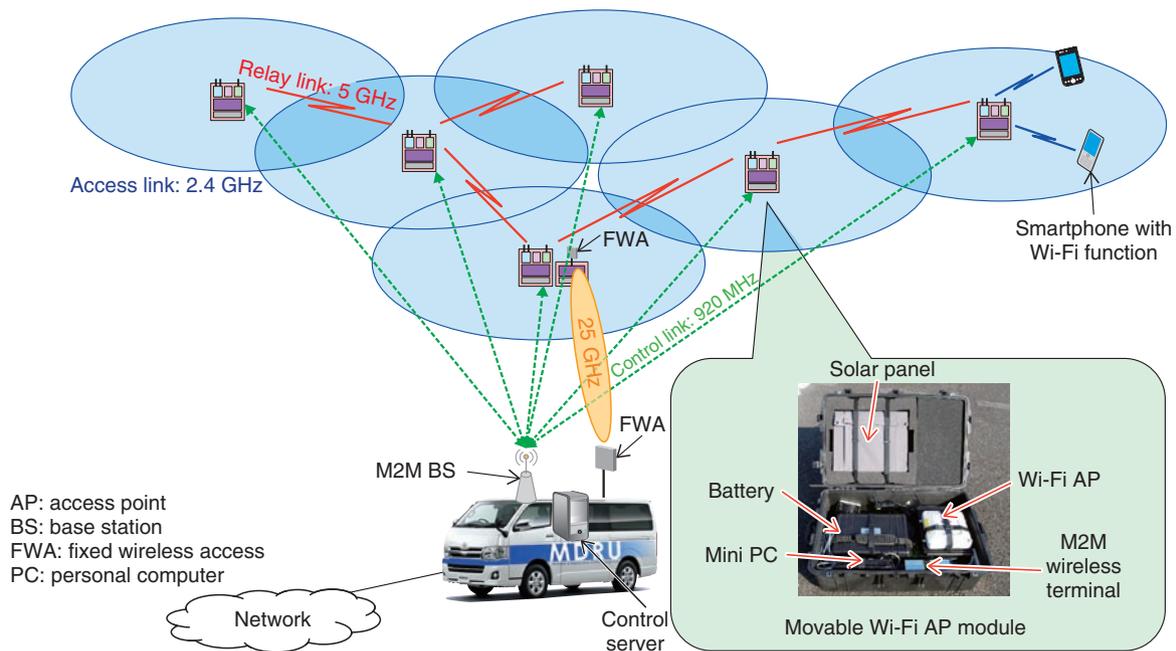


Fig. 1. Wireless access network system using M2M wireless access.

## 2. Wireless access network system using M2M wireless access as the control link

The wireless access network system using M2M wireless access is shown in **Fig. 1**. This system controls the Wi-Fi APs attached to the M2M wireless terminal from the M2M base station (BS) installed by a carrier in the disaster area via an M2M wireless access link. Constructing relay links among the APs provides wide area coverage for communication around the area where the M2M BS is installed. Therefore, the system has two noteworthy features. The first is easy deployment. The complicated Wi-Fi AP settings traditionally performed by engineers are unnecessary due to the remote control capability using M2M wireless access from the MDRU. The system also provides flexibility in establishing connections. If we try to cover the area by using only Wi-Fi APs, many Wi-Fi APs would be occupied by relay traffic. This would degrade throughput due to increases in the transmission delay and processing load. To avoid this situation, the system employs entrance links based on fixed wireless access (FWA)<sup>\*3</sup> systems to reduce the number of relay Wi-Fi APs and to cover a wider area.

The MDRU prototype called the ICT Car has several modules such as an M2M BS module, a movable Wi-Fi AP module with solar panel and battery, and an

FWA module with solar panel and battery. The Wi-Fi AP and FWA modules can be used even if the external power supply is down. After a disaster, the ICT Car arrives at the affected area, and these modules, transported by the ICT Car, are positioned up to 500 m away from the ICT Car. Since the remote control from the ICT Car is used to construct the Wi-Fi access network, we can reestablish the ICT environment [2] effectively and quickly with very few people.

## 3. Technical problems and solutions

If the MDRU is to control the Wi-Fi access network quickly and flexibly, it is essential that large numbers of WLAN APs be properly controlled in a short period by means of M2M wireless access. Unfortunately, M2M wireless access uses very low transmission rates ranging from several kilobits per second to several hundred kilobits per second in order to keep the transmission power of the WTs low and to achieve wide-area coverage, so it takes a comparatively long time to transmit the data to control the Wi-Fi APs and to transmit information from the Wi-Fi APs. To solve this problem, we need a means of effectively

\*3 FWA: A system that enables a radio link to be connected between two points located far away from each other.

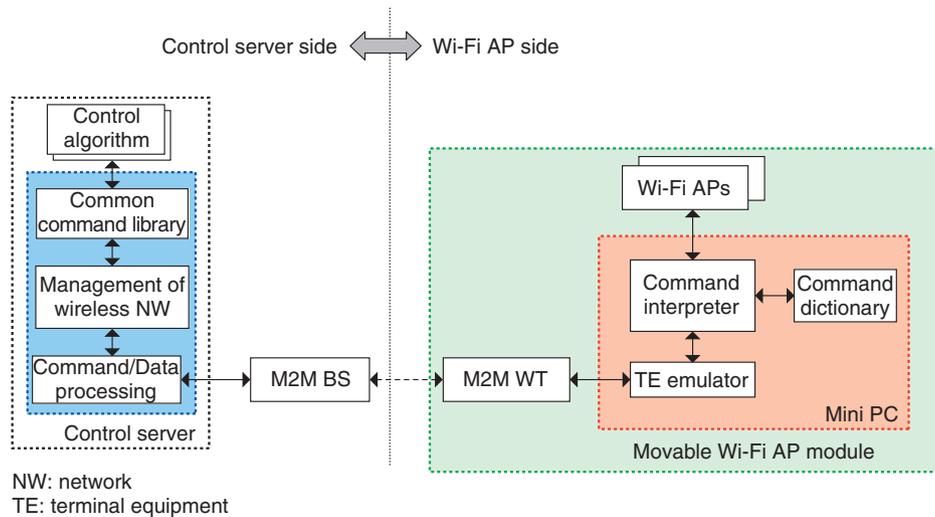


Fig. 2. Prototype platform.

controlling M2M wireless access. Moreover, we need to control a variety of Wi-Fi AP devices, but this is not easy to do since the devices may be from different vendors. We dealt with this by developing a software wrapper technology that enables different WLAN AP devices to be controlled in a common manner.

To assess the wireless access network system, we built a prototype platform as shown in Fig. 2. The platform consists of an M2M BS, a control server, and movable Wi-Fi AP modules including an M2M WT, a mini personal computer (PC), and Wi-Fi APs. To control the widest possible range of Wi-Fi AP devices, the control server has a specific command library with a set of common commands. When the operator issues a command to the Wi-Fi APs, the control server translates the control command into the corresponding common commands by referring to the library, and then sends the commands to the Wi-Fi AP modules via M2M wireless access. When the Wi-Fi AP module receives the commands, the command interpreter of the mini PC converts the commands into vendor-specific commands that correspond to the Wi-Fi device. The platform transmits only critical information in both the uplink and downlink in order to minimize the depletion of wireless resources and reduce the transmission delay. In the uplink, the only necessary information to control is extracted from the information acquired from the Wi-Fi AP in a command interpreter of the mini PC and then transmitted to the control server via M2M wireless access. In contrast, in the downlink, multiple vendor commands are assigned to a common command, which mini-

Table 1. Main specifications of M2M wireless access.

Frequency band	280-MHz band (Experimental purposes only)	
Transmission power	BS: 1 W	WT: 10 mW
Modulation scheme	$\pi/4$ -Shift QPSK	
Demodulation scheme	Uplink: coherent detection Downlink: differential detection	
Access method	TDMA/TDD	
Forward error correction	Convolutional coding (R = 1/2) / Viterbi decoding	

QPSK: quadrature phase-shift keying  
TDD: time-division duplex  
TDMA: time-division multiple access

mizes the number of control sequences passed to the Wi-Fi AP modules.

#### 4. Field experiments and evaluations

We conducted field experiments using our prototype platform at the Tohoku University campus. The platform employs the 280-MHz band, so we conducted field experiments using that band. We used eight different Wi-Fi APs from two vendors, Vendor A and B, in the experiments in order to evaluate the performance of our proposed system. The main specifications of M2M wireless access are listed in Table 1. First, we confirmed that the coverage area was over 400 m by actually controlling Wi-Fi APs that were positioned about 430 m from the MDRU.

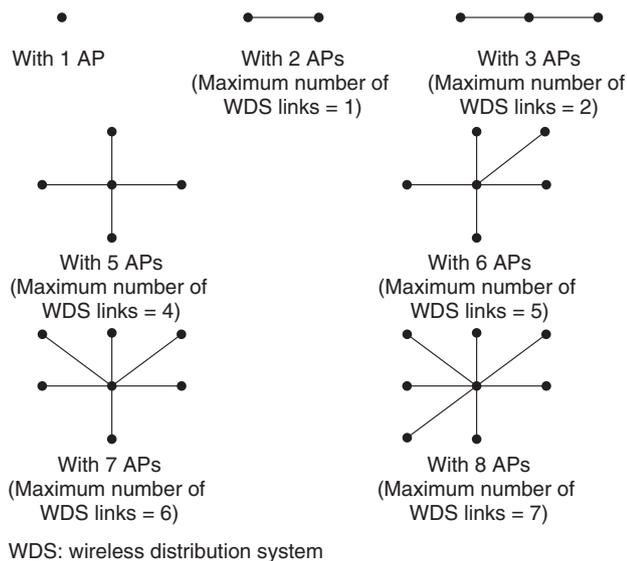


Fig. 3. Measured network topologies.

We evaluated how effective the transmission technique was by collecting wireless environment information of a Wi-Fi AP on our platform before measuring the transmission time. Without our technique, data capture took 167 s, and it took 147 s to transmit the data so gathered. With our technique, data capture took 68 s, and transmission took 45 s. The volume of information was reduced by 1550 bytes.

Next, we constructed a Wi-Fi access network using two kinds of Wi-Fi AP devices to find out whether or not our platform could control different Wi-Fi AP devices. The network topologies we implemented are shown in **Fig. 3**. We selected the topology in which the number of WDS links becomes the maximum given the number of Wi-Fi APs. We conducted wireless environment information collection, SSID<sup>\*4</sup> (service set identifier) setting, and WDS setting, and we also issued link confirmation commands in order to construct the Wi-Fi access network. The time taken to construct the Wi-Fi network versus the number of Wi-Fi APs is shown in **Fig. 4**. The results confirm that the common commands of our platform allowed different Wi-Fi AP devices to be controlled; moreover, a Wi-Fi access network with eight Wi-Fi APs was able to be constructed within 30 minutes. It is possible to shorten this time by adjusting the timer to wait for responses in the Wi-Fi module.

\*4 SSID: An identifier of Wi-Fi APs regulated by standardization.

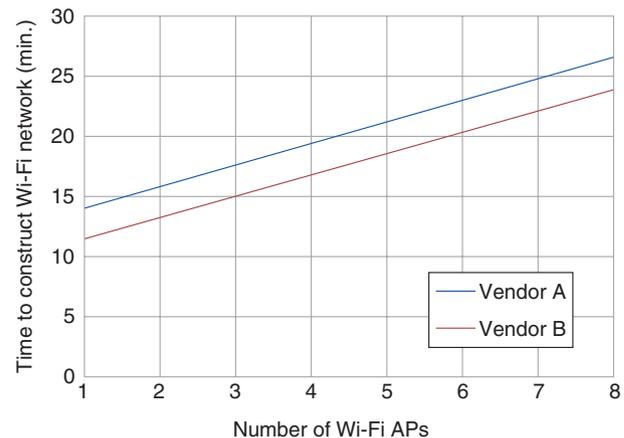


Fig. 4. Time required to construct Wi-Fi access network.

## 5. Future work

We plan to conduct additional field experiments using the 920-MHz band instead of the 280-MHz band in Japan as well as overseas [3] in order to evaluate the effectiveness of the system.

## Acknowledgment

Part of the work described in this article is being conducted under the national projects, *R&D on the reconfigurable communication resource unit for disaster recovery and R&D of "Movable ICT Units" for emergency transportation into disaster-affected areas and multi-unit connection*, both supported by the Ministry of Internal Affairs and Communications of Japan.

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# High-speed and Plug-and-play Optical Interconnection for MDRUs

*Tetsuro Komukai and Toshikazu Sakano*

## Abstract

After a Movable and Deployable ICT Resource Unit (MDRU) is installed and local ICT (information and communication technology) services are established in a disaster-affected area, reestablishing communication service between the disaster-affected area and undamaged areas will be strongly desired by the people in the disaster-affected area. We propose to establish a communication link between the MDRU and the backbone network by connecting 100-Gbit/s digital coherent transponders to the ends of undamaged underground optical cable.

*Keywords: movable and deployable ICT resource unit, digital coherent technology, plug and play*

## 1. Introduction

The Movable and Deployable ICT Resource Unit (MDRU) can be easily transported to damaged areas and used to quickly establish local information and communication technology (ICT) services once it is installed. A Wi-Fi based access network is formed with a radius of several hundred meters from the center of the MDRU; it allows public and municipal employees to communicate with others in the area. In addition, because the MDRU has a datacenter function, it can provide various custom ICT services to local government, hospitals, and the police and fire departments.

However, these services are available only within the limited area around the MDRU, and another strategy is necessary to reestablish communications with those outside the damaged area. There are two main approaches to connect an MDRU to the backbone network. One is to use satellite communications, and the other is to use optical communications. Each approach has advantages and disadvantages, so the selection depends on the situation.

Satellite interconnection makes it possible to avoid the physical difficulties present in the disaster area, although the transmission capacity is limited. For example, only a limited number of conversations can be conducted simultaneously between people in the

damaged area and people in undamaged areas. In contrast, while optical communications offer massive capacity, there may be few facilities available if the damage is severe. However, optical fiber cables laid underground are thought to be robust against disasters. In fact, we (the NTT Group) found that many optical fiber cables remained viable even after all surface structures and equipment had been washed away by the tsunami after The Great East Japan Earthquake. This means that optical links could be established if we could use the undamaged optical fiber cables.

We recently proposed a method to connect an MDRU to the backbone network by using optical fiber cables laid underground [1]. In this article, we explain our method and describe a proof-of-concept demonstration.

## 2. Optical interconnection requirements: MDRU to backbone network

Several difficulties arise when connecting an MDRU to the backbone network via optical links established on optical fibers, as follows.

- (1) It is very difficult to immediately obtain comprehensive information on cable parameters (fiber type, length, etc.) in the damaged area.
- (2) Transmission capacity will need to be expanded

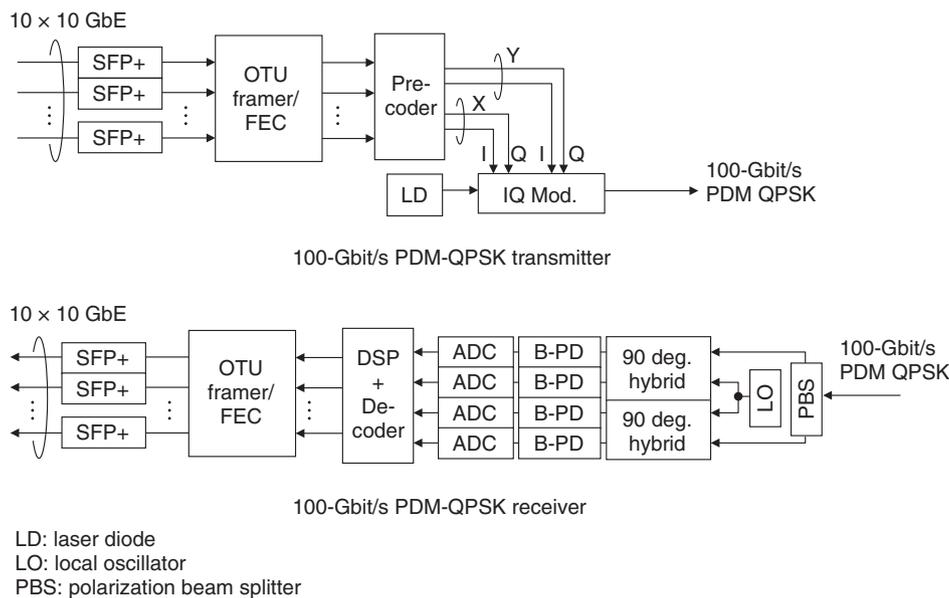


Fig. 1. Configuration of prototype 100-Gbit/s digital coherent transponder.

because the standard voice service will be replaced by a visual information service that needs a wider bandwidth as reconstruction progresses.

- (3) Prompt and flexible reconfiguration of the optical network will be needed in the damaged area because the situation can easily change. This means that the optical path can often change.
- (4) When we connect an MDRU to a faraway data-center in an undamaged area by optical networking only, long-distance optical transmission is needed, which requires chromatic dispersion compensation.

In considering these difficulties, we arrived at the conclusion that a 100-Gbit/s digital coherent transponder should be installed in both the MDRU and a working telecommunication building to enable optical interconnection. A digital coherent transponder can equalize optical signal waveforms automatically by electrically compensating the chromatic dispersion of fibers, so it is therefore expected that optical interconnection can be immediately established by connecting the transponders to the ends of the fiber cables, even though the fiber parameters may be unknown. In addition, the optical interconnection will be immediately reestablished after switching optical fiber cables for rerouting.

To verify the above concept, we developed a prototype of a 100-Gbit/s digital coherent transponder and

experimentally confirmed the robust and immediate connection by virtue of its plug-and-play functionality.

### 3. Optical channel recovery experiment

The configuration of our prototype 100-Gbit/s digital coherent transponder for an MDRU is shown in **Fig. 1**. The prototype is based on a standard 100-Gbit/s polarization-division multiplexing (PDM) quadrature phase-shift keying (QPSK)<sup>\*1</sup> transponder [2] and can compensate the maximum chromatic dispersion (CD) of 40,000 ps/nm. The transponder accommodates ten channels of 10-Gbit/s Ethernet (10GbE) client data, and ten SFP+ (small form-factor pluggable+) modules<sup>\*2</sup> can be installed on the input/output interface part. The 10GbE client data are multiplexed into 100-Gbit/s optical transport network (OTN) signals<sup>\*3</sup> through an optical-channel transport unit 4 (OTU4) framer and with forward error correction (FEC)

\*1 QPSK: A multi-level modulation scheme that uses four points on the constellation diagram and encodes two bits per symbol with four phases.

\*2 SFP+ modules: Optical transceiver modules for 10GbE interconnections.

\*3 OTN signals: Signals that are used in the optical transport network standardized by ITU-T (International Telecommunication Union, Telecommunication Standardization Sector). Ethernet signals are mapped to OTN signals through the OTU framer.

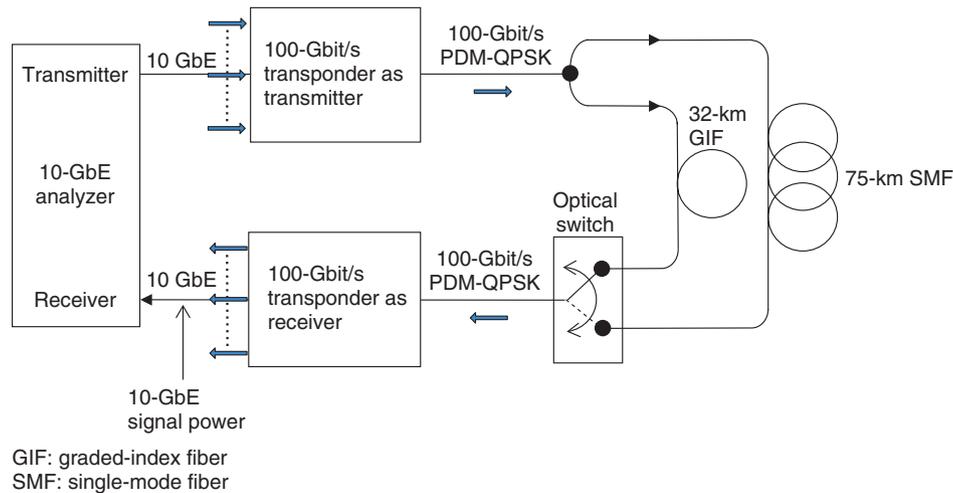


Fig. 2. Experimental setup for optical route switching of 100-Gbit/s signal.

overhead. The data are realigned to  $4 \times 32$ -Gbit/s sequences and fed into an optical IQ (I: In-phase, Q: Quadrature) modulator for QPSK modulation and polarization multiplexing. The transmitted 100-Gbit/s PDM-QPSK signal is received by a digital coherent receiver; I and Q data for each polarization are obtained with a polarization-diversity 90 degree optical hybrid and balanced photodetectors (B-PDs), and digitized with a four-channel analog-to-digital converter (ADC). In the digital signal processing (DSP), CD compensation, polarization demultiplexing and adaptive polarization mode dispersion (PMD) equalization, and frequency-offset compensation and carrier-phase recovery are carried out for the  $4 \times 32$ -Gbit/s data, followed by error correction and demapping to 10 GbE.

We evaluated how fast the optical channel could be recovered when the 100-Gbit/s transmission link was switched between different types and lengths of fibers by a mechanical fast optical switch whose switching time was less than 1 ms. The experimental setup is shown in **Fig. 2**. The 10GbE client data are supplied by a 10GbE analyzer and converted to 100-Gbit/s signals in the transmitter. The transmitted signals are received, and the converted 10GbE client data are fed via another short fiber to the 10GbE analyzer, which counted the received bytes with a resolution of 1 ms. This enabled us to evaluate the influence of link switching on the throughput of the client 10GbE data. The point at which we measured the 10GbE signal power is also shown in Fig. 2 by the arrow in the lower left of the figure.

We evaluated how fast the optical channel could be reestablished when the link was switched from a 75-km single-mode fiber (SMF) to a 32-km graded-index fiber (GIF) and vice versa. The evolution of the received 10GbE optical signal level is shown in **Fig. 3** and **Fig. 4**. After the link was switched, the 10GbE signal output was shut down and remained quiescent for 27 ms until the signal level returned to normal. This indicates that once the channel was disconnected, the DSP was able to complete channel re-estimation and synchronization within 27 ms. The outage time is the same in Fig. 3 and Fig. 4, which indicates that recovery time is independent of the fiber type and length.

For comparison, we measured the evolution of the received 10GbE data traffic associated with the switching by using a 10GbE analyzer; the results are shown in **Fig. 5** and **Fig. 6**. The horizontal axis is the elapsed time after channel switching, and the vertical axis shows the net bit rate calculated from the number of bytes received without failure. The 10GbE traffic recovers after 30 ms. The 3-ms difference from Fig. 3 and Fig. 4 may be due to the processing time in the 10GbE receiver module. Also, it is concluded that a 100-Gbit/s digital coherent transponder can compensate the modal dispersion<sup>\*4</sup> of a GIF about 30 km long.

\*4 Modal dispersion: A distortion mechanism occurring in multimode fibers in which the signal is spread in time because the propagation velocity of the optical signal is not the same for all modes. Although GIF is a kind of multimode fiber, the index profile of the core is designed to reduce the modal dispersion.

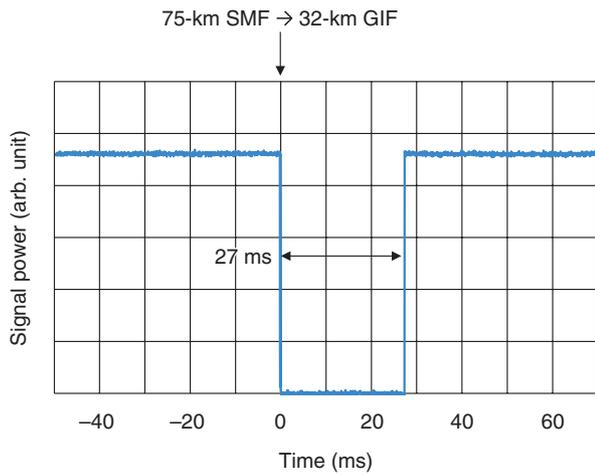


Fig. 3. Evolution of received 10GbE signal level (75-km SMF → 32-km GIF).

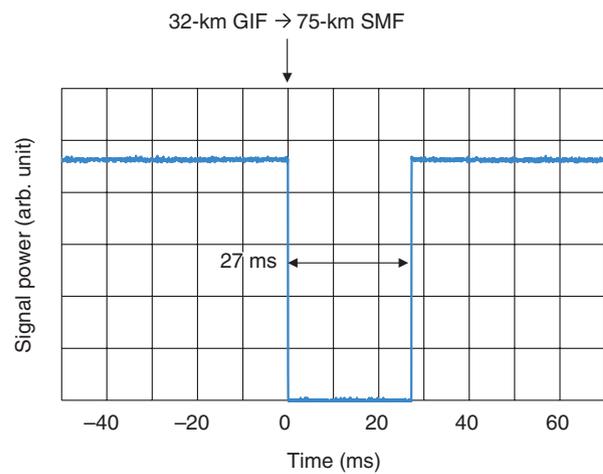


Fig. 4. Evolution of received 10GbE signal level (32-km GIF → 75-km SMF).

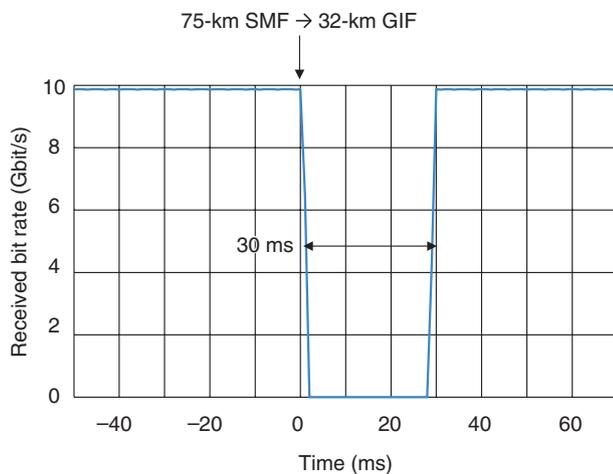


Fig. 5. Evolution of received 10GbE data traffic (75-km SMF → 32-km GIF).

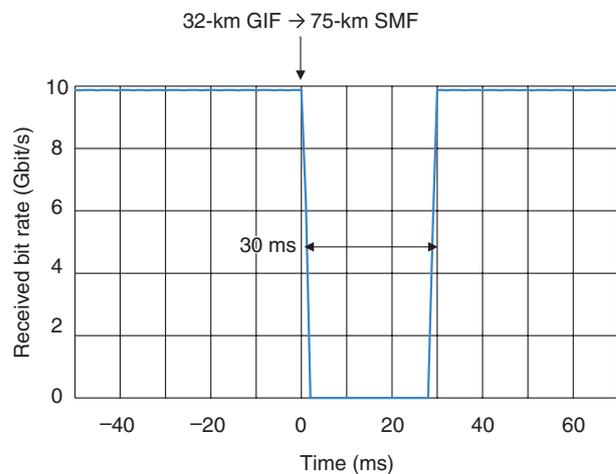


Fig. 6. Evolution of received 10GbE data traffic (32-km GIF → 75-km SMF).

The measured switching performance suggests that the transponder offers true plug-and-play functionality and that fiber parameters do not need to be measured. Thus, the transponder is expected to be effective after disasters for interconnecting MDRUs to the backbone network through underground optical fiber cables.

#### 4. Perspective on optical interconnection for MDRU

In conclusion, with the plug-and-play functionality

based on digital coherent technology, an MDRU can be immediately connected to the working backbone network via an undamaged underground optical fiber cable. We note that not all MDRUs will be sited close to optical fiber that offers unbroken connection to the backbone, as they will usually be placed next to evacuation centers or public facilities. Thus, we will have to interconnect the MDRUs. If there is no physical obstruction between two MDRUs, we can connect them by fixed wireless access. However, when physical obstruction is unavoidable, one alternative is to reuse parts of the underground optical fiber cable

that are still viable.

To realize the above optical interconnection using underground cables, we need to obtain prior agreement from communication carriers and to carry out technical preparations for the connections to the backbone network. For example, we have to obtain agreement as to how or where to set a transponder in a telecommunication building. It is also necessary to develop a way of finding or selecting optical cables in disaster areas and protocols to confirm the corresponding cables in working telecommunication buildings. This will definitely require the support and assistance of communication carriers. In addition, we will have to consider using the optical cables of non-carriers such as local governments.

## 5. Summary

We proposed the application of digital coherent technology to interconnect MDRUs in a disaster area with the backbone network via working telecommunication buildings and underground optical fiber cable. We experimentally confirmed the plug-and-play functionality achieved using digital coherent

technology. We also discussed problems that remain to be solved from a practical application perspective.

## Acknowledgments

Part of the work in this article is being conducted under the national projects, *R&D on the reconfigurable communication resource unit for disaster recovery* and *R&D of “Movable ICT Units” for emergency transportation into disaster-affected areas and multi-unit connection*, both supported by the Ministry of Internal Affairs and Communications of Japan.

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## A Media Storage and Transmission System Using MDRUs

*Takayuki Nakachi, Sun Yong Kim, Atsushi Okada, and Tatsuya Fujii*

### Abstract

Developing information and communication technology (ICT) networks and services that are resilient to disasters is a critical task. NTT Network Innovation Laboratories is promoting innovative research and development on a transportable ICT node called the Movable and Deployable ICT Resource Unit (MDRU), which is designed to promptly recover ICT services after a disaster. In this article, we introduce a media storage and transmission system based on the use of MDRUs. It efficiently provides information such as text and image/video data to people in disaster areas in circumstances when ICT resources are constrained such as when network bandwidth is limited or storage failures occur. We demonstrated its feasibility in a field trial.

*Keywords: layered coding, distributed storage, image/video transmission*

### 1. Introduction

The Great East Japan Earthquake of March 11, 2011 damaged or completely destroyed many information and communication technology (ICT) resources, which demonstrated that the development of resilient ICT networks and services is a critical issue demanding urgent attention. Immediately after a disaster, it is important to rapidly share accurate information. In addition to text data, image/video data are important in disaster recovery. Image/video content can instantly provide detailed information to people in disaster-stricken areas. Examples of information that may need to be transmitted or exchanged after a disaster are shown in **Fig. 1**.

A portable media storage and transmission system can provide such information to people working in disaster relief offices and to evacuees at evacuation centers and in their own homes. Our media storage and transmission system is based on the specially designed Movable and Deployable ICT Resource Unit, which we refer to as an MDRU. MDRUs will be transported immediately to a disaster area to provide recovery of ICT services. The media storage and transmission system must transmit information to the

greatest extent possible within the capacity restrictions posed by MDRUs. The proposed system is implemented by the following steps.

- (1) Transport and activation of stand-alone MDRUs to disaster areas

An MDRU with a cache server is quickly transported to a disaster area. The MDRU holds a cache server that runs software for the media storage and transmission system. Layered storage consisting of random-access memory, solid-state drive (SSD)<sup>\*1</sup>, and hard disk drive (HDD)<sup>\*2</sup> devices is installed in the cache server. The MDRU forms a wireless access network, with or without wired network connections, to reach user terminals such as laptop personal computers (PCs), smartphones, and tablet devices. People within 500 m or so from the MDRU can view information such as text and image/video data stored in the cache server and/or upload data to the cache server.

\*1 SSD: A data storage device that uses integrated circuit assemblies as memory to store data persistently. Compared with electromechanical disks such as HDDs, SSDs are typically more resistant to physical shock and have lower access time and less latency.

\*2 HDD: A data storage device that uses rapidly rotating disks coated with magnetic material. HDDs remain the dominant medium due to advantages in price per unit of storage and recording capacity.

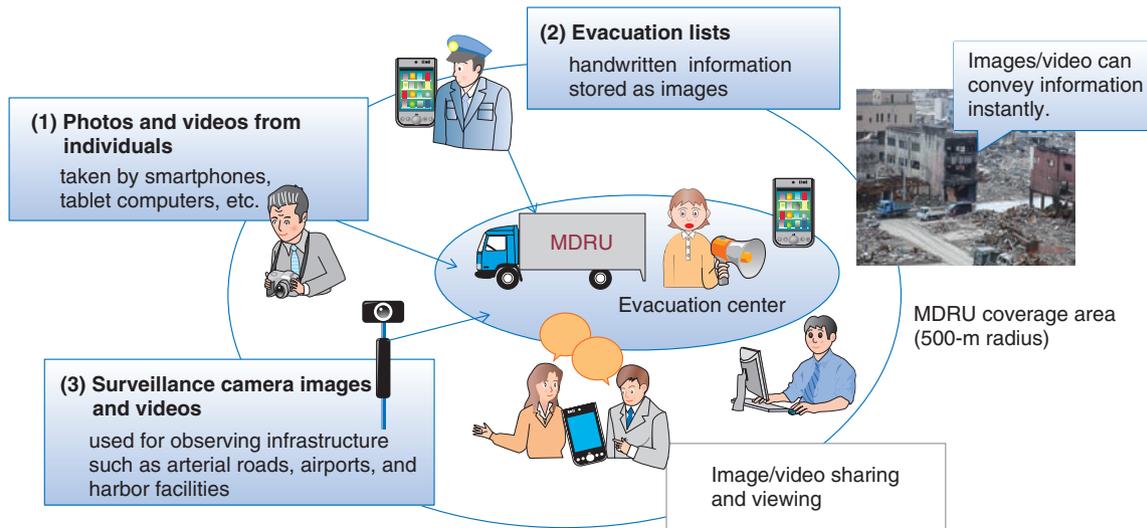


Fig. 1. Information needed in disaster areas.

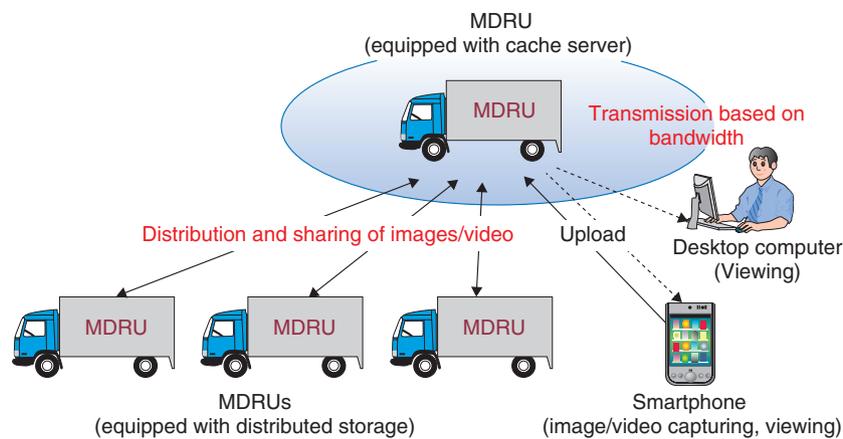


Fig. 2. Operation of multiple MDRUs in local disaster areas.

(2) Operation of multiple MDRUs in local disaster areas

As many MDRUs as needed are deployed to the disaster area. Each MDRU has interworking storage devices that form a distributed storage system along with the cache server. Data uploaded to each MDRU can be backed up to and shared among the multiple MDRUs (Fig. 2).

(3) Operation of multiple MDRUs connected to wide area network

MDRUs will be connected to a local datacenter and wide area network. Information data can be widely shared via the local datacenter. People in the disaster

area can watch news coverage originating outside the disaster area and share information about other areas.

The media storage and transmission system is based on two technologies. One is disaster resilient layered data transmission [1], and the other is networked distributed storage [2]. The former transfers information efficiently to work within the MDRU's limited network bandwidth and power supply. The latter recovers data lost by 1) network congestion or disconnection or 2) storage failures caused by MDRU accidental power-off or MDRU transport. More details of these technologies are given below.

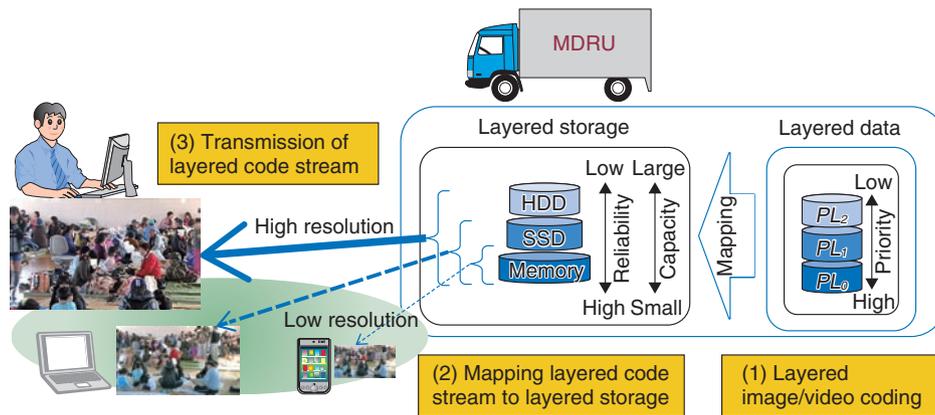


Fig. 3. Layered data transmission.

## 2. Disaster resilient layered data transmission

The proposed disaster resilient layered data transmission system offers image/video services to people in disaster-affected areas through MDRUs. The disaster resilient image/video transmission scheme is designed around three technologies: (1) layered image/video coding, (2) mapping of the layered code stream to layered storage systems installed in the MDRUs, and (3) transmission of layered code streams according to network bandwidth (Fig. 3).

### (1) Layered image/video coding

We utilize the JPEG 2000 standard [3] created by the Joint Photographic Experts Group (JPEG) for layered image/video coding. Input images are decomposed into layered data in a priority manner; that is, JPEG 2000 bit streams are created. JPEG 2000 offers four basic scalability dimensions in each JPEG 2000 bit stream: resolution (R), SNR (signal-to-noise ratio) quality (L), spatial location (P), and component (C). Different scalability levels are achieved by ordering packets within the JPEG 2000 bit stream. We assume that text data consist of handwritten notes on a bulletin board set up in an evacuation center. The handwritten information is captured by smartphones and/or tablet PCs. We use Motion JPEG 2000 (MJ2) for the layered video coding. It specifies the use of the JPEG 2000 format for timed sequences of images (video). Other layered video codecs such as Scalable Video Coding (SVC), which is a scalable extension of H.264/MPEG-4 AVC<sup>\*3</sup>, or Scalable High Efficiency Video Coding (SHVC), a scalable extension of H.265/HEVC<sup>\*4</sup>, can also be used. We selected MJ2 because of its transmission robustness and low-complexity compared with SVC and SHVC.

### (2) Mapping layered code-stream to layered storage

The layered storage system consists of random-access memory, SSD, and HDD devices. The JPEG 2000 bit streams are mapped to the layered storage as shown in Fig. 3.  $PL_0$ ,  $PL_1$ , and  $PL_2$  are priority-mapping layers and are mapped to random-access memory, SSD, and HDD, respectively. The progression order of the JPEG 2000 bit stream is determined in advance. Different scalability levels are achieved by ordering packets and can be arbitrarily assigned to each form of storage. If MDRU power consumption becomes a problem, we can turn off the HDD devices, and if additional energy saving measures are necessary, the SSD devices can be deactivated.

### (3) Transmission of layered code stream

JPEG 2000 is attractive as it can truncate lower priority bit streams from partial ones. This allows for simple responses to changes in network bandwidth and MDRU power consumption. The truncation process consists simply of extracting the required layers from the encoded bit stream; there is no additional

\*3 H.264/MPEG-4 AVC (Advanced Video Coding): A video coding standard that was developed by the JVT (Joint Video Team) of the ITU-T (International Telecommunications Union-Telecommunication Standardization Sector) and the ISO/IEC (International Organization for Standardization / International Electrotechnical Commission) in 2003. It covers common video applications ranging from mobile services and video conferencing to IPTV (Internet protocol television), high-definition (HD) TV, and HD video.

\*4 H.265/HEVC (High Efficiency Video Coding): The most recent standardized video compression standard developed by the JCT-VC (Joint Collaborative Team on Video Coding) of the ITU-T and the ISO/IEC. It reduces the bit rate by around 50% while maintaining the same subjective video quality relative to its predecessor H.264/ MPEG-4 AVC.

processing of the stream itself. The MDRU forms a wireless access network around itself to reach user-held equipment. The truncation consists of extracting the required layers based on the bandwidth between the MDRU and the user. An example of layered transmission is shown in Fig. 3 when the priority of the resolution is selected. One usage example is that the user can see a specific full-resolution image after over-viewing multiple thumbnail-sized images. Sending only the higher resolution components of an image specified by a user results in more efficient use of network bandwidth resources.

### 3. Networked distributed storage

Here, we assume that the following problems occur after installing MDRUs and launching ICT services: 1) network congestion or disconnection and 2) storage failures caused by MDRU accidental power-off or MDRU transport, which can occur when MDRUs are repositioned in a disaster area. The proposed networked distributed storage system recovers data lost because of the above problems to the greatest extent possible. This scheme is based on three techniques:

(1) Unequal error protection of image/video components

Layered data are protected by unequal forward error correction (FEC) codes. For this, we use previously proposed layered low-density generator matrix (LDGM) codes [4]. The layered LDGM codes provide greater protection for image/video components that have been classified as more significant than other components. Furthermore, it is advantageous in having lower computation complexity and communication cost in recovering lost data than the well-known Reed-Solomon (RS) codes.

(2) Optimum source<sup>\*5</sup> and repair<sup>\*6</sup> packet deployment for distributed storage

Generated source and repair packets are deployed to distributed storage (i.e., a number of storage devices), as shown in Fig. 4. To reduce the impact of a storage failure to the maximum extent, source and repair packets are deployed uniformly to each storage device. Furthermore, successive repair packets are deployed to different storage devices; they are not deployed to the same storage device to ensure that they are not lost. This is because if successive repair

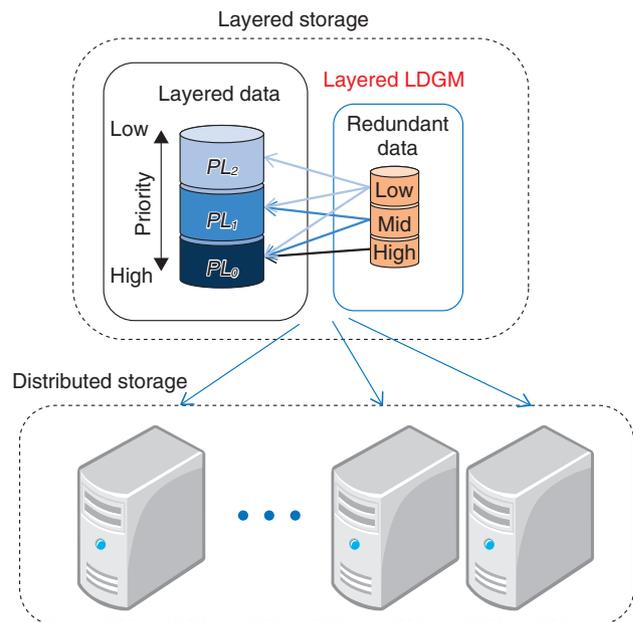


Fig. 4. Source and repair packet deployment for distributed storage.

packets are lost, the error recovery probability decreases because LDGM codes use the staircase matrix.

(3) Implementation compliant with next-generation MMT standard

MPEG Media Transport (MMT) is a new media transport standard being developed as ISO/IEC 23008-1 [5]. MMT specifies technologies for the delivery of coded media data for multimedia services over concatenated heterogeneous packet-based network segments including bidirectional IP (Internet protocol) networks and unidirectional digital broadcasting networks. MMT FEC codes are also specified in ISO/IEC 23008-10 [4]. We developed our networked distributed storage system to be compliant with the MMT standard. Source and repair symbols are packetized to MMT source and repair packets according to the MMT specifications. The packets are delivered by the MMT delivery protocol. This is advantageous in that storage and streaming data can be treated in a unified framework.

### 4. Field trial

We established an experimental environment in order to evaluate the proposed disaster resilient network and services based on MDRUs. We demonstrated its feasibility in a field trial on February 28,

\*5 Source packet: A packet consisting of layered data (JPEG 2000 bit streams).

\*6 Repair packet: A packet containing redundancy information for error correction.

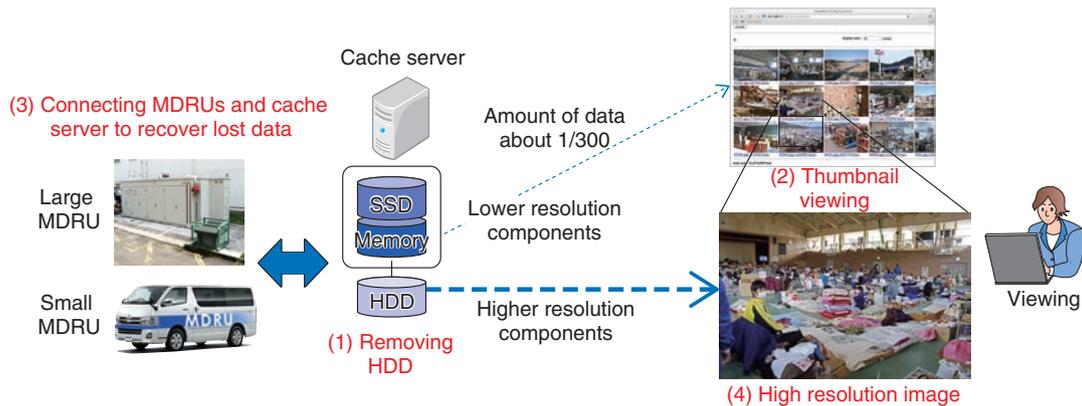


Fig. 5. Overview of hardware trial.

2014 at Tohoku University. A system overview of the field trial is shown in Fig. 5. We assumed that multiple MDRUs had been deployed to a disaster area. The cache server was set in the demonstration room. Distributed storage was installed in both a large MDRU and a small MDRU. Input images were decomposed into six resolution levels. For priority mapping, we respectively assigned the three lower and three higher resolution components to internal (SSD) and external (HDD) storage devices. We connected a user terminal laptop PC to the cache server via a wireless local area network. The trial proceeded as follows:

- (1) The HDD that replicates disk failure was demounted.
- (2) Thumbnails of multiple images were shown using the three lower resolution components stored in the SSD.
- (3) The cache server was connected to distributed storage units, and the three higher resolution components were recovered.
- (4) The three higher resolution components of the specific image specified by the user were transmitted, and the full resolution version of the image was shown.

This trial verified that thumbnails of multiple images could be shown even with the failure of the HDD device. After the thumbnails were overviewed, the full resolution version of the specific image was shown by transmitting only its additional higher resolution components. We showed that lost data were recovered by using the layered LDGM codes. Details on the complexity and performance of image/video coding and LDGM codes can be found in other

reports [1, 2].

This trial also demonstrated the usefulness of the technologies being developed. We plan to continue this research in order to create innovative technologies that will enable rapid access to communication tools under constrained circumstances such as after a disaster.

### Acknowledgement

Part of the work in this article is being conducted under the national projects, *R&D on the reconfigurable communication resource unit for disaster recovery*, and *R&D of “Movable ICT Units” for emergency transportation into disaster-affected areas and multi-unit connection*, both supported by the Ministry of Internal Affairs and Communications of Japan.

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## ICT Service for MDRUs

*Satoshi Kotabe, Toshikazu Sakano, and Tetsuro Komukai*

### Abstract

In this article, we describe an Internet protocol (IP) phone service system and an evacuee management system that were developed as information and communication technology (ICT) services for Movable and Deployable ICT Resource Units (MDRUs) to assist in recovery after large-scale disasters. Deploying an MDRU with IP-PBX (IP-based private branch exchange) functionality to the affected areas makes it possible to immediately provide IP phone services via Wi-Fi. The evacuee management system proposed here enables the efficient collection of evacuee data in evacuation centers.

*Keywords: phone service, IP-PBX, evacuee management system*

### 1. IP phone service for disaster relief

The proposed Internet protocol (IP) phone system employs an extended IP-based private branch exchange (IP-PBX) system that is installed in the Movable and Deployable information and communication technology (ICT) Resource Unit (MDRU). The IP phone system is expected to be used for emergency communication by local governments and residents at evacuation centers when telecommunication services are disrupted for an extended period of time after a large-scale disaster [1]. The features of the system allow quick and convenient startup of the

phone service.

Voice calls can be made using Wi-Fi with smartphones, tablets, or computers. Users can make voice calls immediately simply by registering the telephone number of the terminal they are using. Calls can be made and received with the mobile or landline telephone number normally used. Users can download the application to his/her smartphone from the server in the MDRU. The IP phone application on a smartphone is shown in **Fig. 1**. Tapping the icon on the Disaster Phone application automatically triggers the registration and enables immediate voice calling. The phone is connected to and configured by NTT's

- Connect to MDRU through wireless network (Wi-Fi automatic configuration).
- Register user terminal information in IP-PBX (automatic registration of telephone number).
- Configure *Disaster Phone* software phone, enable voice calling, and launch standard telephone application.
- *Disaster Phone* application (temporary name) operates in the background and displays an icon in the status bar.



Fig. 1. IP phone application for smartphones.

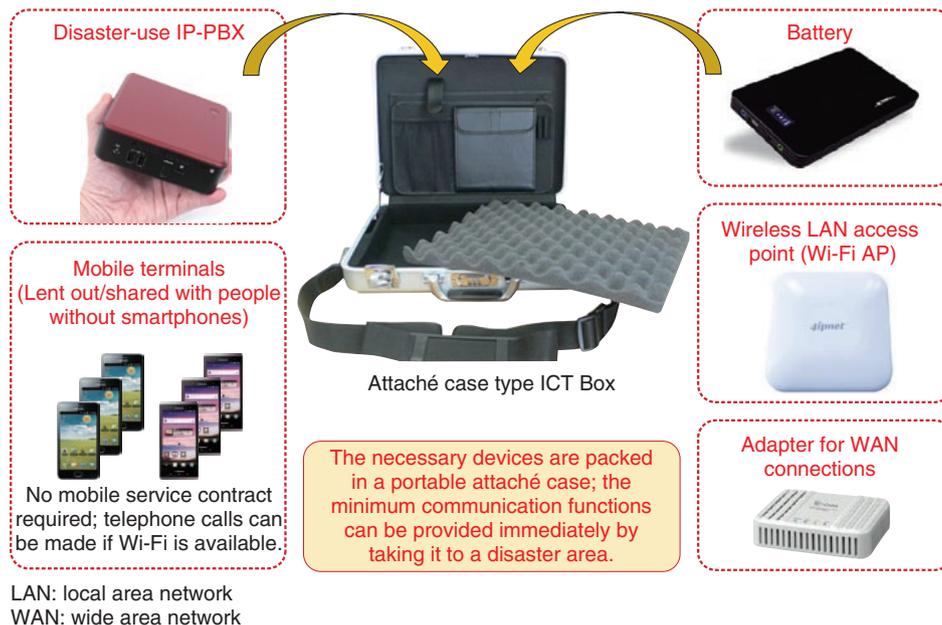


Fig. 2. Attaché case type ICT Box for IP phone system.

FLET'S HIKARI DENWA phone service router, after which calls can be made to, and received from, outside lines.

We also developed a prototype of an attaché case type MDRU (ICT Box), in which the functions necessary for specific services are modularized to improve portability [1]. The ICT Box, which holds the module implementing the proposed IP phone service system, is shown in **Fig. 2**. It consists of a small IP-PBX, mobile battery, Wi-Fi access point, and a VoIP (voice over IP) adapter, all placed within an attaché case. We conducted an experiment and confirmed that the 18,000-mAh mobile battery enabled the portable MDRU to operate for 5 hours, during which time 140 calls were placed. The offered service and ICT resources are limited with this device, but its portability is excellent.

## 2. Evacuee management system

The evacuee management system was also developed as an ICT service essential for recovering from large-scale disasters. It allows data on people affected by the disaster to be rapidly gathered. The features and advantages of the system are shown in **Fig. 3**.

The unified management of data is possible by giving each person an IC card with a unique identification (ID); this ensures seamless data handling regard-

less of whether people are moved from evacuation centers to temporary housing. Accurate management of people by associating facial photographs and personal information (name, age, gender, address, etc.) is also possible. Moreover, it offers questionnaire and statistical analysis functions that make it possible to learn about evacuation center conditions and to find out current requirements in real time.

When the portable IP phone system using the attaché case prototype is connected to the Internet, it is possible to provide the collected data to the “J-anpi [2]” service operated by NTT Resonant Inc.

## 3. Subjective evaluation experiment

We conducted a subjective evaluation experiment of the IP phone service in cooperation with the University of Aizu during a campus festival held in October 2013. A photograph of this event is shown in **Fig. 4**. About 300 men and women ranging in age from their teens to their 70s participated. They were asked to evaluate the service's effectiveness on a 5-level scale. The results of the subjective evaluation are shown in **Fig. 5**. As shown in the figure, more than 95% of evaluators ranked the service as useful or very useful.

We also conducted a subjective evaluation experiment of the evacuee management system. At the

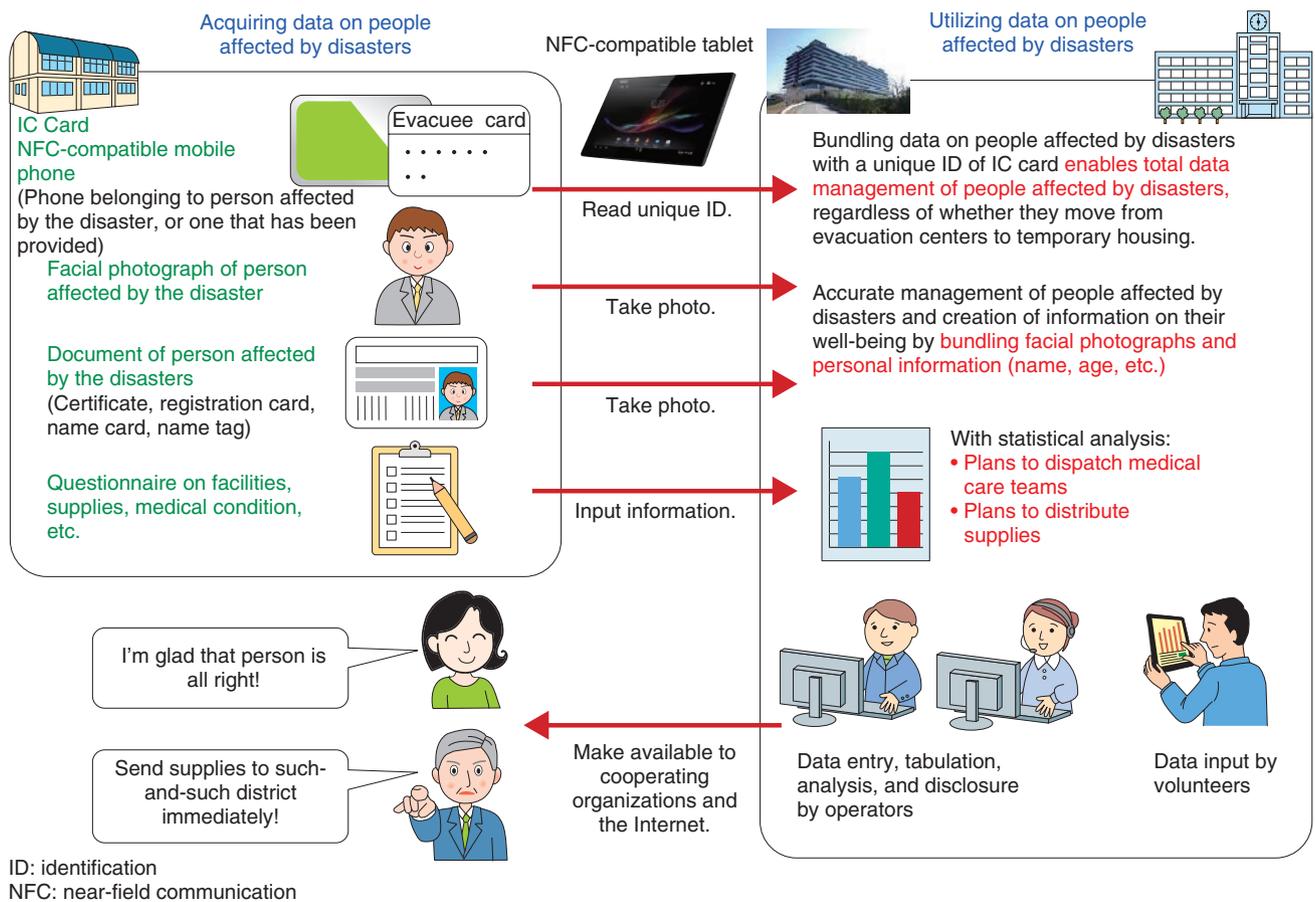


Fig. 3. Features and advantages of evacuee management system.



Fig. 4. Subjective evaluation conducted at University of Aizu.

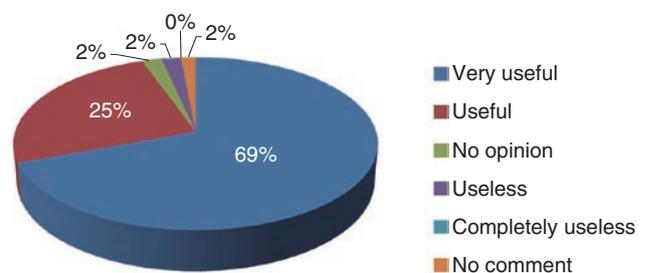


Fig. 5. Subjective evaluation results of IP phone system.

Tohoku Section Joint Convention of the Institutes of Electrical and Information Engineers, Japan, held August 22–23, 2013 at the University of Aizu, a conference area was made into an evacuation center, and

assessment tests were conducted to determine how quickly the participant information database could be created and the collected information utilized. Around 200 of the 500 conference attendees participated in the experiment. The functions of the evacuee management system were assessed through surveys and briefings. The result was that more than 80% of

evaluators ranked the system as useful or very useful during a disaster.

#### 4. Conclusion

We proposed an emergency IP phone service system and an evacuee management system to assist MDRUs in recovering from a large-scale disaster. The systems can be installed in a variety of MDRU units that will be transported to the damaged area after a disaster occurs. Prototype systems were developed, and subjective evaluations were performed. The evaluation results confirmed the effectiveness and feasibility of our proposed system.

#### Acknowledgments

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under the national projects, *R&D on the reconfigurable communication resource unit for disaster recovery* and *R&D of "Movable ICT Units" for emergency transportation into disaster-affected areas and multi-unit connection*, both supported by the Ministry of Internal Affairs and Communications of Japan. The authors would like to express their appreciation to the project members from Tohoku University and Fujitsu Corporation for their collaboration.

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# Overseas Deployment of MDRU: ITU Project in the Philippines, and MDRU Standardization Efforts

*Hideki Nishizawa and Toshikazu Sakano*

## Abstract

The network facility at the San Remigio municipality on Cebu Island in the Philippines sustained enormous damage from super typhoon Haiyan in November 2013. NTT Network Innovation Laboratories, NTT Communications Corporation, and partners initiated a feasibility study on restoring telecommunication and information and communication technology (ICT) infrastructure damaged by typhoon Haiyan through the use of the Movable and Deployable ICT Resource Unit (MDRU), under cooperation between the Ministry of Internal Affairs and Communications of Japan, the Department of Science and Technology of the Philippines, and ITU (International Telecommunication Union). We report on this feasibility study in this article. We also introduce the work being done to standardize the MDRU by NTT Network Innovation Laboratories.

*Keywords: ITU, disaster relief, overseas deployment*

## 1. Introduction

In November 2013, NTT won a prize at the ITU (International Telecommunication Union) Telecom World awards being held in Bangkok, Thailand in the category of *Broadband in all phases of disaster management and risk reduction* for its research and development (R&D) of the Movable and Deployable information and communication technology (ICT) Resource Unit (MDRU) [1]. The effectiveness of the MDRU as an emergency telecommunication platform has since received high commendations from worldwide entities adopting disaster prevention measures, including the nonprofit organization Philippine Central Visayas Information Sharing Network (CVISNET) Foundation, Inc.<sup>\*</sup>, which has been encouraging broad use of ICT in the Philippines.

The islands of the Philippines lie in the typhoon corridor in the Pacific area and experience an average of 20 typhoons per year. Typhoon-fed storms and high water are the most critical problems for the Philippine government and its residents. In November 2013, the Visayas region of the Philippines felt the

full force of the super typhoon Haiyan. Typhoon-fed storm surges grew to several meters high along the sea coast and caused widespread devastation in the area similar to that of a tsunami. To make matters worse, the communication blackout obstructed attempts to evacuate people. About 6200 people lost their lives in the typhoon, and the number of missing remains at about 1800 [2].

National disasters are on the rise because of climate change, and thus, the United Nations and the international community are continuing efforts to find ways to reduce the risk of natural disasters, prevent the loss of lives, and reduce economic losses. In the process, the Government of Japan and the ITU are collaborating to provide assistance to restore telecommunication connectivity in one of the islands most affected by typhoon Haiyan. On May 13, 2014, the Ministry

<sup>\*</sup> The CVISNET Foundation, Inc. is an e-government project in the Philippines funded by the Department of Science and Technology Region 7, and a joint collaboration of the Regional Development Council Region 7, the Government Organization for Information Technology, and the Confederation of Scientific and Professional Organizations.

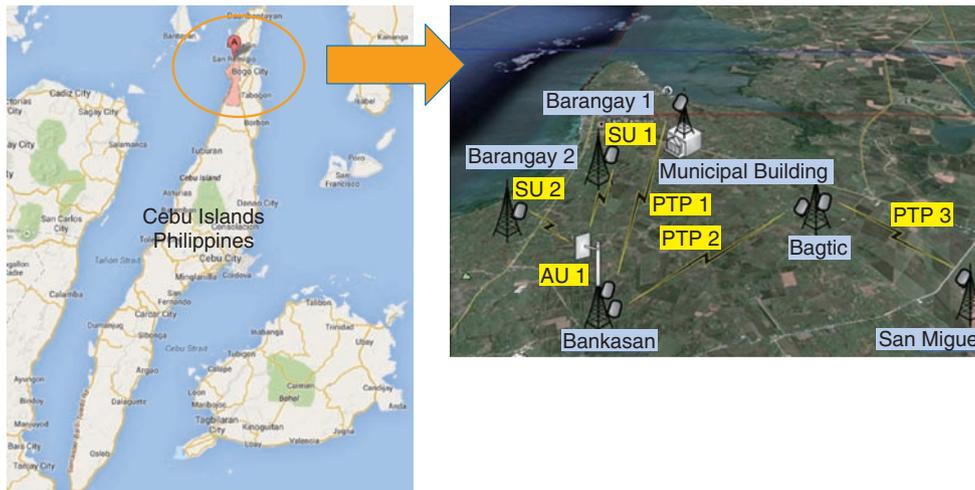


Fig. 1. Location of San Remigio municipality in the Philippines and depiction of wireless network in San Remigio before the typhoon. (The network was destroyed by the typhoon.)

of Internal Affairs and Communications (MIC), the Department of Science and Technology (DOST), and ITU finalized a cooperation agreement for a feasibility study on restoring connectivity through the use of the MDRU and launched the project.

## 2. Summary of ITU project

The ITU project, entitled *Feasibility study of restoring connectivity through the use of the Movable and Deployable ICT Resource Unit* was inaugurated in May 2014 with the objectives of studying the effectiveness of the MDRU in providing immediate communication infrastructure and IT (information technology) facilities in the worst disaster-stricken areas in Cebu, Philippines, and in studying the viability of the MDRU as a communication solution in the aftermath of a disaster. San Remigio municipality on Cebu Island was the location of the MDRU feasibility study. The municipality consists of 27 barangays, or districts, and has a population of about 64,000. On-site reports of the disaster were gathered manually because all communication networks had been destroyed (Fig. 1). The only source of communications to the government was through a satellite phone under the office of the Mayor.

A summary of the feasibility study is given in Table 1, and a press release announcing that ITU, MIC, and DOST had signed the cooperation agreement, along with a photo of the signees, is shown in Fig. 2. The scope of this feasibility study covers tech-

nical testing as well as sustainable operation and management, including the provision of training to local staff and improving the disaster management planning structure in local communities for increased disaster preparedness.

## 3. Launching the feasibility study

After agreement of the cooperation contract was reached, NTT and NTT Communications Corporation (NTT Com) started preparing for the feasibility study in collaboration with local government staff members and residents. The installation of the MDRU, project administration, and support were carried out by NTT Network Innovation Laboratories, NTT Com, NTT Advanced Technologies Corporation, NTT Electronics Corporation, Fujitsu Limited (from Japan), and CVISNET and Diff Sigma Tech Inc. (from the Philippines). NTT Com, Diff Sigma, and Kyocera Corporation respectively provided the MDRU server unit, the MDRU wireless system, and heavy-duty smartphones. The MDRU server unit and the MDRU wireless system used in the project are shown in Fig. 3. They were installed in December 2014 in San Remigio Municipal Hall, and the wireless equipment was installed in a national high school (about 400 m away from the hall), where an evacuation center had been set up. Point-to-point wireless equipment provided a communication link between the municipal hall and the high school. The MDRU team established a wide area Wi-Fi network by

Table 1. Summary of project.

Project scope	Test the feasibility of the newly developed MDRU in disaster-affected areas, including a suitable location for installation. Provide adequate training to local key personnel for sustainable operation and management of the MDRU network. Improve disaster management planning structure in local communities for increased disaster preparedness. Gain feedback from government organizations and local communities on the services powered by the MDRU. Provide feedback on the project to government organizations through monitoring and evaluation of the installed MDRU.
Project management	The project is led by ITU. The ITU Project Manager provides the overall management and administration of the project in close collaboration with MIC and DOST. A steering committee was established immediately after the signing of the cooperation agreement.
Monitoring	ITU will monitor and evaluate the project based on the expected results and key performance indicators.
Term	May 2014–September 2015



Fig. 2. Press release of cooperation agreement issued by the Philippine government and photo of signees.

employing AP (access point)-AP connection between the Wi-Fi APs at the municipal hall and those at the high school, and a 24-GHz FWA (fixed wireless access) connection between the two buildings [3]. We confirmed through the feasibility study that the

MDRU operated effectively in the environment in the Philippines even though there were some differences between Japan and the Philippines.

An example of a use case in the event of a disaster is shown in **Fig. 4**. In this case, the mayor first called municipal employees on the phone to get information about the disaster. Then, the municipal employees took pictures of the disaster-affected area with a smartphone and saved them on the server in the MDRU. This enabled the mayor to gain a visual understanding of the disaster affected area by looking at the pictures stored in the server. The mayor then instructed employees at the municipal hall to provide relief goods in the affected area, and then he reported on the situation to the central government.

We plan to continue working to improve some operation rules, the connectivity, and the specifications of the MDRU by conducting a feasibility study of each use case in order to meet the needs of municipal employees and local residents.

The scope of this feasibility study included not only technical testing but also the provision of training. A training session on installing and running the MDRU applications [4] in the smartphone was held for the residents of San Remigio (**Photos 1 and 2**). Of 30 people who attended, more than 90% of them said that the MDRU phone was “easy to use” or “very easy.” The briefing session is shown in **Photo 3**, in which the essential points and the importance of the MDRU feasibility study were discussed with the engineers in San Remigio, and the technologies used in the MDRU project were explained. We demonstrated that the MDRU was easy to use for residents

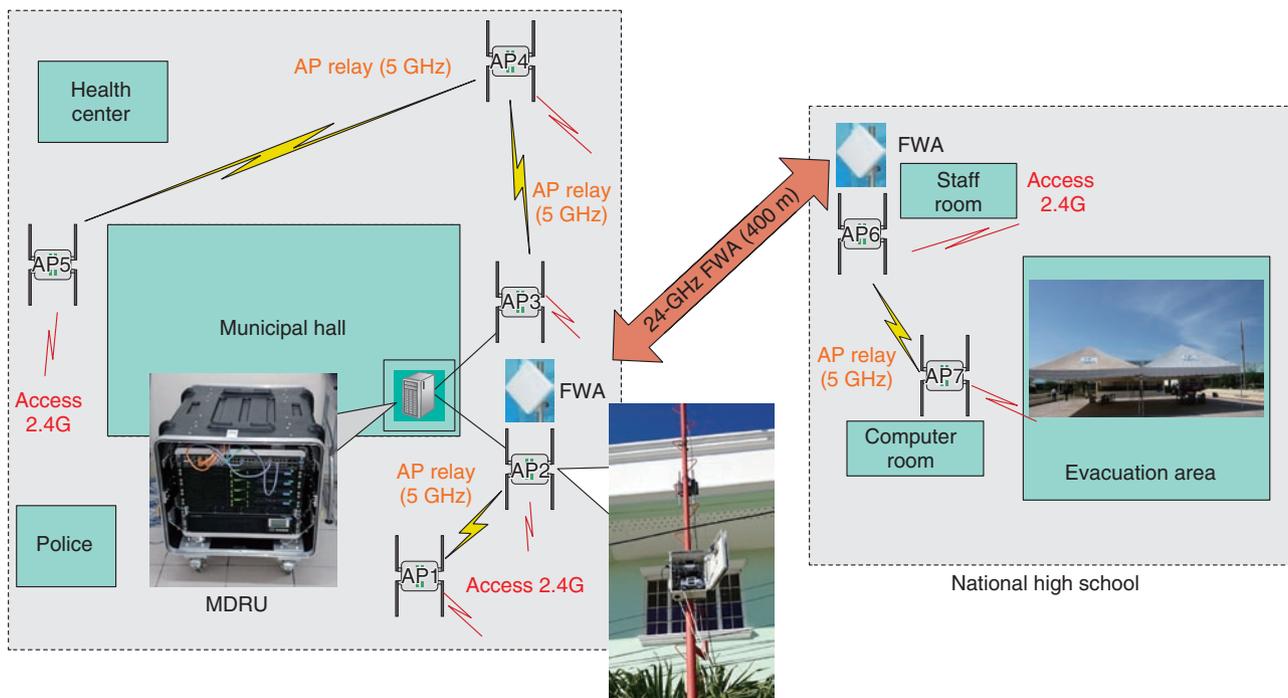


Fig. 3. MDRU and wireless equipment installed at San Remigio Municipal Hall and at a high school.



Relief supplies stored at San Remigio Municipal Hall.



(2) The mayor obtains information on the disaster affected area via smartphone; he gets updates from employees and looks at images of the area stored on a server.



Smartphone



(1) Pictures of disaster-affected area are taken with a smartphone and stored on MDRU server.

Fig. 4. Use case of MDRU: investigating the extent of damage from the typhoon.

in San Remigio through this feasibility study. The MDRU will need to be equipped with a power generator when a long-term power outage occurs, although some UPSs (uninterruptible power supplies) have already been mounted on MDRUs. We plan to

confirm the feasibility and review the rules and operation of the MDRU with local residents.



Photo 1. Training session for residents of San Remigio.



Photo 2. Installing and running the MDRU applications on a smartphone.

#### 4. Standardization

The Japanese government led the discussion on establishing a Focus Group (FG) on disaster relief in ITU-T (ITU-Telecommunication Standardization Sector), and it was agreed to establish the Focus Group on Disaster Relief Systems, Network Resilience and Recovery (FG-DR&NRR). Many Japanese use cases including MDRU had been proposed for the deliverables of FG-DR&NRR during two years of discussions and standardization efforts. Since the FG activities were finalized in June 2014, we have been working on finalizing an ITU-T Recommendation of



Photo 3. Briefing session for engineers in San Remigio on the essential points and importance of the MDRU feasibility study and on the technologies used in the MDRU project.

the MDRU in Study Group 15 by 2016 because ITU-T standardization is the crucial element for promoting broad use of the MDRU throughout the world [5]. The technical report entitled *Requirements on the improvement of network resilience and recovery with movable and deployable ICT resource units* that describes the immediate lessons learned after the Great East Japan Earthquake are already available on the ITU-T FG-DR&NRR website [6].

#### 5. Future plans

NTT and NTT Com are working to promote broad use of the MDRU throughout the world for disaster relief after large-scale disasters and to expand its use in other applications such as in prompt provision of ICT services in developing countries lacking ICT infrastructure.

#### Acknowledgments

The MDRU project is a joint R&D effort between NTT, Tohoku University, Fujitsu Limited, and NTT Com. This R&D project is partially supported by the Ministry of Internal Affairs and Communications of Japan.

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# InP-based Membrane Optical Devices for Large-scale Photonic Integrated Circuits

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### Abstract

Large-scale photonic integrated circuits for telecom and datacom applications have attracted attention for many years. We have developed III-V based membrane optical devices employing lateral p-i-n junctions with buried heterostructures. This article introduces lateral current injection lasers and modulators integrated on an InP substrate and membrane lasers on a SiO<sub>2</sub>/Si substrate as promising building blocks of integrated transmitters.

*Keywords: semiconductor laser, modulator, photonic integrated circuit*

## 1. Introduction

Network traffic is increasing exponentially along with the explosive growth of social media [1]. The development of optical fiber networks has made it possible to achieve high-speed, large capacity, and reliable networks. Device integration has been a key technology in reducing power consumption in electronic and optical devices, making it possible to achieve environmentally friendly networks. Large-scale electronic integration based on complementary metal-oxide semiconductor (CMOS) technology has contributed to the development of high-performance processors and memories with low power consumption. We have now entered an era of photonic integration. Integrated photonic devices such as transmitters and receivers are now available thanks to the advances in fabrication technology. Photonic integrated circuits (PICs) have been developed to provide the following benefits: (1) compactness, (2) a reduction in the number of components, (3) low power consumption, (4) low-cost fabrication, and (5) integration of photonics and electronics. Semiconductor platforms consisting of III-V semiconductors\* and silicon have been developed to meet these requirements.

Wavelength-division multiplexing (WDM) is employed in telecom networks to transmit optical signals. This involves the use of integrated optical devices such as an electro-absorption (EA) modulator integrated distributed feedback (DFB) laser and a tunable DFB laser array on an InP substrate. However, the numbers of devices and functions have been limited. Recently, advanced modulation formats, which use a combination of amplitude and phase modulation, are triggering higher density integration for core and metro networks. InP-based large-scale monolithically integrated transmitters and receivers consisting of more than 100 optical components have been reported [2]. Because the number of components is increasing, these photonic integration technologies are promising in their potential to reduce assembly costs and footprints.

In addition, photonic networks have been expanded to short reach applications such as in access networks and datacom networks. Laser arrays and detector arrays are now used in 100-Gigabit Ethernet transceivers [3]. Each discrete device operates at the speed

\* III-V semiconductor: A semiconductor formed with elements from both the group III and group V compounds.

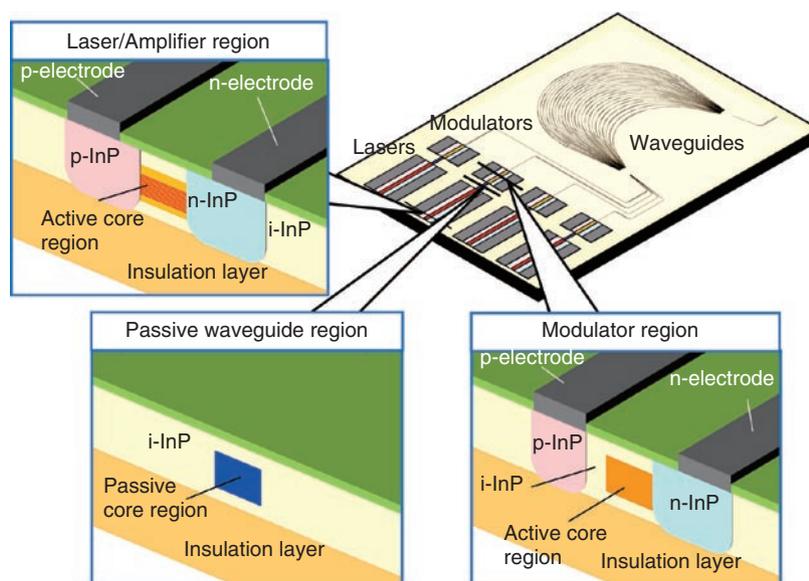


Fig. 1. Concept of PICs based on membrane optical devices.

of 10–25 Gbit/s. The trend in using photonic integration is obviously growing because of the need to reduce the cost and power consumption of networks. In datacom applications, multi-mode VCSELs (vertical cavity surface emitting lasers) are used as light sources for inter- or intra-board transmissions. In the future, WDM transmitters based on integrated single-mode laser and detector arrays will be essential to increase the transmission capacity. Silicon photonics have been actively demonstrated for a wide range of applications [4, 5] and show promise in meeting the above requirements. Although the integration of light sources is a challenge, most of the functions of PICs have been implemented on silicon. Therefore, further integration of III-V and silicon photonics devices are expected to complement each function.

Two other factors are important in order to make further progress: device structure and fabrication. Most optical devices consist of laser/amplifier, modulator/photodetector, and passive waveguide regions; we can fabricate every optical device for every target application by combining these components. Our aim is to develop a flexible and scalable fabrication technique implementing this concept.

In this article, we introduce membrane devices consisting of lateral p-i-n junctions as building blocks for PICs. We employ a selective doping technique to fabricate the p-i-n junctions, as it enables flexible device fabrication. We first clarify the advantages of membrane optical devices. Then we describe lateral

current injection lasers and modulators fabricated on InP substrates for telecom applications. Finally, we discuss III-V optical devices on silicon substrates employing novel fabrication techniques. We also introduce lateral current injection lasers on SiO<sub>2</sub>/Si substrates for datacom applications.

## 2. Concept of photonic integration

Our concept of photonic integration consists of InP-based membrane optical devices (**Fig. 1**). The figure illustrates an example of an integrated transmitter consisting of lasers, modulators, and waveguide regions. Each active region employs a lateral p-i-n structure along the substrate. The electrodes are fabricated on the surface to apply electrical voltage along the lateral direction. We use selective doping techniques to fabricate the p-i-n regions. Each impurity doping region is fabricated on a non-doped epitaxial layer that includes the active and waveguide regions. The selective doping technique is common in CMOS fabrication processes, as it enables mass production.

This configuration provides higher scalability and productivity compared with conventional devices employing vertical p-i-n structures. Generally, the optimum doping condition is different for each active component. In particular, non-doped regions are essential as the passive waveguide regions in order to suppress the optical propagation loss. Conventional devices with vertical p-i-n junctions require a number

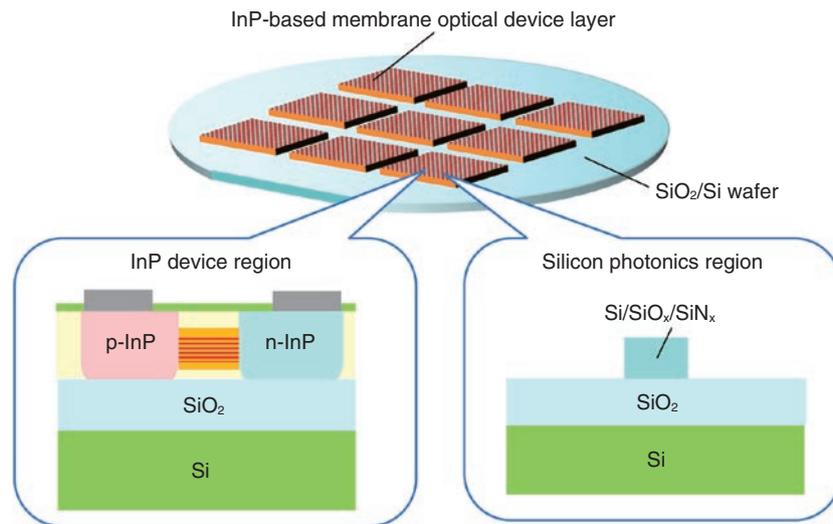


Fig. 2. Membrane optical devices integrated on silicon.

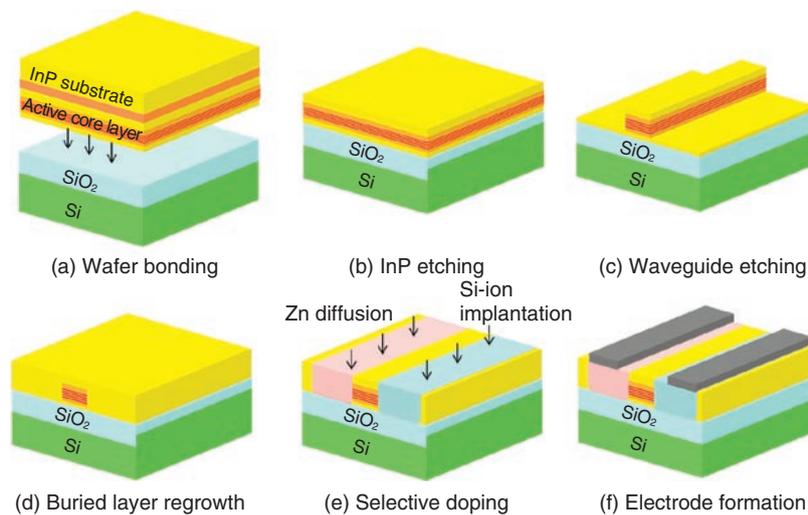


Fig. 3. PIC fabrication processes employing selective doping techniques.

of crystal regrowth processes to integrate optimized components. Our approach can form impurity-doped regions without using epitaxial regrowth processes; in other words, the number of regrowths decreases. In addition, assembly with electrical components is easy because the electrodes are formed on one side.

These applications are not limited to PICs on an InP substrate. We propose a novel process to fabricate III-V devices on silicon. Our approach is shown in **Fig. 2**. This process uses a template consisting of III-V layers bonded on a silicon substrate. The butt-joint sec-

tions, waveguides, buried heterostructures, and doping regions are formed on this template. The use of large silicon wafers improves the yield. In addition, the alignment of III-V devices on the silicon substrate is possible with a level of accuracy in the sub-micrometer range. Therefore, III-V active devices can be easily integrated with silicon photonic devices including silicon-based waveguide structures. Typical fabrication procedures are shown in **Fig. 3**: (a) a III-V wafer including active layers is bonded on a SiO<sub>2</sub>/Si substrate; (b) the InP region is removed; (c)

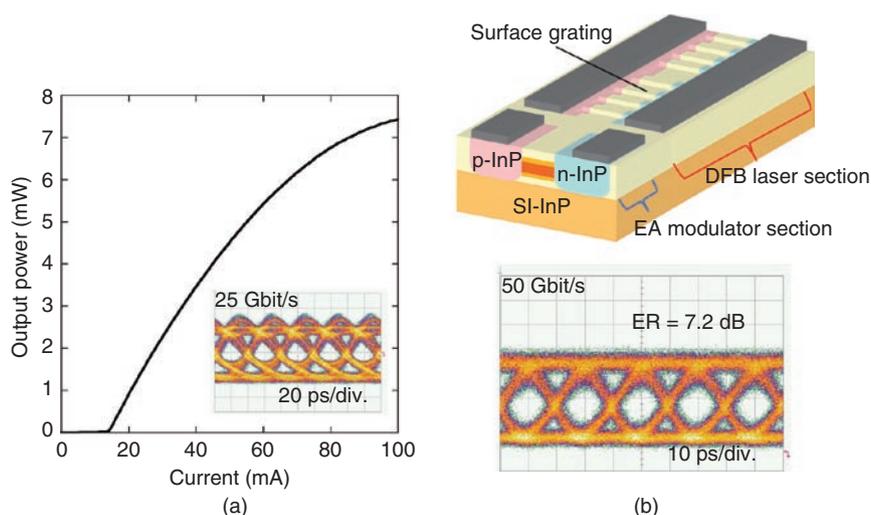


Fig. 4. Characteristics of membrane devices on InP: (a) directly modulated DFB laser, and (b) EA-DFB laser.

waveguides are fabricated by etching; (d) buried heterostructures are fabricated by epitaxial regrowth; (e) p- and n-doped regions are formed by Si-ion implantation and Zn thermal diffusion; and (f) electrodes and surface gratings are formed.

The membrane devices have some advantages in both their device characteristics and their fabrication [6]. A lateral buried heterostructure with a p-i-n junction has lower capacitance compared with vertical p-i-n structures. This feature provides high-speed operation of lasers, modulators, and photodetectors due to the small RC (resistor-capacitor) time constant. In addition, introduction of III-V slab layers sandwiched by low refractive index materials improves the power consumption because of the strong optical confinement. This is advantageous in reducing the power consumption of PICs for short-reach datacom applications. In the next section, we describe the fabrication of lasers and modulators on InP and lasers on silicon.

### 3. Membrane devices on InP substrate: lasers and modulators

We fabricated lateral current injection DFB lasers [7] and EA modulators on an InP substrate [8]. The DFB lasers were fabricated using processes similar to those in Fig. 3 except for the wafer-bonding related processes in Fig. 3(a) and (b). The DFB laser consists of an InGaAlAs-based 14-well active region. A  $\lambda/4$ -shift grating is formed on the InP surface. The static and dynamic characteristics of a laser with a length of

400  $\mu\text{m}$  are shown in Fig. 4(a). The single-mode lasing was observed at room temperature. The threshold current was 14 mA. This laser achieved 25-Gbit/s direct modulation as shown in the inset. This was the first demonstration of direct modulation over 25 Gbit/s for a lateral current injection laser.

We also developed an EA-DFB laser employing lateral p-i-n junctions. The device structure and modulation waveform are shown in Fig. 4(b). The modulator section consists of an 8-well InGaAlAs active region. The EA length is 200  $\mu\text{m}$ . This structure does not exhibit a quantum-confined stark effect, which is an operating principle of conventional quantum-well EA modulators with vertical p-i-n structures. However, we theoretically confirmed a practical optical extinction ratio without sacrificing the modulation speed. The fabricated EA-DFB laser operates at a static extinction ratio over 20 dB. In addition, 50-Gbit/s modulation with a dynamic extinction ratio of 7.2 dB is obtained. This is the first demonstration of a lateral EA-DFB laser. As a result, a sufficient modulation speed for 100- and over 100-Gbit/s laser arrays for telecom applications has been demonstrated.

### 4. Directly modulated lateral current injection lasers on SiO<sub>2</sub>/Si

We also developed membrane DFB lasers on SiO<sub>2</sub>/Si [9, 10]. A schematic of the device structure and an SEM (scanning electron microscopy) image of the cross section are shown in Fig. 5(a). The device

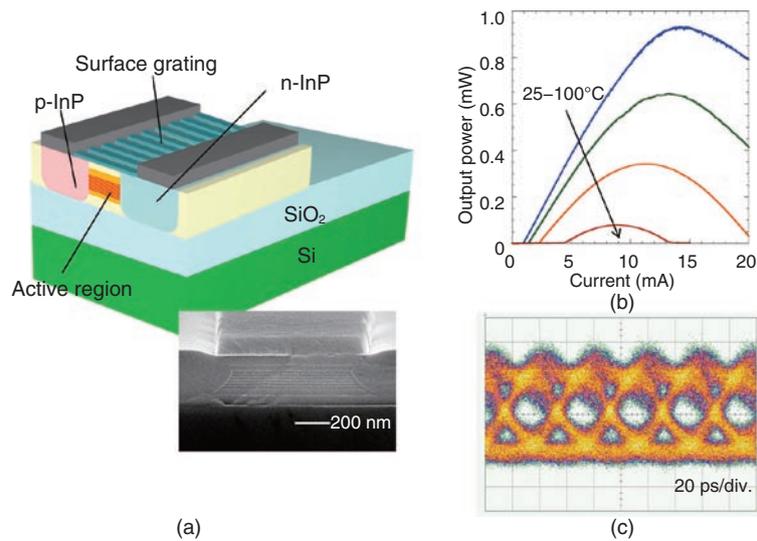


Fig. 5. (a) Device structure, (b) current-output characteristics, and (c) 25.8-Gbit/s modulating waveform of DFB laser on SiO<sub>2</sub>/Si.

consists of a 6-well InGaAsP-active region. The laser was fabricated according to the processes shown in Fig. 3. Suppressing degradation of the III-V epitaxial layer during the fabrication process is a challenging task. Thermal stress is induced during the fabrication because the thermal expansion coefficients are different between the InP, SiO<sub>2</sub>, and Si layers. This stress can cause cracks in the III-V layer. Introduction of a III-V layer that is thinner than the critical thickness under the induced strain solved this problem. Consequently, we successfully fabricated the buried heterostructure without serious degradation by employing the 250-nm-thick III-V layer that included the active region.

The current-light output characteristics of the DFB laser are shown in Fig. 5(b). The cavity length is 73  $\mu\text{m}$ , and the threshold current is 0.9 mA at a temperature of 25°C. Regardless of the high thermal resistance due to the SiO<sub>2</sub> layer, lasing operation was observed up to 100°C. The laser achieved 25.8-Gbit/s direct modulation as shown in Fig. 5(c). The bias current was 3.2 mA. The energy cost of the data transmission was 171 fJ/bit, which is the smallest value of all DFB lasers. We also achieved 40-Gbit/s direct modulation by employing another structure. These results show the feasibility of low-power consumption operation of membrane lasers on SiO<sub>2</sub>/Si.

## 5. Summary

We have presented InP-based membrane optical devices for large-scale PICs for network applications. These devices achieve practical performance as well as simple and scalable fabrication processes by means of selective doping techniques. We successfully demonstrated DFB lasers and EA-DFB lasers fabricated on InP, and DFB lasers fabricated on SiO<sub>2</sub>/Si. All of these devices achieved modulation characteristics applicable to 100-Gbit/s or higher transmitters. In particular, the directly modulated lasers on SiO<sub>2</sub>/Si have the smallest energy cost of all DFB lasers: 171 fJ/bit. We believe these achievements pave the way for further development of large-scale PICs on various platforms including InP and silicon for a wide range of network applications.

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## W3C TPAC 2014 Report and HTML5 Recommendation

*Shigeru Fujimura, Tomohiro Yamada, Kiyoshi Tanaka, Taichi Kawabata, Masayuki Ihara, Kensaku Komatsu, and Akihito Akutsu*

### Abstract

The W3C (World Wide Web Consortium) Technical Plenary / Advisory Committee Meetings Week (TPAC) was held from October 27 to 31, 2014, in Silicon Valley in the USA. The year 2014 was not only the 25<sup>th</sup> anniversary of the creation of the web but also the 20<sup>th</sup> anniversary of the foundation of W3C. On October 28, the W3C published a formal Recommendation of HTML5 (HyperText Markup Language, fifth revision) during TPAC in this anniversary year. In this article, we report on W3C TPAC 2014 and the HTML5 Recommendation.

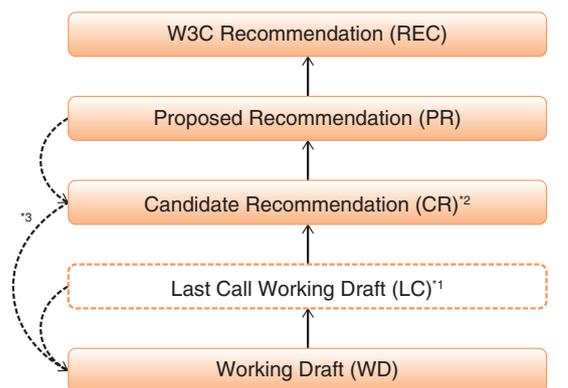
*Keywords: W3C, TPAC, HTML5*

### 1. Introduction

The World Wide Web Consortium (W3C), founded by Sir Tim Berners-Lee, is a nonprofit standardization community that develops web standards. The number of member companies and organizations was 402 as of December 2014; NTT has been a W3C member since December 1995. The W3C develops well-known standards such as those for HTML (HyperText Markup Language) and CSS (Cascading Style Sheets), and its published standards are open and freely available to the public. One of the recent hot topics in W3C is the standardization of several JavaScript application programming interfaces (APIs), which are implemented in web browsers to enhance the power of web applications.

One of the characteristics of the standardization process in the W3C (**Fig. 1**) is that it is tightly coupled with the implementation. For example, the call for the implementation to browser vendors and the preparation of test suites are mandatory at the stage of the Candidate Recommendation, so feedback on ambiguous points and on problems with specifications is given at this stage. As a result, in many cases, W3C standards are already available and in wide use in the

web when they reach the W3C Recommendation stage.



\*1 LC will be unified with CR for faster standardization.

\*2 Call for implementation is announced at this stage.

\*3 If the specification has any problems, the status is rolled back to the previous stage.

Fig. 1. Standardization process of W3C.

## 2. W3C TPAC 2014 report

The Technical Plenary / Advisory Committee Meetings Week (TPAC) is the W3C's annual general meeting held around November every year. Face-to-face meetings are held for not only the Working Groups (WGs) but also the Advisory Committee (AC), which consists of representatives of member organizations and mainly discusses the management policies of W3C. A large number of people attended TPAC 2014 because 2014 was the anniversary of the creation of the web and W3C.

The schedule of TPAC 2014, which lasted five days, was consistent with past TPAC events in that the first and last two days were reserved for WG and AC discussions. On October 29, the third and middle day of TPAC, breakout sessions were held from morning to afternoon (**Photo 1**). The presenters were selected from TPAC participants, and they managed and moderated discussions on issues that would be important in W3C in the near future, so there were active exchanges of opinions in many sessions. On the same day, a plenary anniversary symposium, titled *The Future of the Web*, was held from afternoon to early evening. In this section, we report on some items of interest from TPAC 2014 that are related to NTT.

### 2.1 Advisory Board

The Advisory Board (AB) is an organization that provides ongoing guidance to the W3C on issues of strategy, management, legal matters, and the standardization process. In July 2014, Mr. Jay (Junichi) Kishigami, a senior advisor at NTT, became one of the nine members of the AB and the second Japanese member. He attended the face-to-face AB meeting at TPAC 2014 and actively discussed the future of the web and W3C.

### 2.2 Web and TV IG

Standardization activities focusing on particular industry fields are also carried out by W3C, and the broadcasting field is one of them. One of the representative services that integrates the web and broadcasting is smart TV (television). The Web and TV Interest Group (IG) that comprises telecommunications carriers, broadcasting organizations, manufacturers, and browser vendors discusses requirements and use cases for the future smart TV [1]. NTT has been actively participating in the Web and TV IG since its establishment and is particularly interested in the development of IPTV (Internet protocol TV). The Web and TV IG also serves as a forum for intro-

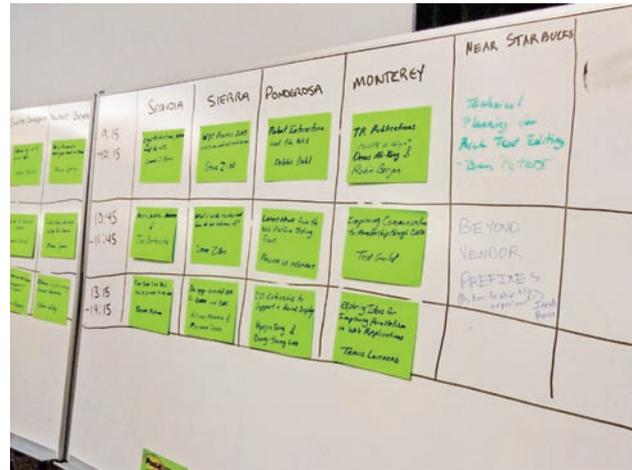


Photo 1. Notices of breakout sessions.

ducing methods for integrating the web and broadcasting such as Hybridcast, which was developed in Japan, and HbbTV, which is mainly used in Europe, and for sharing problems among IG members. At TPAC 2014, NHK of Japan introduced Hybridcast2.0, which covers the exact synchronization of time between broadcasting and IP communications.

### 2.3 NTT Communications activity for the WoT

NTT Communications has been paying attention to and working on the new technology called the Web of Things (WoT), which enhances the potential of the web. The concept of WoT is to realize various new use cases by connecting people and devices, or devices and devices.

One example of the WoT is Chromecast, a small-sized media-streaming device developed by Google Inc. that has been available in Japan since May 2014. This device can seamlessly connect people and devices via a web browser. For example, a movie played in a smartphone can be easily transferred to a large screen TV in a living room. Another example is the AirPlay API by Apple Inc., which realizes the same feature using the web browser in the iPhone.

Although in the present circumstances, these technologies were developed independently by individual companies, a discussion about combining them as the Presentation API [2] has begun in the Second Screen Presentation Community Group (CG) in the W3C, and this API is expected to become a formal Recommendation in the future.

Nevertheless, the main scope of this API focuses only on integration with TVs, and interactive use

cases with other devices such as cameras are not taken into account. Therefore, NTT Communications proposed extending the API target devices with Sony Corporation and Toshiba Corporation in the breakout session (**Photo 2**). The room for this session was so crowded that some attendees had to stand, and the



Photo 2. Presentation in a breakout session.

discussion on our proposal was quite active. As a result, we achieved a formal request to discuss our proposal in the Second Screen Presentation CG.

## 2.4 The Future of the Web symposium

At this anniversary symposium, executives of the W3C and many esteemed guests gave speeches on past successes and future expectations of the web. The speakers included Sir Tim Berners-Lee, W3C Director; Mr. Jeffrey Jaffe, W3C Chief Executive Officer; Mr. Vinton Cerf, one of the inventors of the TCP/IP\*<sup>1</sup> protocol; and Ms. Jessica Rosenworcel, one of the commissioners of the U.S. Federal Communications Commission. The symposium was a great success, and the hall was full of participants (**Photo 3**).

## 3. HTML5 Recommendation

### 3.1 Overview of HTML5 Recommendation

On October 28, during TPAC 2014, the formal HTML5 Recommendation was published by the W3C. The day before its publication, a press event was held at the Computer History Museum in Mountain View in Silicon Valley. Many W3C members gave testimonials on HTML5 to the W3C, as did Mr. Katsuhiko Kawazoe, Vice President of NTT Service Evolution Laboratories [3].

When discussing HTML5, we need to clarify whether we are speaking about the narrowly defined or broadly defined HTML5 (**Fig. 2**). The narrowly defined version simply includes specifications of HTML tags, whereas the broadly defined one includes

\*1 Transmission Control Protocol/Internet Protocol



Photo 3. Future of the Web symposium.

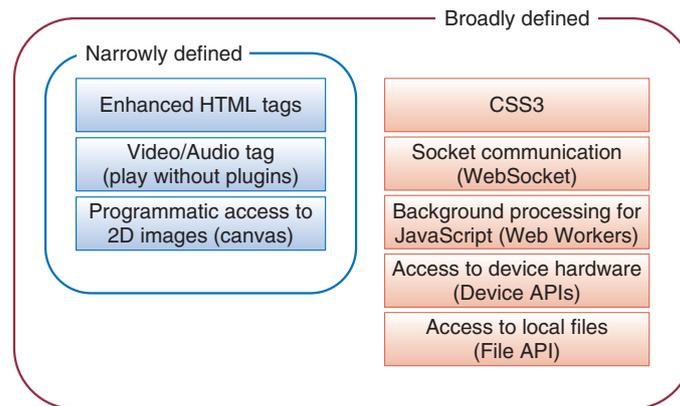


Fig. 2. Narrowly defined and broadly defined HTML5.

various features that are achieved with CSS and JavaScript APIs. This Recommendation is for the narrowly defined HTML5, and it does not include CSS and JavaScript API related specifications that are still under development. This Recommendation was published to match the timing of this anniversary year.

This formal HTML5 Recommendation does not seem likely to generate any sudden changes in the web, as HTML5 is already widespread and widely used in many websites. For example, many readers have probably viewed HTML5 video, which is a specification for playing movies without browser plug-in software.

### 3.2 CSS (ruby, text decoration, and vertical writing mode)

CSS is a style sheet language used to describe the looks and formatting of structured documents written in a markup language such as HTML5. The CSS WG is one of the largest WGs in the W3C and maintains more than 50 specifications now. NTT is involved with several specifications such as those for the vertical writing mode, ruby<sup>\*2</sup>, and text decoration. These specifications are very important for the Japanese writing systems and Japanese e-Books.

CSS specifications are often quite complicated but intriguing, and they are standardized in the same manner as HTML5, as shown in Fig. 1. As stated above, ruby text is especially important for the Japanese writing systems, and it involves both the structure and appearance of text. CSS Ruby has been developed jointly with HTML5 WG, as HTML5 ruby

tags specify the text structure, and CSS ruby specifies how ruby text is displayed.

As mentioned in the previous subsection, HTML5 was formally published as a Recommendation, and it includes a specification for ruby-related tags. However, CSS ruby is still under development, and our efforts will continue until it reaches the stage of W3C Recommendation.

## 4. Other NTT activities related to W3C

### 4.1 Digital signage

The preparation-level discussion on digital signage has been continuing in the Web-based Signage Business Group (BG). In June 2012, the W3C Workshop on Web-based Signage was held at Makuhari Messe, Chiba, Japan. This was the same site as that for Digital Signage Japan 2012, a joint event with Interop 2012. NTT was the host company of this workshop, and the main topic was use cases of digital signage. In November 2012, a face-to-face meeting of the Web-based Signage BG was held at TPAC 2012, which included discussions on use cases and requirements and also featured joint sessions with the MMI (Multi-Modal Interaction) WG and DAP (Device APIs) WG.

The topic of most interest in the Web-based Signage BG is currently the definition of profiles of the Web-based Signage Player, and seven profile specifications (Core, Basic Media, Storage, Basic Reporting, Interactive Menu, Emergency Information, and Scheduling) are still being examined. Staff members of NTT Service Evolution Laboratories are helping with the Emergency Information profile definition and have proposed the requirements for utilizing

\*2 Ruby is small-sized annotated text that appears just above or next to the main text.

digital signage when a disaster occurs. Specifically, we have introduced a mechanism to deliver necessary information to a user device by connecting it to signage through a public wireless LAN (local area network) and a mechanism for administrators to update the content of signage from mobile devices even if users have lost their Internet connection during a disaster.

#### 4.2 Speech recognition for web browsers

In September 2014, NTT announced the development of speech recognition technologies that can be used on multiple HTML5 browsers without plug-in software. In this development, we utilized the latest knowledge on W3C standardization trends and adopted a combination of JavaScript APIs in which the standardization process is progressing on track. This is a characteristic example of W3C standards, in which a specification is implemented in multiple browsers even if its Recommendation has not been formally announced.

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### 5. Future prospects

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The HTML5 Recommendation is a very important milestone not only for W3C but also for the information and communications technology field in general. Further discussions on the next milestone have

already started. That is, technical specifications that improve the capabilities of web applications to the same level as applications running on the OS (operating system), and technical specifications that were excluded in the HTML5 Recommendation are being discussed for the next version, HTML5.1. In the current plan, a Recommendation for HTML5.1 will be completed in the fourth quarter of 2016. In addition, discussions for HTML.next (or HTML6) have also begun.

TPAC 2015 will be held from October 26 to 30, 2015, in Sapporo, Japan, and the requirements for HTML5.1 will be one of the main topics discussed. Upon conclusion of TPAC 2015, the Internet Engineering Task Force (IETF) meeting will be held for a week in Yokohama, Japan, and thus, a discussion on cooperation with the IETF will also be a key topic at TPAC 2015.

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He received the M.S. in engineering from Chiba University in 1990 and the Ph.D. in natural science & technology from Kanazawa University in 2001. He joined NTT in 1990 and began researching video indexing technology based on image/video processing, and man-machine interface architecture design. More recently, he worked on an R&D project involving broadband and broadcast services. In October 2013, he was appointed Executive Producer of 4K/8K HEVC (High Efficiency Video Coding) at NTT Media Intelligence Laboratories. He is a member of IEICE.



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# New NTT Colleagues

## —We welcome our newcomers to the NTT Group

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

### e-shelter

**3<sup>rd</sup> largest datacenter operator in Europe; established in 2000, headquartered in Luxembourg**

Founded in 2000, e-shelter designs, builds, and operates high-availability datacenters, whose infrastructure guarantees the highest standards of physical security and operational reliability. The company operates over 90,000 square meters of datacenter space in four major cities in Germany, as well as in Zurich, Switzerland and Vienna, Austria. One of its main facilities, Campus Frankfurt 1, is Europe's largest datacenter, with some 60,000 square meters of datacenter space. The complex comprises five free-standing buildings constructed specifically as datacenters (**Photo 1**). In March 2015, NTT Communications Corporation, the international communications and ICT (information and communication technology) solutions provider, jointly announced with e-shelter and ABRY Partners, a private equity investment firm, that NTT Communications would acquire 86.7% of e-shelter's issued shares. This acquisition will vault the NTT Communications Group into the No. 3 position for datacenter space in Europe. For further information about e-shelter, please visit <https://www.e-shelter.de/en>



Photo 1. Campus Frankfurt 1.

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# External Awards

## **2014 IEICE Communications Society OCS Young Researchers Award**

**Winner:** Masaki Wada, NTT Access Network Service Systems Laboratories

**Date:** December 11, 2014

**Organization:** Institute of Electronics, Information and Communication Engineers (IEICE)-Technical Committee on Optical Communication Systems (OCS)

For “A Study on Mode-dependent Gain Control of 2-LP-mode EDFA within the C- and L-band.”

**Published as:** M. Wada, T. Sakamoto, T. Mori, T. Yamamoto, N. Hanzawa, and F. Yamamoto, “Modal Gain Controllable 2-LP-mode Fiber Amplifier Using PLC Type Coupler and Long-period Grating,” *The Journal of Lightwave Technology*, Vol. 32, No. 24, pp. 4694–4700, Dec. 2014.

## **2014 IEICE Communications Society OFT Young Researchers Award**

**Winner:** Takayoshi Mori, NTT Access Network Service Systems Laboratories

**Date:** February 19, 2015

**Organization:** IEICE-Technical Committee of Optical Fiber Technologies (OFT)

For “Design of Low DMD Few-mode Fibers Supporting Large Number of Modes for Mode-division-multiplexed Transmission.”

**Published as:** T. Mori, T. Sakamoto, M. Wada, T. Yamamoto, and F. Yamamoto, “Design of Low DMD Few-mode Fibers Supporting Large Number of Modes for Mode-division-multiplexed Transmission,” *Proc. of OFT 2014*, Kushiro City, Hokkaido, Japan, Aug. 2014.

## **SIGCHI Best of CHI Honorable Mention Award**

**Winner:** Ge Gao, Naomi Yamashita, Ari Hautasaari, NTT Communication Science Laboratories; Susan Fussell, Cornell University

**Date:** March 3, 2015

**Organization:** The Association for Computing Machinery (ACM)-the Special Interest Group on Computer-Human Interaction (SIGCHI)

For “Improving Multilingual Collaboration by Displaying How Non-native Speakers Use Automated Transcripts and Bilingual Dictionaries.”

We examine the value of signaling grounding problems to native speakers by displaying how non-native speakers use automated transcripts and bilingual dictionaries. Our findings suggest ways to improve collaboration systems.

**Published as:** G. Gao, N. Yamashita, A. Hautasaari, and S. Fussell, “Improving Multilingual Collaboration by Displaying How Non-native Speakers Use Automated Transcripts and Bilingual Dictionaries,” *Proc. of CHI 2015*, Seoul, Korea, Apr. 2015.

## **SIGCHI Best of CHI Honorable Mention Award**

**Winner:** Paul Luff, King’s College; Naomi Yamashita, NTT Communication Science Laboratories; Hideaki Kuzuoka, University of Tsukuba; Christian Heath, King’s College

**Date:** March 3, 2015

**Organization:** ACM-SIGCHI

For “Flexible Ecologies and Incongruent Locations.”

This study contributes to the studies of systems to support real-time collaborative activities by presenting some form of embodiment. It develops the analysis of fractured ecologies and fragmented interaction.

**Published as:** P. Luff, N. Yamashita, H. Kuzuoka, and C. Heath, “Flexible Ecologies and Incongruent Locations,” *Proc. of CHI 2015*, Seoul, Korea, Apr. 2015.

## **Interaction 2015 Best Interactive Presentation Award**

**Winner:** Masanori Yokoyama, Motohiro Makiguchi, and Daichi Namikawa, NTT Service Evolution Laboratories; Yuji Takano and Satoshi Nakashima, NTT Communication Science Laboratories; Taiga Yoshida, NTT Media Intelligence Laboratories

**Date:** March 5, 2015

**Organization:** Information Processing Society of Japan (IPSJ)

For “Animal Cloud: Crowdsourcing System on the Basis of Animal Cognitions.”

We propose “Animal Cloud,” which is a micro-task crowdsourcing system based on animal cognition. The required conditions of Animal Cloud are as follows: necessity of learning the task, supplement of the task accuracy rate, and securement of the right of choice as to whether the animals do the task or not. As the first step, we implemented an image recognition system based on a rat’s perceptual or cognitive ability as an example of an application that fulfills the required conditions. We conducted the behavioral experiment and simulation to evaluate the feasibility of the system. The results suggested that the system required 50 rats that would learn the micro-task for about 15 days.

**Published as:** M. Yokoyama, Y. Takano, M. Makiguchi, S. Nakashima, T. Yoshida, and D. Namikawa, “Animal Cloud: Crowdsourcing System on the Basis of Animal Cognitions,” *Proc. of Interaction 2015 (the 19th IPSJ Symposium)*, Tokyo, Japan, Mar. 2015.

## **Young Scientist Oral Presentation Award**

**Winner:** Takahiro Inagaki, NTT Basic Research Laboratories

**Date:** March 11, 2015

**Organization:** The Japan Society of Applied Physics (JSAP)

For “Low-voltage Optical Phase Modulation by Electric-field-induced Phase Transition of KTN Crystal.”

**Published as:** T. Inagaki, T. Imai, J. Miyazu, H. Takesue, and J. Kobayashi “Low-voltage Optical Phase Modulation by Electric-field-induced Phase Transition of KTN Crystal,” *Proc. of the 75th TSAP Autumn Meeting*, Sapporo, Hokkaido, Japan, Sept. 2014.

## **2014 IEICE Communications Society OFT Young Researchers Award**

**Winner:** Nobutomo Hanzawa, NTT Access Network Service Systems Laboratories

**Date:** March 11, 2015

**Organization:** IEICE-OFT

For “A Study on Mode Dependent Loss of Rayleigh Scattering.”

**Published as:** N. Hanzawa, K. Tsujikawa, S. Nozoe, L. Ma, and F. Yamamoto, “A Study on Mode Dependent Loss of Rayleigh Scattering,” *Proc. of the 2014 IEICE General Conference*, Niigata City, Niigata, Japan, Mar. 2014.

### Specially Selected Paper

**Winner:** Ryohei Banno, Susumu Takeuchi, Michiharu Takemoto, Tetsuo Kawano, NTT Network Innovation Laboratories; Takashi Kambayashi, NTT Science and Core Laboratory Group; Masato Matsuo, NTT Network Innovation Laboratories

**Date:** March 15, 2015

**Organization:** IPSJ

For “Designing Overlay Networks for Handling Exhaust Data in a Distributed Topic-based Pub/Sub Architecture.”

**Published as:** R. Banno, S. Takeuchi, M. Takemoto, T. Kawano, T. Kambayashi, and M. Matsuo, “Designing Overlay Networks for Handling Exhaust Data in a Distributed Topic-based Pub/Sub Architecture,” *Journal of Information Processing*, Vol. 23, No. 2, pp. 105–116, Mar. 2015.

## Papers Published in Technical Journals and Conference Proceedings

### Underdetermined Blind Separation and Tracking of Moving Sources Based on DOA-HMM

T. Higuchi, N. Takamune, T. Nakamura, and H. Kameoka

Proc. of 2014 IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2014), pp. 3215–3219, Florence, Italy, May 2014.

This paper deals with the problem of the underdetermined blind separation and tracking of moving sources. In practical situations, sound sources such as human speakers can move freely, so blind separation algorithms must be designed to track the temporal changes of the impulse responses. We propose solving this problem through the posterior inference of the parameters in a generative model of an observed multichannel signal, formulated under the assumption of the sparsity of time-frequency components of speech and the continuity of speakers’ movements.

### Aging and Availability of Binocular Disparity and Pictorial Depth Cues in 3D-graphics Contents

K. Kihara, H. Fujisaki, S. Ohtsuka, M. Miyao, J. Shimamura, H. Arai, and Y. Taniguchi

*Journal of the Society for Information Display*, Vol. 22, No. 7, pp. 329–336, July 2014.

Some stereoblind observers do not perceive depth of 3D stimuli that depend on binocular disparity. These individuals, who have no disabilities, comprise over 5% of the general population. In addition, 17.30% of non-stereoblind young (17–24 years old) and young-middle aged (25–39 years old) people do not use disparity information in certain 3D environments, a phenomenon known as pseudo-stereoblindness. This study aimed to investigate the relationship between aging and the proportion of pseudo-stereoblindness in the general population.

### The Effect of Depth Information on Visual Attention under Monocular and Stereopsis Viewings: An Object Substitution Masking Study

K. Miyaji, K. Kihara, J. Shimamura, Y. Taniguchi, and S. Ohtsuka

Proc. of the 10th Asia-Pacific Conference on Vision (APCV 2014), p. 304, Takamatsu City, Kagawa, Japan, July 2014.

Since augmented reality (AR) is rapidly becoming popular, it is important to determine how visual information appears on different depth planes. Object substitution masking (OSM) is a phenomenon in which a target is masked by surrounding dots that remain after the target is offset, which depends on the division of attention. Our previous OSM study focused on a target and masking dots that were presented on different depth planes. It suggested that OSM was attenuated when participants observed binocularly, where depth cues of vergence, disparity, and accommodation were available simultaneously. However, it is still unclear whether OSM is affected by the depth difference between the target and masking dots if either vergence and disparity or accommodation can be used as depth cue(s). To address this issue, we investigated the visibility of a target in OSM with depth separation between the target and masking dots under monocular and stereopsis viewings.

### Load-adaptive Indexing Method for Schema-less Searches

Y. Arakawa, T. Nakamura, M. Nakamura, N. Matsuura, Y. Kawakita, and H. Ichikawa

Proc. of the 2014 IEEE 38th International Computer Software and Applications Conference Workshop (COMPSACW '14), pp. 318–324, Västerås, Sweden, July 2014.

UBI-Tree predicts usage frequencies of each query based on the characteristics of the stored data, and classifies incoming data in the tree so as to improve the search performance of frequently used queries. We propose a new method which improves the search performance of UBI-Tree based on the real load by using a query history. We also experimentally show that the proposed method can improve the average latency and throughput of search processes.

### Experimental Evaluation of Chromostereopsis with Varying Center Wavelength and FWHM of Spectral Power Distribution

M. Tsuchida, K. Kashino, and J. Yamato

Proc. of the 16th International Symposium on Multispectral Colour Science (MCS 2014), pp. 133–141, Cherbourg, France, June/July 2014.

This paper experimentally shows how the center wavelength and spectral power distribution (SPD) of displayed color is related to chromostereopsis (CS). CS is a visual illusion whereby the impression of depth is conveyed in two-dimensional color images. CS can be applied to glassless binocular stereopsis by controlling color saturation even when a commercial liquid crystal display (LCD) is used to display a two-dimensional image. We conducted evaluations of stereoscopic visual effects among monochrome images using an LCD panel and three monochrome backlights whose SPD had a single peak. The center wavelength and full width at half maximum (FWHM) of the SPD for the backlight were varied. The experimental results show that CS does not occur strongly when the FWHM of a backlight is larger than 100 nm. We also suggest that the impression of the depth for monochrome images depends on the center wavelength and FWHM of the color, which indicates CS can be expressed by the chromatic aberration.

### Asymptotic Local Hypothesis Testing between a Pure Bipartite State and the Completely Mixed State

M. Owari and M. Hayashi

Physical Review, Vol. 90, No. 032327, pp. 1–18, September 2014.

In this paper, we treat asymptotic hypothesis testing between an arbitrary fixed bipartite pure state  $|\Psi\rangle$  and the completely mixed state by one-way local operations and classical communication (LOCC), two-way LOCC, and separable positive operator-valued measures (POVMs). As a result, we derive single-letterized formulas for the Stein's lemma type of optimal error exponents under one-way LOCC, two-way LOCC, and separable POVMs, the Chernoff bounds under one-way LOCC POVMs and separable POVMs, and the Hoeffding bounds under one-way LOCC POVMs in the whole region of a parameter and under separable POVMs in a restricted region of a parameter. We also numerically calculate the Chernoff and the Hoeffding bounds under a class of three-step LOCC protocols in low-dimensional systems and show that these bounds not only outperform the bounds for one-way LOCC POVMs but also almost approximate the bounds for separable POVMs in the parameter region where analytical bounds for separable POVMs are derived.

### Fast Signal Reconstruction from Magnitude Spectrogram of Continuous Wavelet Transform Based on Spectrogram Consistency

T. Nakamura and H. Kameoka

Proc. of the 17th International Conference on Digital Audio Effects (DAFx-14), pp. 129–135, Erlangen, Germany, September 2014.

The continuous wavelet transform (CWT) can be seen as a filterbank having logarithmic frequency subband spacing similar to the human auditory system. Thus, to make computers imitate the significant functions of the human auditory system, one promising approach would be to model, analyze, and process magnitude spectrograms given by the CWT. To realize this approach, we must be able to convert a processed or modified magnitude CWT spectrogram, which

contains no information about the phase, into a time domain signal specifically for those applications in which the aim is to generate audio signals. To this end, this paper proposes a fast algorithm for estimating the phase from a given magnitude CWT spectrogram to reconstruct an audio signal.

### Joint Audio Source Separation and Dereverberation Based on Multichannel Factorial Hidden Markov Model

T. Higuchi and H. Kameoka

Proc. of the 2014 IEEE International Workshop on Machine Learning for Signal Processing (MLSP 2014), Reims, France, September 2014.

This paper proposes a unified approach for jointly solving underdetermined source separation, audio event detection, and dereverberation of convolutive mixtures. We previously proposed an extension of multichannel NMF (nonnegative matrix factorization), in which the variations over time of the spectral density and the total power of each source are modeled by a hidden Markov model (HMM). This has allowed us to conduct source activity detection and source separation simultaneously through model parameter inference. While this method was based on an anechoic mixing model, the aim of this paper is to further extend the above approach to deal with reverberation by incorporating an echoic mixing model into the generative model of observed signals.

### Maximum Reconstruction Probability Training of Restricted Boltzmann Machines with Auxiliary Function Approach

N. Takamune and H. Kameoka

Proc. of MLSP 2014, Reims, France, September 2014.

Restricted Boltzmann machines (RBMs) are stochastic neural networks that can be used to learn features from raw data. They have attracted particular attention recently after being proposed as building blocks for deep belief networks (DBNs) and have been applied with notable success in a range of problems including speech recognition and object recognition. The success of these models raises the issue of how best to train them. At present, the most popular training algorithm for RBMs is the Contrastive Divergence (CD) learning algorithm. We propose deriving a new training algorithm based on an auxiliary function approach for RBMs using the reconstruction probability of observations as the optimization criterion. Through an experiment on parameter training of an RBM, we confirmed that the present algorithm outperformed the CD algorithm in terms of the convergence speed and the reconstruction error when used as an autoencoder.

### Training Restricted Boltzmann Machines with Auxiliary Function Approach

H. Kameoka and N. Takamune

Proc. of MLSP 2014, Reims, France, September 2014.

Restricted Boltzmann machines (RBMs) are neural network models for unsupervised learning, but have recently found a wide range of applications as feature extractors for supervised learning algorithms. They have also received a lot of attention recently after being proposed as building blocks for deep belief networks. The success of these models raises the issue of how best to train them. At present, the most popular training algorithm for RBMs is the Contrastive Divergence (CD) learning algorithm. The aim of this paper is to seek a new

optimization algorithm tailored for training RBMs in the hope of obtaining a faster algorithm than the CD algorithm. We propose deriving a new training algorithm for RBMs based on an auxiliary function approach. Through an experiment on parameter training of an RBM, we confirmed that the present algorithm converged faster and to a better solution than the CD algorithm.

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### A Unified Approach for Underdetermined Blind Signal Separation and Source Activity Detection by Multichannel Factorial Hidden Markov Models

T. Higuchi, H. Takeda, T. Nakamura, and H. Kameoka

Proc. of the 15th Annual Conference of the International Speech Communication Association (Interspeech 2014), Singapore, September 2014.

This paper introduces a new model called the multi-channel factorial hidden Markov model (MFHMM) for underdetermined blind signal separation (BSS). We propose extending the multichannel NMF model by modeling the transition of the set consisting of the spectral densities and the total power of each source using a hidden Markov model (HMM). By letting each HMM contain states corresponding to active and inactive modes, we will show that voice activity detection and source separation can be solved simultaneously through parameter inference of the present model.

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### Speech Prosody Generation for Text-to-speech Synthesis Based on Generative Model of $F_0$ Contours

K. Kadowaki, T. Ishihara, N. Hojo, and H. Kameoka

Proc. of Interspeech 2014, Singapore, September 2014.

This paper deals with the problem of generating the fundamental frequency ( $F_0$ ) contour of speech from a text input for text-to-speech synthesis. We previously introduced a statistical model describing the generating process of speech  $F_0$  contours, based on the discrete-time version of the Fujisaki model. One remarkable feature of this model is that it has allowed us to derive an efficient algorithm based on powerful statistical methods for estimating the Fujisaki model parameters from raw  $F_0$  contours. To associate a sequence of the Fujisaki model parameters with a text input based on statistical learning, this paper proposes extending this model to a context-dependent one. We further propose a parameter training algorithm for the present model based on decision tree-based context clustering.

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### Development of Wideband Handset for High Quality IP Telephone Service Trial

M. Okamoto, K. Noguchi, Y. Hiwasaki, and Y. Haneda

Proc. of the 2014 IEEE 3rd Global Conference on Consumer Electronics (GCCE 2014), pp. 523–524, Chiba, Japan, October 2014.

Since 2007, high quality IP telephone service has been provided over a Next Generation Network (NGN) developed by Nippon Telegraph and Telephone Corporation (NTT) Group of Japan. Prior to the commencement of service provision, a wideband telephone handset was developed on an experimental basis and tested in a field trial to verify service validity. The handset demonstrated improved characteristics over those of conventional telephone handsets.

### Harmonic-temporal Factor Decomposition Incorporating Music Prior Information for Informed Monaural Source Separation

T. Nakamura, K. Shikata, N. Takamune, and H. Kameoka

Proc. of the 15th International Society for Music Information Retrieval Conference (ISMIR 2014), pp. 623–628, Taipei, Taiwan, October 2014.

For monaural source separation, two main approaches have thus far been adopted. One approach involves applying non-negative matrix factorization (NMF) to an observed magnitude spectrogram, which is interpreted as a non-negative matrix. The other approach is based on the concept of computational auditory scene analysis (CASA). A CASA-based approach called harmonic-temporal clustering (HTC) aims to cluster the time-frequency components of an observed signal based on a constraint designed according to the local time-frequency structure common in many sound sources (such as harmonicity and the continuity of frequency and amplitude modulations). This paper proposes a new approach for monaural source separation called Harmonic-Temporal Factor Decomposition (HTFD) by introducing a spectrogram model that combines the features of the models employed in the NMF and HTC approaches. We further describe some ideas on how to design the prior distributions for the present model to incorporate musically relevant information into the separation scheme.

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### Efficient POC-based Correspondence Detection Method for Multi-channel Images

M. Tsuchida, S. Sakai, K. Ito, K. Kashino, J. Yamato, and T. Aoki

Proc. of the 22nd Color and Imaging Conference, pp. 113–118, Boston, MA, USA, November 2014.

We propose a new phase-only correlation (POC)-based high-accuracy correspondence detection method for multi-channel images. There is the possibility of improving detection accuracy because conventional POC-based methods do not use color information. In the proposed method, a normalized cross spectrum (or cross-phase spectrum) and weight are calculated for each color channel in the Fourier domain. The weight is determined by the amplitude of the cross spectrum. The weighted normalized cross spectra of all color channels are combined, and inverse Fourier transformation is conducted to obtain a POC function. An experimental evaluation of the matching accuracy between the conventional POC-based method and the proposed method shows that RMSE (root-mean-square error) decreased approximately 25%. This paper also describes an application of the proposed method to stereo image matching. The average detection ratio of correspondences between a stereo-pair image is improved 64% to 95%.

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### Harmonic/Percussive Sound Separation Based on Anisotropic Smoothness of Spectrograms

H. Tachibana, N. Ono, H. Kameoka, and S. Sagayama

IEEE/ACM Transactions on Audio, Speech, and Language Processing, Vol. 22, No. 12, pp. 2059–2073, December 2014.

This paper describes a method to separate a monaural music signal into harmonic components, e.g., a guitar and percussive components such as a snare drum. Separation of these two components is a useful preprocessing step for many music information retrieval applications, and in addition, it can be used as a new kind of music equalizer in itself, which enables a music listener to freely adjust the ratio of the volume of the guitar and the drum by themselves.

### Wideband Injection Locked CMOS Quadrature Ring Oscillator with Small Phase Errors

N. Jahan, A. Anand, T. Kaho, K. Yousef, and R. K. Pokharel

Proc. of the 2014 Korea-Japan Microwave Workshop (KJMW2014), Suwon, Korea, December 2014.

This paper presents a wideband low phase noise complementary metal-oxide-semiconductor (CMOS) quadrature ring oscillator. It employs a novel technique to improve phase errors by single pulse injection with three dummy transistors. The analysis was verified by models in a 0.18- $\mu\text{m}$  CMOS process. The simulation results show that the phase errors can be minimized within  $\pm 1$  degree. It has a wide tuning range from 0.3 GHz to 5.8 GHz at free-run oscillation, and low phase noise with  $-136.8\text{dBc/Hz}$  @ 1MHz offset at 5.25-GHz oscillation with injection locking.

### Unified Approach for Underdetermined BSS, Source Activity Detection, Dereverberation and DOA Estimation with Multichannel Factorial HMM

T. Higuchi and H. Kameoka

Proc. of the 2014 IEEE Global Conference on Signal and Information Processing (GlobalSIP), Atlanta, GA, USA, December 2014.

This paper proposes a novel method for simultaneously solving the problems of underdetermined blind source separation (BSS), source activity detection, dereverberation, and direction-of-arrival (DOA) estimation by introducing an extension of the multichannel factorial hidden Markov model (MFHMM).

### Full Information Maximum Likelihood Estimation in Factor Analysis with a Large Number of Missing Values

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

Journal of Statistical Computation and Simulation, January 2015.

We consider the problem of full information maximum likelihood (FIML) estimation in factor analysis when a majority of the data values are missing. The expectation-maximization (EM) algorithm is often used to find the FIML estimates, in which the missing values on manifest variables are included in the complete data. However, the ordinary EM algorithm has an extremely high computational cost. In this paper, we propose a new algorithm that is based on the EM algorithm but that efficiently computes the FIML estimates. A significant improvement in the computational speed is realized by not treating the missing values on manifest variables as a part of the complete data. When there are many missing data values, it is not clear if the FIML procedure can achieve good estimation accuracy. In order to investigate this, we conduct Monte Carlo simulations under a wide variety of sample sizes.

### Quantum Algorithms for Finding Constant-sized Sub-hypergraphs

F. L. Gall, H. Nishimura, and S. Tani

Proc. of the 18th Conference on Quantum Information Processing (QIP 2015), Sydney, Australia, January 2015.

We develop a general framework to construct quantum algorithms that detect if a 3-uniform hypergraph given as input contains a sub-hypergraph isomorphic to a prespecified constant-sized hypergraph. This framework is based on the concept of nested quantum walks recently proposed by Jeffery, Kothari, and Magniez [SODA'13], and extends the methodology designed by Lee, Magniez, and Santha

[SODA'13] for similar problems over graphs. As applications, we obtain a quantum algorithm for finding a 4-clique in a 3-uniform hypergraph on  $n$  vertices with query complexity  $O(n^{1.883})$ , and a quantum algorithm for determining if a ternary operator over a set of size  $n$  is associative with query complexity  $O(n^{2.113})$ .

### Estimating Spectral Reflectance of Fabrics from High-resolution Multi-band HDR Images

S. Tanaka, A. Takayanagi, M. Tsuchida, Y. Sakaguchi, and H. T. Tanaka

Proc. of the 21st Korea-Japan joint Workshop on Frontiers of Computer Vision (FCV 2015), Mokpo, Korea, January 2015.

We present a spectral reflectance estimation method of high reflectance targets such as fabrics compared with training samples. We show the efficacy from the results of comparing the proposed method and the conventional method. In addition, the spectral reflectance of polyester satin fabric was estimated from high-resolution multi-band high dynamic range (HDR) images. The spectral reflectance including object color was observed strongly in the weft central region.

### Probabilistic Modeling of Pitch Contours towards Prosody Synthesis and Conversion

H. Kameoka

Speech Prosody in Speech Synthesis, pp. 49–69, February 2015.

Since the voice fundamental frequency ( $F_0$ ) contour is an important acoustic correlate of many prosodic constructs, modeling and analyzing  $F_0$  contours can be potentially useful for many speech applications such as speech synthesis, speaker identification, speech conversion, and dialogue systems, in which prosodic information plays a significant role. In this chapter, we formulate a statistical model of  $F_0$  contours by translating the “Fujisaki model,” a well-founded mathematical model representing the control mechanism of vocal fold vibration, into a probabilistic model described as a discrete-time stochastic process.

### Highly Realistic 3D Display System for Space Composition Telecommunication

M. Date, H. Takada, Y. Honda, S. Ozawa, S. Mieda, and A. Kojima

Journal of Display Technology, Vol. 11, No. 2, pp. 121–128, February 2015.

In this paper, we describe a highly realistic 3D display system that generates composites of current and remote places for telecommunication purposes. It uses a 3D projector and head tracking to display a person in a remote place as a life-size stereoscopic image against background scenery. Since it generates displayed images that correspond to the observer's viewing position, it reproduces well the fidelity of existence and the feel of materials. We also describe a simple, fast, and high quality background scenery generation method, the development of which was inspired by the visual effects of depth-fused 3D (DFD) displays, and applied it to a single direction conceptual demonstration system. Our system is a promising means of achieving real-time communication between two different places in cases where a sense of reality is required.

### Impossibility of Classically Simulating One-clean-qubit Computation

K. Fujii, H. Kobayashi, T. Morimae, H. Nishimura, S. Tamate, and S. Tani

arXiv:1409.6777v2 [quant-ph], February 2015.

Deterministic quantum computation with one quantum bit (DQC1) is a restricted model of quantum computing where the input state is a completely mixed state except for a single clean qubit, and only a single output qubit is measured at the end of the computing. It is proved that the restriction of quantum computation to the DQC1 model does not change the complexity classes NQP (Nondeterministic Quantum Polynomial-Time) and SBQP (Small Bounded-Error Quantum Polynomial-Time). As the main consequence, it follows that the DQC1 model cannot be efficiently simulated by classical computers unless the polynomial-time hierarchy collapses to the second level (more precisely, to AM), which answers the long-standing open problem posed by Knill and Laflamme under the very plausible complexity assumption. The argument developed in this paper also weakens the complexity assumption necessary for the existing impossibility results on classical simulation of various sub-universal quantum computing models, such as the IQP (intuitive quantum physics) model and Boson sampling.

### Wavelength-tunable Filter Utilizing Non-cyclic Arrayed Waveguide Grating to Create Colorless/Directionless/Contentionless ROADMs

M. Niwa, S. Takashina, Y. Mori, H. Hasegawa, K. Sato, and T. Watanabe

Proc. of SPIE Photonics West, 938807, San Francisco, CA, USA, February 2015.

We propose here novel tunable-filter architecture that sandwiches a single-stage non-cyclic athermal AWG (arrayed waveguide grating) having flatter-topped passbands between small-scale switches. With this configuration, the optical tunable filter attains low insertion loss, large passband bandwidths, low power consumption, compactness, and high cost-effectiveness. A prototype was monolithically fabricated with PLC (planar-lightwave-circuit) technologies, and its excellent performance was experimentally confirmed utilizing 80-channel 30-GBaud dual-polarization QPSK (quadrature phase-shift-keying) signals.

### Real-time Viewpoint Image Synthesis Using Strips of Multi-camera Images

M. Date, H. Takada, and A. Kojima

Proc. of SPIE Photonics West, 939109, San Francisco, CA, USA, February 2015.

A real-time viewpoint image generation method is achieved. Video communications with a high sense of reality are needed to make natural connections between users in different places. In this paper, we propose a real-time viewpoint image generation method using simple blending of multiple camera images taken at equal horizontal intervals and convergence obtained by using approximate information of an object's depth.

### Consideration of Tunable Components for Next-generation Passive Optical Network Stage 2

K. Asaka

Journal of Lightwave Technology, Vol. 33, No. 5, pp. 1072–1076,

March 2015.

Possible configurations of tunable components for the next-generation passive optical network stage 2 (NG-PON2) are reviewed on the basis of system requirements. Expected network functions in NG-PON2 systems along with the concept of in-service tuning in colorless ONUs are also reviewed.

### Designing Overlay Networks for Handling Exhaust Data in a Distributed Topic-based Pub/Sub Architecture

R. Banno, S. Takeuchi, M. Takemoto, T. Kawano, T. Kambayashi, and M. Matsuo

Journal of Information Processing, Vol. 23, No. 2, pp. 105–116, March 2015.

To provide event-driven services in IoT, scalable methods of topic-based pub/sub messaging are indispensable. Methods using structured overlay networks are promising candidates. However, existing methods have the problem of wasting network resources, because they lack adaptivity to “exhaust data,” which have low or no value most of the time. This problem has two aspects. One is that each publisher node continues to forward data to a relay node even if there are no subscribers. The other is that excessively large multicast trees are constructed for low value data, which will be received by only a small number of subscribers. In this paper, we formulate the desirable design of overlay networks by defining a property called “strong relay-free” as an expansion of the relay-free property. The property involves publishers and subscribers composing connected subgraphs to enable detection of the absence of subscribers and autonomous adjustment of the tree size. We also propose a practical method satisfying the property by using Skip Graph, which we valuated through simulation experiments. We confirmed that the proposed method can suspend publishing adaptively and shorten the path length on multicast trees by more than 75% under an experimental condition with 100,000 nodes.

### Non-linear Matrix Factorization for Group Recommendation

Y. Yoshikawa, T. Iwata, and H. Sawada

Transactions of the Japanese Society for Artificial Intelligence, Vol. 30, No. 2, pp. 485–490, March 2015.

Group recommendation is a task to recommend items to groups such as households and communities. In this paper, we propose a nonlinear matrix factorization method for group recommendation. The proposed method assumes that each member in a group has its own latent vector, and the behavior of each group is determined by the probability distribution of the members' latent vectors. Recommendations of items are performed by using nonlinear functions that map the distributions of the groups into scores for items. The nonlinear functions are generated from Gaussian processes, which are defined by the similarities between distributions of the groups. We can efficiently calculate the similarities by embedding each distribution as an element in a reproducing kernel Hilbert space. We demonstrate the effectiveness of the method using two synthetic datasets and two real datasets in two prediction tasks.

### Dense Space Division Multiplexed Transmission over Multi-core and Multi-mode Fiber

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

Proc. of the Optical Fiber Communication Conference and Exposi-

tion (OFC) 2015, Th1D.2, San Francisco, CA, USA, March 2015.

We review recent progress in space division multiplexed (SDM) transmission and examine our experimental demonstration of dense SDM (DSDM) using both multi-core and multimode, which provide a key advance to ultra-high capacity transmission.

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**Large-scale Optical-switch Prototype Compactly Implemented with Novel Functional Configuration**

K. Ueda, Y. Mori, H. Hasegawa, K. Sato, and T. Watanabe

Proc. of OFC 2015, W3D.1, San Francisco, CA, USA, March 2015.

We propose a novel optical-switch architecture that can be compactly implemented with a novel functional configuration. A highly integrated  $180 \times 180$  optical switch prototype was fabricated using planar-lightwave-circuit technologies, and its good performance was experimentally confirmed.

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**Demonstration of Large-port-count and Compact ROADM that Exhibits Virtual-C/D/C Performance**

S. Takashina, H. Ishida, Y. Mori, H. Hasegawa, K. Sato, T. Watanabe

Proc. of OFC 2015, W3J.6, San Francisco, CA, USA, March 2015.

We demonstrate novel large-scale and cost-effective reconfigurable optical add-drop multiplexer (ROADM) architecture that

exploits the subsystem-modular express switches and tailored transponder banks for add/drop functionality. Simulations show that the proposed ROADM offers virtual-C/D/C performance. Good transmission characteristics are experimentally confirmed.

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**Photospectroscopically Observed Pore-space Correlations of a Wetting Fluid during the Drying Process in Nanoporous Vycor Glass**

S. Ogawa and J. Nakamura

Journal of the Optical Society of America A, Vol. 32, No. 4, pp. 533–537, April 2015.

We use light scattering to study spatial correlations in the pore space of Vycor glass upon draining a wetting fluid. We analyze the transmission spectrum of forward-scattered light on the basis of the theory of dielectric constant fluctuation, whereas conventional light scattering analyzes the scattered light at small angles of monochromatic incident light. Assuming that the drained pores, which are surrounded by filled pores, exhibit long-range correlations of a fractal dimension of 2.5, we analytically derive the corresponding turbidity. The slight deviation from the  $\lambda^{-4}$  Rayleigh wavelength dependence directly provides the correlation length of the interconnected network of drained pores. The estimated length, ranging from 0.5 nm to 18 nm at most, is almost the same order as that indirectly estimated from our previous simple but effective Rayleigh scattering model.