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ICT Contributing to Disaster Prevention and Mitigation

R&D and Societal Activities at the NICT Resilient ICT Research Center

Disaster-prevention Initiatives using AI and Related Information on SNS

Continuing Evolution of Weather Radar Technology

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C O N T E N T S

About ITU-AJ

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R&D and Societal Activities at the NICT Resilient ICT Research Center

— *Focusing on wireless infrastructure technologies* —

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1. Introduction

Information and Communications Technology (ICT) is the foundation of daily activity in society. If we think of the electricity grid and distribution networks playing the same role as blood in the human body, ICT plays the role of the nervous system and brain. With the arrival of the age of the Internet of Things (IoT) and cyber-physical systems, this role will expand and increase in importance.

However, with the Great East Japan Earthquake in 2011, there was extensive damage to communication networks, causing life-threatening delays in obtaining information regarding the damage, as well as causing major difficulty conveying information such as the well-being of survivors and obtaining daily necessities. Learning from this experience, research and development to improve resilience of data communication networks was started, with a third revision to the 2011 MIC budget. Then, in April, 2012, the National Institute of Information and Communications Technology (NICT), Resilient ICT Research Center was established in Sendai City. It was organized for collaboration among industry, academia and government, to promote initiatives in resilient ICT R&D and their implementation in society. In 2014, a building for the center was completed on the Katahira Campus of Tohoku University. Tohoku University has the Research Institute of Electrical Communication, which was established in 1935, the Graduate School of Engineering and the Graduate School of Information Sciences, so there is much active research related to ICT. After the earthquake, it also established the Research Organization of Electrical Communication, gathering faculty with a desire for resilient ICT research.

Initiatives at the Resilient ICT Research Center promote fundamental and applied research on resilient ICT and its implementation in society, to maximize the contribution of the results of such R&D to society. The Planning and Collaboration Promotion Office collaborates with laboratories within and outside of the Center, promotes collaboration with external research organizations, including those in Tohoku University, and works to establish a network among industry, academia and government. It also promotes demonstration and use during real disasters, of resilient ICT research results arising through related collaboration among industry, academia and government, including disaster preparedness exercises, and implementation of research results in society through symposia and exhibitions.

This article gives an overview of recent R&D results, focusing on resilient ICT infrastructure technologies, and demonstrations and other initiatives to implement them in society.

2. Resilient ICT research at the Resilient ICT Research Center

The Center has two laboratories in which it conducts resilient ICT R&D: The Infrastructure Laboratory has the Optical Networks project, and the Applications Laboratory has the Wireless Communication Applications project and the Real-Time Social Knowledge Analysis project.

2.1 Infrastructure Laboratory

Optical networks use low-loss optical fiber to realize long-distance, high-capacity communication, so they are used for wide-area core networks. Before, during and after large-scale disasters, optical networks should be able to switch smoothly among redundant optical network resources to mitigate major congestion, and to quickly establish emergency optical networks to satisfy various communication requirements in disaster areas. We are conducting R&D on the technologies for an elastic optical switching platform and emergency recovery of optical networks.

When a large-scale disaster occurs, due to the increased communication requirements into and out of the affected regions, congestion will happen in wide-area networks. The goal of elastic optical switching technology is to establish fundamental technologies enabling dynamic reconfiguration, in the spectral domain and the time domain, to avoid congestion when a disaster occurs, making the optical network infrastructure more resilient. We have optimized the processing in an optical power equalization system for acousto-optic devices, making it possible to maintain transmission quality with stable response times when the power changes due to optical switching. To realize interconnection with heterogeneous traffic, we have also worked on the data plane of integrated optical networks: we have conducted R&D on interconnection between integrated optical networks and different transport networks such as MPLS, Ether, OpenFlow, and IP. For the control/management plane, we have focused R&D on orchestration technology for interconnection. These technologies enable services delivering traffic crossing over the integrated optical networks and different transport networks during normal times. In addition, during disasters and emergencies, the integrated optical networks (as the core networks) can be employed to relay different types of traffic for the disconnected MPLS, Ether, OpenFlow and IP networks, resulting in quick restoration of communications.

In R&D on emergency recovery of optical networks, we are developing a self-healing control-system technology using multi-function recovery support tools to facilitate rapid emergency recovery of optical networks near a disaster area when optical fiber communications is interrupted. We are also collaborating with enterprise to develop technology for creating and utilizing a temporary shared packet transport network between carriers, implementing automated control without leaking confidential carrier information. Based on this research, we are conducting R&D on carrier-collaboration platform technology that will enable carriers to cooperate during disaster, sharing surviving communication-facility resources with each other. We implement third-party mediation that incentivizes collaboration between carriers (mutual provision of optical path support, balancing of repair tasks), promoting R&D and collaboration that will advance disaster recovery. During a disaster, this platform will make it possible to set a concrete collaboration plan between carriers, including sharing of optical path resources and allocating repair tasks among each other by matching supply and demand for resources.

Since FY2018, we have also been conducting R&D on disaster-resiliency strategies for next-generation metro optical networks under the Joint Japan-US Network Opportunity 2 (JUNO2) project. In this research, we are conducting R&D on a robust telemetry technology that can quickly rebuild lost optical network functions of monitoring and telemetry during disaster, using a temporary control and management planes established with various access methods, such as private mesh networks, 4G, satellite and the Internet. We are conducting trials of telemetry functions that gather monitoring data using open APIs and protocols, and verifying that network management systems can be notified and quickly gain a global view of network conditions, even with limited and unstable bandwidth, prioritizing important information appropriately.

2.2 Applications Laboratory

This laboratory promotes the Wireless Communication Applications Project, which conducts R&D on network utilization technology to guarantee information-flow requirements in environments where network resources are limited, and the Real-time Social Knowledge Analysis Project, which conducts R&D on technology to obtain necessary disaster information by analyzing disaster-related social knowledge on Social Network Services (SNS) and to present it in a user-friendly form.

The next section introduces R&D on a network system technology that the Wireless Communication Applications Project has been actively working on recently, which can be used continuously even when public communication has been interrupted, and how this technology is being deployed in society. A detailed report of work by the Real-time Social Knowledge Analysis Project is also given in another article in this issue, titled "Disaster-prevention Initiatives using AI and Related Information on SNS."

3. R&D on network system technologies that maintain availability when public networks are interrupted and promotion of results

We are conducting R&D on distributed network system technologies that are resistant to interruption through self-management, enabling both internal communication and application services to be maintained, and also facilitating construction and expansion of networks. Municipalities such as cities and towns are being required to respond quickly and with flexibility to various natural disasters that have been occurring more frequently of late. In such conditions, the role of information is extremely important for understanding conditions of the entire disaster as they change from minute-to-minute, and for making timely and appropriate decisions. However, as experienced with large-scale disasters such as the Great East Japan Earthquake, public telecommunications may not always be available due to congestion or damage, so how to maintain the flow of information even under such conditions is an important key to facilitating support efforts on the ground. One network system technology being developed to maintaining information flow, introduced below, is called "Die-hard Networks"[1]. Its objective is to enable continuous disaster-response work, even between distant locations, by collecting information on servers distributed among vehicles and facilities, and synchronizing that information between the servers using various communication channels that have different characteristics.

3.1 Overview of Die-hard networks

3.1.1 Targeted functional elements

Die-hard networks were proposed and developed as a network system technology that will enable workers to continue using systems, even during disasters and under other conditions where public communications are interrupted, and enable sharing of information between various remote locations and organizations, maximizing utilization of limited means of communication. Features of the technology are described below.

(1) Links between distributed on-premises systems

To enable on-site workers to continue their work under any conditions, an autonomous distributed architecture was adopted. Thus, there are no nodes that provide centralized system management and control, or provide services. Each node provides application services and network control on-premises, and detects and connects with other nodes with the same functionality. This enables nodes to autonomously share and synchronize data (document files, images, etc.) and other information with each other, sharing it between distributed systems at different locations.

(2) Proactive use of mobile resources

Sharing of data as described above is performed in an event-driven manner, when there are updates, or when connecting to a new node. The system is designed using a database to manage data, synchronizing data between nodes so that inconsistencies do not occur. This enables each node to add and update data independently, without assuming a constant connection with other nodes, sharing and synchronizing data between devices only when mobile devices are nearby, and using them as a means of storing and transporting information.

(3) Utilization of heterogeneous communication systems

The system implements functions that enable various communication technologies for connections between nodes, combining available means of communication and using them according to their various characteristics from the application level. For example, wireless local area networks (wireless LAN, or “Wi-Fi”) are capable of relatively high capacity data exchange when a mobile station is nearby, but the range is limited, and it can be difficult to predict when a connection to which mobile station will be possible, or when it will be disconnected. Conversely, communication with Low-Power Wide-Area (LPWA) or Convenience Radio is capable of broadcast and communication over relatively longer distances, but has very low speed and is more subject to data loss, so it is not suitable for image transmission or other high-volume data exchange. Long Term Evolution (LTE) connections are capable of very stable, high-speed Internet connections, but contracting mobile service providers only provide private Internet Protocol version 4 (IPv4) addresses, so IP address resolution and direct communication is not possible between nodes behind the NAT gateways, and data synchronization must be done through a cloud service with a global address. The system implements Application Programming Interfaces (APIs) that enable proactive and efficient use of various means of communication, according to their differing characteristics as in the examples above (such as priority, real-time or not, data transmission capacity, broadcast, and single or full-duplex communication) so that distributed, on-premises systems running on nodes can maintain resilient links between each other.

(4) Authentication and access control in distributed environments

Information handled by local governments includes personal information so free access by anyone cannot be permitted. As such, connection to distributed on-premises systems on each node and access to data stored and managed within them must be limited to users and through terminals that have been authenticated. Similar restrictions are also required between nodes for communication between devices and connections through LTE or the Internet. Die-hard Networks do not assume constant connections between nodes or with the Internet, so authorization to connect and access to information is also authenticated between distributed nodes.

3.1.2 Die-hard Network node prototype

We have prototyped a Die-hard Network node. The prototype node specifications are shown in the Table[1]. Under normal circumstances the prototype node uses the mobile phone network (LTE data communication) and implements a mechanism that automatically synchronizes data between each node and a node on the cloud. Besides LTE, each node also has two Wi-Fi interfaces, with one operating as an access point using hostapd[2], and the other operating as a station using wpa_supplicant[3]. The Wi-Fi access points can connect to other nodes and synchronize data, but they are also used to accommodate smartphones, tablets and PCs used by disaster responders, and provide application services to them.

The prototype node implements Fast Initial Link Setup (FILS) on wireless LAN based on the IEEE802.1ai standard[4], providing authentication server, Dynamic Host Configuration Protocol (DHCP) server and Wi-Fi access point functions, so that they are operating on all nodes of the network. This enables high-speed wireless LAN connections with user authentication equivalent to Wi-Fi Protected Access 2 (WPA2) Enterprise. This also allows for more data to be transferred between nodes during the limited time available in scenarios when mobile nodes pass each other, or when mobile nodes pass near nodes in fixed stations.

Each node is also equipped with digital convenience radio

Table: Prototype node specifications

	Specifications
Single Board Computer	Gateworks GW6300 OS: Ubuntu 16.04.05 (Linux 4.14.4) CPU: Cavium Octeon TX Dual Core ARM CPU @ 800 MHz RAM: DDR3 1 GB Storage: SSD 250 GB
Wireless LAN Interface (device driver)	Qualcomm AR9300 (ath9k)×2
Digital Convenience Radio	waveCSR U7000UJC181 351.2 - 351.38125 MHz (30 CH) 4-value FSK 4.8 Kbps RS-232C connection
LTE module	PIX-MT100

equipment, for long distance communication. This is used mainly for transmitting control information between nodes, but when the regular LTE connection is interrupted, it can also be used to transmit high priority application data (low volume text data). The system is also designed so that Long Range (LoRa) and other IoT radio communication devices can be added.

3.1.3 Application software

Application software running on the Die-hard network system is implemented as Web server based applications[1]. Users are able to enter and view information on the system using a Web browser on a PC or smartphone connected to the system by Wi-Fi. The system also implements APIs so that dedicated applications can be developed to facilitate entry of information on a smartphone. Thus, applications can be developed to use the system as required by users, such as: enabling registered users and devices to simplify login to the system, updating information with photos attached, sharing location information for on-site workers, or distributing audio information within groups like a transceiver.

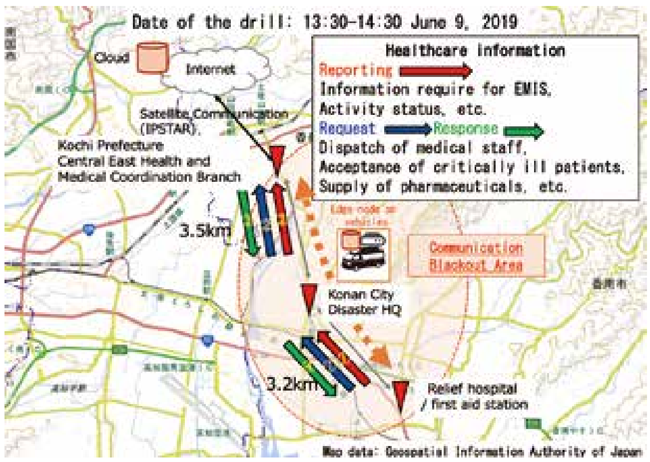
3.2 Use of prototype node in disaster medical drills

The prototype was used in the comprehensive disaster preparedness drill held in Kochi Prefecture on June 9, 2019. The drill supposed conditions in which public communications were completely lost due to an earthquake in the Nankai Trough. As in earlier drills, training was done using conventional means of communication, such as administrative disaster prevention radio systems. Specifically, this involved writing messages on paper based on prefectural forms (e.g., reports from first-aid stations to municipal disaster-response centers, status reports from disaster response centers to prefectural medical coordination office, requests to admit serious patients, and responses), and then transmitting them by FAX. In parallel with this, prototype nodes were installed at the Kochi Prefecture Medical Coordination office (Kochi Prefecture Central-East Health and Welfare Office), the Konan City Disaster Response Office (the Fureai Center), and the emergency medical aid station (Konan City, Akaoka Insurance Center). Drills were then conducted transmitting the same information digitally, without paper, using the prototype nodes with the LTE function disabled[5]. An information transmission application developed for the drills was installed on the prototype nodes, and a Die-hard Network system was configured using several nodes. Figure 1 shows the locations of each of the stations using the system in the drill, and the information transmitted.

With the system, text information entered in reports and requests is automatically synchronized and shared by Digital Convenience Radio with the municipal disaster response center or the prefectural medical coordination center. At each location, a mechanism is implemented to automatically share such status or authorization information by simply performing the approval and authorization processes on the system. City and prefecture staffs participating in the drills were requested to use the system and were able to perform the drill according to the prescribed scenarios. Screen shots of the applications used are shown in Figures 2 and 3.

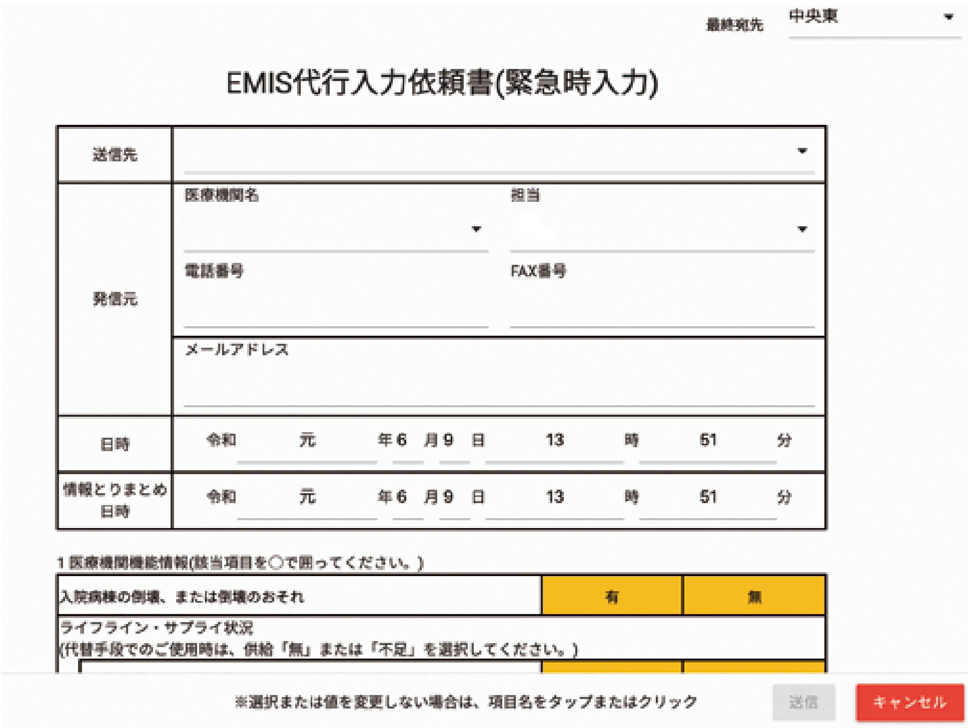
Beyond the scenarios of the drill, we also demonstrated storage and transmission of information that cannot be transmitted using prefecture forms, such as the status of critical patients in care at the first-aid centers, and photographs of triage tags. Prototype nodes on moving vehicles automatically synchronized information through Wi-Fi, so photographic data stored on nodes at first-aid stations was automatically transmitted to the vehicle node, and when the vehicle arrived at the parking lot of the medical coordination center, the photographic data was automatically transmitted to nodes there. We confirmed that photos could be displayed on PCs in the center. In this way, we verified that even high-volume data that is difficult to transmit by Digital Convenience Radio can be shared automatically, transported by vehicle, when public telecommunications are interrupted.

■ **Figure 1: Locations and information transmitted for each location in drills**



■ **Figure 2: Data transmission application screen (Status display screen for Requests/Approvals/ Reports)**

■ **Figure 3: Data input screen matching prefecture forms**



These efforts have shown that this network system technology is effective, providing continuous availability even when public telecommunication systems are interrupted.

3.3 Future prospects

The Die-hard Network system described here is being developed as a technology to provide a continuous means of communication, to share information among aid workers active on-site during disasters, and is being verified in disaster prevention drills.

In the future, we will continue development of individual technical elements necessary for Die-hard Networks, and build them into the Disaster Prevention Information, Communication and Management System in Konan City, Kochi Prefecture. We will also link with the Shared Information Platform for Disaster Management (SIP4D) system[6], create platform functionality that can be shared for various uses, improve extensibility, and expand laterally so that it can also be used by other local governments and disaster-response agencies.

4. Conclusion

Having learned lessons from the Great East Japan Earthquake, the Resilient ICT Research Center is engaged in R&D on ICT that is resilient in the face of earthquakes and other large-scale disasters and is working to implement it in society. In recent years, we have also frequently seen meteorological disasters such as wind and water damage from typhoons, and sudden and heavy “guerilla” rainstorms. Moreover, we have learned that pandemics such as that resulting from COVID-19 have a strong impact to society, similar to large-scale disasters. ICT must function properly in order to minimize damage to life and economy and to support repair and recovery. With development of ICT and in a society where every citizen is connected to the network, we have entered an age that requires construction of cyber-physical ICT social infrastructure that can support everyday social systems and services, and is continuously maintained and operating right through into times of disaster. To realize this vision will require further R&D on technical systems that are, as the word “resilient” indicates, both tougher and more flexible.

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Disaster-prevention Initiatives using AI and Related Information on SNS

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1. Introduction

Since the 2011 Tohoku Earthquake the value of social media and SNS in particular, has been widely recognized. The ability for anyone to send information easily in real-time was shown to be useful for disaster response, but it is also widely recognized that since SNS are quite anonymous, it is also easy to spread erroneous information and cause confusion in society. Seeing the need to use such disaster-related information on SNS despite such qualities, the National Institute of Information and Communication Technology (NICT) began public trials in April 2015, of the DISAster-information ANAlyzer (DISAANA) system, which analyzes disaster SNS data on Twitter, and in October 2016, of the Disaster-information SUMMarizer (D-SUMM) system, which summarizes the state of disaster. These are being used in disaster preparedness drills by local governments and in real disasters, to verify the technology, and support further, ongoing R&D. This article reviews these two systems, how they have been used, and gives an overview of a system called "SOCial dynamics Observation and victims support Dialogue Agent platform for disaster management" (SOCDA) and related initiatives. SOCDA is a chatbot for disaster management intended to resolve problems identified in use of the earlier two systems and is the result of R&D that began in 2018, as a second-term project of the Cabinet Office's Strategic Innovation Program (SIP).

2. Twitter analysis with DISAANA and D-SUMM

Simply put, DISAANA is a question answering system. Question answering is a technology that selects answers to questions from some body of knowledge (usually a large volume of text such as an encyclopedia). Questions could be of various types: Who, What, Where, When, Why, or How; but DISAANA emphasizes understanding what happened and where in a disaster, so the focus is on "What" and "Where" questions. We have a history of R&D on such Q&A technology, and already provide trial access to a Q&A system on the WISDOM X Web page (https://wisdom-nict.jp/). DISAANA can be considered as applying some of the technology used for WISDOM X to Twitter, extending it to process place names appropriately. From the beginning of R&D on DISAANA, we described the prototype system to relevant staff at local governments and asked them about difficulties in gathering information. They pointed out that even thinking of questions and entering them can be difficult, and they did not have time to carefully check all the Q&A results, so they needed a way to comprehend what disaster-related information was on the SNS, in a compact and user-friendly form. In parallel with DISAANA R&D, there was also R&D to automatically extract disaster-related information found on SNS, and we accelerated this work. Since 2014, we received support from the Cabinet Office's Strategic Innovation Project (SIP) for R&D on D-SUMM, a system that automatically extracts disaster-related information from SNS and from it, summarizes disaster conditions in a compact and user-friendly form. Trial operation of the system began in October, 2016. Details of these two systems can be found in references at the end of this article.

3. Bi-directional communication on LINE with SOCDA

Twitter and other SNS enable anyone to post information easily in real-time, immediately sharing conditions in far-away places with photos and videos, so they hold great promise as useful tools during disasters. On the other hand, a person posting disaster information on Twitter and the like can post whatever they want, so the information will not necessarily be useful in disaster response efforts. Furthermore, even if a person is able to post their distress situation on a SNS, and someone at a disaster-response facility sees it and is able to provide information that is useful for the original poster, human resources are limited in times of disaster, and it would not be possible to respond to all such posts. This prompted the idea of developing an AI that could autonomously gather such information and distribute information appropriately, instead of a person. Starting in FY2018, we received Cabinet Office second-term SIP support and began R&D on the SOCDA chatbot for disaster management. R&D on SOCDA is being conducted jointly with the National Research Institute for Earth Science and Disaster Resilience (NIED) and Weathernews Inc. We also collaborated with LINE Corp. and the Japan Institute of Law and Information Systems (JILIS) for trials, operation and to study the system and other aspects of implementation in society.

SOCDA means Dialogue Agent platform for disaster management, and it is a platform for collecting and distributing disaster-related information through bi-directional communication, mainly with text interaction on SNS. Broadly speaking, SOCDA is not intended as a platform for a specific SNS, but currently we are collaborating with LINE Corporation to develop a chatbot program operating on the LINE SNS, together with various back-end programs, so for ordinary users accessing it from a LINE account, SOCDA can be more narrowly defined as a chatbot program on LINE.

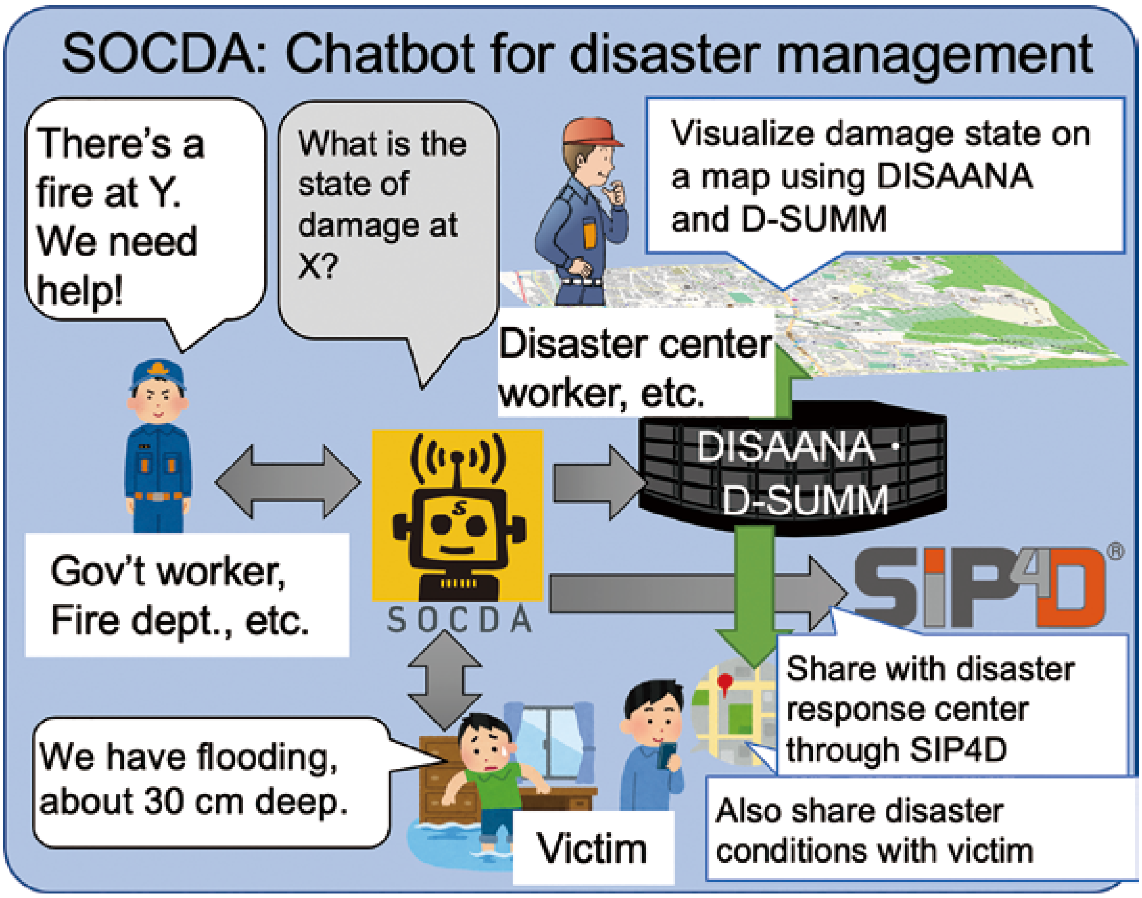
With over 80 million users, LINE is currently the SNS with the most users in Japan, so in terms of coverage, it is promising for implementing a service in society. An overview of SOCDA is given in Figure 1. There are two main functions implemented by SOCDA. One is information gathering, and the other is information distribution. Rather than having individual citizens providing information spontaneously and exhaustively, the desired information can be collected, and processed, and new decisions regarding disaster response can be distributed quickly. NICT has contributed to SCODA R&D with technology to analyze the collected information and visualize it on a map, applying technologies from DISAANA and D-SUMM. In doing so, we have advanced R&D on more user-friendly visualization methods and more accurate methods for analyzing the collected information.

In past R&D on DISAANA and D-SUMM, we have shown that Twitter and other SNS are platforms that treat people as a kind of sensor. However, by implementing bi-directional communication on the SNS, extending the analogy, we can also treat people as actuators. We could also say they are acting as active sensors, rather than passive sensors. As such, we can expect to be able to collect a range of information quickly, even under conditions that we could not previously, such as checking disaster conditions when a disaster has occurred during the night. Reliable positioning information, photographs and video can also be shared now, so it is possible to collect the desired information quickly, and information contributing to evacuation and other activities can be distributed quickly.

When implementing bi-directional communication with this sort of chatbot, it is desirable for the text chat to feel like interacting with a person, but when a large-scale disaster occurs, a real problem is that information needs to be collected from, and distributed to, a huge number of people over an extremely short period of time. As such, we prioritized scalability in the design and implementation of SOCDA, so that we could maintain a minimum level of quality that people can tolerate in the disaster prevention-domain, while handling numbers of interactions in a short time that would be overwhelming if attempted by human personnel.

As a result of active trials with local governments and other organizations since FY2018, most issues are being clarified, including technical but also institutional and other issues. For

■ Figure 1: Overview of SOCDA, a chatbot for disaster management



example, there is a responsibility issue with a chatbot for disaster management. To enable bi-directional communication, members must become friends with the SOCDA account, but without a clear commitment to taking responsibility in handling shared information, it will be difficult to gain members' cooperation. There is also an issue of how the information provided to SOCDA by residents is handled. In prior tests, information was gathered in a format that anyone could look at, and information was used in a way that the information provider remained anonymous. This helped curb any resistance to providing information, but who provided the information and from where was unknown, so it was difficult to encourage cooperation and information sharing within the community.

On the other hand, relatively soon after R&D began, we began studying use of SOCDA for communication with personnel and collaborating facilities such as the fire department, rather than with general residents. Use by government or fire department staff in this way means it is being used at the front lines of disaster response, and we realized there were hardware and other constraints that we had not anticipated earlier (Smartphones require touch, so they cannot be used hands-free. We also want to use speech recognition to simplify input, but could not always obtain the desired results due to noise from heavy rain and other causes).

We also heard from one government agency, that a large amount of effort was required to confirm the safety of people needing help with evacuation when a typhoon was approaching. They inquired whether SOCDA could be used for that purpose. We conducted two trials of this application. In the first trial, we checked the basic functionality using test data, and in the second trial, we had people needing help become friends on SOCDA and LINE, and enter their safety information under conditions similar to a real environment. This showed the technical potential, but also exposed issues requiring further study, such as how personal information should be handled.

In January, 2020, we also conducted a large information gathering drill using SOCDA on a scale of ten thousand participants in Kobe City. We verified performance in collecting a large volume of information in a short time, reduced the volume and increased the speed when providing results of visualizing the information to many during that same short time. We were able to verify and make improvements for even larger-scale use in the future.

We plan to continue implementing various planned features in SOCDA and to verify them in practical tests.

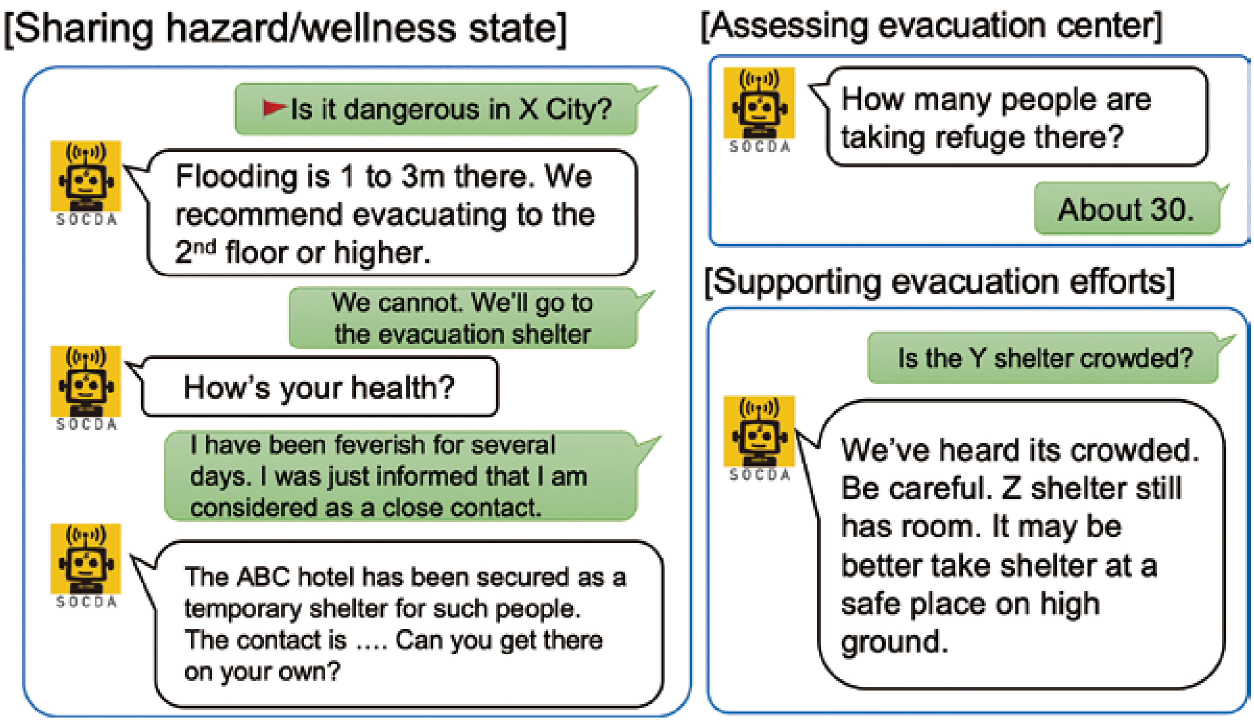
4. Disaster prevention and mitigation using SNS in the Corona Era

From our experience with the spread of the new coronavirus, preventative measures are being taken in all aspects of our lives, including the field of disaster prevention and mitigation. We have experienced large scale storm and flood damage every year for the past several years, so large-scale disasters are sure to occur in the future, and we are studying how to deal with them. There is a wide range of information currently circulating regarding the novel coronavirus, and there may be those who have doubts about an expression like "Corona Era," but here, we use it here to indicate the current state in which we do not have immunity, and live with the possibility that the disease could spread. This applies more broadly than to the current novel coronavirus, and could also apply, for example, to a new influenza virus.

There are two areas of difficulty in dealing with disasters in this Corona Era, particularly related to evacuation efforts. The first is that infected people will evacuate to shelters, producing so-called clusters and spreading the infection. The second is that an increasing number of people are not seeking refuge appropriately for fear of infection and this itself is a threat to their lives. We are working to support disaster response by providing information to help with these issues. Interacting with the chatbot for disaster management can provide support by confirming disaster hazards, checking people's health status, and with decisions whether evacuation is needed or not. Then, if there is suspected infection when checking a person's health before evacuation, SOCDA can automatically provide information regarding suitable facilities that have been prepared by the administration, rather than having a person do it. For people that are considering evacuating, current information regarding evacuation shelters can be provided in a timely manner to encourage appropriate evacuation measures, such as whether they are crowded, or whether appropriate measures to handle infection are being taken. Also, by presenting the option of taking refuge in their own homes based on hazard information such as where flooding is expected to occur, some will be able to avoid the risks of evacuation shelters (enclosed spaces, crowded conditions, close contact), and the risks of traveling to the shelter. An example of a possible interaction with SOCDA for this sort of application is shown in Figure 2.

We call evacuation to protect life, as discussed above, life preserving evacuation, and we have discussed the potential for use of SNS in this phase of evacuation. It is followed by a phase of on-going life at the evacuation location, which we call "ongoing evacuation," and there is also strong demand for SNS in this second phase. The discussion above regarding life preserving evacuation envisioned mainly storm and flood damage, but the situation is somewhat different for earthquakes. Whichever the case, for large scale disasters in the Corona Era, we expect that fully dispersed evacuation will need to be planned. As such, although in the past it was okay to provide the necessary goods and services for ongoing evacuation, such as medical

■ Figure 2: Example of conversation on SOCDA during a disaster considering measures to prevent infection



help, centrally at designated evacuation shelters, in the Corona Era, these must also be provided in a distributed fashion, or each survivor will not be able to receive the support they need. This applies not only to direct support, but is also important for information, and the SOCDA can be used to gather and provide information comprehensively. This involves both (1) gathering information regarding evacuation locations (e.g. finding non-designated or provisional shelter (hotels, etc.) locations) and whether medical treatment is needed, and (2) providing information such as locations where supplies will be available, and providing information necessary to preserve health in ongoing evacuation (e.g. warnings regarding sleeping in a vehicle, etc.).

Most of these features were conceived when R&D on the chatbot for disaster management began, but there was no particular emphasis placed on using it to check the well-being of survivors. In considering disaster response in the Corona Era, this is a significant point of difference from earlier approaches. While it is clear that there is a need to develop a chatbot that can interactively check people's well-being and provide appropriate information in this way, in some cases this could involve handling sensitive information, so various issues regarding operation and organization will require further study, such as who will have access to such collected information, and how will it be used. We also expect that in practical terms, it will be important to have a mechanism to provide specific guidance to an online medical service at an early stage. Discussions on these and other issues will be conducted through the Council on Artificial Intelligence for Disaster Resilience (https://caidr.jp/), which was launched in June, 2019.

5. Conclusion

In this article, we have introduced initiatives using AI with disaster-related information found on SNS, for disaster prevention and mitigation. We first introduced two systems, DISAANA and D-SUMM, which analyze disaster-related information on Twitter. Then, we showed that information posted spontaneously on Twitter is not adequately comprehensive, and we introduced SOCDA, which is a chatbot for disaster management that resolves the issue by implementing bi-directional communication on the LINE SNS. SOCDA is still under R&D, and we will continue working to contribute to disaster prevention and mitigation, while also incorporating features to prevent the spread of the new coronavirus.

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Continuing Evolution of Weather Radar Technology

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1. Introduction

Occurrence of damage due to typhoons, linear-precipitation zones and localized heavy rain has increased recently, and become a new social issue. Weather radar can be effective for observing these sorts of precipitation, spatially and temporally over wide areas, both quantitatively and at fine intervals. Weather radar is operated by various agencies including the Meteorological Agency, the Water and Disaster Management Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), and local governments, and is used for purposes such as managing rivers, drainage and other social infrastructure, for weather forecasts, and to provide information to residents. Japan's weather radar technology is advanced, leading the industry with features such as solid-state transmitters and high-speed observations through electronic scanning. This article gives an overview of weather radar concepts and the development of weather radar technology.

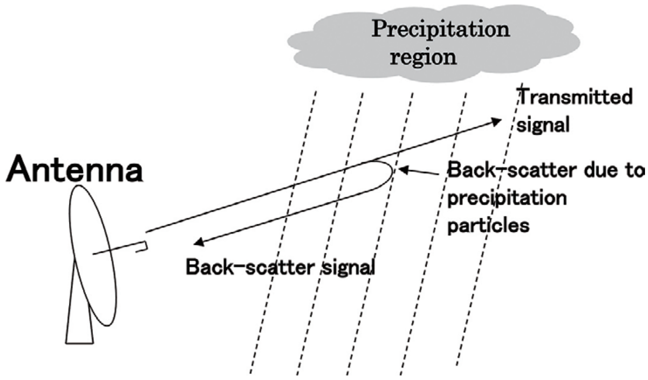
2. Precipitation observations using weather radar

Rain gauges have long been used to understand precipitation, and the Automated Meteorological Data Acquisition System (AMeDAS) operated by the Meteorological Agency takes precipitation measurements, at approximately 840 locations throughout Japan at roughly 21 km intervals, using tipping-bucket rain gauges. Tipping-bucket rain gauges collect and directly measure precipitation so they are very reliable, but they have issues including: (1) they are only able to measure precipitation at the device location, (2) accuracy of instantaneous measurements such as volume/minute is poor, and (3) precipitation amounts can be underestimated if there is cross wind.

In contrast, weather radar observations have advantages including (1) wide area observations ranging from tens to hundreds of km in radius, (2) instantaneous estimates of rainfall, minute-to-minute, and (3) ability to make observations at altitude, and not just at the ground level. In the past, precipitation estimations were not always adequate due to lack of precision and poor maintainability, but these limitations are being removed through new technologies such as dual-polarization observations and solid-state transmitters.

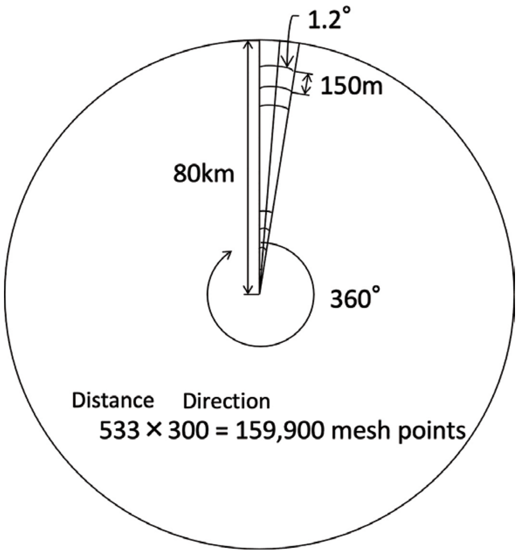
As shown in Figure 1, weather radar transmits radio signals into the air and then the antenna receives the back-scatter signal that occurs when the transmitted signal hits various precipitation particles (rain, snow, hail, etc.) suspended in the air, enabling estimation of the state of precipitation in the air (quantity, movement, particle type, etc.).

■ Figure 1: Weather radar observation principles



Here we use Figure 2 to describe a feature of weather radar: the mesh used for wide-area observations. Typically, the observation range for X-band weather radar is a radius of approximately 80 km, usually operating with resolution of 150 m radially, yielding data from 533 partitions for distance. Direction is divided into 1.2° intervals, yielding 300 partitions over the full 360°. As such, typical X-band weather radar provides measurements at approximately 160,000 points in real time. Characteristics of the data are somewhat different, but in simple terms, a single weather radar installation gives effectively the same results as 160,000 rain gauges deployed over the area.

■ Figure 2: Typical observation mesh for X-band weather radar



3. Development of weather radar technology

3.1 History of weather radar technology

When weather radar was first introduced, large amounts of quantitative observations were not immediately available. The history of the development of weather radar technology is shown in Figure 3.

Initial weather radar sets were analog devices that used a self-excited oscillating electron tube called a magnetron as the transmitter, projected the output signal from the receiver on a black-and-white afterglow display, and indicated rain intensity by brightness. A sketch of this was then made in a darkened room. Later, with the development of digital technology, systems became more stable, high-speed processing became possible, and weather radar capable of quantitative precipitation observations was developed.

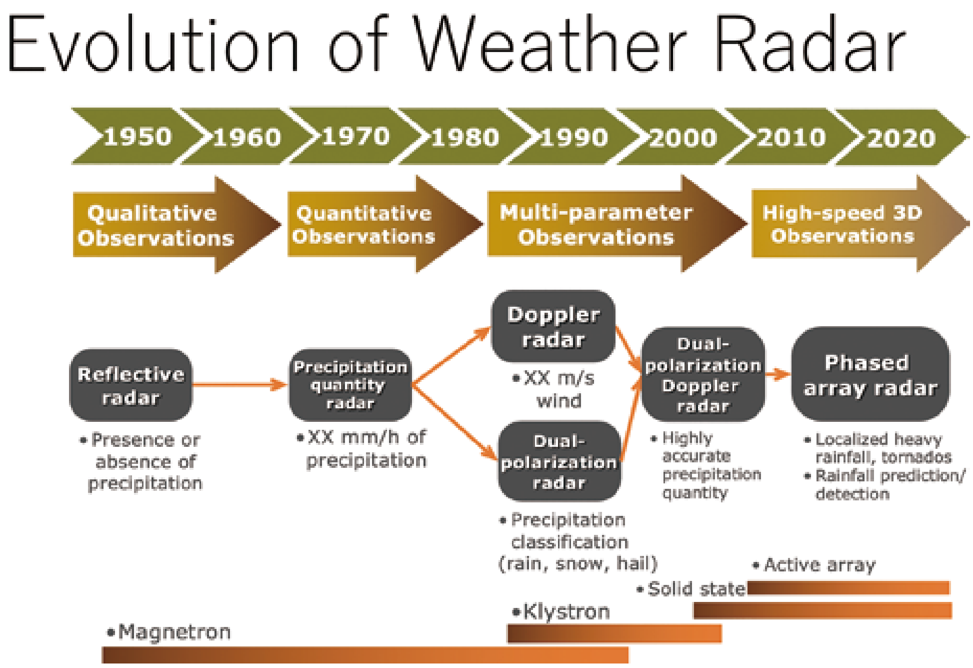
In the 1990s, Doppler radar was developed, capable of observing both precipitation intensity and air flow (estimating wind from phase of the reflected signals). From this time, an amplifying device called klystrons came into mainstream use, enabling stable handling of phase information.

Most types of radar to this point used radio transceivers of only one polarization (generally horizontal), but at almost the same time as Doppler radar was developed, dual-polarization radar, with both horizontal and vertical polarizations, was also implemented. This enabled collection of more information regarding precipitation particles. Observations made using both Doppler and dual-polarization are called multi-parameter observations. Entering the 2000s, radar integrating both Doppler radar and dual-polarizing radar, or true multi-parameter (MP) radar, became practical.

Around this time Japan took the lead in weather radar technology around the world. One factor contributing to this was the development of solid-state transmitters. This was achieved by integrating multiple stages of high-output microwave semiconductors to achieve the transmission power needed for weather radar, successfully transitioning away from the magnetron and klystron electron tube devices (Figure 4). In 2012, phased-array weather radar (horizontal polarization type) was developed, capable of high-speed 3D observations in multiple directions at the same time, and in 2017, multi-parameter phased array weather radar with a dual polarization signal function was developed.

Figure 4: C-band solid-state multi-parameter weather radar

Figure 3: History of weather radar technology



3.2 Multi-parameter observations

Weather radar with a multi-parameter observation function transmits and receives two linear-polarization signals (horizontal and vertical) (Figure 5). As the precipitation particles become larger, they flatten in the horizontal direction due to air resistance (Figure 5). With earlier, non-multi-parameter radar, precipitation volume was estimated from the received intensity of the horizontally polarized signal only, so for the same amount of rain, the volume was over-estimated if the drops were large, and under-estimated if the drops were small, as with light rain.

With multi-parameter radar, both intensity and phase for both horizontally and vertically polarized signals can be measured, and these can be combined to derive various parameters.

The "Specific Differential Phase" (KDP) parameter in particular, has come into broad use to increase the accuracy of quantitative precipitation observations. Radio waves propagating through water travel slower than they do in air. As raindrops get larger, they tend to flatten horizontally, so when radio waves travel through rain, the phase of horizontally polarized signals tend to be delayed relative to vertically polarized signals. Taking the ratio of this phase delay to the rain quantity, regardless of raindrop size, is the principle behind estimation of rain volume using KDP.

Other parameters can also be derived at the same time, including polarization parameters: inter-polarization correlation coefficient (ρHV) and differential radar reflectivity (ZDR); and parameters similar to regular Doppler weather radar: the radar reflectivity factor (Zh), Doppler velocity (V), and Doppler velocity width (W). These parameters help increase the accuracy of precipitation quantity, but are also used in analysis such as particle classification (whether particles are rain, snow, hail, etc.) and determining cloud type (stratification, convectional).

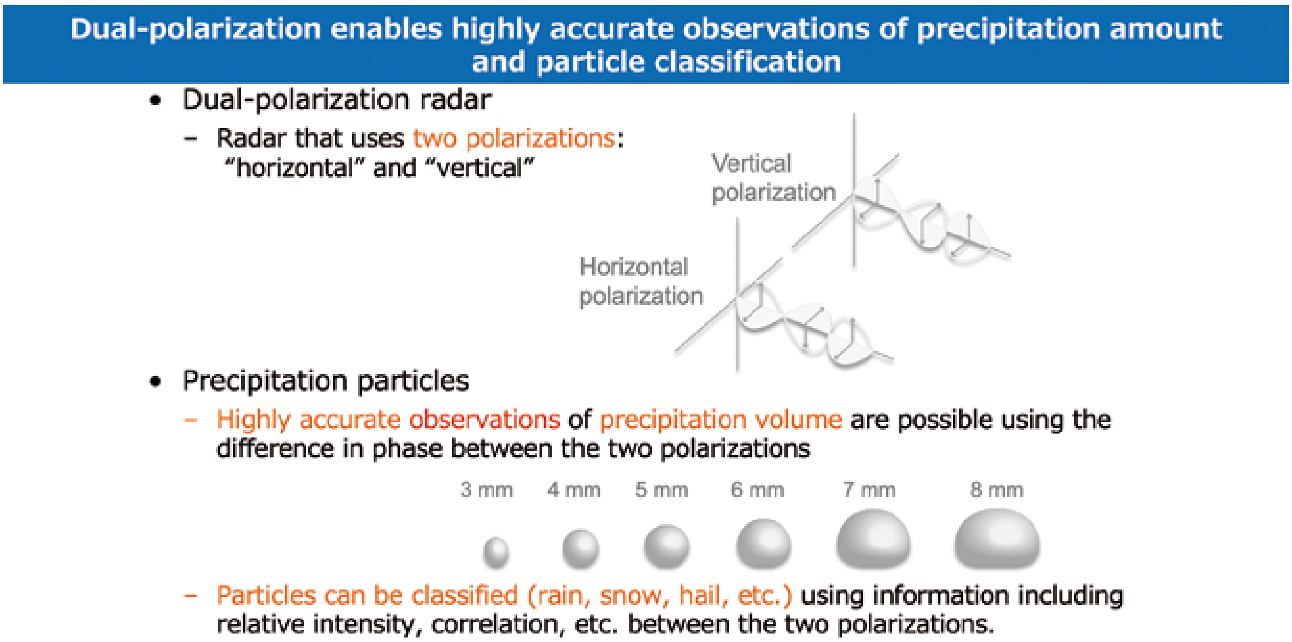
4. Multi-parameter phased array weather radar

Under the direction of a Cabinet Office SIP*1, Multi-Parameter Phased Array Weather Radar (MP-PAWR*2) has been developed (Figure 6), realizing high-density, highly-accurate, and high speed observations. This radar is installed at Saitama University, and is currently undergoing verification tests for real operation.

■ Figure 6: Multi-parameter phased array weather radar equipment (left) and observation range (right)

We now describe the features of MP-PAWR, touching on the differences between MP-PAWR and conventional parabolic-antenna radar. For 3D observations with conventional radar, plan position indicator (PPI) scans are performed, gradually changing the angle of elevation for radar observations. This can take from five to ten minutes to complete. There are also areas spatially between consecutive scans where observations cannot be made. On the other hand, with MP-PAWR, the scan of antenna direction is driven mechanically as with conventional radar, but

■ Figure 5: Dual-polarization radar observation mechanisms



*1 SIP: Cross-ministerial strategic innovation promotion program
*2 MP-PAWR: Multi-Parameter Phased-Array Weather Radar

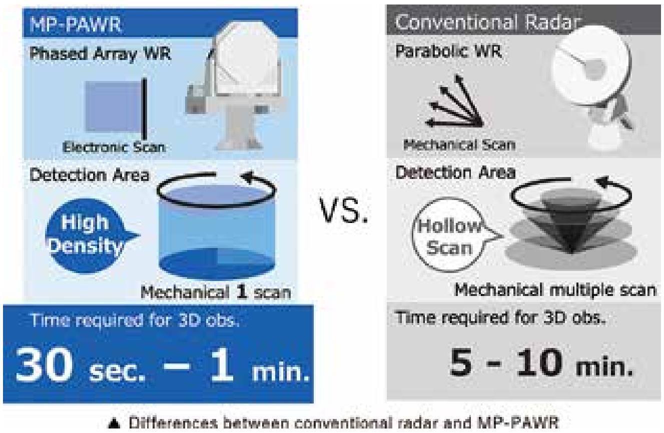
scanning in the vertical direction (altitude) is done electronically. This enables rapid and dense observations of 3D space up to an altitude of approximately 15 km, and requires only 30 seconds to one minute to complete (Figure 7).

Figure 8 shows the results from observations over a 30 s interval, a radius of 60 km and at altitudes up to 15 km. With MP-PAWR, this sort of 3D observation of rainfall distribution can be made every 30 seconds to one minute.

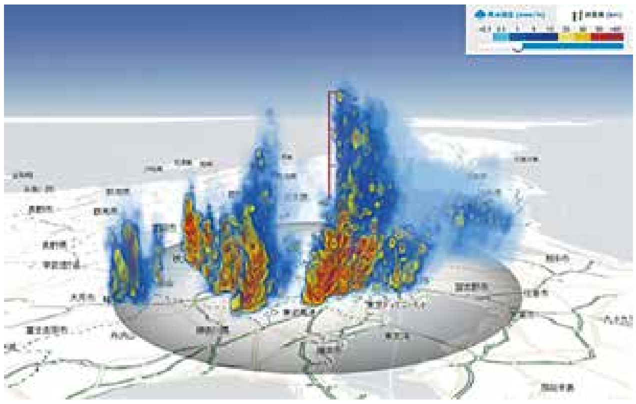
Figure 9 shows how features of MP-PAWR can be used. Various stages of the rapid increase in river water levels after a sudden heavy downpour are represented conceptually as "Raincloud appearance," "Rapid raincloud growth," "Rainfall," and "Water level rise." MP-PAWR is able to observe rainfall amounts in the air at high speed, so during the "rapid raincloud growth" stage before the rain reaches the ground, rainfall can be detected at dense spacing, before it reaches the ground. By computing rainfall in the air based on MP-PAWR observation data detected at this stage, using it as input to predict rainfall amounts, and then to predict water levels, it should be possible in principle to provide this information earlier than with conventional methods.

This approach is comparable to that of emergency earthquake bulletins. For emergency earthquake bulletins, earthquakes are detected, having already occurred at the epicenter, and bulletins are distributed to areas predicted to receive tremors several seconds before they arrive. This information is used to control a range of infrastructure automatically, such as pushing notifications to mobile phones, reducing speed on bullet trains to prevent derailments, and stopping elevators at the nearest floor to prevent people getting trapped.

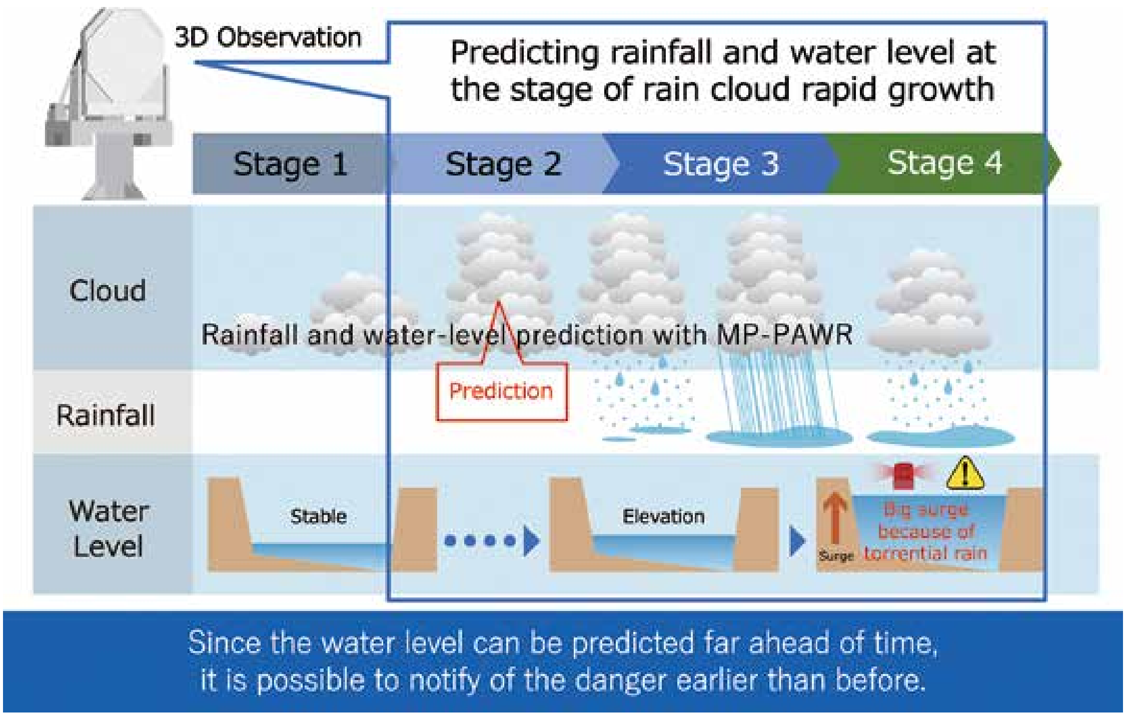
■ **Figure 7: Comparison of conventional radar and MP-PAWR antenna scanning methods**



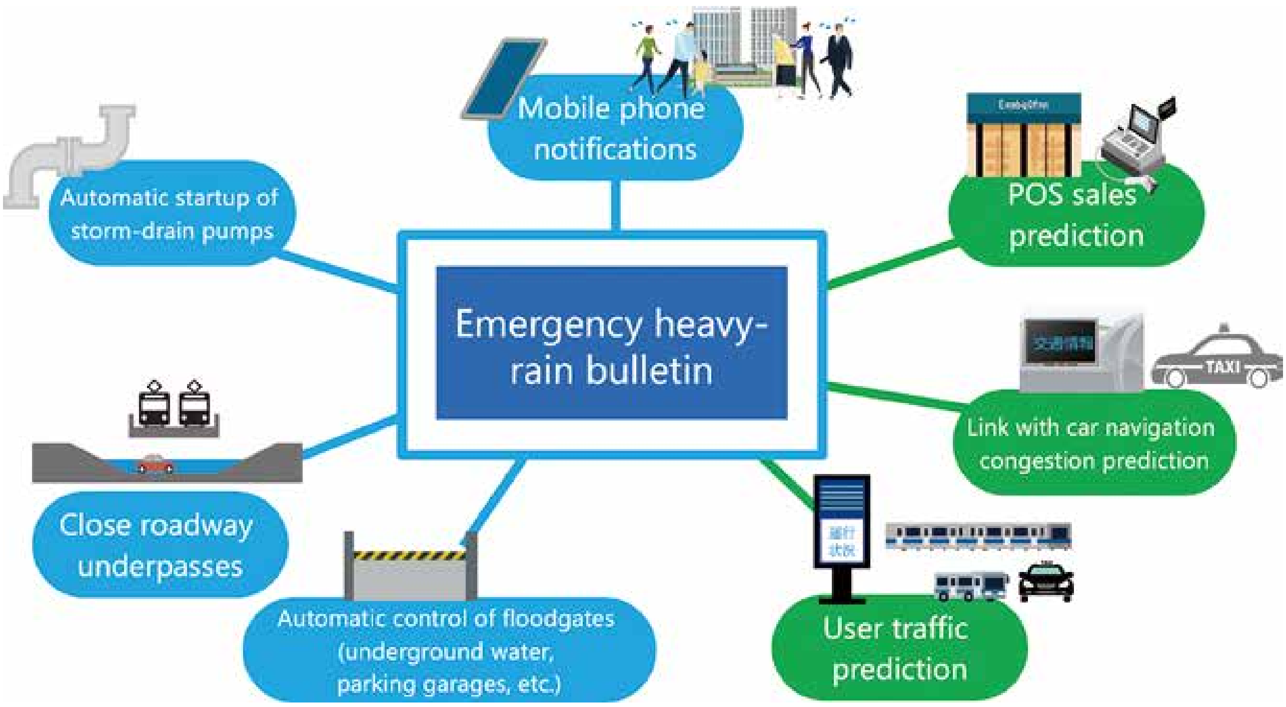
■ **Figure 8: Precipitation observations from MP-PAWR (Aug. 27, 2018)**



■ **Figure 9: Rainfall and water-level prediction with MP-PAWR**



■ **Figure 10: Utilization of MP-PAWR for emergency heavy-rainfall bulletins**



Similarly, emergency heavy-rain bulletins through MP-PAWR could be used to detect and notify of heavy rain that has already occurred in the air, minutes before it reaches the ground. Specific examples are shown in Figure 10, including disaster prevention measures such as automatically starting drainage pumps and stopping entry to roadway underpasses, but also convenience measures such as predicting congestion for car navigation systems.

5. Conclusion

Japan experiences many damage-causing natural disasters including earthquakes, volcanoes, heavy rain and gusty wind, and sudden heavy rain is one such phenomenon that causes damage in society. Reports of conditions made using weather radar and distributed nationally have long been helpful in reducing damage from sudden heavy rain storms.

In the future, we hope to contribute to realizing a safer, more secure society with automatically controlled infrastructure by combining MP-PAWR 3D observations of precipitation before it even reaches the ground, with other technologies such as AI and IoT.

Cover Art

Evening at Takanawa (Takanawa no yukei)

Utagawa Hiroshige (1797~1858)

Collection of the Art Research Center (ARC)
Ritsumeikan University
Object number: BN03828992-1-05

= A Serial Introduction Part 1 = Winners of ITU-AJ Encouragement Awards 2020

In May every year, The ITU Association of Japan (ITU-AJ) proudly presents ITU-AJ Encouragement Awards to people who have made outstanding contributions in the field of international standardization and have helped in the ongoing development of ICT.
These Awards are also an embodiment of our sincere desire to encourage further contributions from these individuals in the future.
If you happen to run into these winners at another meeting in the future, please say hello to them.
But first, as part of the introductory series of Award Winners, allow us to introduce some of those remarkable winners.

Hiroshi Ishikawa

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Fields of activity: 3GPP Core Network Standardization, GSMA Network Group Activities

IMS and 5G Standardization Activities in 3GPP and GSMA

It is a great honor to receive the ITU-AJ Encouragement Award, and I would like to take this opportunity to thank everyone that has supported me, leading to this great award.

One of my first standardization activities was at 3GPP in 2006, introducing Domain Specific Access Control, which allows independent access control for 3G CS and PS domains. I was later involved with IMS and have contributed to "Common IMS," which became the foundation for next generation telecommunication services used by multiple access, including fixed access.

In 2017, I joined 5G standardization activities. In order to roll out 5G in the market as fast as possible, Non Stand Alone (NSA) was standardized first, using existing EPC and supporting enhanced Mobile Broadband (eMBB). At the same time, Stand Alone (SA) has also been standardized using a new core network known as 5GC, in order to support valuable features beyond those provided by eMBB. I contributed to enhancements required in both core networks to provide improved features and user experience compared with the previous system.

I also participated in activities at GSMA dealing with roaming for both 4G and 5G. These included activities to facilitate VoLTE roaming, promoting faster migration from 2G/3G voice roaming, and activities to create new profiles for 5G roaming. While 3GPP defines the features, GSMA defines sets of profiles for its usage, which is important for network operators in rolling out commercial services.

In all of these activities, I believe having active discussions with many delegations, both online and offline, was important to have deeper understanding and contribution to the standards. With networks expected to evolve to 5G, standardizing further 5G network features and methods for migration from legacy networks will be key requirements. I would like to continue to contribute to these activities together with the many other experienced delegates, from both technical and user requirements perspectives, to help evolve the market.

Wataru Ishida

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Fields of activity: ICT development

International Collaboration through APT activities

It is a great honor for me to receive the Encouragement Award from the ITU Association of Japan. I'd like to express my sincere gratitude to all those involved in the ITU-AJ as well as to my supervisors, seniors and colleagues at NTT and NTT East, and the trainees and project members from various countries. In the Global Office of NTT East, I was engaged in international cooperation through the Asia-Pacific Telecommunity (APT), JICA, and NTT Vietnam (currently NTT e-Asia).

For APT, I engaged in the planning and management of human resource development training, international collaborative research, and pilot projects using special contributions from the Japanese government.

In APT training, I planned and managed training courses for policy makers and engineers in the Asia-Pacific region, mainly on broadband, NGN, and e-government, in cooperation with various companies and institutions.

In APT collaborative research, we collaborated with the Advanced Science and Technology Institute (ASTI) in the Philippines and other institutions, conducting proof-of-concept studies such as for agricultural sensing networks in rural areas and investigating and analyzing the correlation between air pollution and traffic volume and flow in Metro Manila.

For APT pilot projects, we carried out a project to build an Internet connection and educational content distribution environment in Indonesia in collaboration with several universities and research institutions in Japan, connecting a city hall, several junior high schools, high schools, universities, and local telecenters.

I hope that results from these efforts will become use cases contributing to solving issues in ICT development, especially in rural areas.

I am currently involved in regional development in collaboration with local governments, local financial institutions, and venture companies, and I am working on designing and building a smart city that will enhance convenience for local residents and tourists, utilizing advanced technologies such as AI and IoT. I would like to continue to work to improve living standards in developing countries, making use of these efforts.

Noriyuki Inoue

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Fields of activity: Spectrum and Radio Regulation

Activity toward reaching a resolution in WRC-19

It was completely unexpected, but I am very happy to receive this ITU Association of Japan Encouragement Award at this time. I would like to offer sincere thanks to everyone at the ITU Association of Japan and everyone in the Japan delegation to APG-19 and WRC-19, from MIC and other organizations, for their guidance and encouragement.

Before participating in WRC-19 as the Japan delegation, I had no idea what sort of assembly the WRC was. I heard from senior members that they competed over frequencies, conflicts of interest occurred, and meetings could continue all night, not reaching a decision until the participants had reached their physical limits. I was given the role of APT coordinator, involving a WRC issue that was considered difficult to reach agreement. Two groups were sharply opposed: one wanting to protect terrestrial business and the other attacking to promote satellite business. As such, to avoid being physically overcome, I paid careful attention to my health as I entered Sharm El Sheikh, Egypt, where WRC-19 was being held.

As the APT coordinator, I was promoting APT proposals created through APG, but many countries have different perspectives on APT. At WRC-19, I could not even get a consistent approval from the various Asian countries, though I would have expected them to be amenable, so at times I felt isolated and helpless. Even so, I had off-line talks with country representatives that had objections, and sought advice from the APG-19 chairperson and others, and was able to get cooperation on APT, to reach a resolution on this issue that was causing so much concern. Fortunately, it did not come down to battle of physical limits.

WRC-19 came to an end, and unexpectedly, I was recommended for chairperson of the Drafting Group for issues in APG-23, leading up to WRC-23. I will take this recognition from the ITU Association of Japan as encouragement, and continue studying and contributing to discussion and creating resolutions at APG and WRC.

Suguru Okuyama

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Fields of activity: Mobile communication

Open Interface Standardization Activities at the O-RAN Alliance

I am very honored to receive this Encouragement Award from the ITU Association of Japan. I would like to offer sincere thanks to the ITU Association of Japan and everyone that has given their guidance and encouragement.

O-RAN was established in February, 2018 by five mobile operators: AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange. The objective was to make Radio Access Networks (RANs) including 5G more extensible, open and intelligent. Today, 230 companies around the world, including 27 operators have joined O-RAN (as of January, 2021).

NTT DOCOMO's 5G network, which began commercial services in March 2020, uses equipment compliant with the O-RAN open front-haul (FH) interface specification, and its biggest feature is that it enables interconnectivity between equipment from different vendors. Previously FH interfaces have generally been vender-specific, O-RAN specifies detailed and comprehensive specifications which enable connections between equipment from different vendors.

O-RAN had participation from more operators and vendors than its xRAN predecessors, so there were companies expressing caution and doubt about feasibility of multi-vendor connectivity in an early discussion phase. I worked tenaciously, repeatedly advocating for the value, feasibility and merits of the effort to both operators and vendors, speaking from NTT DOCOMO's experience with multi-vendor connectivity. I also listened to opinions from other companies and led the discussion using my skill and experience summarizing and guiding the various opinions at 3GPP. As a result, my O-RAN colleagues and I were able to publish the first O-RAN FH interfaces specification in March, 2019.

Hirokazu Kamoda

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Fields of activity: Broadcast Auxiliary Services

Activities related to broadcast auxiliary services

It is an honor to receive this ITU-AJ Encouragement Award. I express my sincere gratitude to the ITU Association of Japan and all those who have given me guidance and encouragement.

I have been acting as a member of the Japan delegation to ITU-R WP5C since 2016, contributing to WP5C mainly on two issues. The first relates to 42-GHz-band wireless systems used in broadcast auxiliary services. This wireless system enables reliable contribution links to be established quickly for HDTV and 4K/8K broadcasting, where neither wired nor wireless communication means exist. I contributed to adding parameters for this system to the recommendation for frequency sharing studies (F.1777). At a time when the frequency identification for IMT-2020 (5G) was taking place, these parameters provided timely input and contributed to the study of frequency sharing.

The other issue concerns WRC-19 Agenda Item 1.14, regarding High-Altitude Platform Stations (HAPS). The 6-GHz band is one of the frequency bands assigned to HAPS and has a regional restriction. WP5C was conducting sharing and compatibility studies to remove the restriction. The 6-GHz band is also used by wireless systems used for live broadcasts and emergency reporting. To examine whether the HAPS interferes with existing fixed wireless systems in Japan, we examined whether the HAPS proponents' sharing conditions were appropriate. I proposed modifying the conditions in consideration of fixed wireless systems in Japan. At the WP5C meeting, I struggled to gain acceptance for our proposal, but it was not accepted. However, through constant negotiations, the parties concerned were able to compromise and agree on a value that could effectively protect the fixed systems. Finally, it was reflected in a new report (F.2437) and the CPM document. I hope both HAPS and existing systems will coexist and develop in better ways.

Through these activities, I was able to experience international negotiations firsthand and learn a lot. I will continue to make efforts to contribute to the effective use of radio waves.

Hiroyuki Saito

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Fields of activity: SG13, SG15

Lessons learned in standardization activities at ITU-T SG13 and SG15

I am very thankful to be receiving this Encouragement Award from the ITU Association of Japan at this time. I consider it yet another gift from everyone who has given their support and cooperation, and I have many to thank.

Through much deliberation on network virtualization and slicing in SG13 and SG15 since 2018, a recommendation was created from our proposed work item in March, 2019 (Y.3151).

One important lesson learned through standardization activities is to discuss issues with delegates from other countries, while understanding and respecting their perspectives. Sometimes I talked with participants from other countries over lunch about topics other than standardization, building good relationships, and this then helped our discussions proceed smoothly. I felt strongly that gaining broad knowledge and education from a global perspective is both interesting and important for cross-cultural communication.

I hope to continue contributing to international standardization activities, participating in deliberation while building good relationships with attendees and others from various countries.

通巻百三十号

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The ITU Association of Japan