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FEATURE

Special Issue on SDG Tech

Special Dialog

KANIE Norichika × TOKUDA Hideyuki

The Role of Information and Communication Technology on the Road to Achieving SDGs

Pick Up

NICT's SDG Tech

Remote Sensing Technology

Space Weather Forecasting Technology

Wireless Network Technology(Underwater drone, NTN)

Resilient ICT

Cybersecurity Technology

Multilingual Speech Translation Technology (VoiceTra)

AI Technology for Dialog (MICSUS)

DUV ICT Device Technology

Quantum ICT Technology

Platform for ICT Research & Development in ASEAN region (ASEAN IVO)

Sustainable Development Goals (SDGs) are guidelines for creating a better future, and all people, organizations, and countries should be aware of them.

In particular, national research institutes are expected to operate with SDGs in mind. NICT's research and development topics include several SDG Tech technologies that can help societies achieve SDGs. The broad variety of these R&D topics reflects the wide range of research and development that we are carrying out in the field of ICT.

For this issue of NICT NEWS, with the theme of "SDG Tech," we have selected ten topics from among the many research and development efforts aimed at achieving SDGs.

SUSTAINABLE DEVELOPMENT GOALS

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FEATURE

Special Issue on SDG Tech

Special Dialog

KANIE Norichika
Professor, Graduate School of Media and Governance, Keio University

Professor KANIE obtained a doctoral degree from the Graduate School of Media and Governance at Keio University and serves on the Japanese government's Round Table at SDG Promotion Headquarters and the Expert Committee for the Promotion of SDGs by Local Governments of the Secretariat for Regional Development. He is also a member of the Earth Commission and is actively engaged in environmental issues both in Japan and overseas. He has been selected as one of the 15 independent scientists who will author the UN's 2023 Global Sustainable Development Report. He currently lives in Washington D.C., where he works on SDGs at the United Nations, so the following conversation was held remotely.

TOKUDA Hideyuki
President National Institute of Information and Communications Technology

He obtained a Ph.D. in Computer Science at the University of Waterloo, Canada in 1983. In 1990, he joined Keio University after working as a Senior Research Computer Scientist at the Department of Computer Science, Carnegie Mellon University, and in 1996 he was appointed as a professor at the Faculty of Environment and Information Studies. He has served as Executive Director of Keio University, Dean of the Faculty of Environment and Information Studies, and Dean of the Graduate School of Media and Governance.
His main areas of research are ubiquitous computing systems, operating systems, distributed systems, and cyber-physical systems. In 2017, he became the President of the National Institute of Information and Communications Technology. He is currently an emeritus professor at Keio University, a member of the Science Council of Japan, President of the Information Processing Society of Japan, Vice President of the B5G Promotion Consortium, a fellow of the Information Processing Society of Japan, a fellow of the Japan Society for Software Science and Technology, and a director of the IEEE Tokyo Chapter.

With the aim of ensuring sustainable development that considers not only economic development but also other factors such as individual freedoms, fairness, and conservation of the environment, Sustainable Development Goals (SDGs) are a set of specific sustainable development targets for the year 2030 that were adopted at the UN Summit in 2015. What contribution can and should information and communication (ICT) technologies be making to these SDGs? We had a chat on this subject with Professor KANIE Norichika of the Graduate School of Media and Governance at Keio University and TOKUDA Hideyuki, President of NICT.

SDGs and ICT have a great affinity

——Nowadays, SDGs are becoming an important issue that must be considered in a wide variety of fields. What are the key points to bear in mind when considering SDGs in the ICT sector?

KANIE SDGs form the core of the mission statement adopted at the 2015 UN Sustainable Development Summit, which was called "Transforming Our World: The 2030 Agenda for Sustainable Development". I think the bit about "Transforming Our World" is the most important point. First, I think it's fair to say that ICT has a very strong affinity with SDGs since it can be a driving force for significant changes in society, so it has an important role to play.
Another important point is that SDGs are just a set of goals. There are no set rules for how to achieve these goals, and people are free to go about achieving them in any way they like, but their progress must be evaluated as accurately as possible. ICT plays a crucial role as the technology responsible for measuring and evaluating the attainment of these goals.

In addition, although the SDGs specify 17 goals, they are not independent. You sometimes see company reports that say they're focusing on one particular item, but in reality, the agenda repeatedly states that these goals are inseparable and should be implemented as a whole. So, ICT is also indispensable for compiling information on all items so that comprehensive judgments can be made.

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TOKUDA Like you just said, ICT has an important role to play, and the NICT has a lot to offer in this regard.

Broadly speaking, the NICT has three functions. Its most important one is the research and development of the next generation of ICT, but it also provides public services such as Japan Standard Time and space weather forecasts, and functions as a funding agency that supports R&D at universities and private companies.

I'll describe our research and development first. Although the SDGs include laying the foundations for industrial and technological innovations, ICT is not only currently essential as part of the social infrastructure that supports industry and everyday living but will also be involved in all sorts of themes as we approach 2030.

In the area of public services, many images from the Himawari weather satellite were recently used in news reports on the explosion of an undersea volcano in Tonga, but in fact it is the NICT that collects all the data from this satellite in real time, converts it into images, and makes it available to domestic and overseas users via a high-speed network.* In this regard, we are also contributing to the dissemination of information and the development and use of space technology.

As a funding agency, we support not only next-generation ICT research promotion projects like Beyond 5G, but also projects that use ICT to solve social and regional issues. For example, NICT proposed and established ASEAN IVO, which is a global virtual organization of ICT R&D institutions and universities in the ASEAN region and Japan, through which we are implementing cooperation between multiple participating organizations in southeast Asia for purposes such as forest fire monitoring projects.

So, the NICT has a multifaceted role, each aspect of which can contribute to the SDGs.

* Himawari real-time web portal: https://himawari8.nict.go.jp/

Quantum ICT expected to deliver energy savings

KANIE From the viewpoint of themes related to the global environment and energy, I'm very interested in quantum computing, which is currently one of the main research themes in ICT. Although ICT plays an important role in the world today, there are concerns that the amount of electricity needed to keep it all running will become enormous. However, quantum computing can significantly reduce the energy consumption of computer systems, which is an interesting direction for the future.

TOKUDA We're also very concerned about energy consumption. It's possible to make a large contribution through initiatives such as "Green by ICT", which uses ICT to promote greener industry, and through environmental monitoring and analysis. But the inescapable fact is that "Green of ICT" cannot be realized due to the large energy consumption of ICT itself.

Due to advances such as the acceleration of AI and the generalization of big data analysis and utilization, large-scale data centers are being put into operation. In fact, NICT also has a data center that is used for research and development of multilingual speech translation technology in the Keihanna area, but even though we're steadily refitting it with energy efficient server equipment, it cannot be denied that its power consumption is still huge.

In this regard, we must move forward with a shift to a new paradigm, such as quantum computing and quantum communication as Professor KANIE mentioned, or the use of neuromorphic chips. These are exactly the sorts of fields where researchers from all over the world are competing, but we must aim to make the technology itself greener. Otherwise, we'll end up with ICT that contributes to energy savings in some regards and negates them in other regards, which would be ridiculous.

Incidentally, there's a team at NICT's Future ICT Laboratory that is looking into how insect brains work, and some day this could lead to the development of neuromorphic chips specialized for AI processing. It's also expected that the development of all-optical networking and computing technologies will enable significant energy savings.

ICT can also contribute to equality and job satisfaction

——In addition to environmental and energy issues, equality and job satisfaction are also major themes in the SDGs, aren't they?

TOKUDA We are now actively promoting work style reforms at NICT. As I mentioned in the New Year's address to NICT staff, the essence of work style reforms is to provide each person in the organization with opportunities for personal growth and development, allow them to demonstrate individual creativity, and create a new sense of fulfillment. I think this is the only way that the diverse individuals of NICT will be able to thrive and carry on creating new ways of working during the pandemic and post-pandemic era.

In particular, the field of ICT R&D is overwhelmingly dominated by male researchers. Although the percentage of female researchers and female career-track employees at NICT is increasing, I think that a better gender balance would also help to balance our future ICT research and development. Our approach to expanding diversity is also one of the major themes in our annual discussions of recruiting strategies.

On the other hand, regarding the employment of people with disabilities, we currently have one of Japan's Paralympic table tennis players, YOSHIDA Shinichi, working here. He says this is a comfortable place to work. In fact, ICT supports a wide variety of roles, so it readily lends itself to providing a workplace that includes people with disabilities. NICT was already introducing remote working before the coronavirus pandemic hit, so we're aware of the need to provide a workplace that suits individual people.

KANIE The under-representation of women in the sciences is an issue that everyone recognizes as important, yet no decisive action has been taken to address it. In high schools and universities, females often achieve better grades in math and science, so I think there's a lot to be said for creating an attractive workplace where women also want to work. But on the other hand, and at least during the transitional period to some extent, I think numerical quotas are still needed.

Regarding the employment of people with disabilities, there have been occasions when I strongly felt the possibility that technology can make it possible for people with disabilities to do the same things as able-bodied people. Last year, I chaired the judging committee of the STI for SDGs award sponsored by the Japan Science and Technology Agency (JST), which recognize initiatives using science, technology, and innovation to solve social issues. The award from the Minister of Education, Culture, Sports, Science and Technology went to a project called Daredemo Piano ("Piano for everyone") that developed a piano where you can play a melody with one finger and have it automatically provide accompaniment and operate the pedals as you play. It was technologically very impressive and should turn out to be very attractive to people with disabilities.

2030 is by no means the final goal

——What points should people look out for in the future?

TOKUDA I have a question for Dr. KANIE.

With the development of the Internet, our living spaces have expanded to include not only physical space but also cyberspace, while at the same time, issues related to safety in cyberspace, like cyber hygiene are becoming very large. Ransomware has robbed businesses of money, and during the COVID-19 pandemic, hospitals have been targeted by cyber-attacks in Europe. In terms of the sustainability of human society, do you think that the safety of cyberspace — or in other words the issue of cybersecurity — should have been clearly stated in the aims of the SDGs?

KANIE Yes, I do. What I can say for sure is that the seventeen goals of the SDGs are by no means perfect as they currently stand. And not just for the cyberspace issue you just mentioned — they're also inadequate for dealing with pandemics such as COVID-19, which humanity is currently being forced to deal with.

In addition, since the SDGs describe themselves as "goals," many people seem to think of them as a final destination, but of course there is a world beyond that point. The year 2030 is just a point we will be passing through.

So about four or five years before we reach 2030, we should start discussing the next set of SDGs, and figuring out what our new objectives should be. When that time comes, I think we should be talking about cyberspace and pandemics.

——Thank you both very much for your time today.

Advanced Electromagnetic Technology Area

Remote Sensing Technology

Radio Research Institute

Remote Sensing Technology for Understanding the Environment and Contributing to a Sustainable Society

HANADO Hiroshi,

Research Manager, Remote Sensing Laboratory, Radio Propagation Research Center, Radio Research Institute

The Remote Sensing Laboratory of the Radio Propagation Research Center, Radio Research Institute is working to meet Sustainable Development Goals (SDGs) through research and development related to electromagnetic wave technology. Achieving a sustainable society requires (1) the construction of a reliable social infrastructure, (2) an understanding of changes and fluctuations in the environment, and (3) a means of responding and adapting to new changes in the environment.

A social infrastructure is constructed from a wide variety of elements, from conservation of national land and provision of electric power, water/sewage, and transport/transportation to disaster prevention and information security, each of which makes use of advanced, high-performance information and communications technology (ICT). Here, it is the use of electromagnetic waves that provides fundamental support for ICT. Since electromagnetic waves are invisible, they are an element like air for human beings in the social infrastructure. At the Radio Research Institute, we are engaged in the research of electromagnetic wave technology to make good use of radio waves as an essential component of the social infrastructure. We are committed to supporting society over the long term and to achieving a sustainable society.

By observing the propagation status and reflection characteristics of electromagnetic waves in a substance, it is possible to grasp changes in the environment over a wide area from a distance. We will introduce in detail specific examples that we are working on in the Remote Sensing Laboratory in the latter half of this report.

A society can respond and adapt to problems caused by changes and fluctuations in the environment by having countermeasures based on scientific understanding and social systems that make them feasible. The Radio Research Institute exploits the characteristics of electromagnetic waves to understand the natural environment, develop realistic technologies based on technical facts to cope with environmental changes, and contribute to a sustainable society.

One theme taken up by the Remote Sensing Laboratory is laser sensing technology for visualizing atmospheric conditions. A feature of this technology is that it can be used to observe extremely small objects such as fine particles (aerosol) and molecules that are difficult to detect by remote sensing technology using radio waves (radar). Differential Absorption Lidar (DIAL) can measure the wind using an aerosol as a tracer and the amount of water vapor by using laser light of two wavelengths that are absorbed by water vapor differently. We are developing technology for a multi-parameter DIAL (MP-DIAL) that can measure temperature by adding a multi-wavelength, high-output laser light source to this DIAL. In this way, we expect that providing data on the temporal-spatial distribution of wind, water vapor, and atmospheric temperature observed by MP-DIAL to a numerical weather model will raise the accuracy of weather predictions and help minimize the damage caused by sudden downpours or tornados, typhoons, and other weather hazards (figure left). Additionally, by adding observations with a wavelength that is greatly absorbed by CO2, the temporal-spatial distribution of wind, CO2, and aerosol can be observed. This will make it possible to understand air-pollution and pollen-dispersal conditions and to monitor an urban environment thereby contributing to the development of comfortable, carbon-neutral cities (figure center).

MP-DIAL is capable of making detailed three-dimensional observations of wind conditions near the earth's surface and can therefore contribute to the safety of upcoming next-generation means of transport and transportation such as drones and skycars (figure right).

We are researching and developing remote sensing technologies using electromagnetic waves including the above laser sensing technologies to help improve disaster prevention and mitigation, enhance the quality of life, and understand changes and fluctuations in the environment.

＊Differential Absorption Lidar (DIAL)
DIAL is a Lidar technique for measuring gas constituents. It can determine the concentration distribution of a gas constituent by making simultaneous Lidar observations with two wavelengths: one that is greatly absorbed by the gas constituent targeted for measurement and the other that is absorbed by a smaller amount.

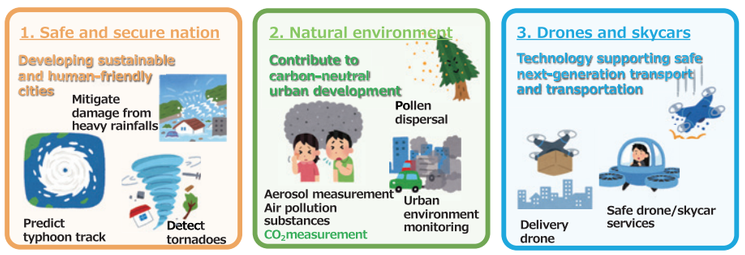

Figure Future Society Pioneered by MP-DIAL
Radio Research Institute: Vision and Mission (https://rri.nict.go.jp/about/vm.html) Excerpted from Fig. 2.7

Advanced Electromagnetic Technology Area

Space Weather Forecasting Technology

Radio Research Institute

Space Weather Forecasting for Constructing a Sustainable Society

ISHII Mamoru,

Director of Radio Propagation Research Center, Radio Research Institute

The Space Environment Laboratory of the Radio Propagation Research Center makes forecasts and distributes space weather forecasts and alerts.
Space weather forecasting involves the monitoring and forecasting of changes in space near the earth caused mainly by solar activity. It is known that large-scale space weather disturbances can affect on our social infrastructure.

The commercial use of high-precision positioning technology using quasi-zenith satellites began in earnest in 2018, and since then, it has come to be used in civil engineering, construction, agriculture, auto-drive vehicles and other fields. In Japan, with its low birthrate and aging population, we can expect this technology to help build a sufficient social infrastructure, ensure a secure food supply, provide countermeasures to traffic accidents, etc. while also enabling advanced applications of drones that are expected to be used for unmanned delivery of goods in a post-COVID society.

On the other hand, it is known that disturbances in the ionosphere, which is one part of space weather, can greatly degrade the accuracy of satellite positioning. In the case of a system receiving a single frequency of radio waves from satellites, it is said that a positive ionospheric storm in which the electron density in the ionosphere is higher than usual can give rise to positioning errors as large as 70 m. Although an increase in ionospheric electron density is not a cause of errors in a system receiving multiple frequencies, the occurrence of "bubbles" within the ionosphere—a phenomenon called plasma bubbles—can lead to extremely complex structures at the boundary and interior of the ionosphere. This, in turn, can cause satellite signals to scatter preventing sufficient reception at a receiver.

Space weather is also an important element in the operation of satellites. In geostationary orbits, it is known that high-energy particles and corona gas from the sun can give rise to errors in electronic circuit signals and that current surges due to satellite discharging phenomena can seriously impact satellite operation. In this regard, businesses that provide Internet services using many low-orbit satellites have been expanding throughout the world in recent years, but there are concerns that disturbances in the atmosphere will affect the orbit of small low-orbit satellites. In particular, there is a phenomenon in which a magnetic storm induced by a large-scale solar storm causes current to flow in the polar regions and the atmosphere to swell thereby increasing the atmospheric friction of low-orbit satellites. A satellite accident thought to be caused by this phenomenon was reported in February 2022.

In addition to solar activity, it is known that the ionosphere can be affected by meteorological and weather changes near the earth's surface. Climate change as typified by global warming is now being studied from a variety of perspectives as a worldwide issue. If global warming proceeds in the troposphere at altitudes below 10 km, research to date indicates that heat that would normally be radiated into space will not reach the upper layers of the atmosphere causing those layers to cool and the altitude of the ionosphere, for example, to decline. It is known that this phenomenon is particularly noticeable in the Arctic and Antarctic regions where airflow is isolated from that of other regions (called a polar vortex). At NICT, we have been making ionospheric observations at the Showa Station in Antarctica continuously since Japan's 1st Antarctic Research Expedition held in the 1957-1958 International Geophysical Year. Analyses based on these data have also supported this tendency for the altitude of the ionosphere to drop over the long term. We are currently investigating the relationship between this phenomenon and climate change.

International cooperation is essential to these types of activities. In the field of space weather forecasting, NICT has been promoting international cooperation for more than 60 years by sharing observation data and forecasts. By preventing accidents from occurring in high-precision satellite positioning and satellite operations through space weather forecasting, NICT aims to support the creation of new industries and the construction of a sustainable society while contributing to countermeasures to climate change with partners from around the world.

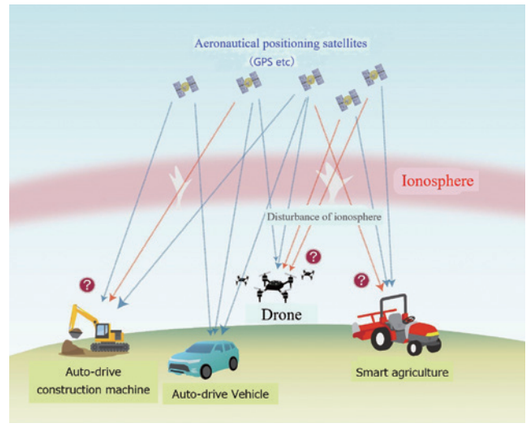

Figure Effects of Space Weather on high-precision positioning

Innovative Networks Area

Wireless Network Technology

(Underwater radio communications, Non-Terrestrial Networks)

Network Research Institute

Securing Communications and Natural Resources with Wireless Technologies that Cover from Subsea to Outer Space

Wireless Networks Research Center,
Network Research Institute

The Wireless Networks Research Center in the Network Research Institute is engaged in research and development on wireless networks to provide reliable connections in a variety of environments and conditions, whether on land, under the sea, in the air or across outer space, as well as wireless communication technology and systems to address different needs. Among the many research projects underway at the Wireless Networks Research Center, we would like to outline two technologies related to SDGs.

The first technology is related to the SDG, "Life below water" and uses underwater radio wave technology. Being an island nation, Japan is fully surrounded by sea and holds the potential to become a resource-rich land in such ocean resources as ocean energy and minerals. Many underwater ocean resources remain undiscovered at depths of hundreds of meters or more, and advanced technologies and innovations will be required for future marine surveys to protect these valuable resources. At NICT we are pushing forward with R&D into under-seabed exploration radar and radio-wave communication technology for effective operation of autonomous underwater vehicles (AUVs) and other devices.

The use of radio wave technology for underwater communications was considered difficult in the past, but R&D into this area accelerated greatly when in 2015 it became possible to measure radio wave propagation to depths of 500 meters using an underwater channel sounder jointly developed by NICT and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). In the ensuing years NICT has developed underwater antenna and established underwater electromagnetic field simulations. We are now verifying high-speed communications in sea water using radio antennas as well as conducting R&D into under-seabed sensing using radio waves. In actual under-sea communication testing, communication speeds of around 1 Mbps have been achieved at a range of 1.5 meters using a frequency of 1 MHz (bandwidth of 83.3 kHz). Radio waves, which are less affected by the influence of turbid water and proximity to other objects, are showing promise as a method of communication in shallow seas, and in the future may have applications beyond ocean resource surveys to such areas as marine life monitoring and the development of overfishing safeguard systems (Figure 1).

Would also like to highlight the Non-Terrestrial Networks (NTN) initiatives being undertaken in relation to the SDG, "reducing inequalities within and among countries". As implicit in the term, digital divide, gaps in information arise when we use information and communication technology (ICT). The ITU announced in 2021 that 2.9 billion of the world's population have not yet used the Internet and 96% of this group reside in developing countries. In African countries, the digital divide still exists between urban areas and other regions. From the standpoint of communication infrastructure, the use of NTN will deliver quicker Internet access to the many areas in Africa where it is difficult to install wired Internet. Also, while the penetration rate of mobile broadband in Africa is extremely high at over 90%, there exist areas with 4G access and areas where only 2G services are available. In Japan the penetration rate for 4G and even 5G continues to increase year on year, but a large-scale natural disaster or accident could knock out base stations and render the Internet unavailable immediately.

NTN is a technology concept for coordinating satellite and ground communication systems to enable Beyond 5G / 6G networks to connect to the Internet at different locations on earth through vertical connectivity from ground and sea to air and outer space. An ultra-thin flat antenna enabling high-speed high-capacity communications was developed by NICT as one of the platform technologies to realize NTN. The antenna has been installed in aircraft and evaluated for performance. If NTN with global coverage becomes a reality, Internet access will become available in areas not equipped for wired-Internet, such as polar regions, deserts, at sea or outlying islands. NTN will also provide backup in times of large-scale disasters when ground-based communications are unavailable (Figure 2).

The Wireless Networks Research Center will continue to conduct R&D activities aimed so that technologies using under-water radio waves and NTN will help to achieve SDGs in the future.

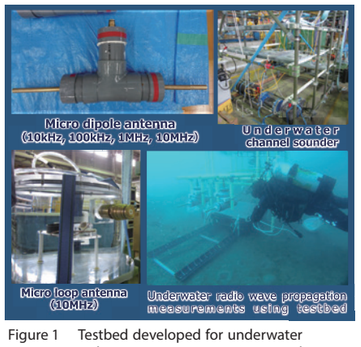

Figure 1 Testbed developed for underwater radio wave communications and view of underwater experiment

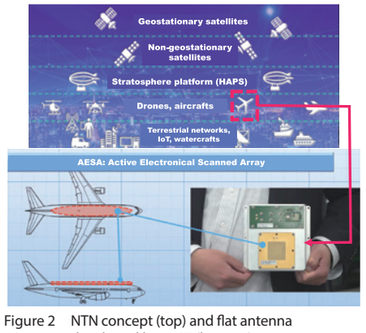

Figure 2 NTN concept (top) and flat antenna developed by NICT (bottom)

Innovative Networks Area

Resilient ICT

Network Research Institute

ICT for Making the World more Resilient

ICT with resilient properties and ICT to make the world resilient

Resilient ICT Research Center,
Network Research Institute

The occurrence of such threats as earthquakes, tsunamis, typhoons, landslides, flooding, avalanches, heatwaves, volcanic eruptions and disease is resulting in the loss of life and social infrastructure in regions all over the world. The realization of "resilient" communities that can guard against such threats, minimize the effects as much as possible and recover quickly is explicitly expressed in the Sustainable Development Goals (SDG) 9, "building resilient infrastructure", and 11, "making cities and human settlements resilient".

The Resilient ICT Research Center is engaged in R&D activities under the catchphrase, "Toward making the world more resilient with ICT", and is promoting community use of our R&D outcomes.

The R&D themes are "ICT with resilient properties" and "ICT for making the world more resilient". The first theme is comprised of three components. The first component is wireless access technology adapted to tough environments that aims to deliver low-latency, highly reliable communications even in tough electromagnetic environments where existing wireless technologies struggle to deliver communications. The objective is to be able to establish alternative connections before the connection in use breaks, known as "make-before-break", providing continuous communication services even in tough electromagnetic environments that suffer from frequency overcrowding and /or transmission complexities, as well as in environments where transmission loss is greater than that prescribed by 5G (3GPP Release 17).

The second component is technology to improve the resiliency of optical networks. We are applying machine learning and other technologies to detect signs of failure in optical networks and conducting R&D of the technology that actively avoids malfunctions. In addition, we are developing interconnection infrastructure technology to improve resiliency by enabling the interconnections and integration of heterogeneous optical network resources which is becoming more difficult as standards become more open. We are also pursuing development that enables optimal utilization of both communication network resources and computing resources (cloud computing). We are developing infrastructure technology for coordinating communication and computing resources to match supply and demand and to speed up fault recovery in the case of large-scale failures and disasters.

The third component of our R&D is the study of edge cloud that function on these resilient networks. Currently, cloud-based information services are the mainstream, and these services are also used for information sharing during times of disaster. However, in disaster scenarios communications are often unstable which hinders information sharing. We are working on research for autopoietic edge cloud technology that continuously provides virtual edge cloud functions by sharing the computing and communication resources of nodes among edge nodes as if cloud services were not affected even in environments of unstable communication.

On the second theme of "ICT for make the world more resilient", we are engaged in research on composite analysis and visualization of various environmental measurement data. Our long-term goal is to establish regional resilience information infrastructure that can detect incidents such as fires, eruptions, river flooding and avalanches, identify and track the location and progress of these incidents, and issue alerts and warnings by integrating data on a GIS space-time data platform and performing composite analysis and visualization. Forming the core of this infrastructure is "Visual IoT" technology that transmits high-resolution video images with low latency even over mobile lines and "Infrasound" sensing technology.

Besides testing these technologies in such areas as Onagawa in Miyagi Prefecture, which was devastated by the Great East Japan Earthquake, Shirahama in Wakayama Prefecture, preparing for an earthquake in the Nankai Trough, volcanos in the Kyushu district, landslide areas in Sri Lanka and mountainous regions of Nepal, we are also moving ahead with the deployment of a disaster prevention and management system in Konan City in Kochi Prefecture in collaboration with the private sector. In addition, we also operate the Resilient ICT Research Council and conduct activities to establish technical standards, including publishing guidelines on the use of resilient infocommunication networks and providing information to ITU and APT.

Figure R&D of the Resilient ICT Research Center and National Resilience Initiatives

Cybersecurity Area

Cybersecurity Technology

Cybersecurity Research Institute

KASAMA Takahiro,

Associate Director of Cybersecurity Laboratory, Cybersecurity Research Institute

INOUE Daisuke,

Director of Cybersecurity Nexus, Cybersecurity Research Institute

Cybersecurity Technologies for Sustainable Development Goals

The number of Internet users was estimated to be 4.9 billion people in 2021, accounting for approximately 63% of the world's population. The Internet is indispensable to our daily lives. Therefore, making the Internet space a safe, secure, and freely accessible place for everyone is an essential factor in efforts to overcome various real-world limitations and solve the many challenges presently faced by people around the world.

While the Internet benefits our lives, cyberattacks on the Internet have become a serious social issue. For example, the malware Mirai appeared in 2016 and infected hundreds of thousands of IoT devices around the world, including routers and webcams left with default ID/Passwords. By exploiting the vulnerability of these IoT devices, the attacker launched a DDoS (Distributed Denial of Service) attack, thereby flooding networks with traffic in excess of 600 Gbps and causing harm to many organizations. Additionally, damage from cyberattacks can be wide ranging, from data leaks of confidential corporate information to operational shutdowns of critical infrastructure, such as petroleum plants.

The Cybersecurity Laboratory in NICT is engaged in research and development (R&D) of practical cybersecurity technologies to counteract increasingly more serious and sophisticated cyberattacks. This paper outlines the NICTER cyberattack observation and analysis system that is one of the major R&D projects being undertaken by our laboratory.

NICTER observes and analyzes cyberattacks happening now on the Internet by conducting observations of traffic arriving at unused IP addresses known as the darknet. The figure below shows a visualization of darknet traffic. Through collaborations with domestic and international research institutes and other organizations we are building the world's biggest darknet monitoring system with approximately 300,000 IPv4 addresses. Normally, packets from the Internet should never arrive at unused IP addresses. However, large volumes of cyberattack-related packets arrive daily, including scanning activity by malware searching for next infection targets. Analysis of darknet monitoring results enables us to identify malware-infected devices around the world and gain a real-time understanding of indiscriminate cyberattack activity. NICTER observed 518 billion packets arrived at our darknet in 2021, indicating that five years after Mirai appeared active cyberattacks on IoT devices continue even today. Through NICTER's observations and analysis, we are identifying new threats on the Internet and engaging in R&D aimed at delivering countermeasures.

From February 2019 NICT has also been conducting the NOTICE project with the Ministry of Internal Affairs and Communications. NOTICE cooperates with Japanese Internet Service Providers (ISPs) to survey vulnerable IoT devices with easily guessed ID/Passwords and alerts the owners of these devices to the problem. As of January 2022, NOTICE has notified ISPs of information on more than 30,000 vulnerable IoT devices in Japan. Details on NOTICE and progress on the project can be found at the official homepage (https://notice.go.jp/en/).

NICT will continue its R&D of countermeasure technologies against cyberattacks, as well as maintain its commitment to promoting social deployment of research results and contributing to the realization of sustainable Internet spaces for the achievement of sustainable development goals.

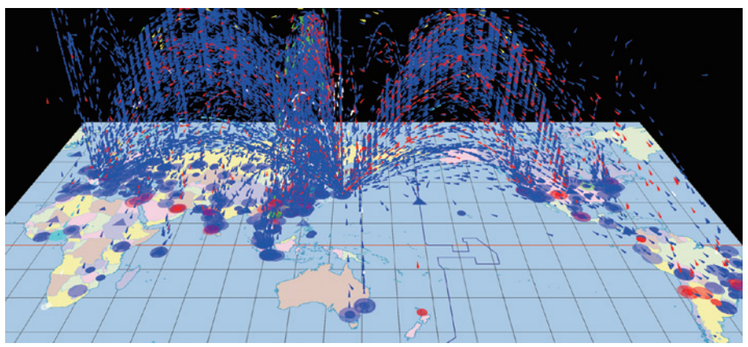

Figure Visualization of cyberattack-related traffic observed by NICTER

Universal Communication Area

Multilingual Speech Translation Technology (VoiceTra)

Universal Communication Research Institute

UCHIMOTO Kiyotaka,

Director General, Universal Communication Research Institute

Eradicating Inequality between People and Nations using Technology that Removes Global "Language Barriers"

In recent years, despite rapid globalization, many people are still reluctant to speak English or other global languages, and such native language differences are hindering equitable interaction. At NICT, we have researched and developed our own multilingual speech translation technology to eliminate this language inequality and realize a society free of language difficulties. This technology is packaged in the network-delivered speech translation application, VoiceTra®, which is now available on AppStore and Google Play. The VoiceTra app is ideal for travel phrases and supports text translations of 31 languages. Speech spoken into a smartphone is, as shown in the diagram, sent to a server over a network, where it is processed utilizing speech recognition, machine translation and speech synthesis technologies. The translated speech is then sent from the server back over the network to be displayed on the user's smartphone. All processes taking place within the server employ a mechanism of learning and processing from a language database (corpus) based on deep learning. The accuracy of speech translations is largely dependent on the capacity and quality of the underlying corpus. At NICT, we have achieved high accuracy by focusing in on specific areas and even utilizing VoiceTra access log information to construct an efficient corpus. To date, we have expanded coverage from travel phrases to fields such as daily conversations, disaster response, and medical discussions. We also recognized that real data, such as VoiceTra log information, is useful for other purposes as well. NICT has utilized VoiceTra's log data to develop technology that can immediately and accurately identify the language of the input speech from multiple languages. With this technology, for example, you will no longer need to select a language on information robots or touch panels, and you will be able to connect effortlessly to call center operators that can assist you in your own language. This automatic language identification technology is also embedded in the VoiceTra app so it's available to try out. These technologies have undergone testing conducted by industry-academic-government collaborations, and their adoption in various forms in private sector services has resulted in multilingual speech translation technology becoming commonplace. Several commercial products and services* adapted to specific fields or usage scenarios have also been created. These products and services are the result of licensing of NICT's multilingual speech translation technology. Being licensed to this technology makes it possible for one to set up on-premise servers and provide services. The purpose of using multilingual speech translation technology is to aid communication, and private sector services are implementing innovative measures to more comprehensively support communications by incorporating other tools and technologies. For example, efforts have been made to find the best combination of technologies to match usage scenarios. These include using multilingual speech translation technology in conjunction with maps or other visual tools, or for connecting seamlessly to telephone interpreting and other such services. We also expect that new ideas on useful ways to leverage this technology will emerge and lead to the creation of more new services in the future.

Although the Covid-19 pandemic has resulted in a dramatic decrease in the number of foreign visitors to Japan in recent times, there has been growing demand for multilingual speech translation technology to be used for such purposes as foreign resident services, remote tourism and virtual conferencing as remote communications increasingly becomes the "new normal." Hoping that our efforts will help eliminate global language barriers, as well as assist in eradicating inequalities between people and nations, in particular the inequality of language, we at NICT are further promoting R&D in partnership with the private sector in an aim to not only advance the consecutive translation capabilities packaged in VoiceTra, but also achieve low-latency AI-driven simultaneous interpreting functions for use in business and international conferencing scenarios.

* https://gcp.nict.go.jp/news/products_and_services_GCP.pdf (in Japanese)

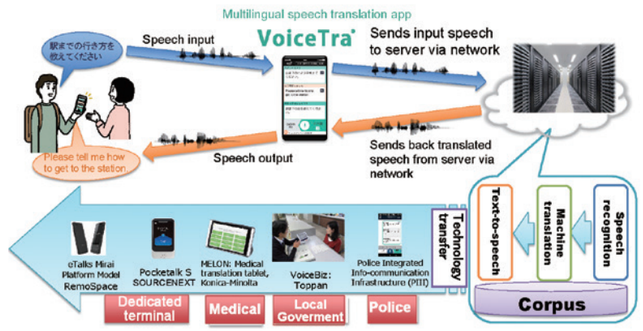

Figure Social implementation of network-based multilingual speech translation technology and system (examples)

Universal Communication Area

AI Technology for Dialog (MICSUS)

Universal Communication Institute

AI Technologies for Spoken Dialog (MICSUS) Research and Development of a Multimodal Interactive System for Care of the Elderly

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When providing what is called care monitoring, qualified care managers visit the homes of elderly people to assist or provide nursing support and assess their health status and/or lifestyle habits. Data obtained from these assessments is used for devising care plans. As care managers regularly look after dozens of senior citizens, assessing each one of them at least once a month for about an hour each time, it is believed that they spend 60% of their workday on care monitoring, including related commuting and report writing. To replace some of these in-person care monitoring duties, NICT has been developing MICSUS, a multimodal*1 interactive system, in partnership with KDDI, NEC Solution Innovators and the Japan Research Institute, as well as with the support of the 2nd period of the Cabinet Office's Strategic Innovation Promotion Program (SIP). This spoken dialog system performs health status assessments based on care management standards*2 via verbal interactions with a terminal embedded in a stuffed toy dog. The system can also recognize the emotional state of elderly users by analyzing their facial expressions, which in turn informs subsequent conversation topics*3.

The system keeps interactions going by asking questions on health conditions and similar topics while also engaging in casual conversations using information collected from the Web and other sources (from tasty ways to prepare foods favored by senior citizens to chats about the music or hobbies they like). The responses from the elderly, however, are interpreted using state-of-the-art deep-learning technologies. For example, when the system asks, "do you eat three meals every day?", even indirect responses like "my stomach is in a good shape lately" are interpreted accurately. Data on these interactions is also sent to care managers in the form of concise summaries, such as "eats three meals a day", which can help reduce the time required to devise care plans.

In fact, the true objective of MICSUS goes beyond replacing care monitoring duties. MICSUS allows conversations to be held at any time which means care managers do not have to commit to the current once-a-month in-person assessment schedule. Depending on the situation, daily interactions with elderly users may yield timely information and even improve the quality of care delivered. Additionally, care managers are able to entrust most health checks to MICSUS and focus their energies on more serious cases requiring in-person intervention. Engaging the elderly in casual conversations and other interactions using information from the Web is also thought to help prevent or alleviate the growing problems of social isolation and lack of human contact that have emerged over the past few years. These problems are assumed to increase mortality rates among senior citizens. Results of recent testing in which elderly residents of a care home engaged in conversations of 5 to 15-minutes over a 15-day period showed that MICSUS can assess health status with an extremely high level of accuracy (Figure). We are committed to performing additional testing to further increase the level of integrity of the system.

MICSUS is also being considered for possible application in such fields as education. There is potential to use the system to educate children by engaging them in conversations, for example about history, taking advantage of such technologies as NICT's advanced Q&A technology*4, which answers questions like "Why was Japan able to rebuild so rapidly after the Second World War?", or "What will happen if global warming continues?". In this scenario we believe that MICSUS could engage children in discussions that are more than just simple conversations or quizzes on memorized facts and extend their range to such topics as causal relationships behind various historical events, with the aim of helping young users to learn mature decision-making skills they will need as they move into adulthood.

*1 Recognizes not only spoken dialog but also the user's facial expressions and gestures, thereby informing subsequent interactions
*2 Technique that enables delivery of care management above a certain standard as required by users by sharing and organizing the knowledge of care managers and other care support professionals https://www.jri.co.jp/page.jsp?id=38679 (in Japanese)
*3 Please refer to https://www.youtube.com/watch?v=gCUrC3f9-Go (in Japanese) or https://keihanna-fair.jp/exhibition/ai/899 (in Japanese) for video presentations on how the system operates
*4 Released as the large-scale WEB information analysis system, WISDOM X. This system is free to use at https://www.wisdom-nict.jp/ (in Japanese).

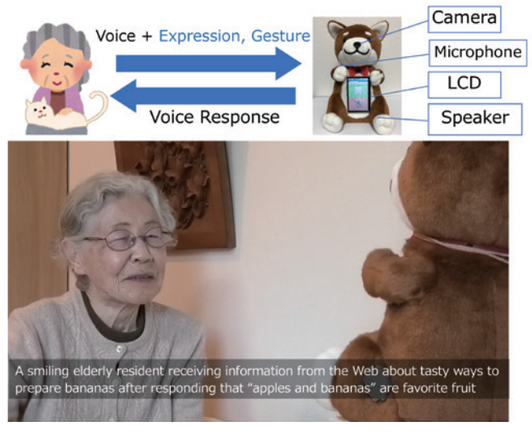

Figure Elderly care-home resident interacting with MICSUS during testing

Frontier Science Area

DUV ICT Device Technology

Advanced ICT Research Institute

Deep-Ultraviolet Light Technology Contributing to a Safe and Secure Life and Preservation of the Global Environment

INOUE Shin-ichiro,

Director of DUV ICT Device Laboratory, Advanced ICT Research Institute

In recent years, grave concerns about the COVID-19 pandemic, water shortages due to climate change, and environmental contamination due to mercury and other substances have spread on a global scale. Against this background, deep-ultraviolet light-emitting diodes (DUV-LEDs) having an exceedingly strong bactericidal effect have been attracting attention as a new means of using science and technology to deal with risks in the global environment that have taken form along with ever expanding human activities (Figure).

The DUV region is usually defined as the wavelength range from 200 nm to 300 nm. Photochemical inactivation of viruses and microorganisms is most effective with photons in the 100- to 280-nm wavelength range (called "UV-C photons") with a peak effectiveness near 265 nm, which is the approximate absorption maximum wavelength for DNA and RNA. Liquid agents like ethanol and sodium hypochlorite are effective for decontaminating hands and fingers or the surfaces of objects (virus inactivation) and are today widely used in this capacity. However, liquid agents cannot be used against aerosol infection, which has become a problem as one of the transmission routes of the COVID-19 virus, so they have not been established as an effective inactivation technique in this area. Under these circumstances, DUV-LEDs that can inactivate viruses and bacteria cleanly through optical radiation without resorting to chemical agents hold the possibility of becoming an effective tool for controlling the spread of aerosolized viruses.

Mercury lamps—a type of gas-discharge lamp—have been widely used as a DUV light source. These lamps, however, are limited in their range of use given their size as a light source and their high driving voltage, and they also include mercury, which is detrimental to human health and the environment. Mercury has the property of evaporating easily at room temperature, and if it happens to be discharged to the outside, it will diffuse into the atmosphere contaminating soil and water and accumulating on a global scale. It has also been pointed out that high concentrations of mercury can be found in large fish and shellfish as a result of bioaccumulation along the food chain. As a result, the international treaty "Minamata Convention on Mercury" went into effect in 2017 reflecting an accelerated effort to phase out mercury products. It is against this background that the development of technology for a new semiconductor solid-state light source as an alternative to mercury lamps has become desirable. Rapid progress has been made recently in the development of AlGaN-based DUV-LEDs. However, despite numerous development efforts, conventional DUV-LEDs continue to have much lower output powers than that of mercury lamps. From a practical viewpoint, one of the most challenging applications for DUV-LEDs is the replacement of traditional high-power mercury lamps.

At NICT, we conducted research and development on DUV-LEDs to provide a high-power and environmentally friendly DUV light source to solve these problems. We have successfully demonstrated high-power DUV-LEDs by developing nanophotonic structure technology and a variety of device technologies to solve the problems of extremely low light extraction efficiency and efficiency droop in AlGaN-based DUV-LEDs. We have developed, in particular, a single-chip DUV-LED that produces a world-record continuous-wave output power over 500 mW at its peak emission wavelength of 265 nm, which is the most effective wavelength for disinfection.

The development of environment-friendly, compact, portable and high-output DUV-LEDs not only solves environmental problems by replacing mercury lamps, but also potentially solves a wide range of social problems such as supplying safe drinking water to regions having no water purification facilities, disinfecting the ballast water of ships to preserve the marine ecosystem, and inactivating aerosolized viruses through use in air purifiers and air conditioners to prevent virus diffusion and spread of infection.

This high-power 265 nm DUV-LED irradiation system developed by NICT has been used to successfully inactivate aerosolized severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) within very short irradiation times in collaboration with Professor Yoshihiro Kawaoka's group at The Institute of Medical Science, The University of Tokyo. For more details please see the following :

https://doi.org/10.1128/msphere.00941-21.

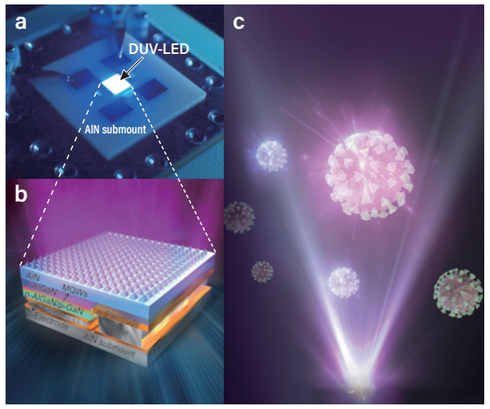

Figure (a) Photograph of the single-chip DUV-LED developed by NICT
(b) Schematic of the DUV-LED layer structure
(c) Image of DUV irradiation of viruses

Frontier Science Area

Quantum ICT Technology

Advanced ICT Research Institute

FUJIWARA Mikio,

Director of Quantum ICT Laboratory,
Advanced ICT Research Institute / Director of
Quantum ICT Design Initiative,
Quantum ICT Collaboration Center

Toward Safe and Resilient Secure Cloud Services through Quantum ICT

Quantum computers have received much press coverage in recent years, since their use, if made practical, will make it possible to immediately solve problems that up to now have been unsolvable. In this capacity, they are expected to find application in a variety of fields. On the other hand, quantum computers can instantly break cryptographic techniques that are currently used on the Internet, so they also come with risks that can threaten the safety of communications.

In response to this issue, there is much activity in the research and development of technologies for achieving safe communications even if quantum computers should come into practical use sometime in the future. Amid this activity, NICT is researching and developing "quantum cryptography" as a technology that can eliminate the threat of eavesdropping regardless of what kind of computers are developed in the future. Quantum cryptography is defined as a combination of (1) quantum key distribution (QKD) that shares a random number with "information-theoretic security" between distant parties and (2) confidential communications using Vernam's one time pad that performs a bit-by-bit exclusive OR operation with the shared random number (key shared by a QKD) at the sender and receiver. At NICT, we have constructed a quantum key distribution network in the Tokyo area (100 km area) using the optical fiber test bed of the Japan Gigabit Network (JGN). Our network (Tokyo QKD Network), which has been in operation since 2010, has the most operational achievements in the world as a quantum key distribution network. In addition to researching confidential transmission, we are also involved in implementing "secret sharing" protocol on this network and in demonstrating distributed storage of data with information-theoretic security. A QKD network equipped with these functions is defined as a "quantum secure cloud," which we are now researching and developing (Figure). As a target of experimental verification, we are promoting trials toward the social implementation of quantum secure clouds using genome data and electronic health records as primary examples of data that needs to be kept confidential over an ultra-long period of time. We have conducted a demonstration of distributed storage of electronic health records within a quantum secure cloud, successfully tested technology for high-speed distributed storage of updates generated by daily transaction data among Tokyo metropolitan public hospitals, and achieved mutual referencing of healthcare data among regional institutions. Additionally, given the nearly yearly occurrence of large-scale disasters in Japan in recent years, we can envision the damage of hospital health records by such a disaster, and with this in mind, we successfully restored information on patients in an acute stage within several seconds from a quantum secure cloud. Additionally, in another experiment, we successfully restored data using a geostationary satellite.

Furthermore, while drug discovery and medical treatment using genome data have become familiar achievements in recent years, technology for protecting genome data—the ultimate in personal information—has been lagging. At NICT, we aim to establish technology for making genome data useful to medical care without having to worry about security through quantum secure cloud technology.

We are also equipping our quantum secure cloud with a powerful computing engine to achieve a system that also enables the safe use of data. This system will prevent unnecessary personal information from being disclosed when using data and will present to medical personnel only the data required for treatment. This function is not limited to the medical field. It can be used, for example, to make it easier to "create new knowledge" from corporate proprietary information in industry, finance, and other fields, the source of Japan's economic growth, and to dispel concerns about leaking information to foreign countries when using an overseas cloud service. In this way, we expect the quantum secure cloud to become a platform for a new era of data usage.

At NICT, we are developing technologies that can only be achieved at NICT by fusing the quantum technologies possessed by the Quantum ICT Laboratory and advanced technologies possessed by other research laboratories and R&D centers. We also seek to accelerate the efficient expansion of medical and industrial technologies using quantum technology as a driving force and to contribute to sustainable development.

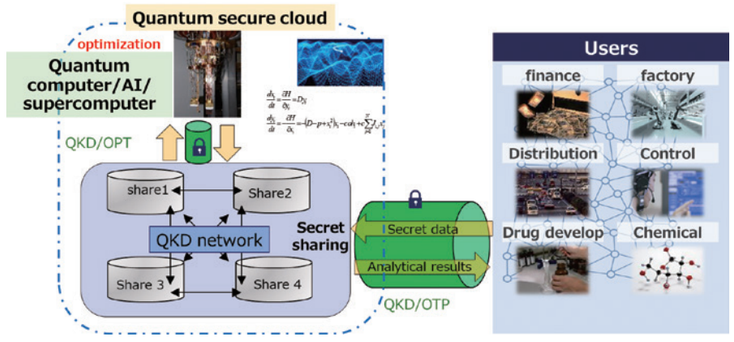

Figure Concept of a Quantum Secure Cloud

Open Innovation

Platform for ICT Research & Development in ASEAN Region (ASEAN IVO)

Global Alliance Department

EMOTO Hiroshi,

Director, International Research Development Office,
Global Alliance Department

Achieving SDGs With ASEAN IVO Initiatives

In February 2015, NICT established ASEAN IVO (ICT Virtual Organization of ASEAN Institutes and NICT) in partnership with a number of research institutes and universities in Southeast Asia. The purpose of this organization is to build an open innovation platform with close connections to the region, with the aim of sharing views on the resolution of societal issues shared by each country and solving common issues through the formation and promotion of joint research projects in the ICT field. With the aim of providing the ASEAN region with solutions to issues such as food supply, smart cities, and disaster resilience, which are also the subject of SDGs, ASEAN IVO holds an annual forum. Countries, organizations and research institutes can share policies for tackling current issues and ideas for approaching future projects and can work towards achieving SDGs through collaborative joint research projects selected by open recruitment.

The ASEAN region is densely populated and predominantly agricultural, which presents challenges in terms of food and water supply. ASEAN IVO has furtherevd projects such as an IoT-based field irrigation system, an IoT-based system for vegetable cultivation in greenhouses, a monitoring system for aquaculture farms, a platform for water management in rice paddies (see Figure), an IoT-based urban agriculture system, a non-invasive food safety confirmation system, and a system for the reuse of water in urban areas of developing countries to tackle the issues in industries such as agriculture, fishing, and water supply.

Due to rapid urban modernization and explosive population growth, ASEAN countries face societal issues including the need for modernizing social infrastructure such as transportation and communication while tackling chronic traffic congestion and ensuring the safety of communication. At ASEAN IVO, we are working on the development of communication methods such as mobile IoT and radio over fiber, and we are developing solutions such as secure communication networks and safe handling of industrial information. We are also promoting the use of new communication methods to improve the efficiency of urban bus transportation systems. By promoting these projects, we are contributing to the realization of smart cities through sustainable urban development and the provision of enhanced living environments.

Natural disasters such as typhoons, floods, earthquakes, tsunamis, and volcanoes have a huge impact on society. With the objective of minimizing the impact of such disasters, since its inception, ASEAN IVO has focused on natural disasters as a common issue affecting the entire region and has selected a disaster-related project almost every year to address this issue. In this regard, we have been working on measures not only for dealing with natural disasters, but also for environmental protection. Examples include sharing disaster mitigation information over networks, constructing networks for disaster mitigation in disaster-stricken areas, implementing wildfire monitoring systems in peatlands, preventing disasters through ionospheric data observation, constructing disaster mitigation systems using mobile information collection and mesh networks, and IoT-based drought monitoring/early warning.

By delivering results over a broader and deeper range of topics, ASEAN IVO will be able to bring about greater ripple effects. Based on the wildfire monitoring system for the prevention of natural disasters in peatlands that we implemented in a joint research collaboration project, the APT (Asia-Pacific Telecommunity) has accepted a proposal to further expand this system with the aim of expanding the monitored area and increasing the number of monitoring points to develop an early warning system based on data collection and analysis. Currently, 71 research organizations and universities from 10 countries in the ASEAN region are participating in ASEAN IVO, which is becoming a leading platform for ICT research and development in the ASEAN region. We will continue our efforts to encourage more researchers to use the ASEAN IVO R&D platform for achieving SDGs and to contribute to solving common issues in the region.

ASEAN IVO Secretariat:
https://www.nict.go.jp/en/asean_ivo/index.html
asean_ivo_sc_nict@ml.nict.go.jp

Figure Field trial of a water management system for paddy fields using IoT technology (Chiang Mai area, Thailand)

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