ISSN 2435-4821 (Print)
ISSN 2434-3854 (Online)

NICT REPORT

National Institute of Information and Communications Technology

2021

NICT Charter

Humanity has achieved progress as it has deepened its mutual understanding and shared its wisdom, overcoming barriers due to national, regional, ethnic, generational, and other differences. Communication is the most critical activity in human society, and information and communications technology (ICT) is the basis of that communication. ICT is also the infrastructure that supports humanity's advanced intellectual and economic activities.

The National Institute of Information and Communications Technology (NICT) promotes the full spectrum of research and development in ICT from basic to applied research with an integrated perspective, and thus promotes the advancement of Japan as an intellectual nation that leads the international community. Moreover, NICT forms close ties with the academic and business communities in Japan as well as with research institutes overseas and returns its R&D findings to society in a broad range of fields. In this way, NICT contributes to the creation of lifestyles that are affluent and safe, a society that is full of intellectual creativity and dynamism, and a world that values harmony and peace.

Message from the President

Last year, COVID-19 spread globally and caused an unprecedented crisis. I would like to express my heartfelt sympathy to everyone overseas as COVID-19 infection spreads worldwide. In Japan, a state of emergency was issued in April last year and non-essential outgoing was refrained. Even though ICT became indispensable for remote working, online learning, and telemedicine, many issues became apparent, such as delays in society's digitalization. To respond to this "new normal," people seek social and economic activities that avoid the "Three Cs," and we must promote society's digital transformation by developing advanced ICT infrastructure ensuring cybersecurity and providing non-contact, remote, and highly realistic experiences.

The National Institute of Information and Communications Technology (NICT) is Japan's sole national research and development organization in the field of ICT. Our mission is to address social issues and create new values through the advancement of ICT. To achieve our mission, we are doing research and development on the world's most advanced technologies and are promoting technology transfer and social implementation of our R&D outcomes through collaboration and open innovation projects with organizations in Japan and overseas.

Looking to a post-COVID-19 society, an open symposium was held onlline last June to discuss the "What is your new normal and the Shape of Society in the Post-COVID-19 Era." To realize such society, we also discussed and demonstrated our next generation ICT such as high-strength deep ultraviolet devices, AI chatbots/multimodal voice dialogue systems, simultaneous interpretation systems, Beyond 5G/6G and cybersecurity.

Under NICT's 4th medium- to long-term plan (FY2016–FY2020), there was steady progress in five focus R&D areas: sensing fundamentals, integrated ICT, data utilization and analytics platforms, cyber security, and frontier research. We created excellent, world-leading technologies in space-time standards technologies, high-capacity transmission using new types of multicore optical fibers, Beyond 5G / 6G, brain-inspired information processing and communications, quantum ICT, and bio-ICT, etc. We accelerated the development of security personnel through practical cyber exercises such as CYDER, Cybercolosseo, and SecHack365. We also started NQC (NICT Quantum Camp) to develop "quantum native" human resources and IDI (Innovation Design Initiative) to support the president's thinktank functions and open innovations. The Ministry of Internal Affairs and Communications also announced the "Global Communication Plan 2025," and R&D of simultaneous interpretation AI has begun, aiming for the Expo 2025 Osaka. Furthermore, both in Japan and overseas, we are promoting joint research and demonstration projects with research institutions, corporations, universities, and local governments. We also promote activities for companies to test and verify the various advanced technologies with NICT testbed facilities and international standardization activities at the ITU, IEEE, IETF, etc.

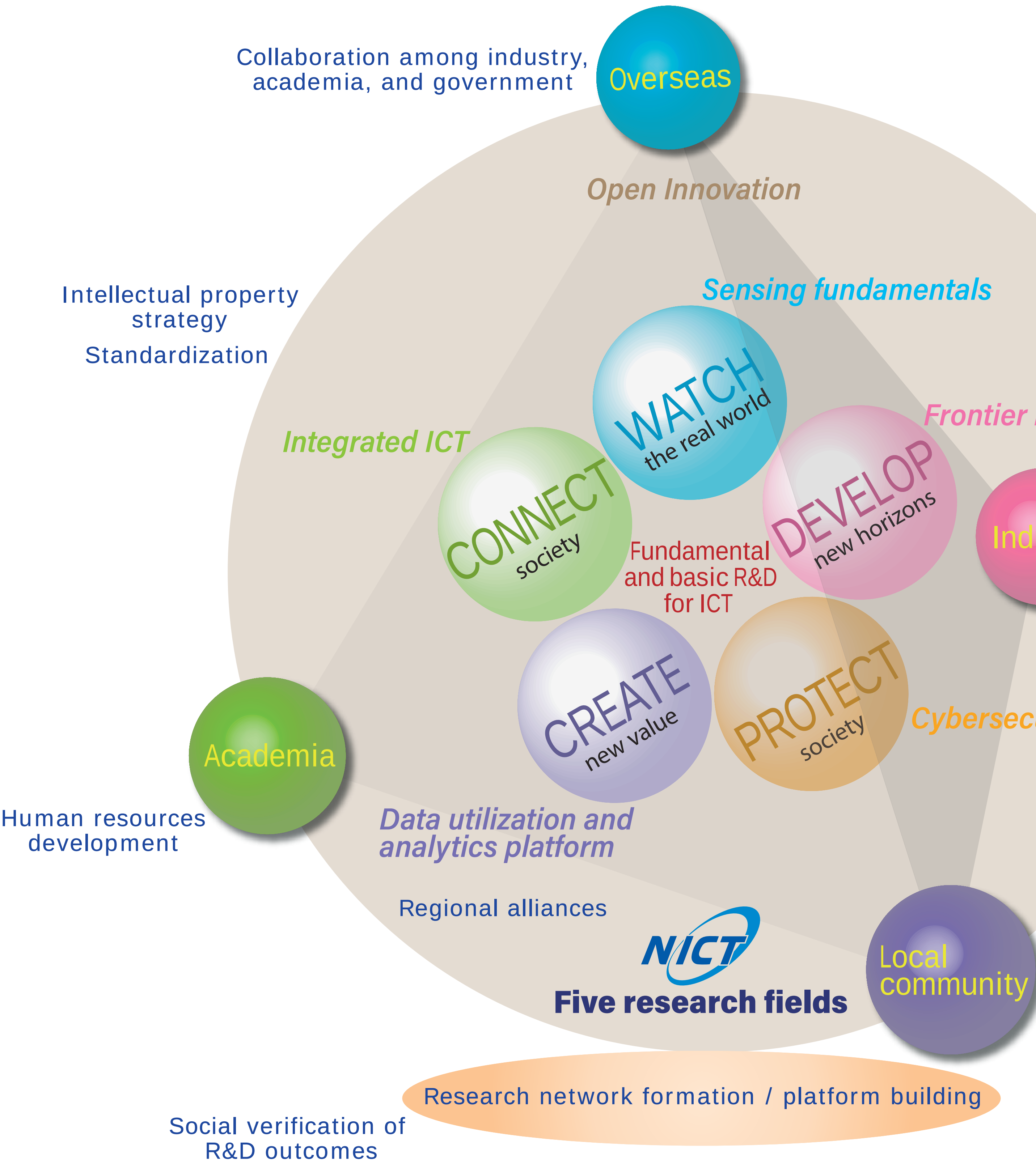
NICT has a management motto "COC": Collaboration, an Open and innovative mind, and a Challenger's spirit. We promote a non-linear R&D model that can accelerate open innovation with various stakeholders in contrast to traditional liner R&D model.

Unfortunately, the recent spread of the infection has restricted the travel of researchers abroad, canceled international conferences and events, and made it difficult to conduct joint F2F research experiments and personnel exchanges. I hope that this annual report will help people to understand what we do here at NICT and promote further cooperation with other organizations, and I look forward to working with you in the near future.

President of the National Institute of Information and Communications Technology

Dr. TOKUDA Hideyuki

Pioneering Future Society wi



th Cutting-Edge ICT

In order to demonstrate its potential fully in the new paradigm, in the Fourth Medium- to Long-Term Plan that started from April 2016, we are devoting ourselves to tackling the world's leading edge fundamental and basic R&D for ICT, based on these five foundations:

- "Watch" the real world through ICT
- "Connect" society through wireless and optical communications technologies
- "Create" new value through data utilization, etc.
- "Protect" society from sophisticated and complicated cyber attacks
- "Develop" new horizons of information and communications,

In addition, improving the quality of research and development, in order to more effectively implement our achievements to society, it is essential to build a system of collaboration among industry, universities, local governments, and research institutions at home and abroad. NICT, as a hub for open innovation in the field of ICT, will comprehensively promote broad range of efforts, in close cooperation with relevant parties, from the basic and fundamental research and development to support for new business activities, and will continue to contribute to the realization of a new social system.

Outline NICT : https://www.nict.go.jp/en/

Table of
Contents

Sensing fundamentals

Applied Electromagnetic Research Institute

Director General TAIRA Kazumasa

In order for humans to create new value using ICT, we must observe and measure various phenomena and conditions in the environment surrounding us to create data and convert them into information. The mission of the Applied Electromagnetic Research Institute is to realize this function through the use of electromagnetic waves. Our goals are "Protecting life and society, using the properties of electromagnetic waves to reveal phenomena that were not previously visible, and taking the lead in the creation of new scientific value." We are also cultivating new fields for the application of electromagnetic waves within NICT as well as promoting collaboration with industry and academia.

We are conducting research and development in areas of remote sensing technology, space environment measurement technology, space-time standards technology and electromagnetic environment technology. Remote sensing technology and space environment measurement technology are used to acquire, collect, and visualize information from various phenomena in the environment using electromagnetic waves. Space-time standards technology provides infrastructure for social and economic activity and for generating, supplying, and using high-quality time and frequency signals. Electromagnetic environment technology provides infrastructure for maintaining electromagnetic compatibility (EMC) among various devices and systems.

Remote sensing technology

To accelerate the deployment of the water vapor measurement network using terrestrial digital broadcasting, we developed a low-cost version of the observation system developed last year (Fig. 1).

We have developed a technology that can stably control the wavelength of a high-power pulse laser over a wide range for a long time, enabling the Doppler Wind Lidar to measure water vapor for the high-accuracy prediction of heavy rainfall.

We studied techniques for extracting advanced information from the data observed by the airborne synthetic aperture radar, Pi-SAR2, and developed a method for determining the shape of structures by high-resolution 3D imaging (Fig. 2).

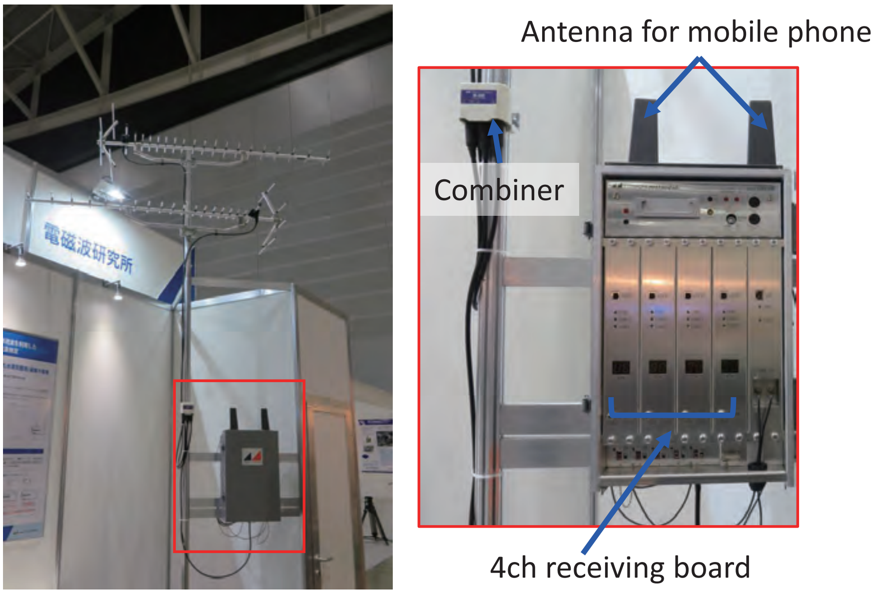


Fig.1 : Mock-up of low-cost version for water vapor measurement system using terrestrial digital broadcasting

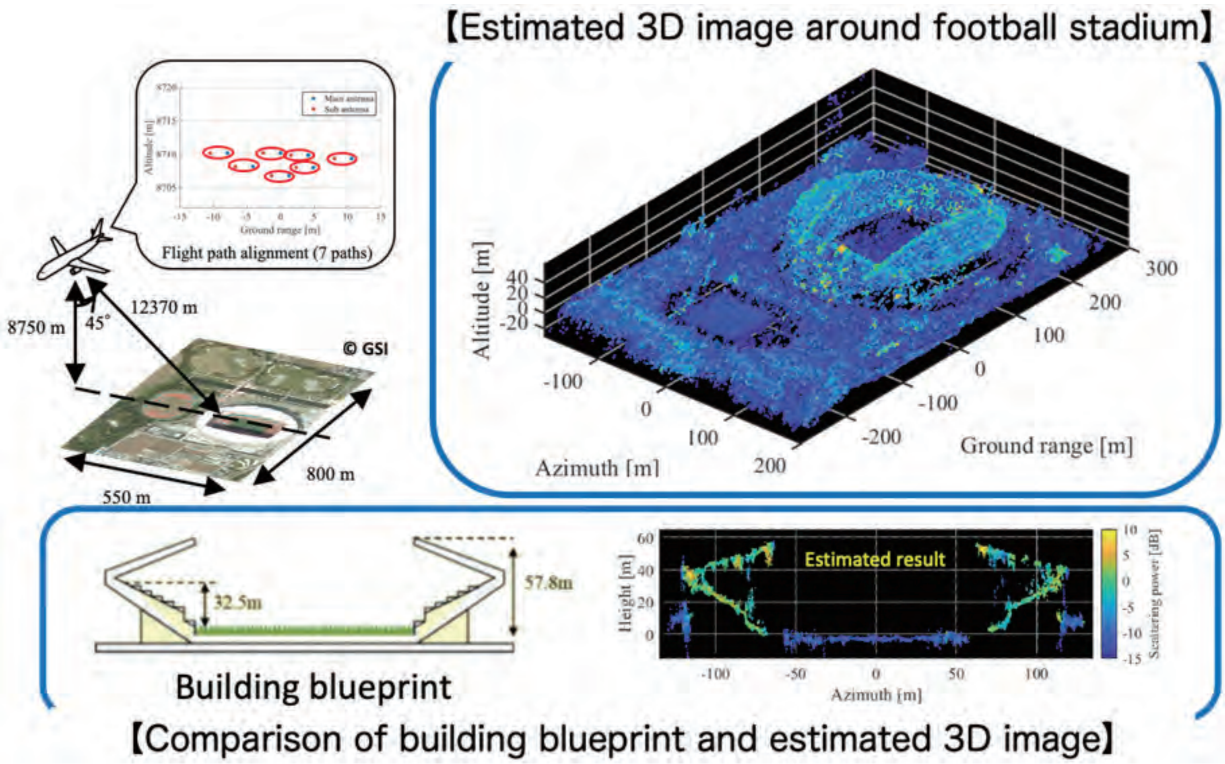


Fig.2 : High-resolution 3D image estimated using seven Pi-SAR2 images

Fig.3: Service-in Ceremony for ICAO Global Space Weather Center on Nov. 7, 2019 at NICT headquarters

Space environment measurement technology

We have been conducting ionospheric observations with ionosondes 24/7 at four radio observatories in Japan and at the Antarctic Pole, monitoring solar radio emission at Yamagawa observatory, and providing space weather forecast information twice a day for the stable use of radio communications. We started 24/7 manned space weather forecast operation on Dec. 1, 2019. We also started operations as one of the Global Space Weather Centers of the International Civil Aviation Organization (ICAO) (Fig. 3) at the same time.

A VHF radar for plasma bubble observation was installed at Chumphon, Thailand, and observation was started in mid-January 2020. Contributions to the application of high-precision positioning by satellites by constantly monitoring plasma bubbles near the magnetic equator (Fig. 4) are ex-

Fig.4 : VHF radar for monitoring Equatorial Plasma Bubbles, installed in Chumphon, Thailand

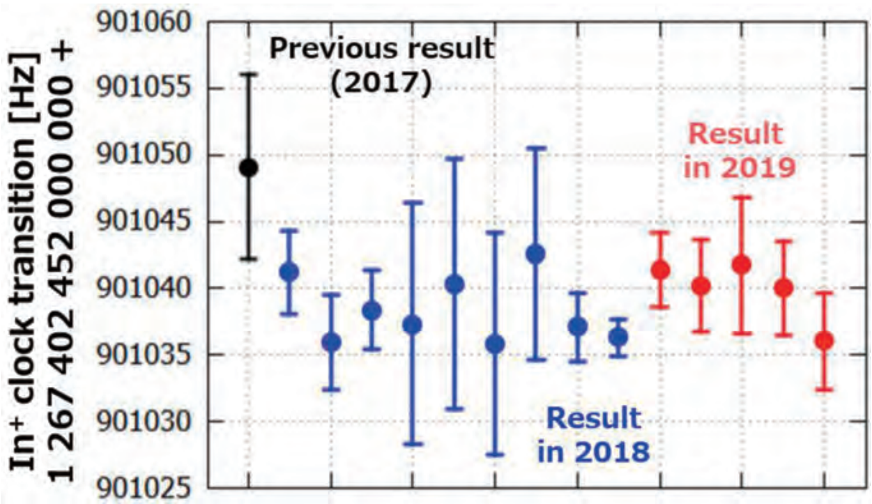


Fig.5 : Reduced uncertainty in the In^+ clock frequency

pected.

An operational system of the solar radiation warning system WASAVIES was developed in November and released to the public. This system is used as a source of important information for the ICAO Global Space Weather Center.

Space-time standards technology

We continue to steadily provide frequency standardization, broadcast standard radio wave signals, and report standard time. The availability of the standard radio wave emission is 99.99% per year, and the Network Time Protocol (NTP) service receives more than 4 billion queries daily.

NICT's strontium (Sr) optical lattice clock provided up-to-date calibration of the international atomic time to the International Bureau of Weights and Measures. Progress on the indium ion (In^+) optical frequency standard now allows frequency measurements with fractional uncertainties in the 10^{-16} range (Fig. 5).

In pursuit of chip-scale atomic clocks, we developed a GHz-band MEMS oscillator with an improved frequency range and designed a VCSEL with wavelength tunability. Newly developed miniaturized gas cells helped to narrow down the CPT resonances and enabled the world's first operation of such a MEMS-based atomic clock.

Electromagnetic environment technology

We have developed a device for measuring broadband spurious emissions from marine radar at high speed and evaluated its performance (Fig. 6). The development costs are also considerably reduced by using a commercially-available general-purpose measurement system in high-speed-processing part and combining it with a custom-made band-pass filter used in the high-performance front-end part.

To understand the electromagnetic characteristics of tissues such as skin and muscle that constitute the human body, a method of measuring the electric constants of biological tissues was developed, and a database of the electric constants of biological tissues up to the submillimeter wave band was constructed.

Exposure assessments were performed to quantify the relationship between the intensity of radio waves incident on the human body and the increase in body temperature in the quasi-millimeter- and millimeter-wave bands used in 5G, and the results obtained were adopted as the basis for the revision of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines and the IEEE international standard.

Electromagnetic application technology

In the nondestructive sensing project, the microwave imaging technology has been demonstrated to be an effective technique for investigating the internal structure of concrete buildings in joint experiments with a construction company. In addition, at the request of the Italian Ministry of Culture, we used terahertz time-domain imaging technology to visualize the substructure of the mural painting "The Last Supper" by Leonardo da Vinci (Milan, Italy) (Fig. 7).

NICT invented hologram printing technology (HOPTEC) as an innovative means to develop optical devices. This year, the accuracy of the printing technology itself has been considerably improved, and we have promoted external cooperation with optical equipment and automotive parts manufacturers who are considering the use of this technology and have also started a new joint research project with external funds.

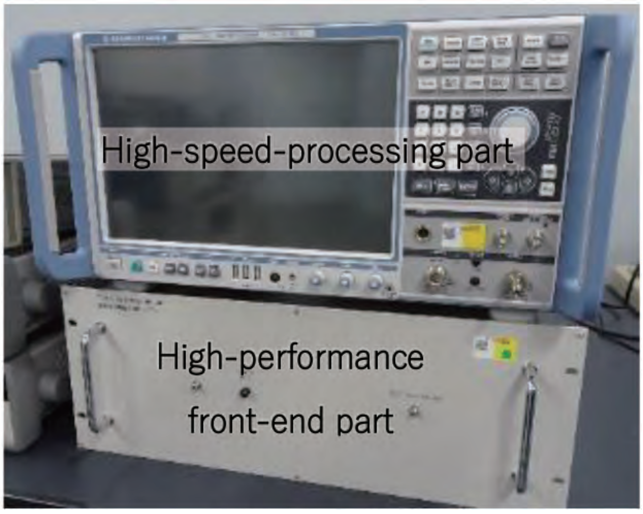


Fig.6 : High-speed spectral measurement system for broadband spurious waves has one-tenth the test time of the previous system.

Fig.7 : Examination of “The Last Supper” (Milan, Italy) using terahertz waves

Integrated ICT
Network System Research Institute

Director General　HAMAGUCHI Kiyoshi

The Network System Research Institute promotes fundamental research and development of global and advanced network system technologies to meet the recent explosive growth in data traffic and for the diversification of communication quality and network service. This research aims to create a "connected society" that provides its citizens with new opportunities and revolutionizes business and social interactions.

Optical access network technologies

Optical access networks constitute the fastest growing branch of optical fiber technologies. They include passive optical networks (PON) such as fiber-to-the-home (FTTH), the coming mobile fronthaul for 5G/B5G services, and intra data-center networks (DCN). Research and development of optical access networks technology focuses on low cost and power consumption, and supporting a large number of users. NICT has research and development on novel optical access networks technology with a large user count, extended communication distance and high-capacity transmission by spatial division multiplexing (SDM) technologies.

- Novel amplification techniques for PON systems: Low-cost amplification in PONs was proposed using two cascaded semiconductor optical amplifiers (SOAs) and Volterra nonlinear equalizer with 20-Gbit/s PAM4 format. It allowed long-distance and multi-branch transmission, assuming a 1024-way split, 70-km PON uplink (Fig. 1). The product of the transmission distance and the number of branches (users) is 100 times larger than current Gigabit PON.

- High-capacity SDM optical interconnects: A high capacity 1.3-Tb/s bidirectional optical interconnect for DCNs was demonstrated using an 8-core multi-core fiber with standard outer diameter of 125-µm. Low-cost O-band (1.3-µm) systems were used with 4-cores per direction, each carrying 4 wavelengths with 32.5 GBaud PAM-8 signals.

- First analysis of latency in a field-deployed SDM network: In collaboration with the University of L'Aquila, the latency of a field-deployed SDM network was evaluated for first time. The analysis reported the inter-core propagation delays of a 6-km 8-core multicore fiber installed underground.

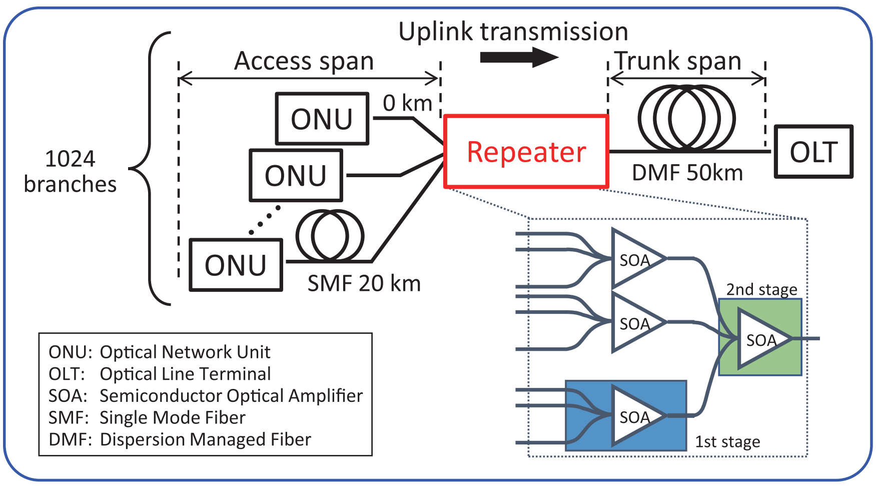


Fig.1 : Demonstration of 1024-way split, 70-km PAM4 transmission using cascaded SOAs for PON uplink

Innovative networking using AI and machine learning

We conduct research on innovative network technologies that optimize the diversifying usage environment for communication and satisfy required communication service quality. To construct and control virtual network slices satisfying the resource demands from applications and services, we studied two aspects of the complete automation of virtual network construction and control mechanism: (1) autonomic resource control architecture (ARCA), which automates the appropriate distribution of virtual network resources (i.e., bandwidth and computational power) for each network service and the construction of virtual networks; (2) intelligent adaptive service function chaining (IA-SFC), which assures service quality even when the network infrastructure topology or traffic condition changes by the arbitration of available resources among the services.

For (1), we incorporated a network monitoring and control mechanism using artificial intelligence (AI) and machine learning (ML) for dynamically adjusting network resources and published the results in ICIN 2020. Furthermore, we submitted the research outcome for standardization to the Internet Engineering Task Force (IETF) and Internet Research Task Force (IRTF) and designed verification experiments in collaboration with a domestic carrier partner (see Fig. 2).

For (2), we studied an AI-based mechanism for the autonomic arbitration of computational resources between multiple service function chains. In FY2020, we developed an algorithm incorporating stable SFC migration and reconstruction plans by training the AI models with the time series data of computational resource usage status and published these results in IEEE NetSoft 2019. This research was conducted as part of a national project funded by the Ministry of Internal Affairs and Communications; the project was commissioned to us and three private companies in FY2018.

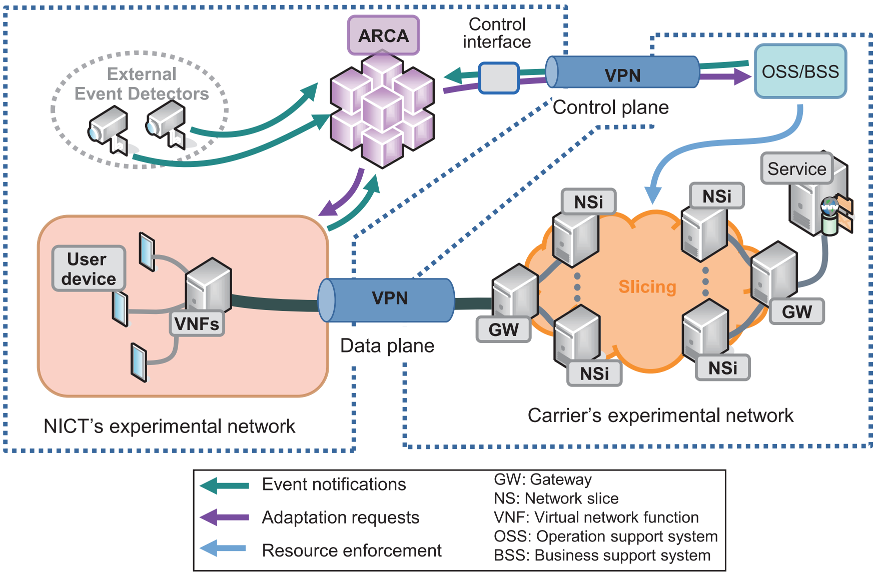


Fig.2 : Layout of ARCA validation with carrier's experiment network

Heterogeneous photonic integrated circuit technology

In the dedicated moderate range communication (DMRC), it will become important to conduct the research of an innovative network technologies that seamlessly integrates light and radio waves (e.g., millimeter waves, terahertz waves). We have conducted the research of "Heterogeneous photonic integrated circuit technology (PIC)" which enables the lens-free integration of multiple devices composed of dissimilar materials. In FY2019, we investigated the high-temperature operation of the optical gain region and the temperature controllability of the light-wave control circuit region. An ultra-compact tunable-wavelength laser shown in Fig. 3 is a heterogeneous PIC in which an optical gain chip and optical wave control circuit are joined together. It was confirmed for the first time that the optical amplification of an 80-Gbaud high-speed signal without pattern effects under the high-temperature environment of 60 °C was possible by using quantum dots (QDs). Furthermore, the optical control circuit region is composed of a passive integrated circuit using a silicon-photonics-based optical ring resonator; however, the refractive index of silicon has a high temperature dependence. Therefore, we incorporated a fine temperature sensor using a PN junction into the PIC as shown in Fig. 3. We could stabilize the optical circuit temperature by controlling the silicon optical circuit based on the chip temperature. Japanese company also manufactured and commercialized the QD semiconductor wafers with transferring the QD technology developed at NICT. We expect that this QD wafer will contribute to a higher quality and improved environmental resistance performance of optical gain devices, and contribute to the development of future quantum-effect devices. In the future, we will continue to actively promote industry–academia–government collaboration and the social development of new technologies researched and developed at NICT.

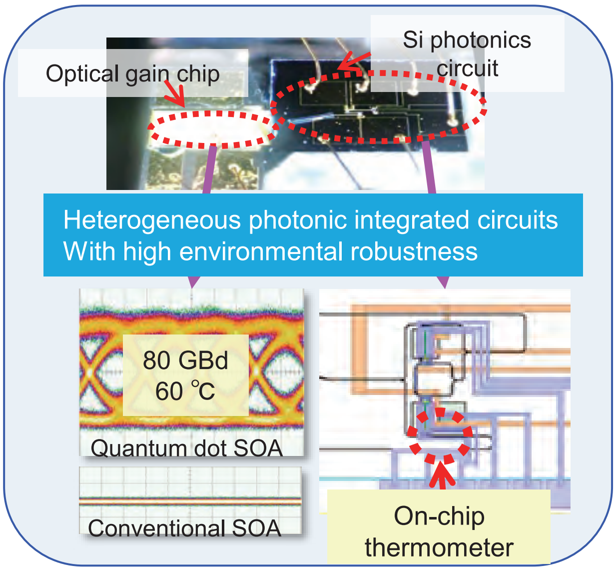


Fig.3 : Photonic integrated circuits technologies for high environmental robustness

Integrated ICT

Wireless Networks Research Center

Director General　HOSAKO Iwao

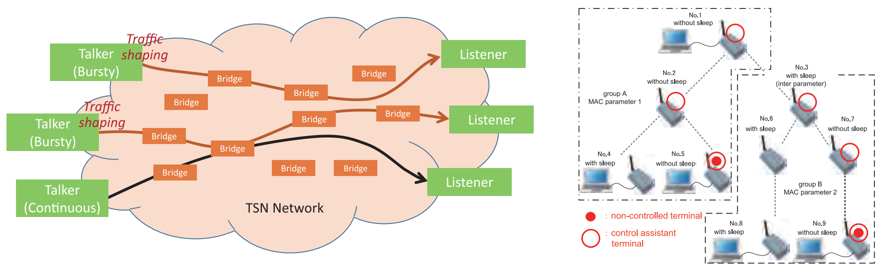
The use of wireless communications in information and communication networks has grown dramatically in recent years, becoming an indispensable part of daily life. This trend has generated a need for R&D toward technologies that can further enrich life through the use of radio waves as part of a wide-ranging network environment that includes ground, marine, and space communications. The goal here is to create new value such as the next-generation mobile communications system (5G), large-capacity satellite communications, and the Internet of Things (IoT) and to achieve systems and applications that can provide users with unprecedented reliability and peace of mind.

Wireless network management technology

We are promoting R&D on private micro-cell structures and have conducted practical tests of advanced railway wireless systems and others, with consideration for trends in the spread of local 5G. In these tests, we have proposed a virtual pre-connection technology, which performs cell connection processing before the wireless terminal arrives at the private microcell, so that service can begin more quickly after arrival, and have conducted successful trials on commercial rail lines in collaboration with rail companies (Fig. 1 (a)). We have also continued R&D on STABLE, a wireless access method providing both low-latency and large numbers of connections, which will improve connectivity for 5G and B5G. We have also successfully tested a multi-access edge computing (MEC) application (Fig. 1 (b)), improved the quality of the MIMO technology, made plans to expand areas, and conducted successful transmission trials crossing Tokyo Bay.

(a)　(b)

Fig.1 : Wireless network management technology: (a) Railway demonstration experiment employing the private microcell structure, (b) STABLE enhancement verification test harmonized with MEC functions



(a)　(b)

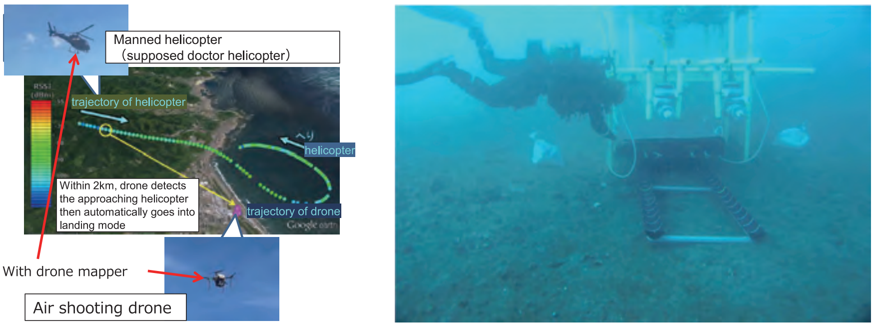
Fig.2 : Wireless network customization technology: (a) Concept of latency controlled factory data forwarding, (b) Different MAC parameter support in the wireless grid employing SUN devices

Wireless network customization technology

We are contributing to IEEE 802 standardization by promoting FFPJ, a joint research organization pursuing wireless operations for factories, and leading testing to verify data collection in a real factory. We have focused on the differing requirements for tolerable delay between data points within a factory and studied methods for controlling allocation of resources appropriately based on permissible delay (Fig. 2 (a)). We plan to summarize the results in a white paper for IEEE 802. We have also continued to study and test autonomous operation and low-power operation of wireless devices topology called wireless grid, through extensions to the SUN MAC specifications. We also successfully verified application of different MAC parameters within the same wireless network (Fig. 2 (b)).

Wireless network reinforcement technology

We are working on deployment of "Command Hopper," a wireless control system for non-line-of-sight operation of drones in environments that have many



(a) (b)

Fig.3 : Wireless network reinforcement technology: (a) Helicopter-drone collision avoidance test employing Drone-Mapper technology, (b) Under seabed radio sensing verification test

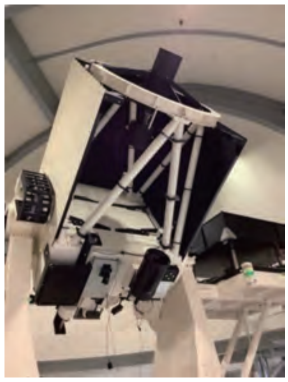


Fig.4 : NICT Optical ground station (Koganei) and fine tracking system at Nasmyth focus (in the right, black box)

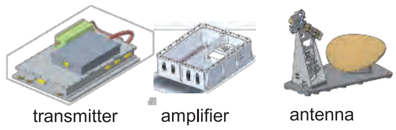


Fig.5 : Design of onboard beacon transmitter

radio-wave obstructions, such as in the mountains, and "Drone Mapper," which shares real-time location information between aircraft (drones, manned helicopters, etc.) sharing the same space. We have conducted successful trials in which location information is obtained from drones flying at distances of up to 10 km away, using the 920 MHz band LPWA drone location sharing system developed by NICT. This information is relayed by a fixed-wing drone flying at a higher altitude, and then monitored at a ground station via a satellite connection. We also collaborated with the Disaster Medical Assistance Team (DMAT) in disaster prevention drills, for the first time, conducting successful tests using a system that shares location information using direct communication between drones and manned helicopters to avoid crashes between them (Fig. 3 (a)). In underwater wireless communication, we successfully tested communication using a combination of wide-band communication and MIMO technologies. For sensing of objects buried on the ocean floor, we tested a principle using simulated objects buried in a shallow region and were able to verify that buried metal objects could be detected using 1 MHz radio waves (Fig. 3 (b)).

Global optical satellite communications network technology

In response to increasing expectation for larger satellite communication capacity and to resolve restrictions in bandwidth resources, we have been conducting R&D on 10 Gbps-class satellite optical communications technologies between the ground and a geostationary satellite, aiming to launch it on Engineering Test Satellite 9 (ETS-9), and on improving communication quality in free-space optical communications. We are developing onboard ultra-high-speed optical satellite communication devices and building ultra-high-speed optical transceiver equipment. To work toward a global optical satellite communication network and promote research collaboration with space agencies and companies within and outside Japan, we have also equipped the 1 m optical telescope at the NICT optical ground station (in Koganei) with a fine-tracking system for optical satellite communications, and conducted performance tests to confirm tracking accuracy (Fig. 4). As part of these tests, we conducted successful optical communication tests between the NICT optical ground station (in Koganei) and the SOLISS optical satellite communication terminal developed by Sony CSL, which is mounted in the exposed facility of the Kibo module on the International Space Station. In R&D on satellite quantum cryptography technology, we also advanced development of a transportable optical ground station built on a modified eight-ton truck and conducted performance tests necessary for tracking satellites using the stars.

Maritime and space broadband satellite communications network technology

We are advancing R&D on high-speed, high-capacity, wide-area satellite communication technologies that will enable communication for anyone, anywhere and at any time, integrating every aspect from the ground to space. We have implemented a Ka-band high-capacity satellite communication system with capacity for 100 Mbps-class communication per user on user links. We are conducting R&D on ground-station technology and wideband, high-speed communication system technology that can provide broadband communication with flexibility and agility, when terrestrial communication networks become congested during emergency, or interrupted across oceans or in space, to ensure communication links both in regular operation and during disaster.

As an opportunity to verify our R&D for the ETS-9 communications mission, we completed the total evaluation and onboard device manufacture, and performed detailed design of the beacon transmitter (common component) needed for user experiments as the representative research institute developing the onboard fixed multi-beam communication equipment for the ETS-9 communications mission (Fig. 5). Further, to promote linking of satellite communication and 5G, we started a study group for linking satellite communications with 5G among 19 domestic institutes and companies, conducted concrete studies of use cases, technical issues and other topics, and published the white paper report of the results.

Data utilization and analytics platform

Universal Communication Research Institute

Director General UCHIMOTO Kiyokata

We are conducting R&D of human-friendly and intelligent communication technologies that can make ordinary people's everyday life richer and more secure. In particular, we are aiming at technologies that can extract and exploit the vast amount of knowledge and information circulating in our society, which we call "social knowledge," from a wide range of information media on the internet, including the WWW and SNS. Though such social knowledge sometimes circulates only inside communities of experts, we are aiming at making expert knowledge available even to non-experts.

The systems we developed so far can extract and accumulate a large amount of social knowledge and allow users to access the accumulated knowledge through simple question answering. Some of our systems also enable users to generate hypotheses easily, or to look at summaries of a vast amount of social knowledge. We are also collaborating with the Resilient ICT Research Center on the R&D of technologies used to help local governments and disaster victims to collect, from SNSs, information useful for reducing disaster damages. The technologies and systems we have described so far are focusing on social knowledge in the form of text, but we are also conducting R&D on an image analysis technology that can provide support for taking various actions.

Multimodal spoken-dialog system MICSUS

Supported by the Cross-ministerial Strategic Innovation Promotion Program (SIP), 2nd period, and with the collaboration of KDDI Corporation, NEC Solution Innovators, Ltd and the Japan Research Institute, Limited, we have developed the Multimodal spoken-dialog system MICSUS. By partly substituting itself to human workers doing health monitoring of elderly people, i.e., regularly having interview with elderly people to check their health condition and well-being, this system shall help reducing the work load of health-care workers and allow more frequent health check-ups of elderly people to tune the elderly care programs to individual elderly.

We at NICT are developing neural technologies that can understand a wide range of elderly people's dialogs. Also, by integrating these technologies as well as NICT's next generation spoken dialog system WEKDA into MICSUS, the system can do chit-chat with them, in which a huge amount of knowledge extracted from billions of Web pages and make their life more lively, thus preventing social isolation of these elderly users.

This fiscal year, we performed real-life experiments with a number of people over 80 years old three times in nursing homes and obtained satisfactory results (Fig. 1). Most of the elderly people appreciated the quality of the dialogs with the system. At NICT, we have also during this fiscal year developed technologies based on the powerful BERT model, which are "pre-trained" using a large amount of Web texts and actually improved the quality of the dialogs by MICSUS.

Large-scale real-life experiments on the disaster management chatbot SOCDA

Under the support of the government's SIP (2nd period) and with the collaboration of the National Research Institute for Earth Science and Disaster Resilience (NIED), Weathernews Inc., LINE Corporation, and the Resilient ICT Research Center at NICT, we are developing the disaster management chatbot SOCDA, capable of collecting disaster related information through chat through an SNS (LINE). Combined with the disaster SNS information analysis systems DISAANA and D-SUMM, we performed real-life experiments targeting 10,000 citizens of the city of Kobe and other activities gearing towards deploying the system in the society (Fig. 2).

In FY2019, a method which localizes landmarks that frequently appear in an image set was studied as one of the technologies for constructing a sightseeing image corpus. As shown in Fig. 3, given a sightseeing image set, the system esti-

Fig.1 : MISCUS, Multimodal dialog system for elders

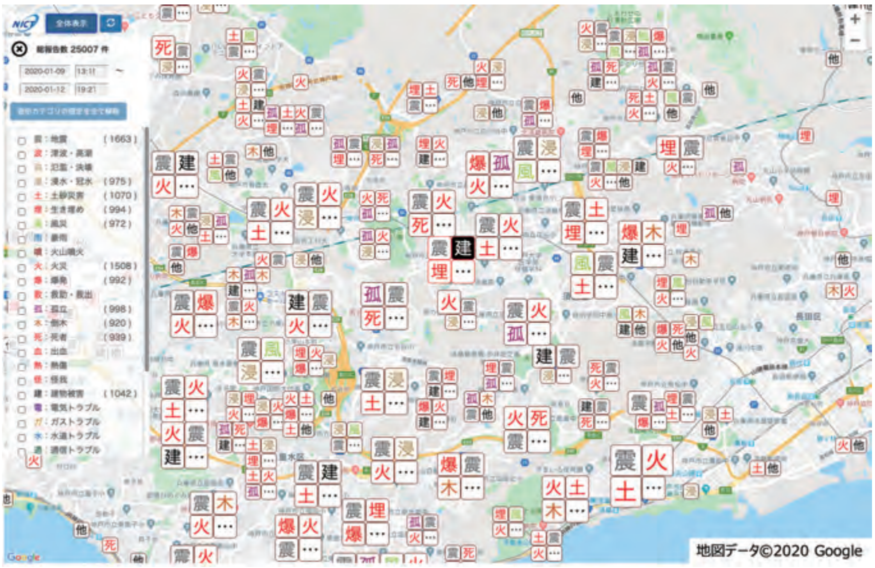
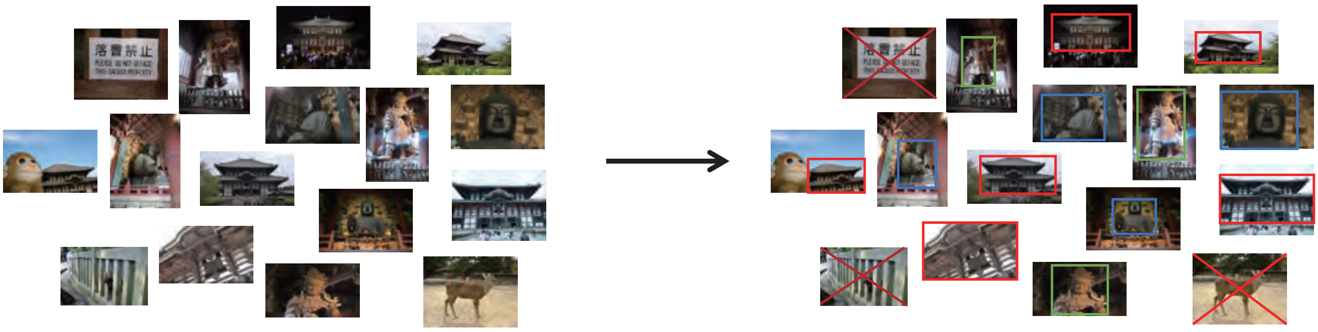


Fig.2 : SOCDA a snapshot at social experiment in Kobe city



A sightseeing image set

Object localization results

Fig.3 : Unsupervised object localization

mates the locations of the objects that appear frequently in the image set. The region of the object in each image was estimated by extracting multiple object proposals with high likelihoods and by performing data mining using the graph structure to represent the relationship between their image features. The object localization accuracy of the conventional method was 52.9%, while the proposed method significantly improved up to 66.6%.

We also developed a travel assistant bot as a demonstration system of these technologies and showcased them at the annual Open House and at the Keihanna Information and Communications Fair (Fig. 4).

Fig.4 : Travel assistant bot

Data utilization and analytics platform

Center for Information and Neural Networks

Director General YANAGIDA Toshio

The Center for Information and Neural Networks (CiNet) is an organization performing interdisciplinary research in the fields of brain information science and information-communications. Centered about NICT, Osaka University, and the Advanced Telecommunications Research Institute International (ATR), CiNet promotes collaborative research with other universities, research institutions, and corporate enterprises. To create a new level of information and communications technology (ICT) that can improve the lives and well-being of people, CiNet aims to establish technologies for measuring activities related to cognition in the human brain—the source for sending and receiving information—and sensation and movement and technologies for efficiently using that brain information in decoding and encoding.

Analysis of brain functions and next-generation ICT research

Our analysis of brain functions is laying the foundation for next-generation ICT research and development. As part of this research, we investigated in detail the neuroanatomical basis for brain rhythms such as alpha waves and discovered that a relationship exists between individual differences in alpha waves and optic radiation (white matter fiber connecting the lateral geniculate nucleus and primary visual cortex) characteristics (Fig. 1 A). More specifically, we observed a relationship between alpha-wave frequency and an index called the intracellular volume fraction (ICVF) that reflects the cell density of white matter fiber (Fig. 1 B). However, we did not observe a relationship between alpha-wave frequency and an index called the orientation dispersion index (ODI) that reflects the state of fiber orientation or an index called macromolecular tissue volume (MTV) that reflects the degree of myelination (Fig. 1 C, D).

Evaluation-platform research based on brain information

As part of this research, we constructed an information representation model that describes the relationship between cognitive functions and brain activity by preparing a group of diverse cognitive tasks associated with the visual and auditory senses, memory, recollection, logical judgment, etc. and by analyzing brain activity during the execution of each task. In the experiment, we asked human subjects to perform 103 types of cognitive tasks in-

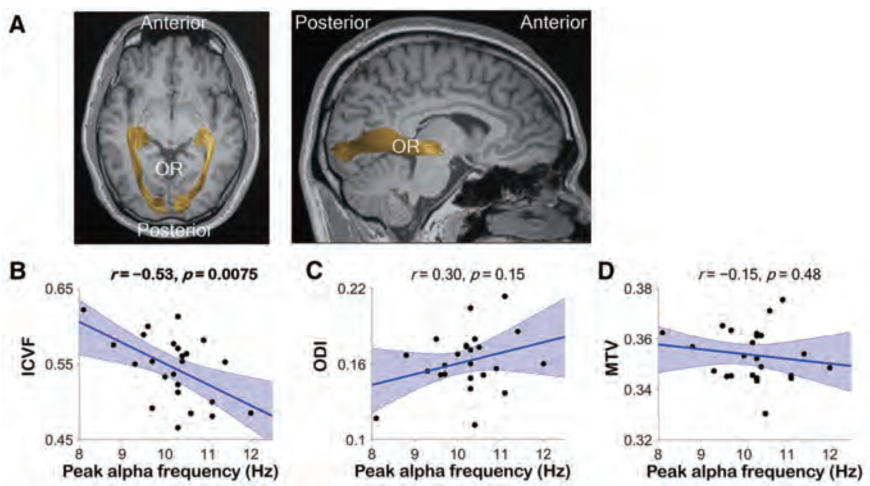


Fig.1 : Relationship between the peak alpha frequency (PAF) and the properties of the optic radiation (OR). The PAF was correlated with intracellular volume fraction (ICVF), not with orientation dispersion index (ODI) or macromolecular tissue volume (MTV)*1.

volving, seeing, hearing, memorizing, imagining, and making judgments, measured brain activity using functional MRI (fMRI), and constructed and analyzed the resulting information representation model. We then performed principal component analysis with the obtained contribution data and visualized the cognitive information representation space within the human brain that shows the relationships among these 103 tasks (Fig. 2).

New imaging method for fMRI

While fMRI is a widely used method for measuring brain functions, its resolution is limited, and when using 3-tesla fMRI (3T-MRI), no more than average neural activity across a breadth of several mm can be measured. We proposed a new imaging method for fMRI that enables us to determine cortical depth by using the same imaging sequence for capturing functional images and structural images and using the features of activity on gray matter structure. This technology makes it possible to accurately separate the cerebrospinal fluid in functional images, white matter, and gray matter and to remove hemoglobin changes in the ventricular-surface blood vessels. In this way, we achieved high-resolution brain-function mapping (Fig. 3).

*1 Minami, S., Oishi, H., Takemura, H., Amano, K. (2020): Inter-individual differences in occipital alpha oscillations correlate with white matter tissue properties of the optic radiation, 7(2) ENEURO.0224-19.2020.

*2 Nakai T, Nishimoto S. (2020) Quantitative models reveal the organization of diverse cognitive functions in the brain. Nat Commun. 11(1):1142.

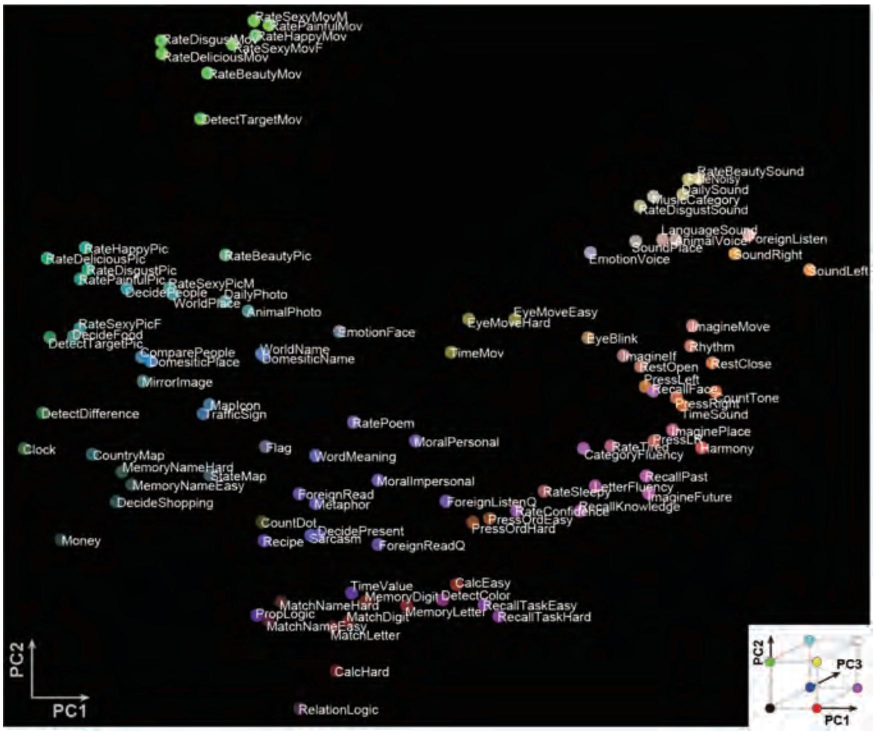


Fig.2 : Two-dimensional visualization of the cognitive information representation space using principal component analysis. Colors and spatial positions represent the relationship between cognitive tasks*2.

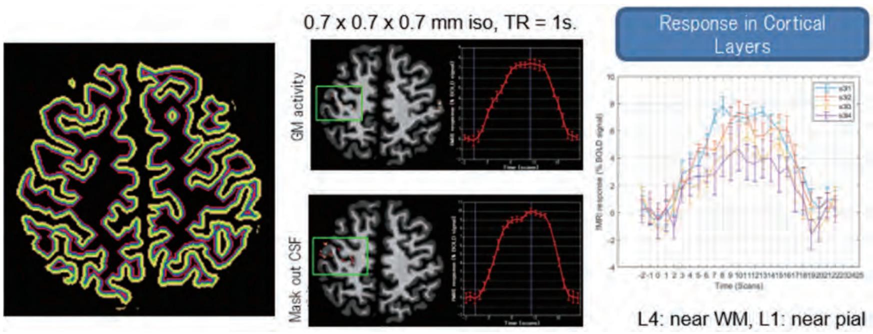


Fig.3 : Left: Five layers extracted from the functional images directly; Middle: BOLD response at gray matter (top row) and CSF (cerebrospinal fluid, can be masked out using this method, bottom row); Right: BOLD response at different layers of the cortices marked by the green rectangle in middle top row.

Data utilization and analytics platform
Advanced Speech Translation Research and Development Promotion Center

Director General KIDAWARA Yutaka

The Advanced Speech Translation Research and Development Promotion Center (ASTREC) promotes research and development of multilingual speech translation technology and its social implementation. Our work has been based on Japan's Global Communication Plan, which aims to eliminate the world's language barriers and facilitate human interaction on a global scale, while forming part of a nationwide initiative that includes skilled researchers and engineers both from NICT and private companies.

In FY2019, we continued to make efforts from the previous year to reduce the language barriers faced by foreigners visiting Japan for the Tokyo 2020 Olympic and Paralympic Games by improving the accuracy of our multilingual speech translation technology and expanding the range of languages and fields in which it can operate. We have also conducted field experiments in various fields in cooperation with private companies, one of which started a multilingual speech translation platform service, another launched a speech translation software licensing business, leading to more technology transfers and further applications of the multilingual speech translation technology. At the end of March 2020, the Global Communication Plan 2025 was announced by the Ministry of Internal Affairs and Communications (MIC), as the successor of the previous Global Communication Plan. The new plan aims to realize a practical high-precision low-latency simultaneous interpretation technology and its dissemination by the year 2025.

Progress of VoiceTra (FY2019)

Fig. 1 shows the progress of VoiceTra made in FY2019. To name a few, improvements in speech recognition, machine translation, text-to-speech (TTS) accuracies have been made for the 10 most frequently-used languages by foreign visitors to Japan as specified in the Global Communication Plan, plus 5 languages targeted for foreign residents in the country. In addition, the language identification technology was implemented into VoiceTra, which has enabled the app to automatically identify which of the 8 languages (Japanese, English, Chinese, Korean, Thai, Myanmar, Vietnamese, and Indonesian) is being input.

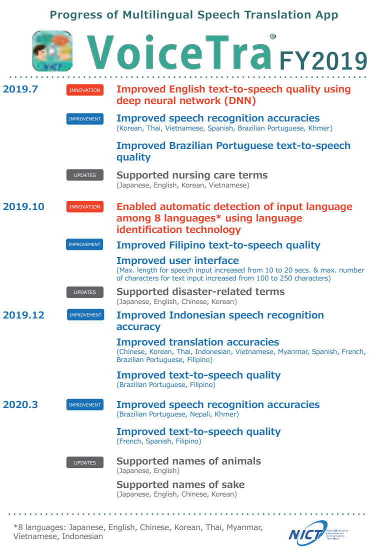


Fig.1 : Progress of VoiceTra (FY2019)

9 new products and services that utilize NICT's technology have been launched, e.g., "POCKETALK S," a cloud-based voice translator by SOURCENEXT, remote medical interpretation tablet "MELON" and hybrid multilingual interpretation service "KOTOBAL" by KONICA MINOLTA, and "Native Heart" by BRICKS, which is a service that combines phone-based human interpretation and automatic speech translation. The number of licenses concerning our multilingual speech translation technology—software and databases which are the R&D results of its component technologies—has expanded to as many as 65, which shows how the technology is being widely utilized in society.

Text-to-speech technology

Although the method proposed in the last fiscal year realized high-fidelity TTS based on an attention mechanism, it contained serious problems when considering practical use such as stopping during an utterance or skipping certain phonemes. To solve these problems, we have proposed a new TTS model (Fig. 2) which employs state-of-the-art deep neural network (DNN) only for acoustic feature prediction and speech waveform generation, while keeping the conventional method based on phoneme alignment instead of the attention mechanism. The proposed model successfully solved the aforementioned problems while maintaining the same synthesis quality and speed (0.16 seconds to generate 1 second of speech using a GPGPU) as the previous method.

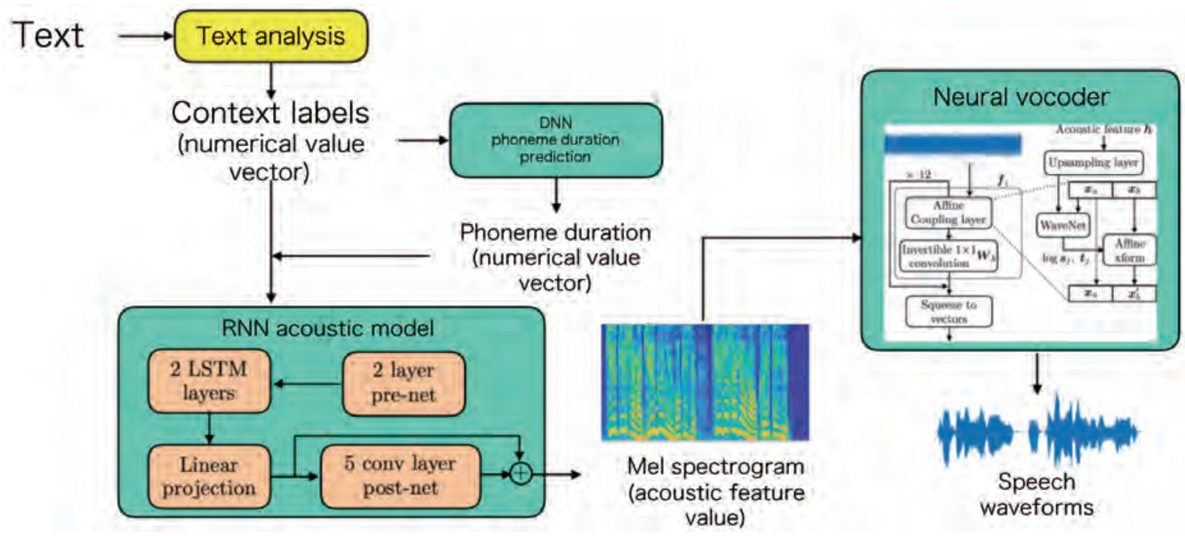


Fig.2 : High-quality neural TTS model

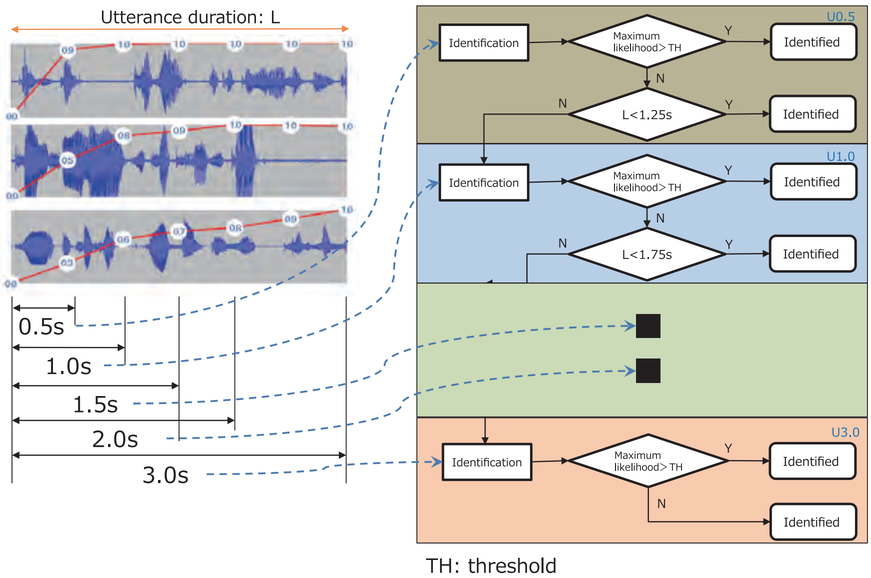


Fig.3 : Progressive language identification method

Language identification technology

By constructing a new speech corpus, we have successfully expanded the number of supported languages and developed a new language identification method where speech is input to the system progressively. The conventional method used a fixed amount (the first 1.5 seconds) of the input speech to identify the language, which occasionally caused identification errors depending on the nature of the utterance and its speed. In order to prevent these errors, we created individual identification models for multiple speech durations ranging from 0.5 to 3 seconds as shown in Fig. 3. As a result, the new method significantly improved the identification accuracy while maintaining the same low latency rates as the conventional method.

Machine translation technology

We have successfully constructed the world's largest-scale translation corpus (the amount is undisclosed) of spoken language in 10 languages targeted for 4 different fields. We have also added Brazilian Portuguese and Filipino to the corpus considering the population of foreign residents in Japan.

"Hon'yaku (Translation) Bank (https://h-bank.nict.go.jp/)," collect translation corpus for written language, has achieved widespread recognition as the number of companies that have provided us with their translation data has greatly increased in the pharmaceutical field. Furthermore, we were not only able to collect new translation data from fields such as automobile, IR and finance, but also white papers from central government offices of Japan, in co-operation with the MIC and AI Science Research and Development Center of NICT. As such, our multidisciplinary approach has led to a huge expansion of translation data and Hon'yaku Bank was awarded the 2nd Japan Open Innovation Prize, Minister of Internal Affairs and Communications Award (Feb. 10, 2020).

Cybersecurity

Cybersecurity Research Institute

Director General KUBOTA Minoru

Cyberattacks on vulnerabilities in IoT and other devices continue to increase globally each year, and targeted attacks on enterprises and public facilities are wreaking havoc. On the other hand, use of Big Data to solve societal issues continues, and technology to ensure the safety of such systems is increasingly important. To handle such social issues, the Cyber Security Research Institute is conducting R&D on the latest practical cybersecurity technologies and encryption technologies, which provide theoretical support for safety and security in society.

Cybersecurity technology

Based on large volumes of wide-ranging, cybersecurity-related information collected and stored using the NICTER incident analysis center and various other systems (Table 1), we are conducting data-driven research integrating machine learning and cybersecurity, and R&D on CURE*[1], which performs large-scale consolidation and cross-sectional analysis on this related data.

In research integrating machine learning and cybersecurity, we are working on three main issues, which are prioritizing incidents, automating analysis of malware features, and attack detection and threat prediction (Fig. 1).

For incident prioritization, we have classified and reduced the number of alerts output from security devices using a method called Isolation Forest. Then, to analyze large-scale malware specimens quickly and successively, we performed high-speed clustering using an IoT malware taxonomy, achieving accurate results. These results were reported at ICONIP 2019.

In automation of malware feature analysis, we were able to detect Android*[2] malware accurately using a multilayer perceptron (MLP), which was reported at SAC 2019.

In attack detection and threat estimation, we have been able to detect the synchrony of malware infection behavior accurately, in real time, using a method called the Graphical Lasso (GLASSO), and demonstrated the potential for early detection of the spread of infections (reported at TrustCom 2019). These analysis technologies are shown in Fig. 2, with accuracy data.

To strengthen external collaboration with the STARDUST cyberattack enticement platform, we added participation from three new facilities, extending participation to 12 facilities. To increase performance in processing cyberattacks, we also expanded the scope of attribution verification testing using mock data (Fig. 3), building 11 parallel networks and testing using more than 100 samples. To conduct demonstrations of cybersecurity technology and cybertraining more efficiently, we developed new collaboration features in STARDUST and NIRVANA*[3], and generated a white list from STARDUST observations (reported at CyberHunt 2019).

Table 1 : Retained cybersecurity information

	Examples of accumulated data
Darknet related data	Data on the traffic sent to unused IP address spaces. This includes pcap files, statistical information, and malicious host information.
Livenet related data	Traffic data within NICT. This includes pcap files, flow data, security alerts generated by security appliances.
Malware related data	Malware samples, static and dynamic analysis results, etc.
Spam related data	Spam (double bounce) mail data, statistical information, etc.
Android related data	APK files and applications' metadata, e.g., category and description of applications
Blogs and articles	Tweets, security vendor blogs, etc.
Web crawler	URL list, Web contents, their evaluation results, etc.
Honeypot data	Data from High-interaction/low-interaction honey pots and high-interaction/low-interaction client honey pots
Threat Intelligence	Information on the sites hosting malware, bot, C&C server list, domain history, malware samples, threat reports, etc. purchased from VirusTotal, SecureWorks, Anubis, DomainTools, Malnet, Team 5, etc.

Cryptographic technology

To solve security issues in a space development, referred to as NewSpace, we have jointly developed an information-theoretically secure scheme as a secure communication technology for small spacecraftts, in collaboration with Interstellar Technologies Ltd. and Hosei University.

*1 CURE: Cybersecurity Universal REpository
*2 Android: Android is a registered trademark of Google Inc.
*3 NIRVANA: Nicter Real-network Visual ANAlyzer
*4 CRYPTREC: Cryptography Research and Evaluation Committees. A project that evaluates and monitors the security of e-Government recommended encryption, and conducts surveys and investigations of implementation and operation methods suitable for encryption technologies.

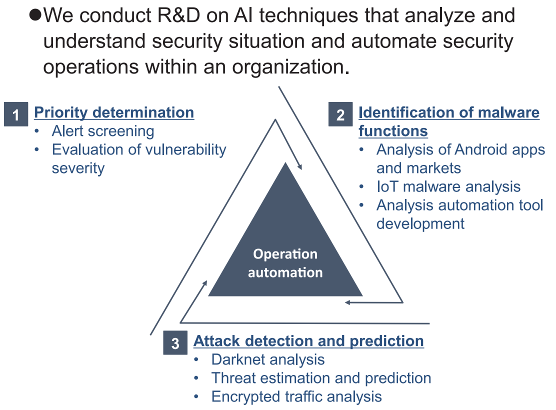


Fig.1 : Issues in integrated research on machine learning and cybersecurity

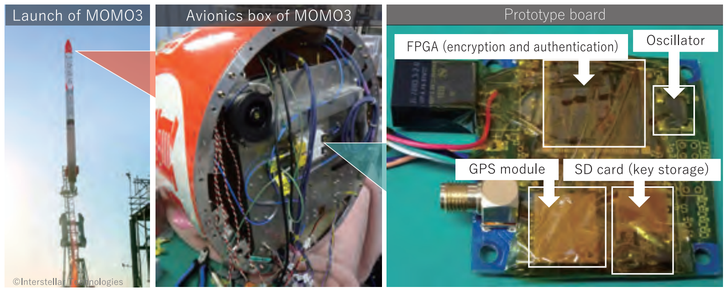


Fig.4 : Launch of the small rocket used in flight tests and test circuitry developed for this technology

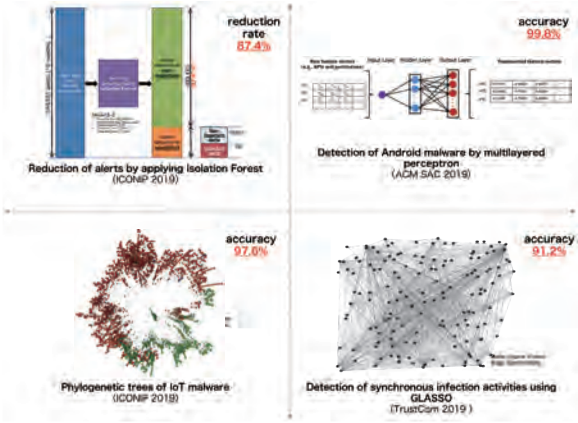


Fig.2 : Strengthening integrated research on machine learning and cybersecurity

Fig.3 : Concept of medium-scale-attack source attribution using beacon files
When an attacker views a beacon file (mock data), a tracking beacon is issued.

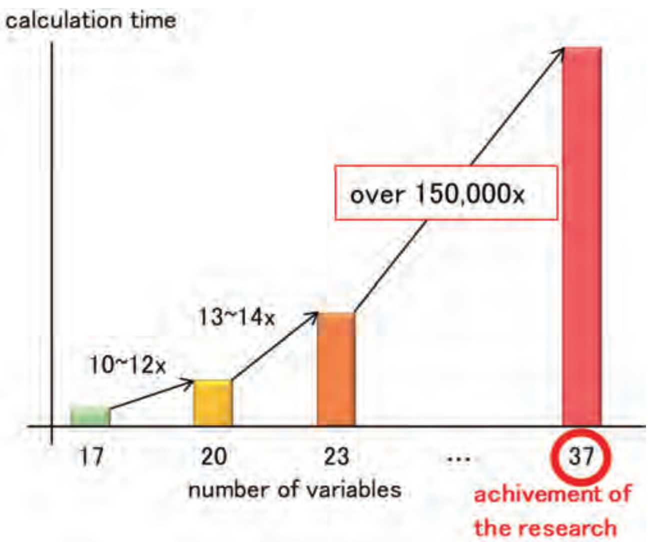


Fig.5 : Difficulty of solving a system of multivariate quadratic equations
We achieved world records in Fukuoka MQ challenge, solving Type II problem with 37 variables in 75.7 days, and Type III problem with 37 variables in 56.1 days. To safely use MPKC will require evaluation of how many variables used in a system of multivariate quadratic equations can be solvable.

We developed a prototype system for a sounding rocket, and confirmed behaviors in a flight environment (Fig. 4).

At CRYPTREC*4, our joint project with the Ministry of Internal Affairs and Communications (MIC), the Ministry of Economy, Trade and Industry (METI), and the Information-technology Promotion Agency (IPA), a report on research trends in post-quantum cryptography (PQC) was issued in April, spreading information about PQC (e.g. global trends in PQC, the features of the main and typical PQCs, and specific configurations of those PQCs) in Japan. We also established a "Cryptography for the Quantum Computer Era" task force in June. To evaluate the security of multivariate public-key cryptography (MPKC), which is a candidate for PQC, we proposed an algorithm to break MPKC in collaboration with Tokyo Metropolitan University, and achieved a world record in a contest (Fukuoka MQ challenge) to decipher MPKC (June 27, 2019 press release, Fig. 5). This result was reported at the international conference, IWSEC 2019, and received a Best Paper Award.

In privacy protecting data-analysis technologies using AI, we continue societal implementation of DeepProtect, which is a deep-learning privacy protection system that applies deep learning among data sets from multiple participants, while maintaining reciprocal confidentiality. We currently have three banks participating in trials. To ultimately enable cooperative learning, we are currently evaluating shared data formats and suitable machine learning methods, and have begun analysis for two of the banks. We have also designed an accelerated version of DeepProtect and verified an 80-times increase in learning speed. In joint research with Kobe University, we have also proposed a privacy-preserving multi-layer perceptron that can compute predictions in real time. In analysis of privacy policies, we built a tool that supports user understanding when reading privacy policies and conducted a Web survey to have users evaluate it.

Frontier research

Advanced ICT Research Institute

Director General WADA Naoya

The Advanced ICT Research Institute promotes groundbreaking and advanced research and technology development on a foundation of high-level basic research. In the current Medium- to Long-Term Plan, it features a system consisting of the Frontier Research Laboratory, which performs research and development using the functions and principles of innovative materials, biological systems, etc., and the Quantum ICT Advanced Development Center, Green ICT Device Advanced Development Center, and DUV ICT Device Advanced Development Center, which serve as research centers that aim to turn research results into practical technologies as rapidly as possible. To contribute to the creation of a prosperous and human-friendly ICT society, the Advanced ICT Research Institute promotes an evolving basic research system that can respond flexibly to social needs and changing times based on a solid R&D foundation built up over many years.

Advanced ICT Research Institute 30th Anniversary Symposium

The 2019 fiscal year marked 30 years since the founding of the Kansai Advanced Research Center, the forerunner to the Advanced ICT Research Institute, in Kobe, Japan. To commemorate this 30th anniversary, a symposium, exchange meetings, and poster presentations were held on June 7, 2019. The 30th Anniversary Symposium, which was attended by 161 affiliated persons and guests, five lectures were given from inside and outside NICT including Professor Shizuo Tokito of Yamagata University. In the exchange meetings and poster presentations that followed, researchers directly introduced their research and achievements in each project at the Advanced ICT Research Institute in a poster format, which led to enthusiastic discussions (Fig. 1).

High-performance ICT device

As part of our research toward next-generation high-speed wireless communications, we developed a broadband terahertz (THz) detector using electro-optic (EO) polymer having a high-efficiency EO conversion function and material having low THz absorption. Using a transfer pro-

Fig.1 : 30th Anniversary Symposium

cess, we fabricated a prototype of a THz detector having an EO polymer waveguide and demonstrated for the first time in the world direct optical modulation by 90 GHz electromagnetic waves (Fig. 2). The experimental results of this research will serve as a foundation for THz over Fiber (ToF) technology toward next-generation high-speed wireless communications (Beyond 5G). Additionally, from a materials perspective, we discovered an appropriate performance index for optical modulators and evaluated various types of EO polymers after controlling their molecular structures based on that index. Then, using the results of this evaluation, we succeeded in developing an EO polymer capable of modulating light even in the short-wavelength band of 640 nm – 980 nm on a level equivalent to or greater than that in the C band. Furthermore, in technology for the practical application of compact ultra-high-speed optical modulators, we confirmed high-efficiency optical modulation ($V\pi L$ = 0.81) achieved by inserting a charge-injection suppression layer by atomic layer deposition (ALD).

Bio ICT Technology

In research related to the building of information-detection systems using biomolecules, we are developing techniques for organizing artificially modified biomolecules. In this work, we succeeded in organizing biomolecular devices through DNA cargo and in building a molecular transporter that can slide over long distances on a DNA rail while confirming that recognition of a specific rail lies in the type of transporter (Fig. 3 (1)). These are significant results toward the building of biologically inspired devices that can autonomously perform sensing, calculations, and actuation.

Furthermore, in research toward the building of information processing systems consisting of organisms and biomaterials, we found that RNA-protein complexes formed on chromosomes play a key role in determining chromosome specificity via mutual recognition of liquid–liquid phase separation (LLPS) droplets (Fig. 3 (2)). This result clarifies a portion of the information-recognition mechanism based on biological macromolecules and provides valuable knowledge toward the building of information-processing systems modeled on living organisms.

International standardization of quantum cryptography

Discussions on the international standardization of quantum cryptography have begun at major international standardization bodies around the world. In particular, standardization activities have begun at ITU-T in relation to the architecture and security of quantum key distribution (QKD) networks. NICT is actively contributing to those discussions together with Toshiba and NEC. In the drafting of a recommendation on the basic configuration of a QKD network, NICT, Toshiba, and NEC led the preparation of documents resulting in "ITU-T Y.3800: Overview on networks supporting quantum key distribution," the first recommendation in the field of quantum cryptography at ITU-T. This recommendation was published in October 2019 in a form reflecting Japan's technical specifica-

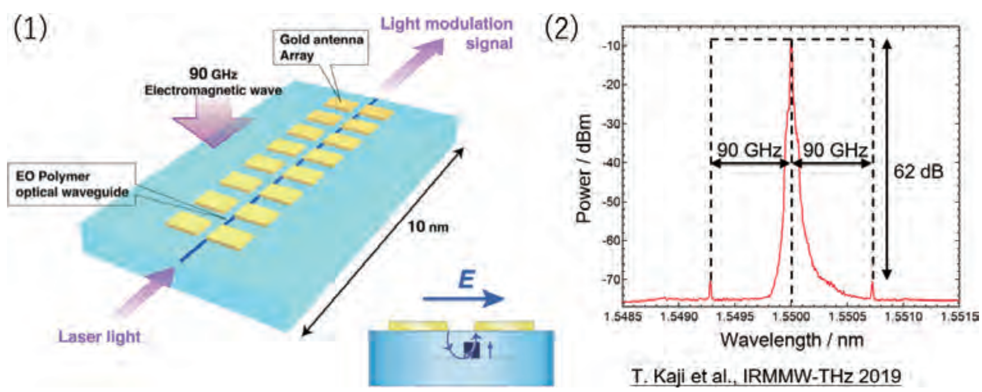


Fig.2 : EO polymer waveguide type terahertz detector
(1) Structure of the prototype detector and detection method
(2) Observation of optical modulation sidebands under 90 GHz electromagnetic wave irradiation

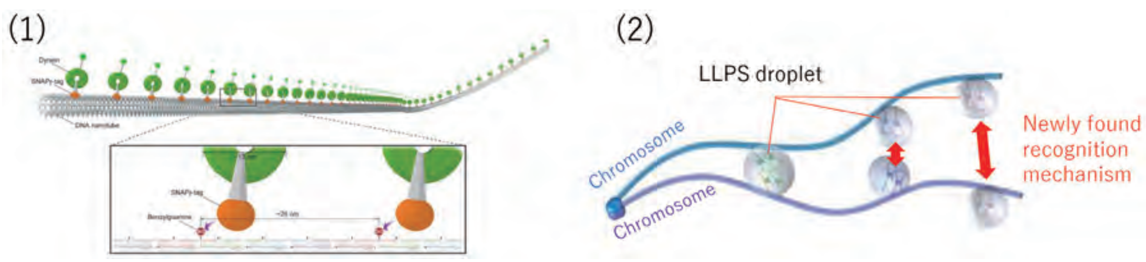


Fig.3 : (1) Reconstitution of biomolecular system by using DNA scaffold
(2) Discovery of molecular recognition mechanism by liquid-liquid phase separation (LLPS) droplets

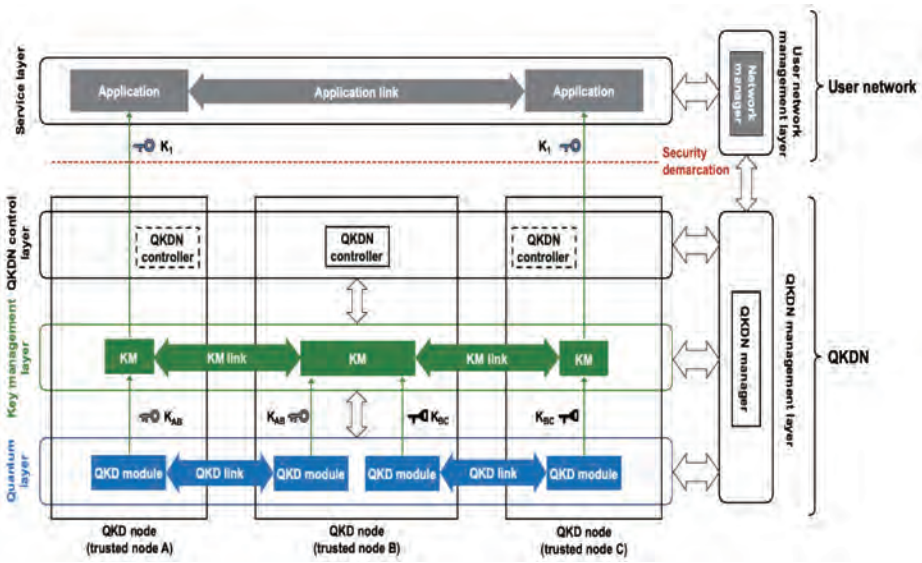


Fig.4 : QKD Network defined in ITU-T Y.3800

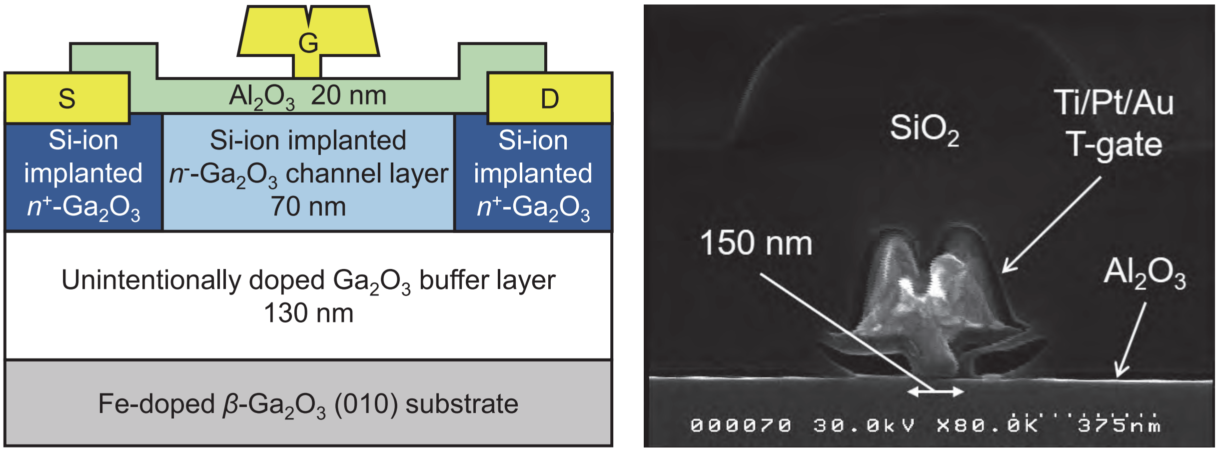


Fig.5 : (a) Cross-sectional schematic of Ga_2O_3 FET structure and (b) micrograph of submicron T-gate

tions for a QKD network (Fig. 4).

Development of high-frequency Ga_2O_3 devices

Researchers at the Green ICT Device Advanced Development Center have their eyes on the great potential of gallium oxide (Ga_2O_3) transistors as extreme environment devices. They are engaged in exploratory research and development of these devices with the aim of surveying specific practical applications and frequency bands. In the 2019 fiscal year, they fabricated a lateral submicron-gate Ga_2O_3 transistor and evaluated its high-frequency device characteristics. This transistor is expected to be applied mainly to wireless communications. A cross-sectional schematic diagram of the fabricated transistor and a micrograph of the gate section are shown in Figs. 5 (a) and (b), respectively. For this transistor with a gate length of 0.08 μm, we obtained a current-gain cutoff frequency (f_T), which corresponds to the limiting frequency in high-frequency operation, of 10 GHz. Furthermore, for a gate length of 0.2 μm, we achieved a record maximum oscillation frequency (f_{max}), which corresponds to an important performance index in high-frequency power amplification, of 27 GHz. This value of f_{max} represents an approximately 60% increase in the maximum value of 17 GHz reported up to now for Ga_2O_3 transistors.

Development of Deep Ultraviolet LED

Deep-ultraviolet (DUV) light in the wavelength range of 200 – 350 nm has the shortest wavelength among light that can propagate through air. In particular, light with a wavelength of 280 nm or shorter, i.e., the ultraviolet C (UV-C) light, is absolutely absorbed by the ozone layer and cannot reach the Earth's surface. DUV light is therefore expected to be applied to communications and sensing unaffected by sunlight background noise and also to non-line-of-sight (NLOS) optical communications owing to its strong atmospheric scattering characteristics. In addition, UV-C light can be absorbed by the DNA

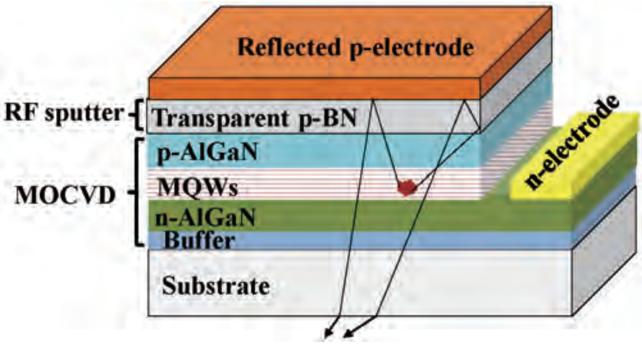
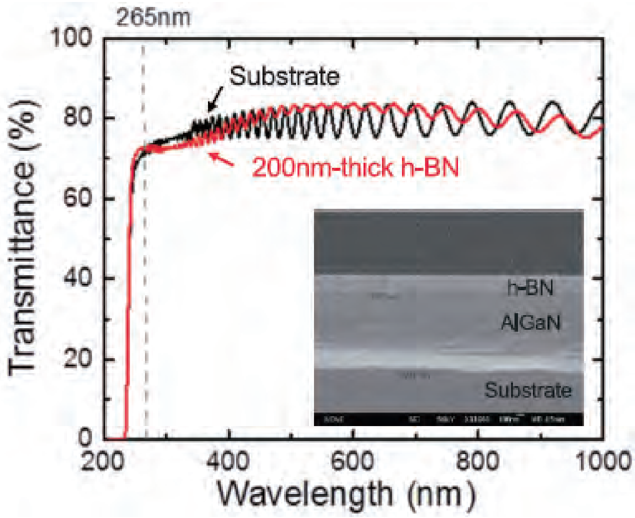


Fig.6 : (a) A schematic of a DUV-LED device using h-BN/$Al_{0.7}Ga_{0.3}N$ hetero-structure



(b) Transmission spectra of deposited h-BN/$Al_{0.7}Ga_{0.3}N$ heterostructure and substrate. Inset shows the cross-sectional scanning electron micrograph of the film.

and protein of living organisms making it possible to kill harmful bacteria and viruses in an extremely effective way without any use of chemical agents like chlorine. However, DUV light does not exist in the natural world. There is therefore heightened anticipation for using DUV light-emitting diodes (LEDs) as new compact and environmental-friendly DUV light sources to replace toxic mercury lamps that have been traditionally used for these purposes. For DUV LEDs, comprehensive designs are required including the finding of suitable materials to overcome vulnerabilities in the physical properties of each material when integrating various materials into one device. We have studied DUV LEDs by combining a materials search and nano-structured device technology with the aim of achieving high-output-power, high-efficiency DUV LEDs under high driving current with an emission wavelength of 265 nm, which possesses the most effective bactericidal property.

We have proposed a h-BN/$Al_{0.7}Ga_{0.3}N$ heterostructure as a new transparent contact structure in the DUV region (Fig. 6(a)), and have achieved high-quality h-BN hetero-film (> 200 nm) on AlGaN by RF sputtering at a low temperature (300°C) which can prevent the active region of LEDs from being damaged. The transmittance of fabricated film in the DUV region is extremely high (≈ 98% @ λ = 265 nm) (Fig. 6(b)).

In addition, we have developed large-area device-package technologies for achieving high-output-power and high-reliability DUV LEDs and fabricated a prototype device that achieved a lifetime over 10,000 hours under a driving current of 1 A.

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General　HARAI Hiroaki

The ICT Testbed Research and Development Promotion Center has merged several testbeds, including JGN, a High-Speed R&D Network Testbed; RISE, Wide-Area SDN Testbed; StarBED, a Large Scale Emulation Testbed; and JOSE, a Large Scale IoT Service Testbed; to develop NICT's Integrated Testbed and to provide various services. In this way, we have built and have been operating a testbed that covers a range of environments, from real platforms to emulated environments, which enables us to support various types of IoT related demonstration experiments.

We also conducted R&D on platform technologies needed for implementing the StarBED testbed, which is a large scale emulation platform that can perform technology testing in various environments by combining parts of the platform that are simulated, with a large-scale, real testbed composed of JGN, RISE, and JOSE, which can perform highly practical technology tests developed on the latest, real platform ICT (Fig. 1).

Expansion of collaboration with international research facilities

In FY2019, a memorandum regarding the Asia-Pacific-Europe Ring network for research and education was concluded among facilities within and outside of Japan, consolidating a global network connection environment (Fig. 2) that can provide speeds over 100 Gbps, spanning Asia, Europe and North America when combined with agreements already concluded for 100 Gbps high speed connections in the Asia-Pacific Ring (APR). This enables international research and educational networks to provide backup for each other and strengthens cooperative relationships between research and educational facilities within and outside of Japan. Since 2017, this international connectivity environment has been used in projects including Super Computing (SC), Sapporo Snow Festival testing, the Data Mover Challenge technology contest, a project for international sharing of elementary particle experimental data, and in international technology tests such as expansion of the Himawari Real-time Web into Asia.

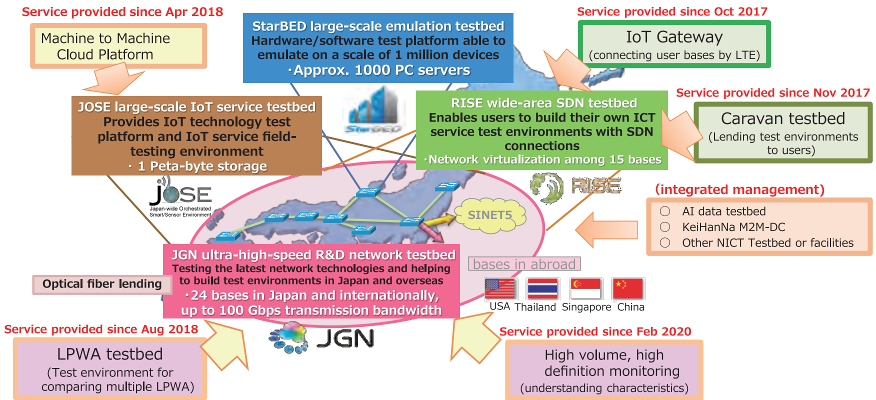


Fig.1 : NICT Integrated Testbed

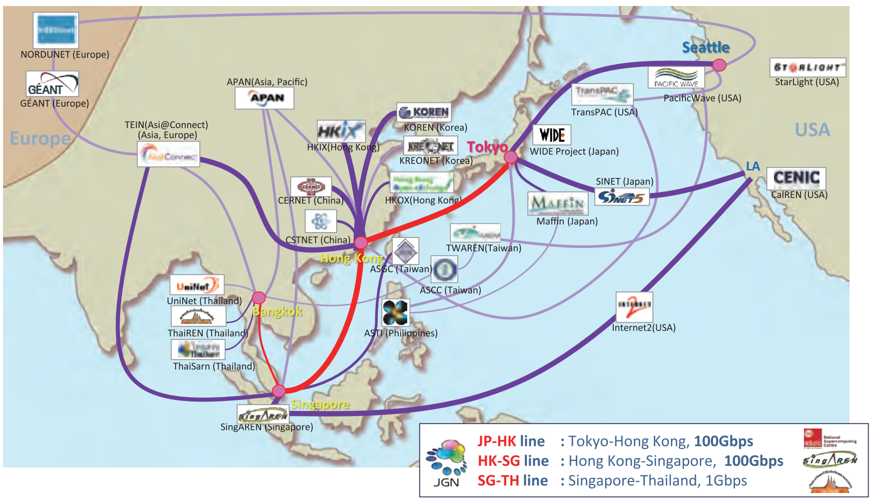


Fig.2 : Global 100+ Gbps network via APR and AER

IoT platform technology initiatives

Since the previous fiscal year, we have shifted our R&D focus to work on more-advanced IoT platform technologies. In FY2019, we worked on the following two initiatives.

In the area of autonomous cooperative communication frameworks for connected cars and other masses of mobile objects, we developed a Delay Tolerant Network (DTN) control algorithm for uploading to the cloud and reported on its effectiveness at the IEEE COMPSAC 2019 international conference. We also developed extensions to gather and share information between vehicles in real time, implemented wireless communications functions for operation in real vehicles, and began trials testing the system using actual moving vehicles (Fig. 3).

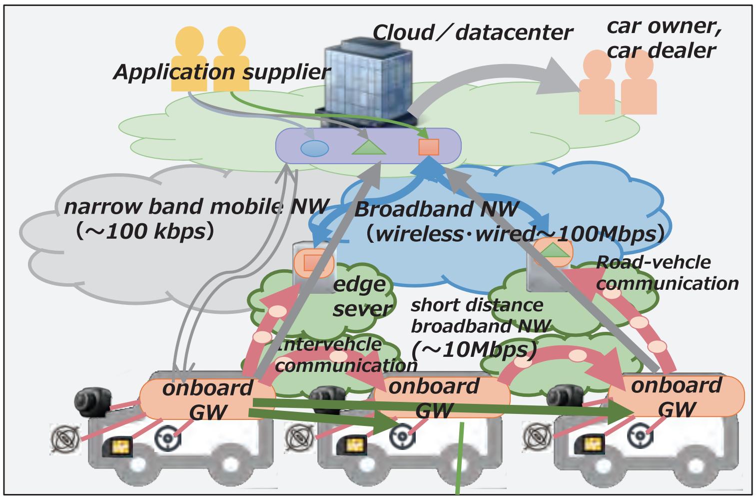


Fig.3 : Connected car data collection platform

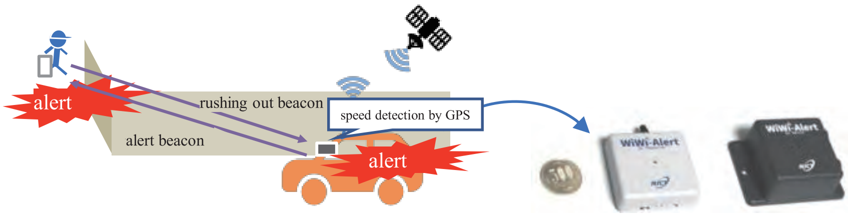


Fig.4 : WIWI Alert integration of GPS and Wi-Sun communication

Design and development of a regional IoT service platform based on "local production and consumption of data" concept, and not dependent on a mobile telephone network

We continue to develop and implement IoT devices and systems integrating Wi-SUN and various other wireless technology components. In collaboration with enterprise, we have developed software for an IoT wireless router that enables construction of a regional IoT service platform that can connect to the smart-meter platform provided in every household. Such a platform would be capable of tasks such as collecting or distributing information related to local projects such as watching over vulnerable residents, by equipping local business vehicles with the devices. We have begun studying commercialization with devices price around 10,000 yen. We have also transferred technology for a low-power GPS module developed at NICT to an electronics manufacturer and are preparing to develop and sell it as a location tracker product. We also developed the WiWi-Alert traffic safety system, integrating this GPS module with Wi-SUN communication functionality (Fig. 4). A robot business has begun studying implementation of the system.

Use of the simulation and emulation collaboration platform called "Smithsonian"

In collaboration with Nagoya University and the Japan Advanced Institute of Science and Technology, we have developed the ARIA open disaster mitigation platform, utilizing the simulation and emulation collaboration platform called "Smithsonian," which is being developed during the first half of this year (Fig. 5). As a use case simulating evacuation during a flood, we linked GIS data, flood analysis (simulation) using physical models, multi-agent simulation of the movement of people, smart devices held by people, and an escape-route search server (emulation), enabling us to check effects between these components in a single simulation. This enabled us to test hardware and software implementations in a real environment, while adjusting various simulator parameters. We are also studying use of the system to predict conditions in the near future when a disaster occurs, by entering real data from IoT sensors and other sources into the platform, and using such predictions for official purposes such as evacuation announcements.

Linking of simulators for water-level changes and behavior of people, an escape-route search server for real environments, and an application implemented for smart devices.

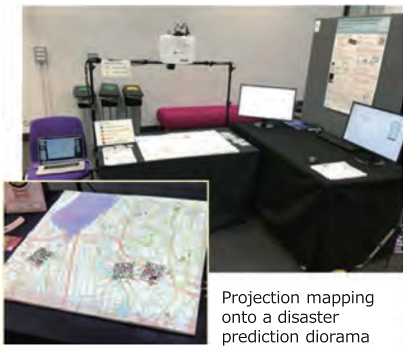


Fig.5 : Demonstration of ARIA open disaster mitigation platform

Open Innovation
National Cyber Training Center

Director General　SONODA Michio

The National Cyber Training Center was established on April 1, 2017. Its purpose is to plan and promote practical cyber training by making the best possible use of NICT's technical know-how, research results, and research facilities. To train professionals in the fields of cybersecurity and ICT, we are engaged in training practical security operators and R&D-oriented security innovators, and we are also conducting our own research and development relating to these two aspects of our training (Fig. 1).

CYDER

CYDER (Cyber Defense Exercise with Recurrence) is our hands-on cyber-defense training program that provides practical training using actual equipment from incident occurrence to post-incident response in an environment that simulates the network environment of the trainee's organization (Table 1). CYDER program, which was established in FY2013 under the direction of the Ministry of Internal Affairs and Communications (MIC), originally took in about 200 trainees annually with a focus on organizations in the Tokyo metropolitan area. Then, after its transfer to NICT in FY2016, CYDER operation system and operation content have been enhanced and expanded annually as in the preparation of new exercise scenarios tailored to the target trainee. At present, CYDER administers about 100 training courses annually taking in more than 3,000 participants across all of Japan's 47 prefectures making it the largest cybersecurity training program in the country. The cumulative number of participants to date exceeds 11,000.

In FY2019, we exhibited CYDER at a number of security events and introduced CYDER to many parties involved in security. We also collaborated with a total of 11 telecommunication bureaus and general offices throughout Japan in conducting detailed public relations activities directed at local governments. As a result of these efforts, we conducted a total of 105 training courses in all 47 prefectures enabling 3,090 individuals to participate in CYDER training. After CYDER training, participants can put the skills they've gained into practice whenever actual incidents occur within their organizations. In this regard, the National Cyber Training Center has the role of gathering comments from participants based on actual experience, such as "Participating in CYDER enabled us to reassess the CSIRT (Computer Security Incident Response Team) in our own organization and fortify our security system," and of serving as a hub for strengthening security within Japan.

We have also been commissioned to provide standard training on information systems as implemented by MIC for personnel in ministries and agencies of the central government and has conducted courses based on CYDER as part of this training. In this way, the range of CYDER training has been steadily expanding.

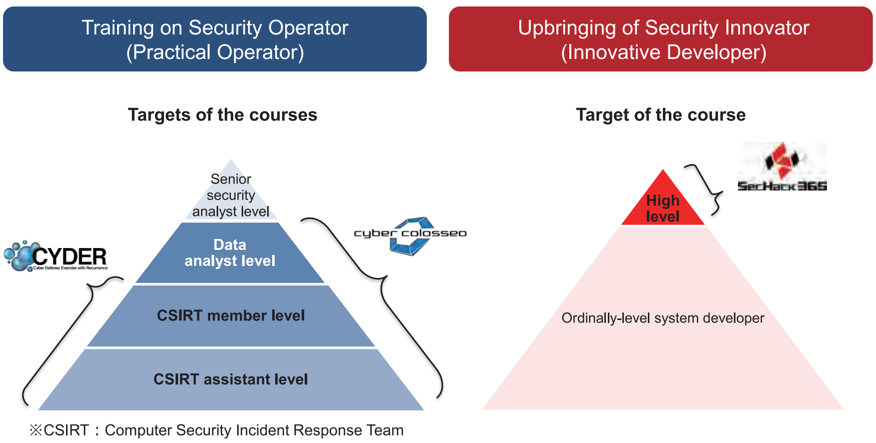


Fig.1 : Overview of the National Cyber Training Center

Cyber Colosseo

There were expectations that hackers would mount sophisticated cyber attacks against organizations involved with the Tokyo 2020 Olympic and Paralympic Games. The Cyber Colosseo initiative, which began in FY2017, began to expand its number of trainees and provide online on-demand study content from FY2018. In addition, Colosseo College (20 courses) was established in FY2018 as a group of selective supplementary lectures with the aim of providing the knowledge and skills necessary for taking the Colosseo Exercise program and of raising the level of exercises.

Table 1 : CYDER basic information

Purpose	To acquire practical measures to minimize the damage caused when organizations suffer a cyberattack.
Eligibility	National institutions, designated corporations, independent administrative agencies, local public institutions, critical infrastructure providers, private companies, etc.
Course Length	1 hour of pre-learning + 1 day of group exercises *Annual attendance is recommended
URL	https://cyder.nict.go.jp/

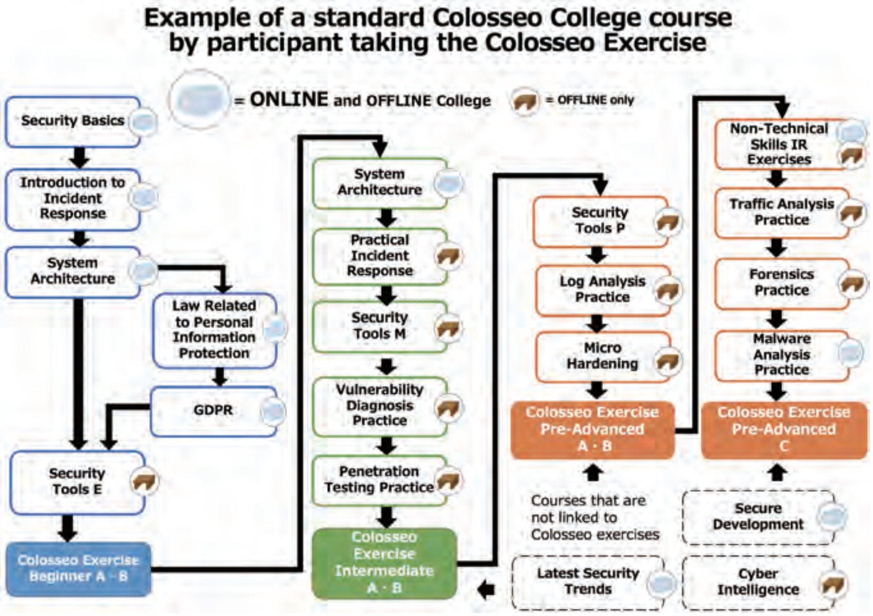


Fig.2 : Colosseo College courses in FY2020

Fig.3 : Scene from the SecHack365 Returns event held annually to support continuation of graduate activities

This approach clarified the role of Colosseo Exercise. Here, the ratio of lectures was lowered and the time spent on exercises with real equipment was expanded to maximize the training effect.

Then, in FY2019, in addition to expanding the scale of training as laid out by the initial Cyber Colosseo three-year plan, the number of trainees was further expanded thereby accelerating part of the FY2020 training schedule. This development was based on current conditions including requests from the Tokyo 2020 Organizing Committee. In FY2019, Colosseo Exercise and Colosseo College trained a total of 193 and 992 people, respectively.

In FY2020, due to the impact of the COVID-19 pandemic, some of the courses in Colosseo College have been set up for both online and offline training as an option for trainees (Fig. 2).

SecHack365

SecHack365 was established in FY2017 as a one-year training program for young people to provide extensive instruction in the research and development of security-related technology with the aim of producing future cybersecurity researchers and entrepreneurs.

In this program, more than 40 trainees are selected annually from several hundred applicants to participate in a total of six group training events and online instruction held over a period of about one year. At the end of this training, a presentation meeting is held to introduce projects and products undertaken by each trainee. In FY2020, all group training and events were held online due to the COVID-19 pandemic.

At first, SecHack365 instruction was provided through three different courses, but to provide flexible instruction to a diverse group of trainees and enrich course-specific training, this was expanded to five courses in FY2019 with trainees recruited on a course-by-course basis at the time of recruitment. This approach improved the SecHack365 program such as by matching the needs of trainees with instruction content.

Additionally, to enable alumni of this one-year training program to continue participating in activities, it was decided to form an alumni community and provide support such as by introducing communication tools and holding a “SecHack365 Returns” event annually targeting SecHack365 graduates (Fig. 3).

In 2019, two persons chosen by SecHack365 graduates participated in CyberTechTokyo, which was held in Tokyo based on a Memorandum of Cooperation (MoC) between Israeli authorities and MIC, and made presentations before world experts in cybersecurity. In this way, places for SecHack365 graduate activities are expanding.

Open Innovation

National Cyber Observation Center

Director General KUBOTA Minoru

To contribute to cybersecurity for IoT devices, based on Article 8, paragraph 2 of the Supplement of the Act on the National Institute of Information and Communications Technology (hereinafter referred to as "NICT"), NICT has conducted surveys of IoT devices with weak password settings and provided information to Internet Service Providers (hereinafter referred to as "ISPs"), using its technical expertise, with a subsidy from the national government.

Overview of NOTICE

Along with the rapid increase in the number of IoT devices, threats that these IoT devices will be exploited to conduct cyberattacks have become apparent.

In response to the increasing seriousness of cyberattacks exploiting IoT devices, the Act on the NICT was amended, adding the survey of IoT devices with weak password settings to NICT operations (for a period of 5 years). and came into force on November 1, 2018. In accordance with Article 9 of the Supplement of the Act on the NICT, the plan on the implementation of the work prescribed in Article 8, paragraph 2 of the Supplement of the Act on the NICT (hereinafter referred to as "Implementation Plan"), was submitted for approval on January 9, 2019, and was approved by the Ministry of Internal Affairs and Communications (hereinafter referred to as "MIC") on January 25, 2019.

With approval of the Implementation Plan, NICT established the National Cyber Observation Center on January 25, 2019, as the organization that would carry out duties related to the survey of IoT devices with weak password settings.

On February 1, 2019, a press release was issued regarding the project called the "National Operation Towards IoT Clean Environment" (hereinafter referred to as "NOTICE"), conducted by MIC and NICT, in cooperation with ISPs and others, to survey vulnerable IoT devices at risk of being exploited in cyberattacks, and to alert users to the problem. NICT began conducting this NOTICE project on February 20, 2019 (Fig. 1).

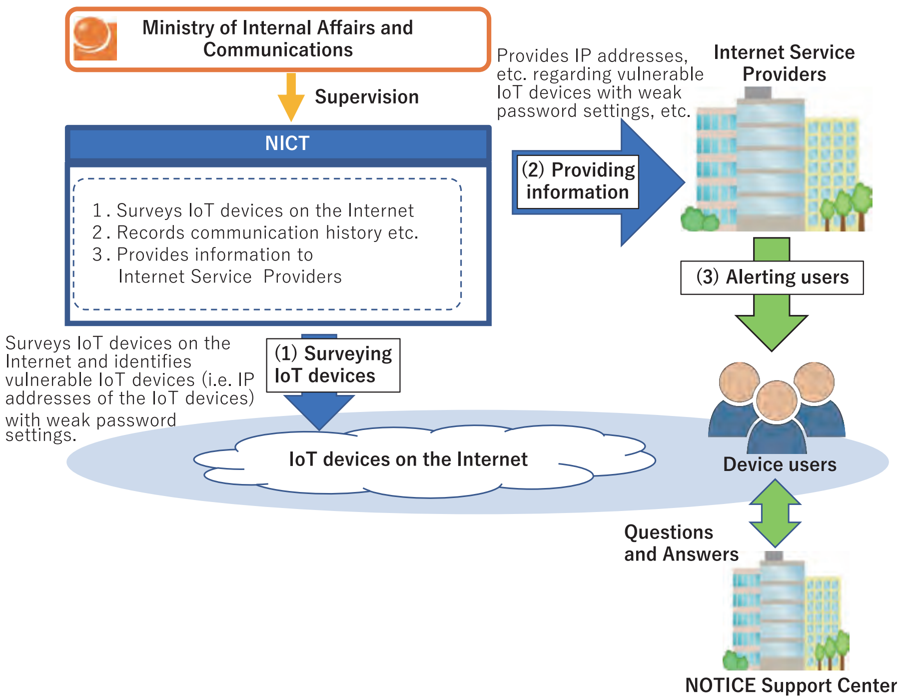


Fig.1 : Overview of NOTICE

Process of NOTICE

1. Procedure of surveys to identify vulnerable IoT devices

(1) Port Scan

NICT sends connection requests to IoT devices at global IP addresses (IPv4) allocated to Japan, to check whether sessions can be established.

(2) Accesses for identification of vulnerable IoT devices

With regard to IoT devices that require IDs and passwords authentication, NICT enters easily guessed IDs and passwords to these IoT devices to check whether log-in to these IoT devices is possible (accesses for identification of vulnerable IoT devices). The survey are carried out by development and construction of programs and systems.

2. Creation of electronic records of communication history and other factors

In relation to IoT devices subject to the "accesses for identification of vulnerable IoT devices" described in the Section 1, NICT creates electronic records of communication history including source IP addresses, destination IP addresses, timestamps and other information during communication with IoT devices.

3. Notification to ISPs

If NICT succeeds "accesses for identification of vulnerable IoT devices", NICT notifies ISPs associated with the destination IP addresses which are successfully logged-in to with weak password settings and are subject to user alert, to request these ISPs to take appropriate actions for addressing vulnerability of IoT devices, by-sending the electric records of communication history described in the Section 2 as evidences.

Progress on the NOTICE project (as of August 2020)

As of August 2020, NICT have conducted surveys on approximately 110 million IP addresses associated with 62 ISPs that have completed the procedure to participate in the NOTICE project. In FY2019, the total number of IP addresses which were successfully logged-in to with weak password setteings and were subject to user alert reached 2,249, and although the survey was not conducted in April due to the COVID-19 pandemic, in FY2020 this number reached 1,227 during the period from May to August 2020 (Fig. 2).

Changes to Implementation Plan (as of September 2020)

On September 2, 2020, an application to change the Implementation Plan was submitted, adding IDs and passwords to be entered during "accesses for identification of vulnerable IoT devices" and source IP addresses to be used for "accesses for identification of vulnerable IoT devices", and it was approved by MIC on September 11, 2020. NICT plans to conduct the surveys based on the changed Implementation Plan approved by MIC from October 2020.

- NOTICE conducts a monthly survey of IoT devices which can be logged-in using specific easily guessed IDs and passwords
- **62 ISPs** have completed the procedure to participate in the "NOTICE" project as of August 2020. A survey on about **110 million IP addresses** of the ISPs was conducted.
- **309 IP addresses were successfully logged-in to with weak password settings, were subject to user alert and the ISPs have been notified (August 2020).**

Ref) Total number in FY2020: 1,227 (in FY2019: 2,249)
Devices in which password could be entered: 123 thousand

Trends in Number of IP addresses which were subject to user alert

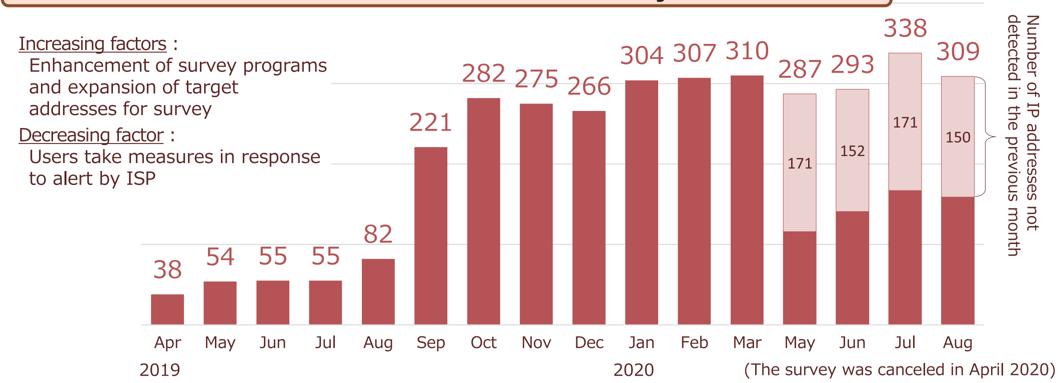


Fig.2 : Progress on NOTICE

Open Innovation

AI Science Research and Development Promotion Center

Director General KIDAWARA Yutaka

The AI Science Research and Development Promotion Center (AIS) was established in April 2017 as an organization for promoting strategic research and development based on open innovation in relation to artificial intelligence (AI) technology in the field of AI science.

AI Japan R&D Network

NICT participated as a constituent member in the "AI Steering Committee" first held in October 2019 under the Artificial Intelligence Technology Strategy Council based on "AI Strategy 2019" decided in June 2019 by the Integrated Innovation Strategy Promotion Council of the Japanese government. At that time, we engaged in discussions on formulating an action plan to promote R&D to help enhance and fundamentally reform Japan's AI-related core centers, namely, the RIKEN Center for Advanced Intelligence Project (AIP), Artificial Intelligence Research Center (AIRC) of the National Institute of Advanced Industrial Science and Technology (AIST), and NICT's Universal Communication Research Institute (UCRI) and Center for Information and Neural Networks (CiNet). These discussions led to the establishment in December 2019 of the "AI Japan R&D Network" centered about the above AI-related core centers and including participating universities, research institutions, etc. (Fig. 1).

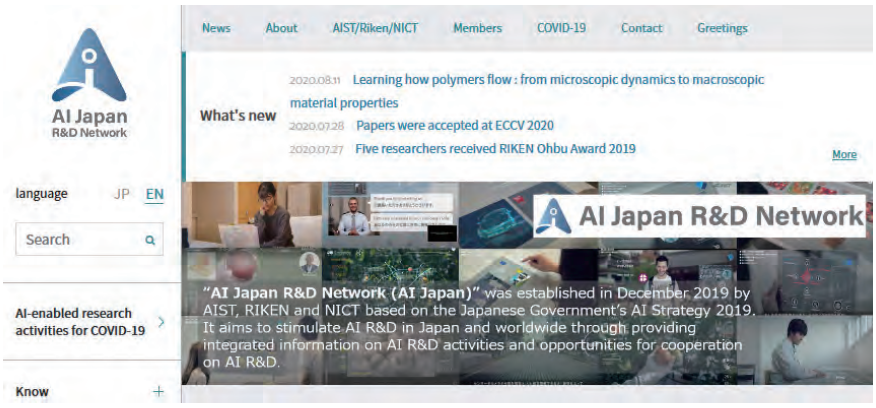


Fig.1 : AI Japan R&D Network website

Collection of translation data in Hon'yaku (Translation) Bank

Under the "Global Communication Plan" of the Ministry of Internal Affairs and Communications (MIC) that aims to implement multilingual speech translation technology in society by 2020, NICT has been researching and developing automatic translation technology (neural translation) using neural networks having a deep hierarchical structure as widely used in AI technologies. To raise the accuracy of automatic translation using neural translation, it is important that large amounts of translation data from a variety of fields be collected and stored in addition to improving neural network algorithms.

At the same time, government institutions, prefectural and city governments, municipal governments, and private firms are in possession of many and diverse types of documents including general papers, white papers, pamphlets providing information on sightseeing, etc., business description materials, and instruction manuals that have been prepared in multiple languages.

With this in mind, NICT began to operate Hon'yaku (Translation) Bank in September 2017 in cooperation with MIC as a national program for collecting translation data. We expect this translation data that will continue to be collected by NICT through Translation Bank to help improve the accuracy of Japan-developed translation technologies and diversify their target fields.

In FY2019, thanks to stepped-up efforts in collecting white papers and other types of translation data from prefectures, ministries, and agencies, the Translation Bank received translation data from one prefecture and seven ministries.

R&D of AI data testbed

We designed and constructed an AI data testbed as a platform for storing, managing, and searching as well as sharing and releasing various types of AI-related datasets and began operation of a website for releasing these datasets to the public in May 2019. As of July 1, 2020, 49 datasets in

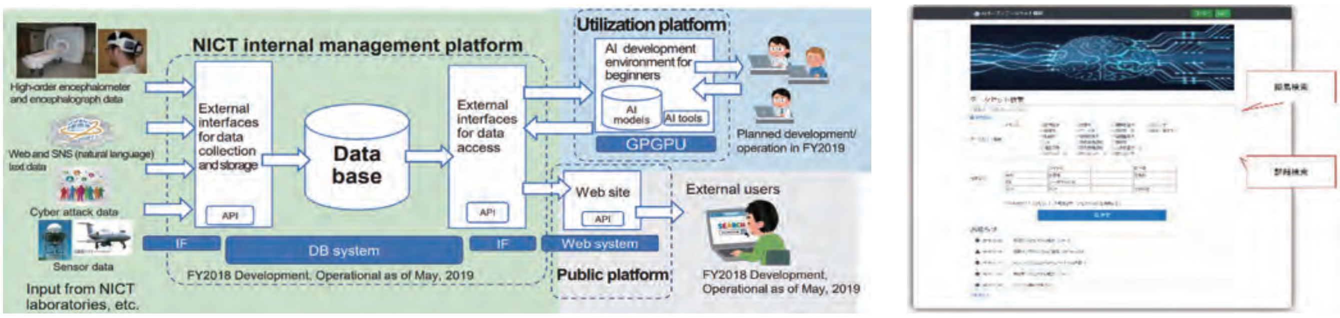


Fig.2 : Overview of AI data testbed system

7 genres had been released (Fig. 2). Additionally, with the aim of making this public website even more convenient to use, we designed and implemented an ambiguous search function and began this service in April 2020.

R&D on AI × Security

In FY2019, with the aim of promoting an open-innovation type of research project, we developed a prototype system for automating security operations in cooperation with the NICT Cybersecurity Research Institute. In this project, we focused on the following three tasks: (1) automating Android-malware function analysis, (2) achieving quick detection of malware activities on the Internet (Fig. 3), and (3) automating the priority level of responses to incidents. We also made academic presentations of our results and undertook the provision of security-related data and the research and development of audio security technology.

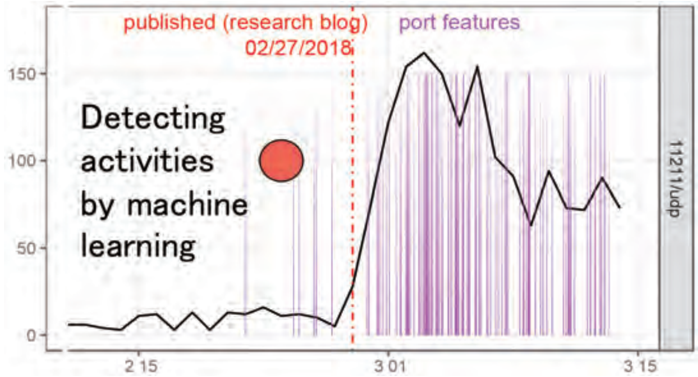


Fig.3 : Automatic detection of malware activities

R&D on AI × Brain Science

In cooperation with the Center for Information and Neural Networks (CiNet), we analyzed fMRI/EEG brain activity data under human cognitive activities using machine learning, constructed a training dataset for the purpose of explaining brain functions and developing engineering applications, and conducted preliminary tests of deep learning methods applicable to brain data analysis (Fig. 4). Specifically, we applied deep learning to the analysis of MRI brain data under long-term video viewing, narrowed down effective metadata (annotations) to clarify information expression in the brain in relation to understanding a story, and constructed a dataset consisting of approximately 20 hours of data in total.

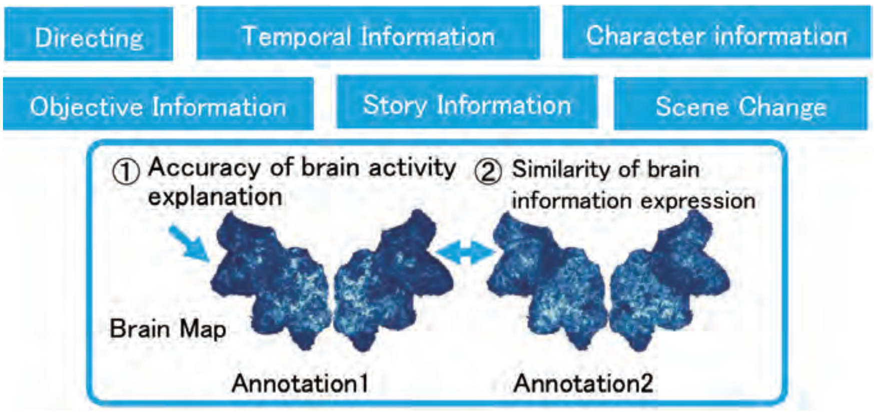


Fig.4 : Design and development of annotation for analyzing information expression in brain

Open Innovation
Resilient ICT Research Center

Director General SUZUKI Yoichi

Learning from the damage to communications networks caused by the 2011 Great East Japan Earthquake, the Resilient ICT Research Center was established in April 2012 in a campus of Tohoku University located in Sendai City, creating a base for research in the disaster affected area. Its purpose was to conduct R&D on ICT resiliency to such disasters under a framework of collaboration among industry, academia, and government. Resilient ICT Research Center carries out initiatives in both fundamental research on disaster-resilient technologies and their implementation in society to maximize the results of R&D. The center also carries out initiatives on implementing its achievements in society, planning and holding demonstrations that apply research results, collaborating with external organizations, and establishing regional research bases.

Collaborative activities toward social implementation of resilient ICT and dissemination of research results

Toward the social implementation of resilient ICT based on research results achieved with its collaborators, the Resilient ICT Research Center participates in disaster management drills held by local governments assuming an actual disaster and presents its activities through symposiums and exhibitions related to disasters. In FY2019, the center jointly organized the general assembly of the Resilient ICT Research Forum in January 2020 and presented recent research results in the Disaster and Crisis Management ICT Symposium 2020 in February 2020. Moreover, to exhibit our achievements, we participated in ASTAP31 (Tokyo, June 2019), ICT Fair in Tohoku 2019 (Sendai, June 2019), Disaster Prevention Festival 2019 (Nagoya, October 2019), World BOSAI Forum (Sendai, November 2019), and the 24th Earthquake Technology Expo (Yokohama, February 2020). All in all, the Center participated in 17 disaster-prevention drills (one of which is shown in Fig. 1) and 18 conferences and exhibitions during FY2019.

Elastic optical switching technology project

We are studying next-generation optical switching technology for dynamically controlling high-speed power equalization of wavelength-multiplexed optical signals. Power fluctuations in optical signals that occur when switching multiple wavelengths rapidly during large changes in traffic must be compensated for. The method used for achieving power equalization of multiple wavelengths has been to inject multiple RF control signals of different frequencies into a simple acousto-optic device. We previously developed a system using a field programmable gate array (FPGA) to perform collective control of the optical paths of eight wavelengths. This method was expected to achieve high-speed compensation of spectral and temporal fluctuations, but elimination of power jitter was left as a future research issue. For this reason, we optimized the processing section of the optical power equalization system and showed that it could effectively suppress power jitter when equalizing eight wavelengths in a response time of 500 μs (Fig. 2). In this way, we were able to achieve a uniform response time and maintain transmission quality in the face of power fluctuations due to optical switching.

We also studied and developed internetwork orchestration technology for achieving interoperability control between an optical packet and circuit integrated (OPCI) network and other transport networks. In this fiscal year, our research and development efforts centered on orchestration technology for interoperability control on the control/management plane (Fig. 3). As a transport network with a

Fig.1 : Itami City flood simulation drill

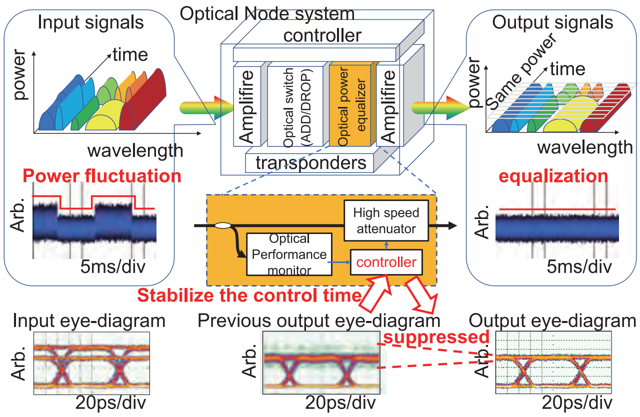


Fig.2 : Power jitter suppression in high-speed multiple-wavelength equalization system

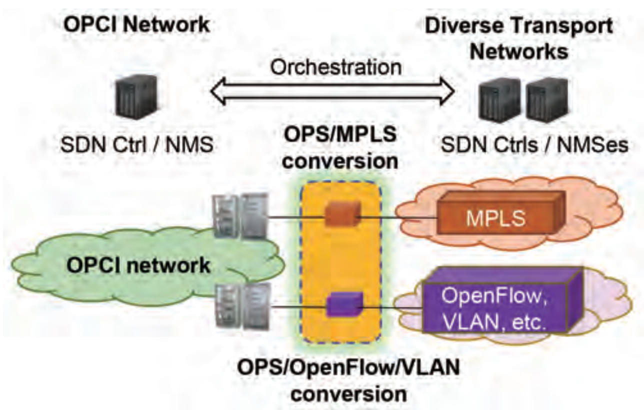


Fig.3 : Orchestration for interoperability control between diverse transport networks and optical packet & circuit integrated network (OPCI)

large-capacity OPCI network at its core, this technology makes it possible to quickly relay diverse types of traffic such as MPLS, Ether, OpenFlow, and IP at the time of a disaster while enabling early recovery of interrupted communications.

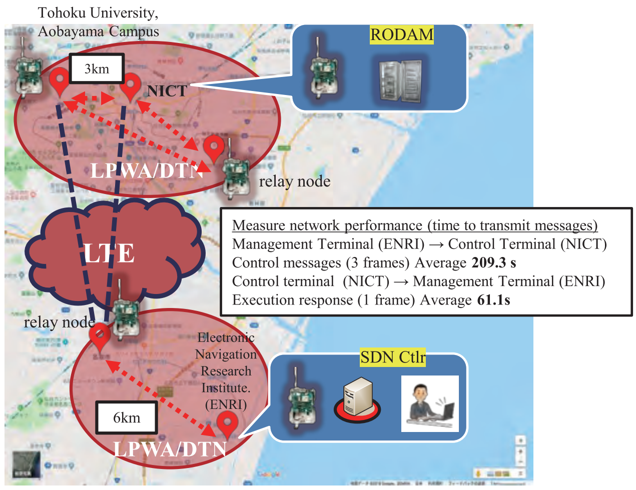


Fig.4 : Field-trial experiment of FRENLL in the south area of Sendai

Wireless communications application project

We developed technology that enables dynamic deployment and operation of services via remotely distributed computer resources by applying information synchronization and sharing technology of regional private networks. Additionally, envisioning a serious environment in which LTE services are only partially available at the time of a disaster, we constructed a test environment combining the LTE and private LoRa (Long Range) to demonstrate emergency recovery of the optical control network as a world's first (Fig. 4).

As technology for quick network construction, we developed a distributed edge-processing infrastructure for cooperative and integrated operation between nodes without assuming always-on Internet connections. At a Kochi Prefecture comprehensive disaster management drill, we conducted a field experiment on healthcare-information sharing and communication to manage the assumed disaster using our short-range high-speed device-to-device radio connection technology and demonstrated its effectiveness under an environment in which Internet connections are not maintained.

Real-time social intelligence analysis project

We have been developing DISAANA, a system that analyzes disaster-related information on SNS, and D-SUMM, a system that automatically extracts disaster-related information from SNS and summarizes them in a compact format. To study a view towards social implementation of these systems, they were applied in the comprehensive disaster management drills held in Oita Prefecture and Hirakata City and their effectiveness was clearly shown.

In the second period of the Cross-ministerial Strategic Innovation Promotion Program (SIP) of the Cabinet Office, we continued our work on the "research and development of SOCial dynamics observation and victims support Dialogue Agent platform for disaster management (SOCDA)" to develop the world's first chatbot for disaster-management. This project is conducted in cooperation with the National Research Institute for Earth Science and Disaster Resilience, Weathernews Inc., and LINE Corporation. In FY2019, by using SOCDA implemented as a LINE official account, we first tried applying SOCDA to a safety confirmation service for people requiring support and showed its effectiveness.

Our research and development of DISAANA, D-SUMM, and SOCDA is conducted in cooperation with the Data-driven Intelligent System Research Center of the Universal Communication Research Institute, NICT. We ask the reader to refer to their sections in this issue as well.

Open Innovation

Big Data Integration Research Center

Director General ZETTSU Koji

Big Data Integration Research Center is researching and developing technology for enabling advanced situation awareness and behavior support through the cross-domain and integrated analysis of data collected from sensors and other IoT devices with the aim of achieving optimal and efficient social systems. Specifically, we are researching and developing data collection and analysis technology for the purpose of collecting and analyzing real space information closely related to social life such as torrential rains and environmental changes and of using that information effectively in people's lives. We are also researching and developing data mining and AI technology so that effects on and associations with specific social systems such as transportation can be analyzed as model cases by integrating and performing cross-domain correlation analysis on sophisticated environmental data and diverse types of social data. Here, we are also performing R&D work on a mechanism for using the results of such analyses in real space. We are linking these R&D results to user needs in fields such as healthcare, transportation, and disaster prevention/mitigation and conducting demonstration experiments in an open-innovation format in collaboration with universities, private enterprises, and local governments.

xData Platform

In FY2019, we engaged in collaborative activities with the research community toward deepening our fundamental technologies and with business partners toward social implementation through open development using the xData (cross-data) platform that we previously constructed.

Specifically, using datasets collected, for example, at the Datathon held in Fukuoka City in FY2017 and FY2018, we proposed a task called "Lifelogging for Wellbeing" for benchmarking methods for environmental-data search and environmental-quality prediction at the MediaEval 2019 international workshop. Eleven teams of researchers from Europe, China, Southeast Asia, etc. participated in this task from May to October during which time they proposed and evaluated improved methods. Superior techniques proposed in this task were fed back to the xData platform implementation. We also began joint research to further develop this task with Vietnam National University, Ho Chi Minh City, a task participant. This task received a special commendation for its distinctive feature of data association and analysis based on real-life examples, and in this sense, it was considered significant from both a scientific perspective and its value to society while involving the research community.

In addition to the above, we released the Geographical Information Systems (GIS) analysis tool for Synthetic Aperture Radar (SAR) data that we previously constructed on the xData platform. Using the tool, we organized the SAR Data Analysis Challenge (April – May 2019) of extracting GIS data such as flood and landslide areas from NICT Pi-SAR data to generate a disaster map. Thirty individuals made up of researchers, engineers, and students from universities and companies in GIS/IT fields, construction, and civil engineering participated in this challenge, which involved online training in a SAR data analysis program and competing in various tasks. Participants gave high marks to this challenge commenting, for example, that they were able to quickly give form to their ideas for various types of maps using SAR data. We released the programs and hazard maps developed by participants (under GPL v2 license) and encouraged their reuse (Fig. 1).

Development of efficient method for discovering high-utility frequent itemsets

In the processing for discovering highly correlated data in rare cases such as accidents and disasters, discovering highly useful itemsets from a database is an important problem for which a variety of applications exist in the real world. In past research related to high-utility itemsets discovery, less-frequent itemsets of no interest could be discovered and computational costs were high, so results were of no practical value. To resolve these issues, we extended a previously developed data mining method (Sequential/Parallel Weighted FP-growth) and developed the Spatial High Utility Itemset Mining (SHUIM) method for efficient discovery of local high-utility association rules (Fig. 2).

Here, by pruning useless association patterns and devising termination conditions for pattern discovery, we succeeded in significantly reducing execution time and memory usage. We also developed a

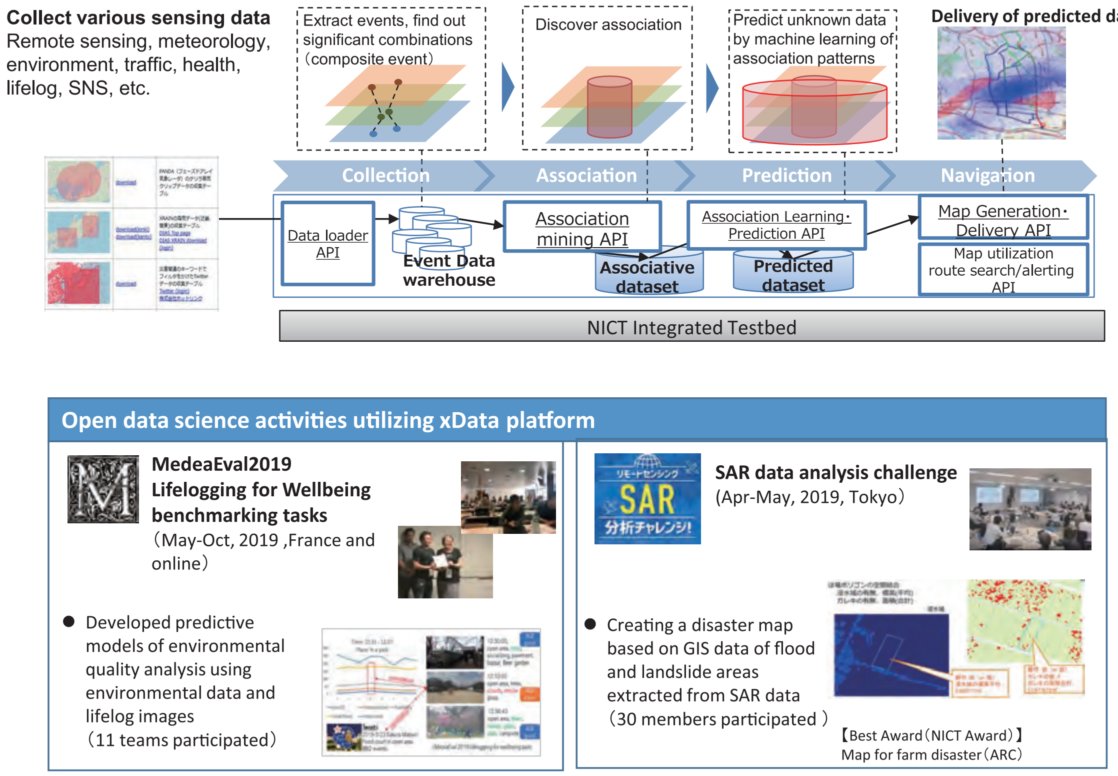


Fig.1 : Outline of xData platform

scalable model for all-weather traffic congestion prediction (called VEENA) based on SHUIM and showed it to be sufficiently effective. For example, we demonstrated that it could achieve a prediction accuracy of 80% in an evaluation experiment based on past case studies targeting the prediction of traffic congestion on peripheral roads during heavy rainfall. We published a paper based on the above results at SSDBM2019, a top conference in the data-mining field (paper acceptance rate: 14%). We also received the Best Paper Award at the IEA/AIE-2019 International Conference. These conferences recognized this work as an outstanding academic achievement.

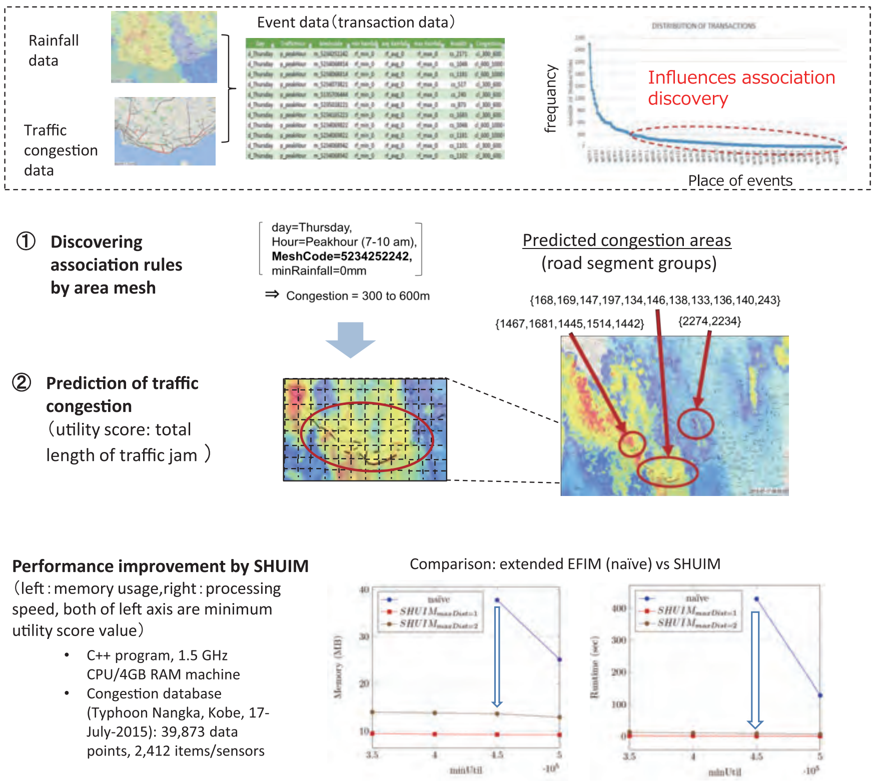


Fig.2 : Applying SHUIM method to scalable model of all-weather traffic congestion prediction

Open Innovation

Terahertz Technology Research Center

Director General HOSAKO Iwao

The terahertz band corresponds to electromagnetic waves at frequencies ranging from roughly 100 GHz to 10 THz, which lies between so-called radio waves and light waves. Electromagnetic waves in this region have so far been difficult to generate and detect. As a result, the terahertz band remained unused and unexplored. The Terahertz Technology Research Center has concentrated NICT's diverse activity in R&D ranging from materials to systemization and has driven forward with the research and development of cutting-edge measurement technology to support the realization of terahertz wireless communication systems. In addition, by working with organizations such as the Terahertz Systems Consortium, we will promote joint studies with industry and academia and contribute standardization aimed at improving the environment so that the terahertz band can be used effectively (Fig. 1).

Core technology for terahertz radio testbed

To realize 100 Gbps-class terahertz communication technology, we are developing technologies to generate terahertz signals based on fiber-radio and advanced optical fiber communication technologies. In FY2019, we studied a technique for generating a single ultra-wide-band signal by combining multiple transmitters, each having a limited bandwidth. We used digital signal processing to partition a single-carrier multi-level modulated signal with 85 GHz bandwidth (modulation rate of 80 Gbaud) into three frequency bands, and assigned them to each of three transmitters with bandwidths of under 45 GHz. We then tested a method to receive and demodulate them together as a single, wideband signal at the receiver. A schematic diagram and spectral distribution for the system are shown in Fig. 2. Comparing the received and demodulated signal with the one transmitted using a single wideband transmitter showed that the wideband signal can be generated by partitioning the bandwidth, with no particular degradation.

Fundamental technologies for terahertz spectrum measurements

In spectrum measurement, we require an octave-spanning bandwidth (0.3—0.6 THz) to enable measurement of spurious signal characteristics specified by the Radio Regulations. Our goal is to establish fundamental technology able to take spectrum measurements more quickly and accurately than previously, while handling this bandwidth in a single instrument. One method that has been proposed to realize this is to convert to multiple bands using a filter bank that partitions the measurement band into several equal bands, and to measure each of the partitioned frequency bands simultaneously using frequency comb signals as local oscillators. In FY2019, we conducted experiments to check the multi-band spectrum measurement concept using technology elements developed earlier (Fig. 3).

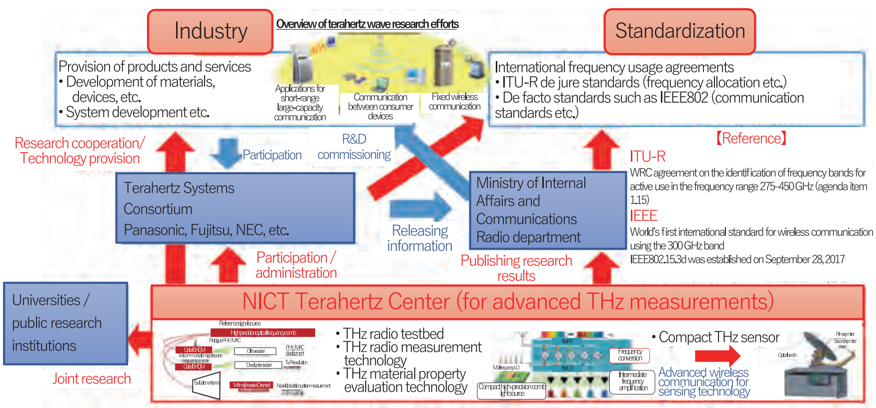


Fig.1 : Overview of Terahertz Technology Research Center

International standardization activities

We performed standardization activities according to WRC-19 agenda item 1.15, "Identification of frequency bands for use by administrations for the land-mobile and fixed services applications operating in the frequency range 275–450 GHz," achieving the following results in FY2019:

(1) Completed ITU-R report SM.2450, "Sharing and compatibility studies between land-mobile, fixed and passive ser-

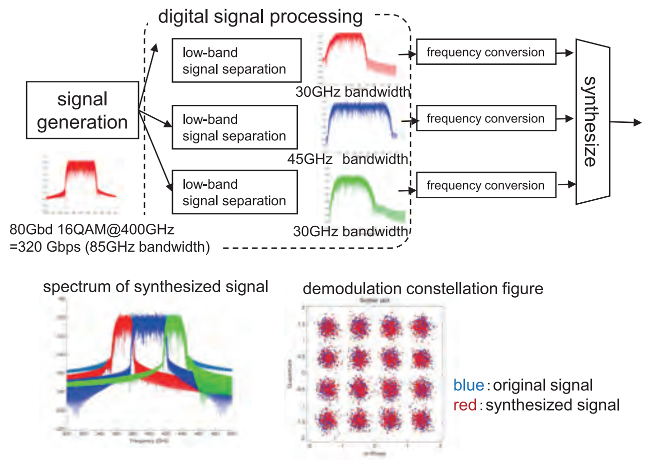


Fig.2 : Ultra wideband signal generation technology

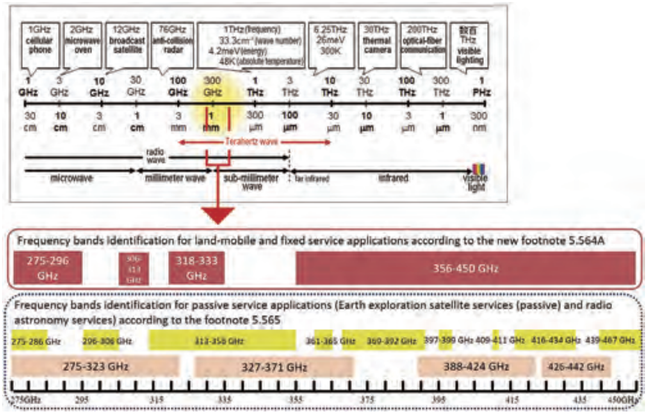


Fig.4 : Standardization of Terahertz band: WRC-19 frequency identification results

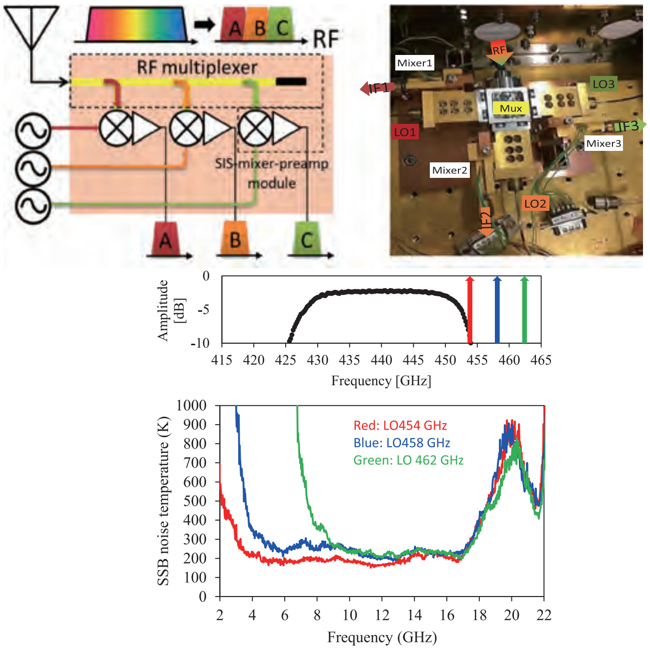


Fig.3 : Evaluation system concept for 3-band receiver and a photo of the inside of the cryostat (top), Ch.2 filter characteristics (middle) and receiver noise temperature at different LO frequencies (bottom)

Fig.5 : Advanced ICT Device Lab Workshop

vices in the frequency range 275–450 GHz," in ITU-R WP1A (Spectrum engineering technology).

(2) Completed the APC (APT joint proposal) regarding WRC-19 agenda item 1.15 in APG19-5 (APT WRC-19 preparatory meeting) and input it from the APT to WRC-19.

(3) Collaborated with the APT coordinator and CEPT coordinator in WRC-19 to add a new note identifying the four bandwidths shown in Fig. 4 (275–296 GHz, 306–311 GHz, 318–333 GHz, and 356–450 GHz) for land-mobile and fixed services applications in the radio communication regulations.

Advanced ICT Device Lab

The Advanced ICT Device Lab has clean rooms (CR) at two locations: its headquarters (Koganei City, Tokyo) and Kobe branch; each with their own specializations. The headquarters focuses research mainly on innovative device platform technologies for the Beyond 5G era and integrating optical and radio (especially high-frequency millimeter/THz signals), quantum communication device technology, and oxide semiconductor device technologies that will contribute to reducing ICT power consumption. On the other hand, the Kobe laboratory focuses R&D on elementary devices using advanced materials such as superconductor electronics, nano and organic devices, and deep ultraviolet devices. In FY2019, the Advanced ICT Device Lab recorded use by 162 researchers from 36 external organizations (using the headquarters CR). This covered an extremely wide spectrum of research fields, from fundamental research on materials to social applications of systems. To provide a place for generating innovation through organic interaction among these researchers from different fields, we started the Advanced ICT Device Lab Workshop (Fig. 5) in January 2020. It included presentations of many results from NICT's collaborative research and from research led by external facilities at universities and enterprise, and opened up active technical exchange among students and researchers from enterprise and from NICT.

Open Innovation

Innovation Promotion Department

Executive Director SHIOZAKI Mitsuhiro

The Innovation Promotion Department cooperates with government, industry, and academia and makes great efforts in the following mission with the aim of maximizing research and development (R&D) achievements.

- ***Promote efficient and effective R&D by making effective use of external research resources through collaborative research, commissioned research, and funded research.***
- ***Promote open innovation by implementing R&D achievements in society through appropriate securing and effective use of intellectual property and effective standardization activities.***

Joint research with other enterprises, universities, and public research institutes

(1) Collaborative research

In FY2019, NICT was engaged in 582 collaborative-research contracts (including those continuing from the previous fiscal year). Of these, a total of 141 contracts were newly concluded in FY2019 with 127 of these being domestic contracts and 14 being contracts with overseas research institutions (Fig. 1).

(2) Funded collaborative research

In ordinary collaborative research, NICT and the collaborating institution define a common research project and divide up the research work to be performed. In funded collaborative research, the collaborator is also asked to bear part of the research expenses incurred by NICT with the aim of accelerating collaborative research. In FY2019, NICT was involved in a total of 29 projects of funded collaborative research (including those continuing from the previous fiscal year).

(3) Collaboration with universities

To deepen collaboration and cooperation in agreements between universities and NICT on collaborative and cooperative research, we previously conducted “matching research support projects” with Tohoku University and Waseda University to support feasibility studies for uncovering new common research themes that would leverage the research potential of both parties. In FY2019, we added to this list by conducting a matching research support project with Kyushu Institute of Technology. Overall, we conducted collaborative research on projects selected by each university and a review committee (11, 4, and 4 projects with Tohoku University, Waseda University, and Kyushu Institute of Technology, respectively). These activities have so far led to the acquisition of external funds for 13 projects.

In addition, NICT and the National Astronomical Observatory of Japan (NAOJ) signed a comprehensive collaboration agreement with the aim of contributing to the further development of information-communications in Japan through mutual cooperation (Fig. 2). NICT has concluded 18 comprehensive collaboration agreements with universities and others.

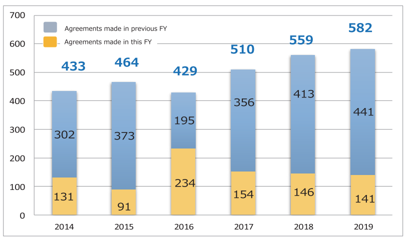


Fig.1 : Trends in number of joint research contracts

Fig.2 : Comprehensive collaboration agreement between NICT and NAOJ

Promotion of commissioned research

In FY2019, NICT worked on 30 research projects continuing from the previous fiscal year and launched 6 new research projects. NICT researchers oversee commissioned research as project officers and carry out research and development in an integrated manner with NICT R&D with the aim of maximizing effects. In terms of research results, there were 314 paper presentations, 389 general oral presentations, 22 standardization proposals, and 64 industrial property rights applications (31 domestic and 33 overseas).

(Column) Example of commissioned research completed in FY2019: R&D of compact optical phase-locked loop for low-cost receiving and monitoring of optical signals

Looking to the future, researchers envision ultra-high-speed network distribution of ultra-multilevel optical data with extremely complex signal waveforms through digital coherent technology. This will require the development of an optical measurement technique for detecting optical waveform information in real time and a monitoring system for analyzing optical transmission signals likewise in real time. In this research project, we developed compact optical phase-locked loop (OPLL) technology using silicon-photonics and optoelectronic-integration techniques and used this technology to achieve a compact OPLL system that can observe constellations and Q factors in real time (Fig. 3).

Acquisition of external funding

Expanding commissioned research from other institutions and increasing grant-in-aids for research has a number of positive effects. For example, it can demonstrate the excellence of NICT technologies with respect to government policies and social needs. It can also improve the R&D capabilities of NICT itself, expand collaboration with other research institutions, and create new technology seeds (Fig. 4).

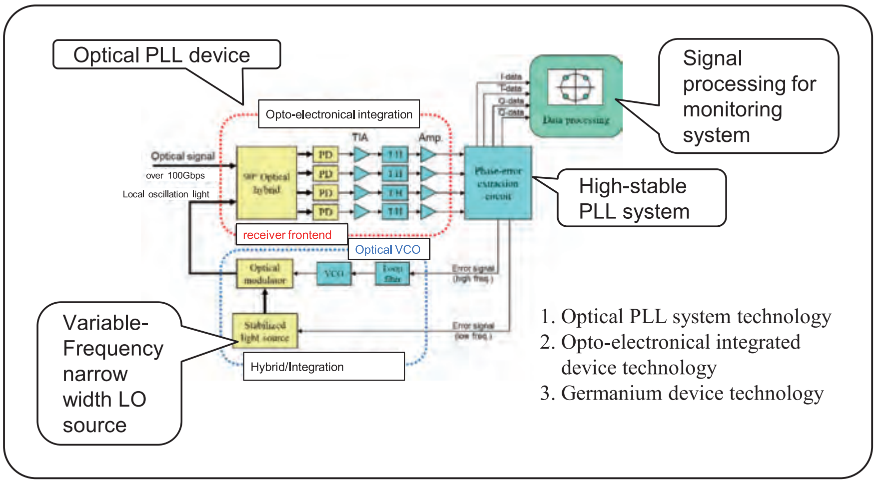


Fig.3 : Optical PLL information monitoring system

Appropriate management of intellectual property and effective promotion of technology transfer

(1) In FY2019, NICT concluded 42 new licensing agreements including those for horn antennas for making standard measurements and software for radio equipment on the Smart Resource Flow platform and expanded the licensing of its multilingual speech translation software. These activities contributed to the implementation of NICT research achievements in society and helped drive intellectual property revenue up to 210,100,000 yen (Fig. 5).

(2) NICT released, provided, and disseminated research results consisting of NICT intellectual property, research data, technology use cases, etc. via various media and venues including websites and exhibitions. In July of FY2019, NICT co-sponsored a New Technology Explanatory Meeting with Japan Science and Technology Agency (JST) and introduced technologies that have the potential of being useful to business from among patent applications based on recent research results.

Returning research results to society through international standardization

To reflect R&D results in international standards, NICT participates actively in meetings and other events at various international standardization bodies, and in FY2019, it submitted a total of 211 contributions based on R&D results. In addition, a total of 48 individuals from NICT served as chairpersons, editors, etc. in various committees related to standardization and in meetings of international standardization bodies. These activities contributed to the formulation of 10 international standards based on NICT R&D results including ITU-T Recommendation Y.3800, the first international standard dealing with quantum key distribution (QKD).

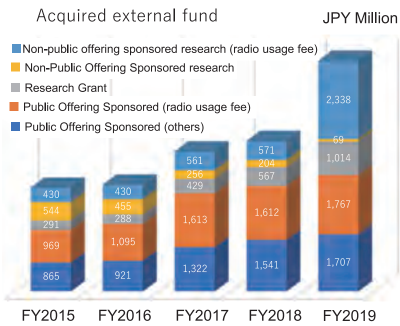


Fig.4 : Revenue from joint research with external institutions by year

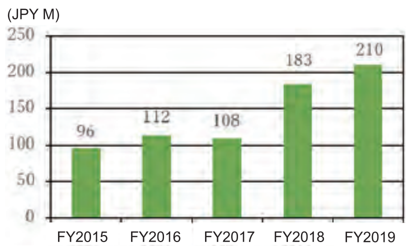


Fig.5 : Revenue from intellectual property by year

Open Innovation

Global Alliance Department

Executive Director FUKAHORI Michiko

The Global Alliance Department promotes international collaboration in NICT R&D activities and international expansion of R&D results, and, by promoting open innovation with a global perspective, we also contribute to strengthening Japan's international competitiveness in the field of information and communications technology.

Promotion of international research collaboration

NICT has built and maintained international collaborative relationships by exchanging 19 new memorandums with overseas universities and research institutions (for a total of 99 memorandums with 30 countries and 95 institutions as of March 2020 (Fig. 1)), supporting examinations by the Security Export Control Review Board of 24 joint research contracts and 15 non-disclosure agreements (NDAs), and welcoming 5 visits from overseas institutions (Defence Science and Technology Group, Department of Defence, Australia; National Institute of Metrology (NIMT), Thailand, and others) for the purpose of collaborative research. On the basis of these memorandums, we have begun new international collaborative activities, including international research gatherings such as a workshop with Queen's University Belfast in the United Kingdom and the launch of two joint research projects with National Applied Research Laboratories (NARLabs), Taiwan.

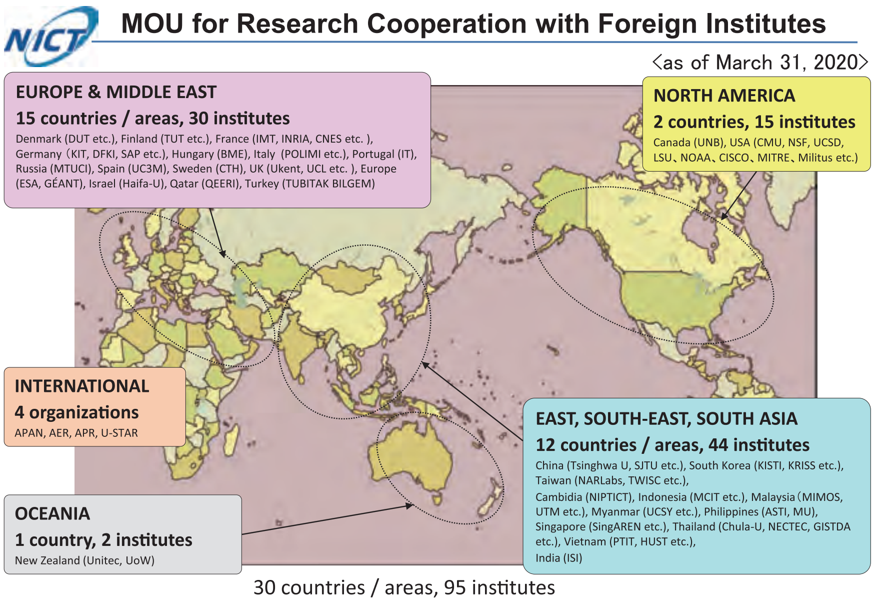


Fig.1 : Foreign institutes with which we have exchanged research memorandums (as of March 2020)

Promotion of international joint research with the United States and Europe

Under the Japan-US Network Opportunity 2 (JUNO2) program, managed jointly by NICT and the US National Science Foundation (NSF), five joint research projects are being conducted in the area of trustworthy networking. A Principal Investigator (PI) meeting, which is conducted for sharing research information among participants, was held in the United States in 2019 and online in 2020. In parallel with the above, a call for new joint research projects to begin in 2021 was made in the Collaborative Research in Computational Neuroscience (CRCNS) international research program, whose participants include the United States (NSF, National Institutes of Health (NIH)), Germany, France, Israel, Spain, and Japan (NICT).

In Japan–European international joint research, which is run jointly with the European Commission and the Ministry of Internal Affairs and Communications (run under the Horizon 2020 program in Europe), review meetings were held for five projects (for the themes of public big data, information-oriented networks, ICT for an aging society, IoT security, and Beyond 5G) in Tokyo in 2019 (Fig. 2) and online in 2020. In addition, discussions were held on proposals for joint research projects that are scheduled to begin under the Horizon Europe program, to be launched in 2021.

Promotion of international joint research in Southeast Asia by ASEAN IVO and expansion of research results

ASEAN IVO (ICT Virtual Organization of

Fig.2 : First review meeting of a Japan-EU joint research project "M-Sec."

Fig.3 : ASEAN IVO Project "Smart Aquaculture Quality Monitoring System with IoT"

Fig.4 : Development of research results: activities for creating international projects

ASEAN Institutes and NICT), a collaborative research organization led by NICT and operated in cooperation with research institutions and universities in the ASEAN area, has been raising its profile through various activities, including a self-introduction given at the 31st APT Standardization Program Forum (ASTAP-31) (Tokyo, June 2019), sponsored by the Asia-Pacific Telecommunity (APT). These activities have helped to grow ASEAN IVO to 61 institutions (an increase of 7 institutions over the last fiscal year). ASEAN IVO promoted 17 joint research projects (including 4 new projects) in 2020, with the aim of finding ICT solutions to social problems common to the ASEAN area. To date, ASEAN IVO has promoted a total of 28 projects and its activities have grown to include more than 300 participants from around 170 institutions. Fig. 3 shows activities at a crab farm in Thailand as part of a smart-aquaculture project. The ASEAN IVO Forum was held in Manila in 2019 and online in 2020. The plan is to create new projects for launch in 2021 under the theme of ICT for food, environment protection and disaster prevention, secure and smart community, and health and welfare (including COVID-19 countermeasures).

Expansion of research results: creation and promotion of international projects

We exhibited disaster-resilient network technology (NerveNet) at ASTAP-31 (described above) and at the 16th APT Telecommunication/ICT Development Forum (ADF-16) (September 2019, Cambodia), and we visited Nepal to introduce NICT technologies to ministries and agencies, universities, and telecommunications carriers (Fig. 4). As a result of these activities, projects that include the use of these technologies were proposed to APT from five countries, two of which were selected (demonstration of a Smart City platform in Sri Lanka and a disaster-resilient information sharing platform for mountainous regions in Nepal) and launched as projects to run from 2020 to 2021.

In an international development fund program managed by the Global Alliance Department, seven projects proposed from within NICT were conducted in both 2019 and 2020 resulting, for example, in the development of a system for high-speed delivery of high-definition images from Japan's Himawari-8 meteorological satellite to Thailand, the Philippines, and Taiwan.

Open Innovation

ICT Deployment and Industry Promotion Department

Executive Director HIROSHIGE Kenji

Information communication provides the infrastructure for social and economic activity. We are currently engaged in many activities in this field, such as providing support for startups that give rise to new services, enhancing our infrastructure to facilitate the use of diverse new forms of communication, promoting information barrier-free environments where information communication services can be used by anyone, promoting basic research in the private sector, and supporting international exchanges in research and development. Through these activities, we are helping to stimulate industry and facilitate rich lifestyles that are both safe and secure, and in order to support the adoption of highly convenient information communication services in our society, we are implementing the following initiatives.

Support for foreign guest researchers / international research conferences

Through our own International Exchange Program and the International Research Cooperation Japan Trust Project, which operates through contributions from private volunteers, NICT conducts projects to hire foreign guest researchers at research facilities besides NICT, and also provides support for holding international research conferences.

In the International Exchange Program in FY2019, five foreign guest researchers were hired at research facilities including Tohoku University and Nagoya University. In the International Research Cooperation Japan Trust Project, two guest researchers were hired, at the IIJ Innovation Institute Inc., and the Hayakawa Institute of Seismo Electromagnetics Co. Ltd. We also supported ten international research conferences, including Compound Semiconductor Week 2019, and a 2019 IEEE Circuits and Systems Conference.

Entrepreneurship support

(1) Entrepreneurs Koshien/Entrepreneur Expo

The Entrepreneurs Koshien and the Entrepreneurs Expo were held in Tokyo on March 4 and 5, 2020, respectively. Due to the outbreak of COVID-19, presentations by startups were given by video, judging was conducted by telephone Q&A sessions and viewing at the venue was cancelled.

In the Entrepreneurs Koshien results, "Radio Security System" of Hokkaido University of Science (a Deferred-monitoring signal detector) received the Minister of Internal Affairs and Communications Award, and Kwansei Gakuin University's "GUIBO" (a free service for independent English learning in Japan) and the University of Miyazaki's "PioneerPork" (pig management using IoT technology) were selected for the Judge's Special Award (Fig. 1). At the Entrepreneur Expo, Enishia Inc.'s "Development and expansion of the SATOMI AI software for summarizing patient charts" (a service that simplifies checking of treatment histories, reducing time required to create medical reports and other documents) was selected for the Minister of Internal Affairs and Communications Award, and Sonoligo Inc.'s "Event participation subscription service" (a paid-

Fig.1 : Entrepreneurs Koshien

monthly event participation service enabling event organizers to maximize participants and sales) was selected for the Judging Committee Special Award.

(2) Trade show exhibits, Silicon Valley Boot Camp

Medmain Inc., which received the Ministry of Internal Affairs and Communications Award, had an opportunity to present at TechCrunch DISRUPT SF 2019, held in October 2019 in San Francisco (Fig. 2).

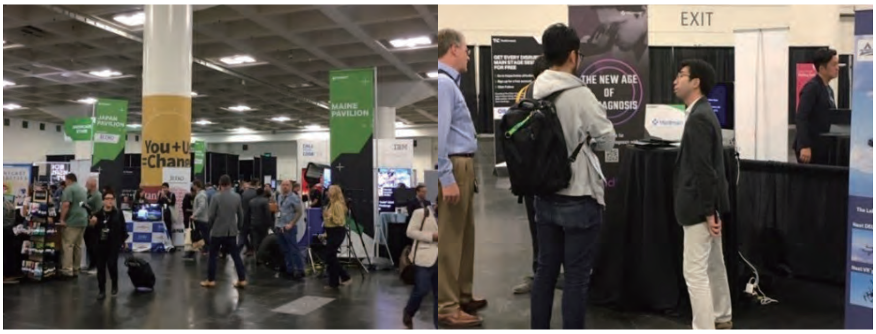


Fig.2 : TechCrunch DISRUPT 2019

Then, in February, 2020, we held the Silicon Valley Entrepreneur Boot Camp, which provided participants in the Entrepreneurs Koshien an opportunity to expand their global perspective in Silicon Valley, by meeting ICT startups in the area and hearing lectures from active local entrepreneurs (Fig. 3).


Fig.3 : Silicon Valley Boot Camp

Promoting information barrier-free environments

(1) Subsidies for production of programs with captions, described video, and sign language

In FY2019, we provided subsidies to 122 broadcasters and other companies throughout Japan for 52,833 programs, contributing to expansion of broadcast programming with captions, described video and sign language.

(2) Subsidies for providing sign-language translation video

In FY2019, we supported integration of sign-language translation images with 121 broadcast programs, contributing to opportunities for those with hearing disabilities to obtain information.

(3) Subsidies for providing and developing work on information barrier-free communications and broadcasting

In FY2019, we supported six projects, for communications and broadcasting work related to improving accessibility for users with physical disabilities.

(4) Providing information barrier-free related information

NICT is providing, through our “Information Barrier-free Information Web Site,” information that is useful for disabled persons, the elderly and social-service-related organizations, and also descriptions of our subsidy system and the NICT-subsidized information barrier-free projects, along with results from these programs. In FY2019, the site was accessed approximately 930,000 times.

At the 46th International Home Care & Rehabilitation Exhibition (H.C.R.2019) held in September, 2019, NICT demonstrated the automatic voice translation service, or “Koetra,” which was a result from NICT research and development. Some private companies also made demonstrations on their information barrier-free projects that were subsidized by NICT (Fig. 4).


Fig.4 : International Health Care and Rehabilitation Exhibition in Tokyo

Research Highlights

WATCH

Commencement of VHF radar operation in Thailand for observation of plasma bubbles

High-precision plasma-bubble observation with VHF radar from initial bubble generation at magnetic equator

NICT conducts research and development related to the monitoring and forecasting of space weather, including ionospheric and solar activities, for the purpose of providing information on forecasts and warnings about radio propagation conditions. NICT has delivered the "Space Weather Forecast" every day since 1988. In recent years, the need for space-weather information has increased in various fields. This need is particularly high in the aviation industry. For example, the Global Space Weather Center of the International Civil Aviation Organization (ICAO) started providing space-weather information services on November 7, 2019. As a member of the center, NICT has also been providing information on communications, satellite-based navigation, and radiation exposure.

One of the most significant effects of space weather on society is the degradation of satellite-based navigation, such as GPS, due to ionospheric disturbances. “Plasma bubbles” that occur around the magnetic equator, which is the equator of the Earth’s magnetic field, are one type of intense ionospheric disturbance. Radio propagations are disturbed in the vicinity of a plasma bubble, which may reduce the accuracy of satellite-based communications and navigation, or in a worst-case scenario, disable them (Fig). For this reason, there has been a significant need for continuous observation and forecasting of plasma bubbles in recent years.

NICT, in collaboration with King Mongkut's Institute of Technology Lad-

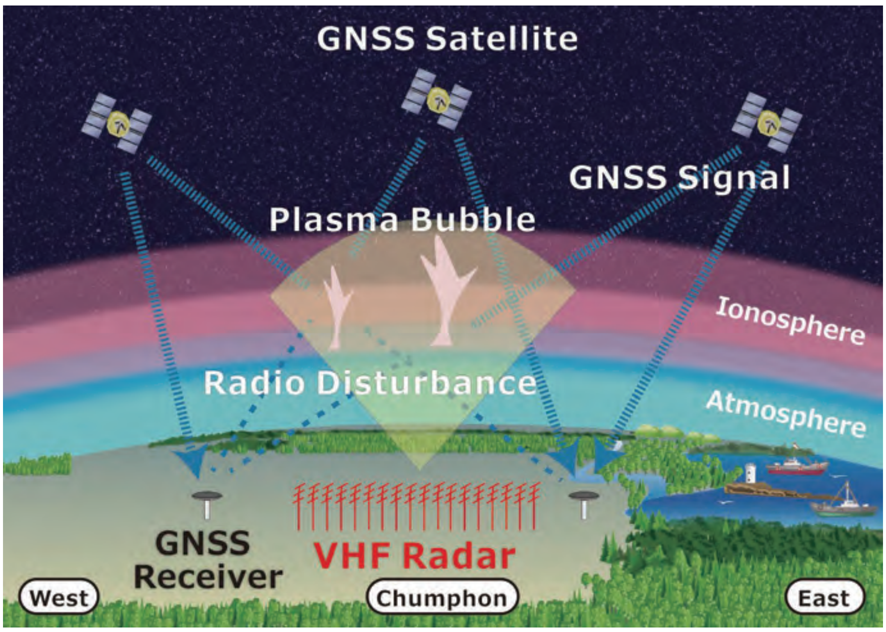


Fig. : Schematic illustration of monitoring plasma bubbles with VHF radar system krabang (KMITL), started operation of the radar installed at KMITL Prince of Chumphon Campus in Thailand (Fig.) on January 17, 2020 to observe plasma bubbles that cause radio propagation disturbances. Chumphon is close to the magnetic equator, where plasma bubbles tend to generate, and is an ideal place to observe plasma bubbles from their initial generation stage. The routine observation of plasma bubbles with this radar is expected to be a major advancement in expanding the use of precise satellite-based navigation in fields such as agriculture and construction.

The radar system consists of 18 antennas equidistantly installed in the east-west direction at a spacing of about 5 m, using radio waves in the VHF band (39.65 MHz). The radio waves transmitted from the radar are reflected by the plasma irregularity that the plasma bubbles in the ionosphere cause. By observing the reflected radio waves, the location and velocity of the plasma bubbles can be monitored.

For future work, using GNSS receiver networks in Japan and Thailand in addition to this radar system, we will investigate the effects of plasma bubbles on various satellite-based navigation methods and conduct research to reduce these effects. We aim to provide these results as one of the Space Weather Forecast services.

Reference

Movie: Generation and propagation of plasma bubbles:
https://www.youtube.com/watch?v=FDhZF9-ixv8

CREATE

Visualization and decoding of complex information representation in the human brain

Building a quantitative model of human cognition

Our daily lives are supported by a diverse combination of neural functions such as seeing, hearing, remembering, imagining, and deciding. In previous neuroimaging studies on human beings, it has not been clear how the various and complex cognitive functions governing our everyday lives are represented in the brain. CiNet researcher NAKAI Tomoya, and Senior Researcher NISHIMOTO Shinji, have built a quantitative information representation model that explains the relationship between cognitive function and brain activity, by preparing a diverse set of 103 cognitive tasks, such as vision, hearing, memory, recall, and reasoning, and analyzing records of brain activity (fMRI) while performing these tasks. In this way, they were able to create an information representation space for how cognitive information is represented within the brain, and an information representation mapping that shows how it is distributed through the entire brain, for various cognitive functions. They were also able to accurately decode the cognitive task being performed by a subject from their brain activity; in other words, they were able to interpret the content of what the person was feeling or thinking.

In the experiments, subjects performed 103 cognitive tasks involving seeing, listening, remembering, imag-

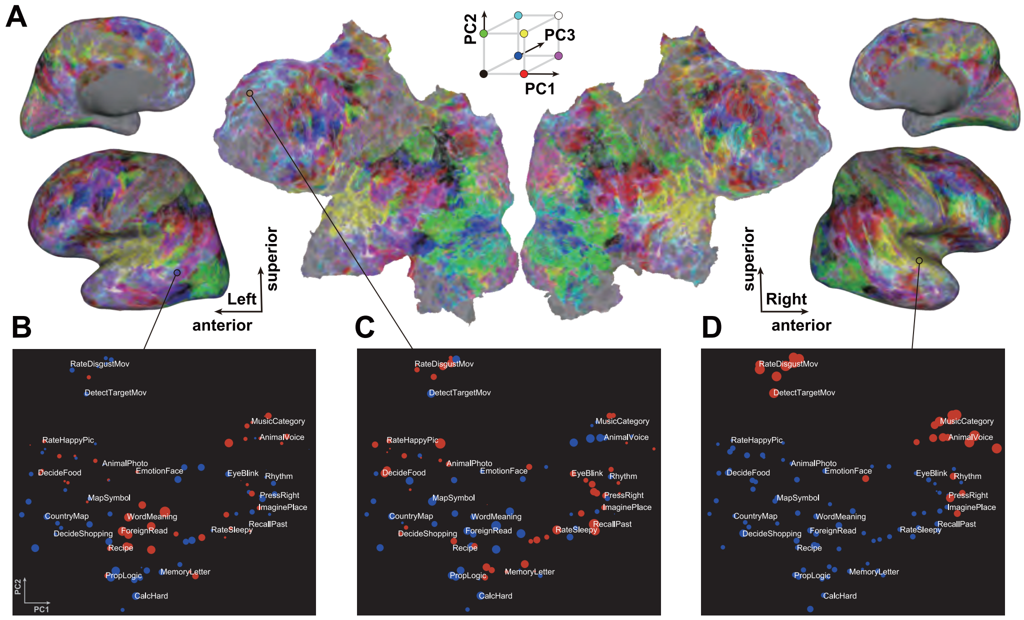


Fig. : (A) Brain cognitive information representation map (left/right brain inflated view and flattened view) (B-D) Left hemisphere, middle temporal gyrus (B), left hemisphere, prefrontal cortex (C) and right hemisphere, superior temporal gyrus (D) cognitive function structure in 2 mm cube regions. Here, tasks to which each region contributes are shown in red, and task for which the contribution is small are shown in blue. (Nakai and Nishimoto, 2020 Nature Communications, Creative Commons CC BY license)

ining and deciding, over a period of three days. While they were doing so, their brain activity was measured by using MRI equipment to measure changes in blood flow due to neural activity. These measurements were non-invasive, causing no injury to the subjects. Two types of information representation model were built to analyze the brain activity measurements, as described below.

The first model is a task-type model, representing feature values of each task discretely as zeros and ones. For each of the 103 tasks, data for contribution to the task from each region of the brain was extracted, and a principal component analysis (PCA), which is a method that finds representations with a minimal number of dimensions, was performed on the extracted data to determine axes that best explain the data distribution. Then, visualizations were created of the cognitive information representation space showing the relations among the 103 tasks. In this space, tasks with similar representation in the brain are arranged closer, with similar colors. The brain was then partitioned into 2 mm cubes, and the contribution from each region was mapped to the same color as the large cognitive representation, to visualize the whole-brain cognitive information representation map and show the relationships between the cognition representation and brain regions.

For the second model, the data from the task-type model indicating contributing-brain-region for each task was compared with a database of past brain function imaging research to create a cognitive-factor model that uses a cognitive-factor space with many (715) dimensions to represent tasks. With this model, cognitive tasks are represented by a continuous space of high dimension, and this enables predictions to be made for new cognitive tasks. This made it possible to successfully decode new cognitive tasks being performed by subjects accurately from brain activity.

Possible future work includes clarifying a basis for more-complex cognitive activities, such as behavior in the interactive or imagination representation spaces. We also hope to apply these techniques to visualizing quantitative differences between people with various abilities.

Reference

Tomoya Nakai and Shinji Nishimoto, "Quantitative models reveal the organization of diverse cognitive functions in the brain," Nature Communications, vol.11, 1142, 2020
DOI: 10.1038/s41467-020-14913-w

CONNECT

Fast handover from 5G public network to private network

Proves within 5 second handover to the millimeter-wave private spot cell along railway

Local 5G*[1], which provides privately-operated communication services within a limited area, such as a building or particular property, using the same innovative 5G technologies used to build public infrastructure networks, is currently attracting attention. The 28 GHz band (28.2-28.3 GHz), which is a quasi-millimeter-wave band, has been established for outdoor Local 5G use, but due to the high frequencies, the areas where service can be provided (cell size) are small, and this presents difficulties in terms of cost and expanding the physical service area.

NICT Wireless Networks Research Center, collaborating with JR East and the Railway Technical Research Institute, has successfully demonstrated platform technology that enables mobile devices connected to public networks and travelling in a train or automobile through a private spot cell*[2]

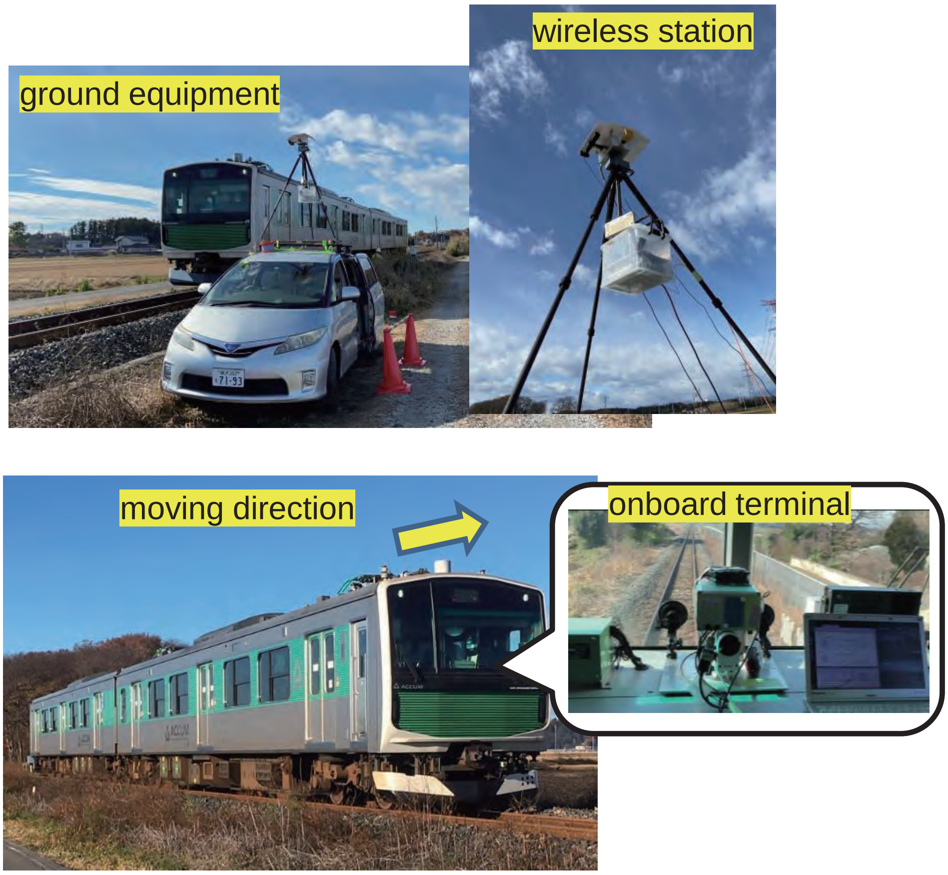


Fig. : Radio equipment used for the demonstration on the ground (above) and on the train (below) moving in a privacy-preserving and secure manner established by a private network operator*3, to switch wireless networks smoothly from the public to the private network.

For this demonstration, a privately-operated linear spot cell was built along the JR East Karasuyama line (Tochigi Prefecture) using the millimeter-wave band and the technology was demonstrated using a device on the train (Fig.). In the demonstration, the time required to switch from the public to the private network, which took more than four minutes earlier, was reduced to less than five seconds on average, and even the largest value was about 10 seconds. The demonstration also confirmed the ability to simultaneously transmit video from multiple locations to the device on a train traveling through the linear spot cell, with lower latency than when connected to the public network.

This platform technology was developed by NICT, and does not require to share subscriber information between the private and public network operators. The time required to switch between the networks can be greatly reduced by just accessing the private network beforehand through the public or other network connection. For Local 5G private spot cells, which are expected to spread in the future, connections can be made very quickly, and stable services can be provided. We can expect development of various area-limited services by private operators, including, but not limited to railway operators.

Footnote

***1 Local 5G**
Privately operated networks built by enterprises or local governments using technologies implemented for 5G, such as ultra-high speed, ultra-low latency, and very large numbers of connections.

***2 Private spot cell**
A cell limited to a particular area, established by a private network operator.

***3 Private network operator**
Different from the national communications operators, a private network operator installs their own base stations within a given area, such as an office, train station or commercial area, to provide dedicated communication services.

Reference

IEICE Conference paper
"Demonstration Experiment of Virtual Pre-Connection Scheme for Trains with Millimeter Wave Railway Linear Cell,"
https://www.ieice.org/ken/paper/20200423g1xI/eng/

CREATE

NICT's multilingual speech translation technology incorporated into the National Police Agency's system

Installed on devices used in 47 prefectures nationwide

The Advanced Speech Translation Research and Development Promotion Center (ASTREC) of NICT has been promoting R&D of multilingual speech translation technology and its social implementation under the Global Communication Plan—established in 2014 by the Ministry of Internal Affairs and Communications (MIC) with the aim to eliminate the “language barriers” and facilitate barrier-free human interaction on a global scale. We have also been conducting field experiments in various areas, one of which has led to a practical application by the National Police Agency followed by a nationwide implementation by the prefectural police of Japan.

In response to the rising numbers of foreign tourists visiting Japan in recent years, in fiscal 2019, the National Police Agency constructed its own speech translation server and incorporated multilingual speech translation functions using NICT's technology into its “Police Integrated Info-communication Infrastructure.” The speech translation function can be used on a total of 50,000 devices, smartphones, and tablets (Fig.) disseminated throughout 47 prefectural police departments across the nation and is anticipated to support inquiries for directions and lost properties from foreign visitors who are expected to increase during the Olympic and Paralympic Games. We have high expectations that this would lead to a safer and more secure society.

This is the first time that an independent server/application using NICT's speech translation technology has been put into operation on a nationwide scale by a public organization; we believe that our technology has been highly evaluated for its accuracy and reliability. The translation is supported between Japanese and 29 languages; 14 of which supports speech input, and 13 of which supports speech output*. Based on the “Global Communication Plan 2025” announced by the MIC in 2020, we will further promote R&D in cooperation with the MIC as well as private companies to enhance our technology and to realize an AI simultaneous interpretation technology by the year 2025.

*Supported Languages

The multilingual speech translation function incorporated into the system currently supports translation between Japanese and 29 languages: Speech input is available in 14 languages, and speech output is available in 13 languages.

Reference

NICT Press Release (in Japanese)
https://www.nict.go.jp/press/2020/06/25-1.html

Fig. : Screenshots of the multilingual speech translation function

Supported languages (translation between Japanese and 29 languages)

🎙 Speech input (14 languages supported) 🔊 Speech output (13 languages supported)

🎙	🔊	Japanese	🎙	🔊	Myanmar			German
🎙	🔊	English	🎙		Filipino			Turkish
🎙	🔊	Chinese (Simplified)	🎙	🔊	Brazilian Portuguese			Nepali
🎙	🔊	Chinese (Traditional)	🎙	🔊	Khmer			Hungarian
🎙	🔊	Korean			Arabic			Hindi
🎙	🔊	Thai			Italian			Portuguese
🎙	🔊	French			Urdu			Malay
🎙	🔊	Indonesian			Dutch			Mongolian
🎙	🔊	Vietnamese			Sinhala			Lao
🎙	🔊	Spanish			Danish			Russian

CREATE

Instantaneous color holography system for sensing fluorescence and white light

Joint-development of single-shot color-multiplexed 3D fluorescence microscopy with holography

Image sensing technologies and systems that capture three-dimensional (3D) information at a single point in time have been actively researched all over the world to contribute to life science, material science, industry, arts, and our daily life. Incoherent digital holography can record 3D information using natural light without a laser, so its applications to 3D fluorescence microscopes, 3D nonlinear optical microscopes, and natural light hologram sensors are expected. However, color hologram sensing for natural light has conventionally required a color filter array or multiple recordings; creating a technology that can acquire a clear hologram with high light-use efficiency and enable a single-shot recording is a challenging research subject. Therefore, the development of a 3D microscope for simultaneously recording color self-luminous objects that contain multiple molecular compositions as a single bright hologram has not yet been accomplished.

NICT, the Japan Science and Technology Agency (JST), Toin University of Yokohama, and Chiba University have succeeded in developing a color-multiplexed holography system with which self-luminous specimens in a 3D space and 3D information of objects illuminated by a white-light lamp are recorded as a single multicolor hologram. Simultaneous color 3D sensing of multiple self-luminous objects was successfully demonstrated by recording a single color-multiplexed hologram of fluorescence light. Multicolor 3D imaging with a white-light lamp

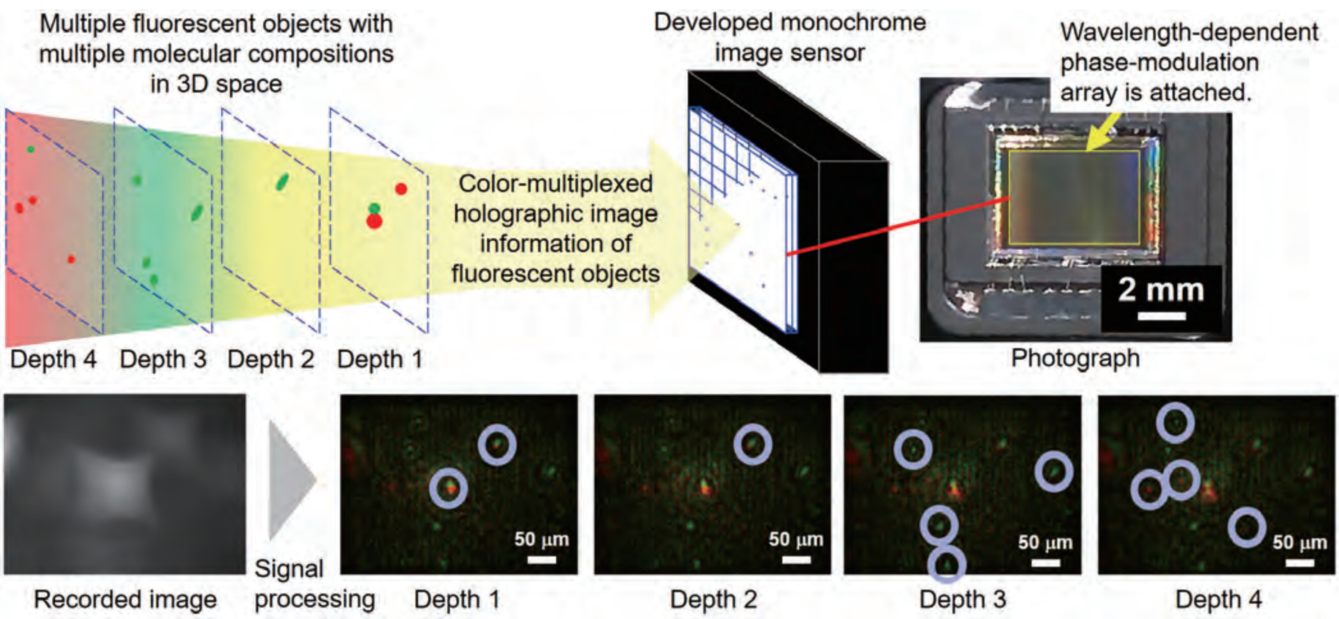


Fig. : Experimental results for application to single-shot color-multiplexed fluorescence holographic microscopy was also demonstrated with a single-hologram recording. This recording is accomplished with a specially designed and developed monochrome image sensor. Single-shot color-multiplexed fluorescence holographic microscopy exploits digital holography and computational coherent superposition (CCS), the latter having been proposed by NICT. CCS is a holographic multiplexing technique and is adopted to record a color-multiplexed hologram on a monochrome image sensor without any color filter. As a result, the developed microscope acquires the color 3D information of self-luminous objects with a single-shot exposure and no color filter array. The developed system does not require a laser light source and is able to conduct multicolor 3D motion-picture sensing of biological samples and moving objects at video-rate. Further development will be conducted for multicolor 3D microscopy of extremely weak light such as autofluorescence and nonlinear light.

In the next step of this research, we will continue to work toward the following targets:

- Increasing the recording speed in multidimensional holographic microscopy sensing of extremely weak self-luminous light sources
- Expanding applications to multicolor holographic 3D motion-picture image sensing for spatially incoherent light

This work was supported by the Japan Science and Technology Agency (JST) Precursory Research for Embryonic Science and Technology (PRESTO) (JPMJPR16P8 and JPMJPR17P2), Japan Society for the Promotion of Science (JSPS) (18H01456), Research Foundation for Opt-Science and Technology, and Konica Minolta Science and Technology Foundation.

Reference

Journal: Applied Physics Letters
"Single-shot wavelength-multiplexed digital holography for 3D fluorescent microscopy and other imaging modalities,"
Tatsuki Tahara, Ayumi Ishii, Tomoyoshi Ito, Yasuyuki Ichihashi, and Ryutaro Oi
URL: https://aip.scitation.org/journal/apl
DOI: 10.1063/5.0011075

WATCH

Signals from distant Stars connect optical atomic clocks across earth for the first time

Transportable radio telescopes could provide global high-precision comparisons of the best atomic clocks

The Bureau International des Poids et Mesures (BIPM) in Sèvres, near Paris, routinely calculates the international time recommended for civil use (*UTC, Coordinated Universal Time*) by comparing atomic clocks via satellite communications. However, the satellite connections that are essential to maintaining a synchronized global time have not kept up with the development of new atomic clocks, namely, optical clocks that use lasers interacting with ultracold atoms to give a very refined measure of time.

Using radio telescopes observing distant stars, scientists have connected optical atomic clocks on different con-

Fig. : Antennas and optical lattice clocks used in the measurements

Upper left: Transportable 2.4 m antenna installed at the INAF radio observatory in Medicina, Italy
Upper middle: Transportable 2.4 m antenna installed at NICT in Koganei, Japan
Upper right: 34 m antenna located at NICT in Kashima, Japan
Bottom left: Ytterbium optical lattice clock IT-Yb1, operated at INRIM in Torino, Italy
Bottom right: Strontium optical lattice clock NICT-Sr1, located at NICT in Koganei, Japan

tinents through an international collaboration between 33 astronomers and clock experts at NICT, the Istituto Nazionale di Ricerca Metrologica (INRIM, Italy), the Istituto Nazionale di Astrofisica (INAF, Italy), and BIPM, France.

In this new research, highly energetic extragalactic radio sources replace satellites as the source of reference signals. The group of SEKIDO Mamoru at NICT designed two special radio telescopes, one deployed in Japan and the other in Italy, to achieve the connection using very long baseline interferometry (VLBI). These telescopes are capable of observations over a large bandwidth, while antenna dishes of a mere 2.4-meter diameter keep them transportable. "We want to show that broadband VLBI has the potential to be a powerful tool not only for geodesy and astronomy, but also for metrology," commented SEKIDO. To attain the required sensitivity, the small antennas worked in tandem with a larger 34-m radio telescope in Kashima, Japan, during the measurements taken from October 14, 2018 to February 14, 2019. For the Kashima radio telescope, these were among the last observations before the telescope was irreparably damaged by Typhoon Faxai in September 2019.

The goal of the collaboration was to connect two optical clocks in Italy and Japan, separated by a baseline distance of 8700 km. These clocks load hundreds of ultra-cold atoms in an optical lattice, an atomic trap engineered with laser light. The clocks use different atomic species: ytterbium for the clock at INRIM and strontium at NICT. Both are candidates for a future redefinition of the second in the International System of Units (SI). "We observed the signal not from satellites but from cosmic radio sources. VLBI may enable those of us in Asia to access the UTC relying only on what we can prepare by ourselves," commented IDO Tetsuya, director of the Space-Time Standards Laboratory and coordinator of the research at NICT.

Besides improving international timekeeping, such an infrastructure may also open new ways to study fundamental physics and general relativity, to explore variations of Earth's gravitational field, and even to examine the variation of fundamental constants underlying physics.

Reference

Marco Pizzocaro, Mamoru Sekido, Kazuhiro Takefuji, Hideki Ujihara, Hidekazu Hachisu, Nils Nemitz, Masanori Tsutsumi, Tetsuro Kondo, Eiji Kawai, Ryuichi Ichikawa, Kunitaka Namba, Yoshihiro Okamoto, Rumi Takahashi, Junichi Komuro, Cecilia Clivati, Filippo Bregolin, Piero Barbieri, Alberto Mura, Elena Cantoni, Giancarlo Cerretto, Filippo Levi, Giuseppe Maccaferri, Mauro Roma, Claudio Bortolotti, Monia Negusini, Roberto Ricci, Giampaolo Zacchiroli, Juri Roda, Julia Leute, Gérard Petit, Federico Perini, Davide Calonico, Tetsuya Ido, "Intercontinental comparison of optical atomic clocks via very long baseline interferometry," Nature Physics.
DOI: 10.1038/s41567-020-01038-6

CREATE

Social media information can predict a wide range of personality traits and attributes

Findings could bring new technologies to mental health diagnostics and personalized nudges

Social networking services (SNS) have quickly become universal tools for communication. Previous research has shown that information about an individual's Facebook and Twitter use can reveal a limited number of core personality traits such as the Big Five. However, it remains unknown how widely personality traits and attributes can be predicted and which types of SNS information contribute to pinpointing specific personality traits and attributes.

Principle Investigator HARUNO Masahiko and MORI Kazuma at CiNet report the use of machine learning to analyze behavior on Twitter and predict a wide range of personality traits and attributes such as intelligence and extraversion. Specifically, the study uses component-wise gradient boosting to demonstrate that network features, such as numbers of individual's tweets and likes, and word usage on Twitter are predictive of social (e.g., extraversion) and mental-health (e.g., anxiety) personality traits, respectively.

A statistical analysis found significant correlations between measured personality and attribute scores and predicted ones, with correlation coefficients around 0.25. This value is not

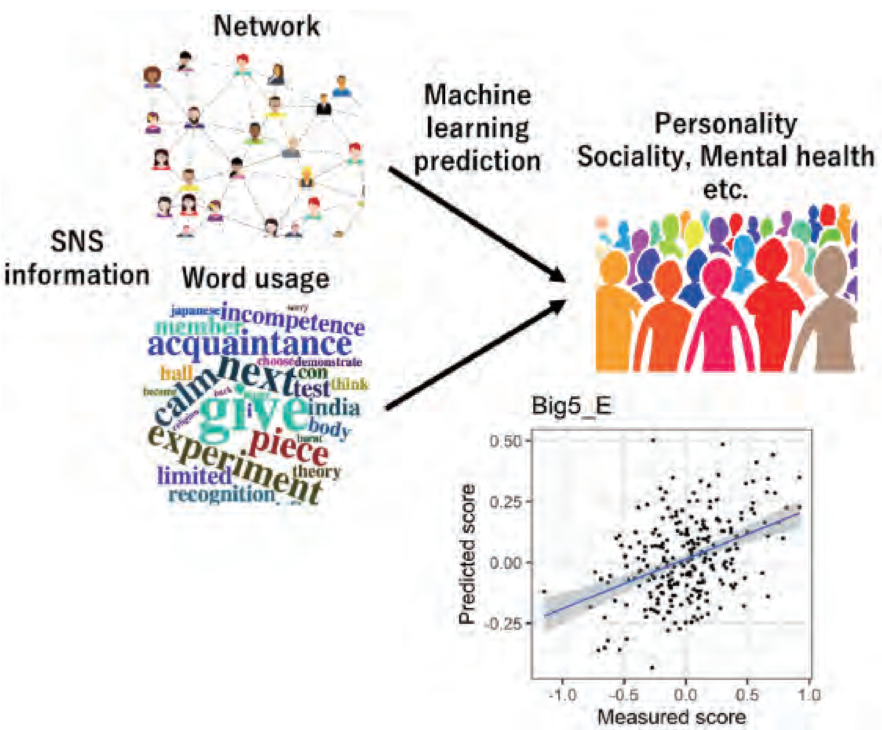


Fig. : Overview of the study

sufficient for determining an individual's personality traits precisely, but with a sufficiently large population sample, this technology could provide informative group statistics.

The study collected social media information from 239 participants (156 men, 83 women; average age 22.4 years old) who took personality tests that measured 24 personality traits and attributes (52 subscales). Of the 52 subscales, the Twitter information could be reliably used to predict 23 of them.

The analysis revealed that several social personality traits such as extraversion, empathy, and autism could be predicted from network features. Other personal attributes such as socioeconomic status, smoking/drinking behavior, and even depression or schizophrenia were predictable from the language usage features.

The research group is expanding the analysis to thousands of subjects. The method described in this study could be used for mental health diagnostics and personalized nudges to act in accordance with individual differences. This method will also help pin the neural mechanisms underlying individual differences in personality traits.

Reference

Kazuma Mori, and Masahiko Haruno,
"Differential ability of network and natural language information on social media to predict interpersonal and mental health traits,"
Journal of Personality, July 2020
https://onlinelibrary.wiley.com/doi/abs/10.1111/jopy.12578
DOI: 10.1111/jopy.12578

Open Innovation

IoT wireless utilization technology that supports a robot-assisted society in the "new normal" era

Development of a non-contact multi-story navigation support system for humans and robots which behaves in a cooperative manner

In the "new normal" era of pandemic countermeasures it is expected that there will be significant growth in the use of diverse types of robot, including not only security, sanitation and guidance robots, but also robots performing tasks such as sterilization, contact-free transportation, and automatic vending of beverages and the like. If these sorts of robot services are to be deployed more widely within premises and inside buildings, it will be essential for them to have the ability to move between floors. In the past, this issue has been addressed by requiring elevators to be placed under the control of a management center that is capable of controlling actions such as stopping, selecting a destination floor and opening/closing the doors. When a robot wishes to move between floors, it communicates with the management server by using such means as a mobile phone network to provide information including its current location and intended destination, whereupon an elevator is summoned by remote control. However, when an elevator is being used by a robot and is being controlled by the management server, it difficult to share the elevator with people.

At the Social ICT System Laboratory in the NICT ICT Testbed Research and Development Promotion Center, we used a combination of standards including the Wi-SUN*[1] license-free IoT wireless communication standard and BLE*[2] short-range wireless communi-

Fig. : Configuration of our experimental multi-story navigation support system using an autonomous mobile delivery robot, and photos of the system in action

cation technology to develop a multi-story navigation support system whereby smartphone users and autonomous mobile robots can easily move between floors by calling an elevator, boarding it, and selecting a destination floor without having to touch anything. This system was implemented simply, quickly and at low cost without having to modify the existing elevator control system. All that was required was the installation of miniature IoT button pressing devices on the call buttons and floor select buttons inside and outside the elevators.

This multi-story navigation support system is implemented by installing IoT communication devices using BLE, which is supported by ordinary smartphones, into on-premises mobile robots and elevator buttons. Accordingly, based on the same principle as the latest Coronavirus contact tracing applications, it is possible to detect and record contact with people who have the virus, and to use Wi-SUN to transmit information to devices that have departed from the vicinity, which is expected to be of use in facilities such as hospitals. In addition to being used within indoor limited spaces, this technology is also expected to be useful in outdoor spaces, for example, as a contact-free way of operating crosswalk signals.

We exhibited this technology at the CEATEC 2020 ONLINE exhibition, which was held online from October 20th to 23rd, 2020. We are currently planning to carry out indoor and outdoor demonstration trials in collaboration with East Japan Railway Trading Co., Ltd. and Androbotics, Inc.

Footnote

***1 Wi-SUN**
An international standard for IoT that is being promoted by the Wi-SUN Alliance (https://www.wi-sun.org/). It is widely used in Japan for smart meter applications, and is supported by over 90 million devices worldwide. It can handle communication speeds of up to 100 kbps.

***2 BLE**
Bluetooth Low Energy — an extension of the Bluetooth standard for short-range wireless communication technology, characterized by its ability to communicate at extremely low power. It was developed as part of the Bluetooth 4.0 standard announced in July 2010.

Reference

NICT Press Release (in Japanese)
https://www.nict.go.jp/press/2020/10/20-1.html

PROTECT

Enhancements to the CURE integrated security information platform

More efficient security operations by integrating natural-language analysis data

To improve the security of an organization requires use of many different types of cybersecurity-related information, such as the organization's own cyberattack observations and open source intelligence (OSINT) published by external agents. For this purpose, NICT has developed the CURE integrated security information platform and is researching large-scale collection and cross-sectional analysis of cybersecurity-related information. CURE was already able to integrate information used in cyberattacks, such as IP addresses, domain names, and malware; and to make associations among data from different observations. However, handling security reports and analysis results that are written in natural languages has been an unsolved issue.

NICT Cybersecurity Laboratory has enhanced the functionality of CURE, so it is now able to rapidly integrate and perform cross-sectional analysis with analysis results written in natural languages. An important data source is the ATT&CK framework provided by the MITRE Corporation in the USA, which provides systematic and comprehensive descriptions of cyberattack tactics and techniques and other issues, written in English. By developing functionality to make associations using natural language processing together with CURE, we have been able to integrate information written in natural languages into CURE and to conduct cross-sectional analysis. We have added a natural language processing functionality to CURE to extract important tags from information, and to make associations between different types of information using these tags. This enables us to integrate security reports, the MITRE ATT&CK and other natural language analysis data into the CURE database and perform cross-sectional

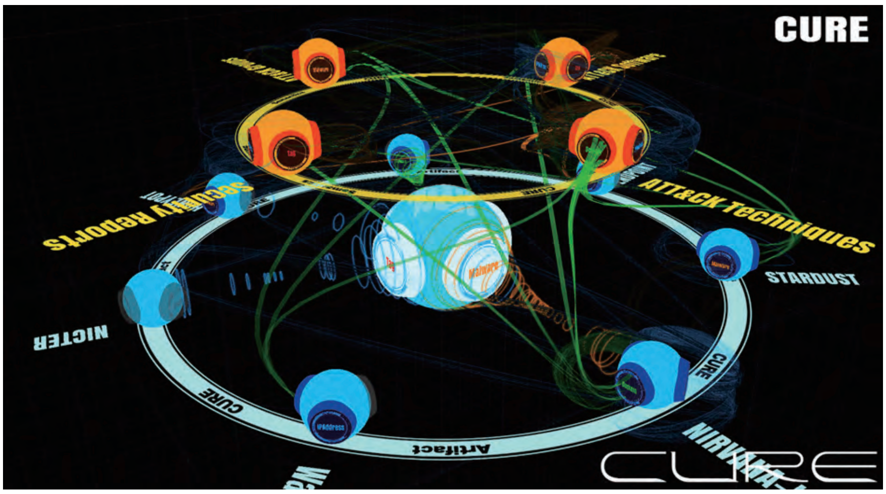


Fig. : CURE Overview
The central blue sphere is the main CURE module, and the surrounding smaller blue and orange spheres are a set of databases, each storing Artifacts (observations) or Semantics (analysis data). The CURE main module conducts cross-sectional analysis using IP addresses, domain names, malware data and natural language tags, and draws links when matching data is found.
(Blue: IP address, green: domain, orange: malware, red: tag)

analysis so as to make associations between external analysis data and internal observations with flexibility, with potential to improve security operations efficiency.

We have also divided CURE structure into two layers, an Artifact layer and a Semantics layer, enabled associations between the layers using the natural language tags, and developed a visualization function for the two-layer model. In addition to the darknet observation data (NICTER) and internal alert data (NIRVANA-KAI) that we have gathered in CURE, we have now integrated new attack observation data from Web browsers (WarpDrive). Furthermore, various security reports and articles from MITRE ATT&CK including ATT&CK Groups, ATT&CK Techniques, and ATT&CK Software have also been integrated.

These enhancements to CURE functionality give us flexibility in creating associations between our internal observations and analysis data published by external agencies, which should improve efficiency in organizational security operations. With CURE, we aim to integrate many diverse types of security Big Data, and contribute to improving security in Japan by creating an integrated cybersecurity knowledge platform.

Reference

NICT Press Relaese (in Japanese)
https://www.nict.go.jp/press/2020/10/27-1.html

DEVELOP

NICT, Toppan, QunaSys, and ISARA launch collaboration to establish quantum secure cloud technology

Secure communication, storage, and use of data enabled by quantum computing and quantum cryptography technologies

The ability to minimize damage to resources such as offices, plants, and data centers to continue (or promptly restore) core operations in the event of emergencies such as natural disasters, large-scale fires, and terrorist attacks has become increasingly important for business in recent years. However, there are technical limitations to this ability to ensure resilience against unforeseeable disasters, be they natural or man-made. This creates a need for ultra-long-term, high-security cloud technologies for the distributed and secure storage, and complete recovery, of information.

The cryptography currently in wide use enables secure communication for now, but the practical application of quantum computing technologies anticipated for around 2030 will enable the decryption of highly-sensitive communications, such as electronic payments and digital application forms containing personal data. Society will require uncrackable encryption technologies as it faces the need to bolster security.

NICT, Toppan, QunaSys, and ISARA have announced the launch of a collaboration with the goal of establishing quantum-secure cloud technology that enables advanced information pro-

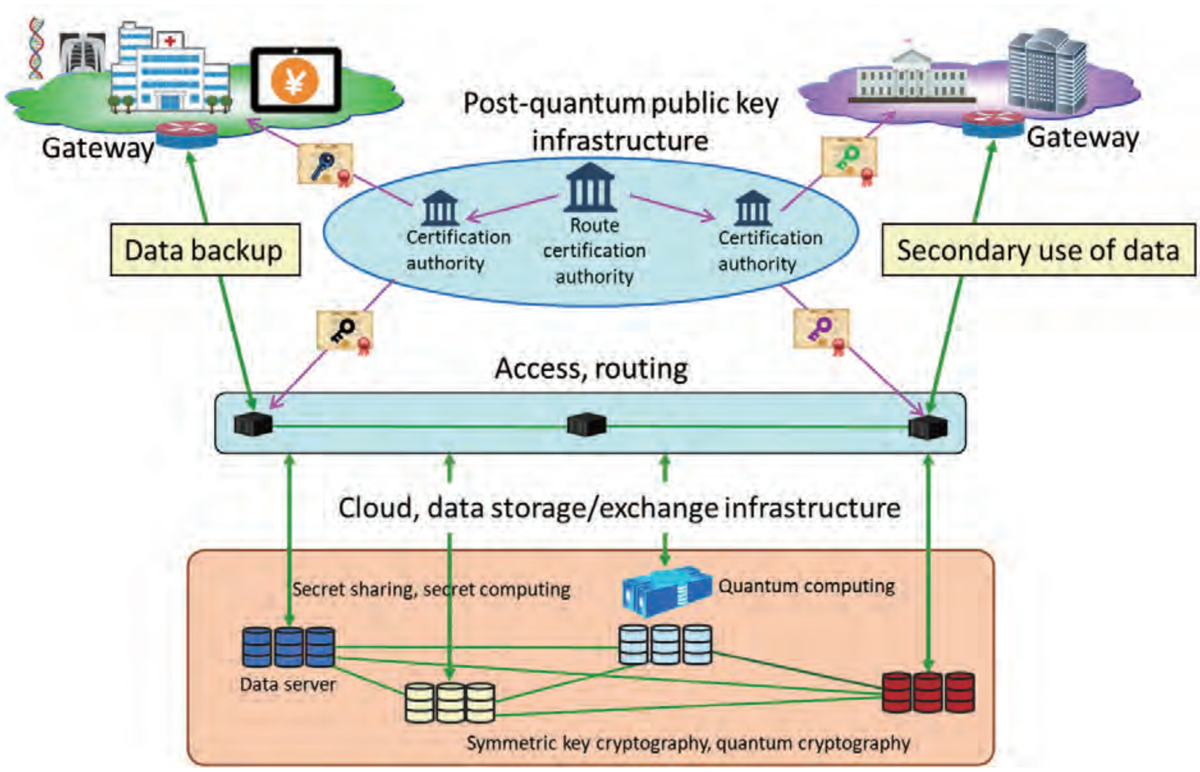


Fig. : Concept for quantum-secure cloud technology

cessing and secure communication, storage, and use of data.

Quantum-secure cloud technology fuses quantum cryptography and secret-sharing technologies to facilitate secure data communication, storage, and use. Establishing this technology will not only ensure a high level of security that makes tampering and decryption impossible but will also enable the collection, analysis, processing, and use of highly sensitive personal and corporate information accumulated in such fields as medical care, new materials, manufacturing, and finance. NICT, Toppan, QunaSys, and ISARA will collaborate to combine their various accumulated technologies, expertise, and experience for development. Pilot testing of application software for implementation in wider society is scheduled to begin during fiscal year 2022, with limited practical implementation targeted for fiscal year 2025, and the launch of services planned for fiscal year 2030.

"NICT has been working on the development of quantum cryptography for more than 20 years. With this collaboration, we hope to establish a 'made-in-Japan' quality-assurance platform for the standardization of quantum cryptography and ensure that Japan takes the lead going forward. It is vitally important that businesses and users are able to store, share, and use information securely. I am confident that we will be able to enhance Japan's competitiveness by realizing quantum-secure cloud technology with this collaboration and establishing the foundations to support Society 5.0," said SASAKI Masahide, Distinguished Researcher, Advanced ICT Research Institute, NICT.

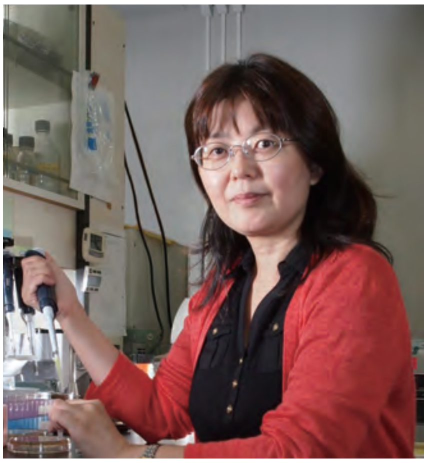
The collaboration between the four organizations will aim to establish quantum-secure cloud technology as infrastructure for data storage/transfer and post-quantum public key authentication. This development will be based on system design, consideration of specifications, application of the latest quantum cryptography technologies, implementation of backup and data storage using secret-sharing technologies, and implementation of digital signatures based on post-quantum public key cryptography.

A part of this work was performed for Council for Science, Technology and Innovation (CSTI), Cross-ministerial Strategic Innovation Promotion Program (SIP), "Photonics and Quantum Technology for Society 5.0"(Funding agency :QST).

Reference

NICT Press Release
Toppan, NICT, QunaSys, and ISARA Launch Collaboration to Establish Quantum Secure Cloud Technology
https://www.nict.go.jp/en/press/2020/10/19-1.html

Researchers
Person 1



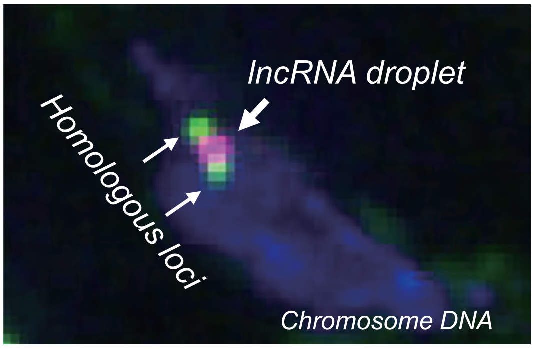
Ding Da-Qiao
Senior Researcher, Frontier Research Laboratory, Advanced ICT Research Institute

DING Da-Qiao received her Ph.D. in Botany from the University of Tokyo in 1991. She joined the Communications Research Laboratory (currently NICT) in 1992. Since then, she has engaged in research on molecular and cell biology of chromosome dynamics using fission yeast. Ph.D.(Science).

From seeing to believing-Exploring the way of inter-chromosomes communications

Meiosis is an essential process for sexual reproduction in eukaryotes. In this process, pairing and recombination between homologous chromosomes from parental generation occur. How these chromosomes find their homologs and make pairs is an open question. Using live cell observations and many molecular and cell biology tools, we found that the fission yeast sme2 RNA, a meiosis-specific long noncoding RNA (lncRNA), accumulates at the sme2 chromosomal loci and mediates their robust pairing in meiosis [1]. We further identified several conserved RNA-binding proteins that are required for the integrity of the lncRNA dot as well as robust pairing of homologous chromosomes [2]. These proteins accumulate mainly at the sme2 and two other chromosomal loci together with meiosis-specific lncRNAs transcribed from these loci. Chromosomal accumulation of these lncRNA–protein complexes is required for robust pairing. Furthermore, the lncRNA–protein complexes exhibit liquid-liquid phase separation (LLPS) properties, since 1,6-hexanediol treatment reversibly disassembled these lncRNA-protein droplets and disrupted the pairing of associated loci. We concluded that lncRNA–protein complexes assembled at specific chromosomal loci mediate recognition and subsequent pairing of homologous chromosomes through LLPS. Our finding that LLPS, a generic physicochemical property, is involved in inter-chromosome communication may provide a new way for developing novel communication technology.

[1] Ding DQ, Okamasa K, Yamane M, Tsutsumi C, Haraguchi T, Yamamoto M, and Hiraoka Y., "Meiosis-specific non-coding RNA mediates robust pairing of homologous chromosomes in meiosis," Science, vol.336, issue 6082, pp.732-736, May 2012.
[2] Ding DQ, Okamasa K, Katou Y, Oya E, Nakayama J, Chikashige Y, Shirahige K, Haraguchi T, Hiraoka Y., "Chromosome-associated RNA–protein complexes promote pairing of homologous chromosomes during meiosis in Schizosaccharomyces pombe," Nature Communications, vol.10, 5598, 2019.



A phase separated lncRNA droplet links homologous chromosome loci.

Q&A

What is the most interesting point in your research?

How homologous chromosomes find and pairing each other is a basic and unsolved biology question. My researches provide an answer to this question.

What has been your happiest moment with your current research theme?

Being the first one in the world to discover two important biological phenomena: first one is the discovery of nuclear movement in meiotic prophase; second one is the RNA droplet formation in between the homologous chromosomes.

What are the social meaning /importance and future prospects of your research?

Homologous chromosome pairing is the first step in the process of exchanging genetic information between individuals. Learning from the communication mechanism in living organism will lead creation of next generation communication technology.

Researchers
Person 2

Rademacher, Georg Friedrich
Researcher, Network Science and Convergence Device Technology Laboratory, Network System Research Institute

After graduating from TU Berlin in 2015, Georg joined NICT as a JSPS post-doctoral fellow. He joined the photonic network system laboratory as a fixed-term researcher in 2016 and is investigating next-generation high speed optical communications systems. Dr.-Ing. (Ph.D. Engineering).

Exploring next-generation high-capacity fiber-optic transmission technologies for the digital society

Most high-capacity optical transmission systems that are employed today use single-mode fibers through which many data signals can be transmitted simultaneously over different wavelengths or colors of light. The technological advancement of the past three decades has allowed a tremendous increase of data rates in such single-mode fibers. But it has become clear that a capacity limitation exists for such fibers, mostly due to nonlinear signal distortions, and that current commercially available transmission systems already operate only by a factor of 2-3 from this capacity limits. To further support the exponential increase of data rates, a drastic change of paradigms is required. Space Division Multiplexing (SDM), where different data signals are transported over spatially diverse transmission paths of a common medium is considered as one of the most promising solutions for a strong increase of the data rates in optical transmission systems, while at the same time opening opportunities to increase the efficiency and lower the power and price per transmitted bit of information.

Since 2011, NICT has been a strong driver for SDM research. Since I joined NICT in 2016, my research has had three distinct focuses: identifying capacity limiting transmission effects in novel SDM fibers, such as dynamic crosstalk [1] or intermodal nonlinear signal interactions [2]; using novel transmission effects for new sub-systems, such as all-optical intermodal nonlinear wavelength conversion [3]; performing record optical transmission demonstrations such as breaking the record for the largest data rate transmitted in a single fiber [4] and our latest demonstration of wide-band, long-haul transmission over a coupled-core multi-core fiber [5].

[1] G. Rademacher, R.S. Luís, B.J. Puttnam, Y. Awaji, and N. Wada, "Crosstalk dynamics in multi-core fibers," Optics Express, vol.25, no.10, pp. 12020-12028, 2017.

[2] G. Rademacher, R.S. Luís, B.J. Puttnam, R. Maruyama, K. Aikawa, Y. Awaji, H. Furukawa, K. Petermann, and N. Wada. "Investigation of Intermodal Nonlinear Signal Distortions in Few-Mode Fiber Transmission," Journal of Lightwave Technology, vol.37, no.4, pp. 1273-1279, 2019.

[3] G. Rademacher, R.S. Luís, B.J. Puttnam, Y. Awaji, and M. Suzuki, T. Hasegawa, N. Wada. "Wideband Intermodal Nonlinear Signal Processing with a Highly Nonlinear Few-Mode Fiber," IEEE Journal of Selected Topics in Quantum Electronics, vol.26, no.4, pp.1-7, 2020.

[4] G. Rademacher, B.J. Puttnam, R.S. Luís, J. Sakaguchi, W. Klaus, T. Eriksson, Y. Awaji, T. Hayashi, T. Nagashima, T. Nakanishi, T. Taru, T. Takahata, T. Kobayashi, H. Furukawa, and N. Wada. "10.66 Peta-Bit/s Transmission over a 38-Core-Three-Mode Fiber," Optical Fiber Communication Conference (OFC), Paper Th3H.1 2020.

[5] G. Rademacher, R.S. Luís, B.J. Puttnam, R. Ryf, S.v.d. Heide, T.A. Eriksson, N.K. Fontaine, H. Chen, R.-J. Essiambre, Y. Awaji, H. Furukawa, and N. Wada. "172 Tb/s C+L Band Transmission over 2040 km Strongly Coupled 3-Core Fiber," Optical Fiber Communication Conference (OFC), Paper Th4C.5 2020.

Q&A

What is the most interesting point in your research?

Besides the scientific interest in fiber optical communications, I very much enjoy the collaborative nature of our systems experiments. Only together with our colleagues from Europe, America, Australia and Japan we can bring together devices and knowledge to perform large-scale optical transmission demonstrations.

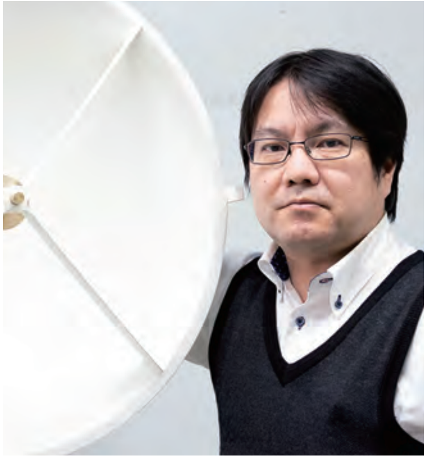
What has been your happiest moment with your current research theme?

High data rate and long-haul optical transmission demonstrations require a long planning phase and many pieces of equipment need to work in perfect synchronization with each other. Seeing that a plan works, and all the different parts work together is a very happy moment.

What are the social meaning /importance and future prospects of your research?

Optical transmission systems are the backbone of the global communications infrastructure. Connecting people all around the world is the fundamental motivation for our research and will have even larger impact as digital technologies become more and more important in our daily lives.

Researchers
Person 3



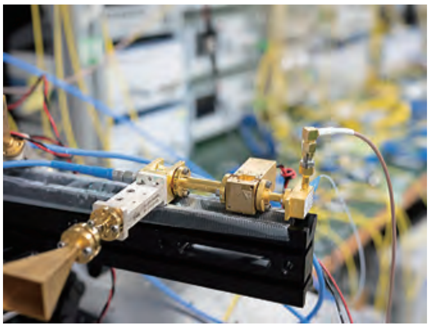
KANNO Atsushi
Research Manager, Network Science and Convergence Device Technology Laboratory, Network System Research Institute
Planning Manager, Strategic Planning Office, Strategic Planning Department

After earning a Ph. D. in Science and working as a post-doctoral Fellow in University of Tsukuba, since 2006, he has been with the NICT, where he has been involved in the research and development of high-speed optical communication, millimeter-wave and terahertz-wave radio over fiber systems, and their applications.

Seamless convergence between millimeter-/terahertz-wave and optical technologies for future communication and sensing systems

Handheld smart devices such as smartphones are now indispensable for enhancing our quality of life. I have many such devices, including three smartphones, three tablets, and a smartwatch. All the devices are connected wirelessly to the Internet. However, wireline (optical) communication supports these mobile and wireless access networks as a backend network. My research interest is the convergence technology between wireless (radio) and optical networks in a physical layer. We never need to be aware of the connections in which a network is activated nowadays. From the viewpoint of network configuration, radio and optical systems are separated; signal conversions with digital signal processing are required for connections when the network changes from a radio system to an optical system and vice versa. The processing at the interface of the networks causes latency and excess energy consumption. These costs will increase dramatically in future networks such as those beyond 5G / 6G.

Radio-over-fiber and microwave photonics technologies can perform direct conversions between radio and optical signals. These technologies are rooted in the nature of a light wave: ultra-broadband and extremely high carrier frequency. These technologies help to encapsulate all radio waves, including millimeter-waves and even terahertz-waves, into optical signals. In other words, a terahertz-wave signal can be generated and received by optical technology, which is compatible with optical-fiber communication systems. The seamless convergence system enables the high-speed millimeter-wave communication system of high-speed trains [1] and the high-precision terahertz-wave measurement system [2]. I hope this technology will be an "unsung hero" in our future everything-connected society.



[1] NICT press release (in Japanese)
https://www.nict.go.jp/press/2019/01/29-1.html
Or, A. Kanno, P. T. Dat, N. Yamamoto, T. Kawanishi, N. Iwasawa, N. Iwaki, K. Nakamura, K. Kawasaki, N. Kanada, N. Yonemoto, Y. Sato, M. Fujii, K. Yanatori, N. Shibagaki, and K. Kashima, "High-Speed Railway Communication System Using Linear-Cell-Based Radio-Over-Fiber Network and Its Field Trial in 90-GHz Bands," J. Lightw. Technol., vol.38, no.1, pp.112–122, 2020.
[2] NICT press release (in Japanese)
https://www.nict.go.jp/press/2020/06/18-1.html
Or, Y. Samura, K. Yamada, O. V. Minin, A. Kanno, N. Sekine, J. Nakajima, I. V. Minin, and S. Hisatake, "High-gain and Low-profile Dielectric Cuboid Antenna at J-band," EuCAP2020, P2.031, June 2020.

Q&A

What is the most interesting point in your research?

The microwave photonics technology is in an interdisciplinary field between radio and optical systems. The same equations can describe both optical and radio signals. I'm excited about discovering the same and different things in optical and radio systems described by these equations.

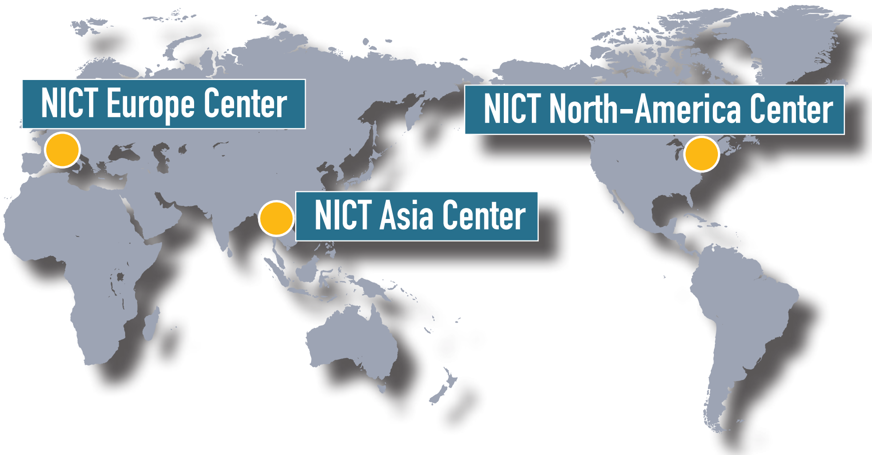
What has been your happiest moment with your current research theme?

I'm pleased to have found the "first light/radio" after constructing the experimental setup. Also, I appreciate that many researchers with differing expertise suggest various issues and challenges, whether the research progresses as expected or not.

What are the social meaning / importance and future prospects of your research?

I would like to be a "full-stack" researcher who works with the research and development of low-layer devices, middle-layer links/networks, and upper-layer architecture. My first area of research was semiconductor physics, so I'm now elevating the layer of my research from physics to subsystems.

NICT Overseas Centers



Disseminating NICT's Outcome Globally

As hubs to support NICT's international expansion, NICT has established the North-American Center in Washington, D.C., the USA, the Europe Center in Paris, France, and the Asia Center in Bangkok, Thailand. At each of these overseas centers, along with spreading information and conducting publicity about NICT's research and development accomplishments, we gather the latest information on ICT policy and research and development trends in each region that can only be obtained on the ground by networking with experts and specialists. In addition, we find cooperative research partners and develop relationships with them, provide planning and assistance to enable cooperative research to progress smoothly, and manage communications with said partners.

Specifically, the North-America and Europe Centers gather and analyze the latest information on policies and technological trends related to cutting-edge ICT such as wireless systems and cyber security, quantum communication, 6G (Beyond 5G), and AI in order to effectively and efficiently advance international research cooperation and international standardization activities at NICT. We provide this information and analysis to the relevant departments within NICT such that it may be used effectively in NICT's research activities. We also explain NICT's research and development initiatives to each region's government agencies, research facilities, universities, organizations, and other stakeholders, striving to network with them. As part of the international expansion of NICT's research and development accomplishments, along with hosting NICT's own international seminars, we also proactively participate in events such as international exhibitions.

In addition, at the Asia Center, along with gathering regional information in Southeast Asia and developing networks with relevant agencies, we promote and support collaborative research projects through the activities of ASEAN IVO (ICT Virtual Organization of ASEAN Institutes and NICT), a virtual research-cooperation organization with research facilities and universities within the ASEAN area. We also strive to improve NICT's presence in the region by participating in exhibits and assisting with workshops with the coordination and cooperation of the relevant departments within NICT. Furthermore, we act as an intermediary for the utilization of NICT's research and development accomplishments on the basis of the research needs of the ICT field in the region.

Here, the general directors of each overseas center introduce their centers' recent activities.

NICT Overseas Centers

Asia Center

Director of Asia Center
KONO Takahiro

https://www.nict.go.jp/en/global/overseas_centers/asia

It is now 18 years since the predecessor of the Asia Center, the CRL Asia Research Center, was established in Bangkok, Thailand in 2002. The center has been working, mainly in South-East Asia, gathering information, promoting and supporting research collaboration, and building relationships with other organizations as needed for this work.

One of these activities is to exhibit our activities at the National Science and Technology Fair (NSTF) held In Thailand, each year in August. It is a very large event with a million visitors each year according to the organizer. NICT has an exhibit every year, with the help of many internal and external collaborators. The NICT booth received VIP Thai observers last year, and visitors (most of whom were Thai) were able to receive explanations in Thai, with help from students from our partner research organizations in Thailand. This contributed to their deeper interest and understanding of NICT activities. (Note: NSTF2020 was postponed till November due to COVID-19).

COVID-19 is having a huge impact, both on daily life and on our activities. Since we are overseas, we are feeling the importance of meeting people face-to-face more than ever. But by adjusting our work style, like using online measures more than ever before under this restricted situation, we will continue to make the best use of our connections and resources to support NICT R&D activities from our base in Bangkok Thailand.

Fig.1 : NICT Booth staff

Fig.2 : Japan Pavilion staff and Thai VIPs

NICT ASIA Center
100th Year Engineering Building,Room 703. Floor 7th,Chulalongkorn University
254 Phayathai Road, Wang Mai,Pathumwan, Bangkok 10330, Thailand
Tel & Fax: +66-2-252-1512
E-mail: int_asia@ml.nict.go.jp

Quiet University Cafeteria under COVID-19

Due to COVID-19, Chulalongkorn University, where the center is located, was closed from the end of March to June 30, 2020, and access to the campus was restricted. During this time, the center basically operated by tele-work. At one point, we noticed by chance that a cafeteria and coffee shop were opened, and one could have meals there. It was apparently available for students and others living in dormitories on the campus. At the time, many restaurants and cafeterias within Bangkok were not operating due to COVID-19, so we used these facilities, with thanks, while tele-working.

Fig 3 : Quietly opened cafeteria at Chulalongkorn University (taken on May 5, 2020)

NICT Overseas Centers

North-America Center

Director of North-America Center
SASAKI Akihiko

https://www.nict.go.jp/en/global/overseas_centers/north_america

This year marks exactly 20 years for NICT North-America Center since the establishment of NICT's predecessor organization in its Washington office in October 2000. The current office is located near central Washington DC in walking distance of the White House and federal government organizations, which makes it easy for us to carry out our mission.

The work of NICT North-America Center is centered on the following activities:

(1) Promote and support international joint research with research institutions in the United States through participation in international conferences

(2) Collect, analyze, and report information on ICT policies and R&D trends at research institutions, universities, and corporations in the ICT field

(3) Support the international expansion of NICT research and development achievements by holding exhibits and demonstrations and participating in conferences in addition to public relations activities

Specifically, we participate in conferences and meetings on topics such as wireless communications, space weather, artificial intelligence (AI), cyber security, and neural networks, and more recently, on topics in advanced fields such as Beyond 5G/6G and quantum communications. At these gatherings, we strive to explain NICT's research and development initiatives, exchange opinions with relevant institutions, and network with attendees while collecting and issuing up-to-date information for use inside and outside Japan. In particular, we have been issuing reports on the latest research topics in the United States on a weekly basis since the summer of 2020 for use in conducting research activities and dispatching research outcomes by NICT management and researchers.

Before the COVID-19 pandemic unfolded, we had an opportunity to arrange a keynote speech about NICT's research achievements related to Smart City at the Japan-U.S. Smart City collaboration event hosted by the Ministry of Internal Affairs and Communications (MIC) in cooperation with the U.S. Department of State (Fig. 1). I also made a presentation on NICT research results such as VoiceTra, a multilingual speech translation application, at an event held by the Japanese Embassy to introduce Japanese technology to Latin American and Caribbean countries (Fig. 2). These presentations were well received by many visitors.

In the United States, much attention is now being focused on the research and development of quantum information technology and AI as well as 5G supply chain security as a counter to China, and at the same time, calls are being made to revise regulations on the so-called "GAFA" big tech companies with respect to the handling of personal information, market dominance, etc. Amid such ICT-related policies and market trends that seem to change from day to day, we would like to contribute to NICT R&D activities by leveraging the knowledge and networking that we have cultivated "on the ground" here in the United States.

Fig.1 : NICT booth at the Japan-U.S. Smart City collaboration event

Fig.2 : Presentation at an event held by the Japanese Embassy

NICT North-America Center
Office:1020 19th Street NW Suite 880,
Washington DC 20036
Tel.:202-857-0070
email:nac@ml.nict.go.jp

Expecting ICT Utilized Post Corona Society

Up until the time that sports events were cancelled because of the COVID-19 pandemic, I watched games of four major professional sports leagues especially those in which Japanese athletes were active—such as Shohei Otani in MLB and Rui Hachimura in the NBA—along with family, colleagues, or fellow Japanese on business trips after work or on holidays (Fig.3). Today, as COVID-19 rages through the United States, most people are teleworking and schools are implementing remote learning by distributing computers and supporting communication networks. This has been going on for more than half a year without any major problems. Although the future after COVID-19 is still not clear, we can expect further advances in 5G and beyond communication technologies and in virtual reality (VR), augmented reality (AR), and other advanced technologies, so I think the day of high-reality, high-presence sports viewing is not far off.

NICT Overseas Centers

Europe Center

Director of Europe Center
ISHITANI Yasuki

https://www.nict.go.jp/en/global/overseas_centers/europe

Avenue des Champs-Élysées is known as the most beautiful street in the world. One street over in an office district is our Europe Center. The Europe Center forms and deepens networks with research institutes, government agencies, and industry groups; spreads information and conducts publicity for NICT's research and development within Europe and accumulates information on policy and technological development trends related to ICT.

With the complicated state of recent world affairs, there are many agencies that see Japan as an excellent, trustworthy partner. More parties are approaching NICT, too, regarding collaborative research and other types of coordination. The Europe Center plays the role of intermediary between agencies abroad and NICT's headquarters.

For example, the Europe Center founds collaborative partners for promoting the shift to wireless communication in manufacturing processes in factories. We held joint events on Industry 4.0 promotion with European industry groups at large-scale industrial trade fairs. We also visited the Fraunhofer Institute for Open Communication Systems (FOKUS) together with NICT President Dr. TOKUDA Hideyuki to exchange information.

In addition, we have been engaged in PR activities for multilingual speech translation technology developed by NICT to enable foreign tourists in Japan to enjoy their stay. At present, trade fairs are being cancelled one after another due to the COVID-19 pandemic. So far, we have introduced the multilingual speech translation app "VoiceTra" to people interested in Japan at tourism exhibitions and Japan-related exhibitions.

Furthermore, in May 2020 amid the COVID-19 outbreak, we linked up with the National Research and Development Agency having an office in Paris to contribute to local activities under COVID-19 such as holding online classes for elementary and secondary schools.

In Europe, as well, advanced technologies such as artificial intelligence (AI), 5G, and quantum information technology are attracting attention. Going forward, the Europe Center will continue to work vigorously in establishing mutually beneficial relationships between NICT and research institutions, universities, and other stakeholders in Europe.

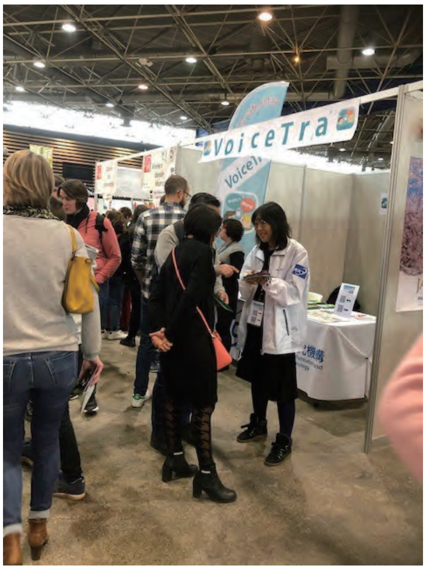
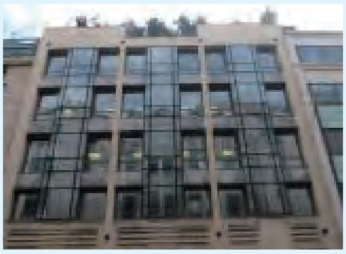


Fig.2 : Scene at Japan Touch in December 2019



NICT Europe Center
28 rue de Berri 75008
Paris FRANCE
tel: +33 9 83 60 35 40
fax: +33 9 83 91 35 40
E-mail:eu@ml.nict.go.jp

Fig.1 : Scene from visit to FOKUS in February 2020

A Glimpse of "the New Normal"

In Paris where the Europe Center is located, the streets are quiet as never seen before, as the number of tourists drops and company employees adopt teleworking due to the COVID-19 pandemic.

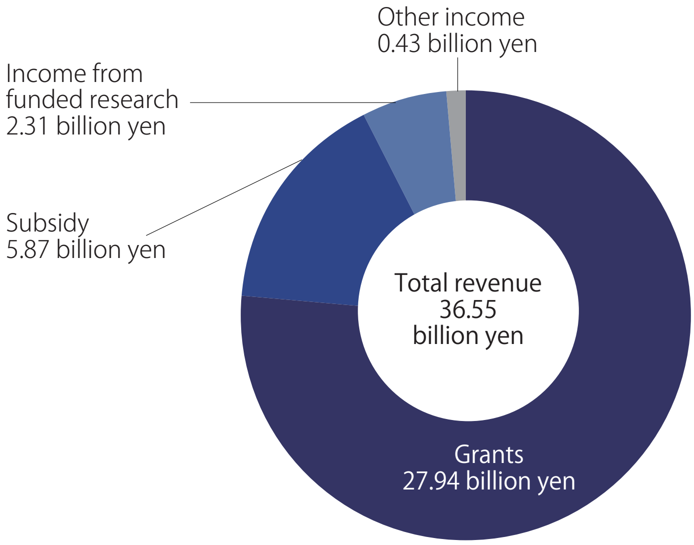
Under these conditions, more and more people are opting for electric bicycles and electric scooters instead of public transportation as a means of getting to work or school.

In Paris, a sharing service for electric bicycles and scooters using a smartphone app was already in widespread use, but since the COVID-19 outbreak, it's become increasingly popular. These rental stands can be seen all around the city. Certainly, this is one example of the "new normal" in Paris.

Budget

The original budget for FY2020

Income from funded research or others during the fiscal year is not included.



Total expenditure for FY2019 was 66.02 billion yen in a reported basis.

Yen-dollar conversion ratio: 107.98yen/dollar (Aplil 2020)

Work Force

1195 (as of April 1, 2020)
(Including fixed term employees)

History

● Communications Research Laboratory (CRL) ● Telecommunications Advancement Organization (TAO)

Oct. 1896	●	Radio Telegraph Research Division is established as a part of the Electrotechnical Laboratory, Ministry of Communications
Jan. 1915	●	Hiraiso Branch opens
May 1935	●	Testing and Examination for Radio Equipment Type Approval starts
Jan. 1940	●	Frequency Standard Radio Service (JJY) starts (Kemigawa)
June 1948	●	Radio Physics Laboratory is integrated
Aug. 1952	●	Radio Research Laboratory is established
May 1964	●	Kashima Branch opens (30-m diameter Parabola Antenna Facility completed)
Aug. 1979	●	Communications and Broadcast Satellite Organization (CBSO) is established
Aug. 1982	●	Kimitsu Satellite Control Center opens
April 1988	●	Reorganized from Radio Research Laboratory to Communications Research Laboratory
May 1989	●	Kansai Branch opens (Kobe)
Oct. 1992	●	Renamed as the Telecommunications Advancement Organization (TAO) Commencement of advanced communication and broadcasting research and development
July 1997	●	Yokosuka Radio Communications Research Center is established
July 2000	●	Keihanna Info-Communication Research Center is established
Jan. 2001	●	Ministry of Posts and Telecommunications becomes Ministry of Public Management, Home Affairs, Posts and Telecommunications
April 2001	●	Communications Research Laboratory, Incorporated Administrative Agency is established
July 2001	●	Promotion system on facilitating research and development in private basic technology commences
March 2002	●	Satellite control operations are terminated
April 2003	●	Partial takeover of operations of Promotion Center for Facilitating Research and Development in Private Basic Technology
April 2004		National Institute of Information and Communications Technology, an incorporated administrative agency (NICT) is established by merging CRL and TAO
April 2012		Resilient ICT Research Center is established
April 2013		Center for Information and Neural Networks is established
April 2015		Renamed as National Institute of Information and Communications Technology, National Research and Development Agency

NICT Primary Facilities

Headquarters

Koganei-shi and Kodaira-shi, Tokyo

Applied Electromagnetic Research Institute
Network System Research Institute
Cybersecurity Research Institute
Open Innovation Promotion Headquarters
ICT Testbed Research and Development Promotion enter
National Cyber Training Center
National Cyber Observation Center
AI Science Research and Development Promotion Center
Big Data Integration Research Center
Terahertz Technology Research Center

Resilient ICT Research Center
Sendai-shi, Miyagi
(Tohoku University Katahira Campus)

Hokuriku StarBED Technology Center
Nomi-shi, Ishikawa (Ishikawa Science Park)

Universal Communication Research Institute
Advanced Speech Translation Research and Development Promotion Center
Seika-cho, Souraku-gun, Kyoto
(Keihanna Science City)

Ohtakadoya-yama LF Standard Time and Frequency Transmission Station
Tamura-shi and Kawauchi-mura Futaba-gun, Fukushima

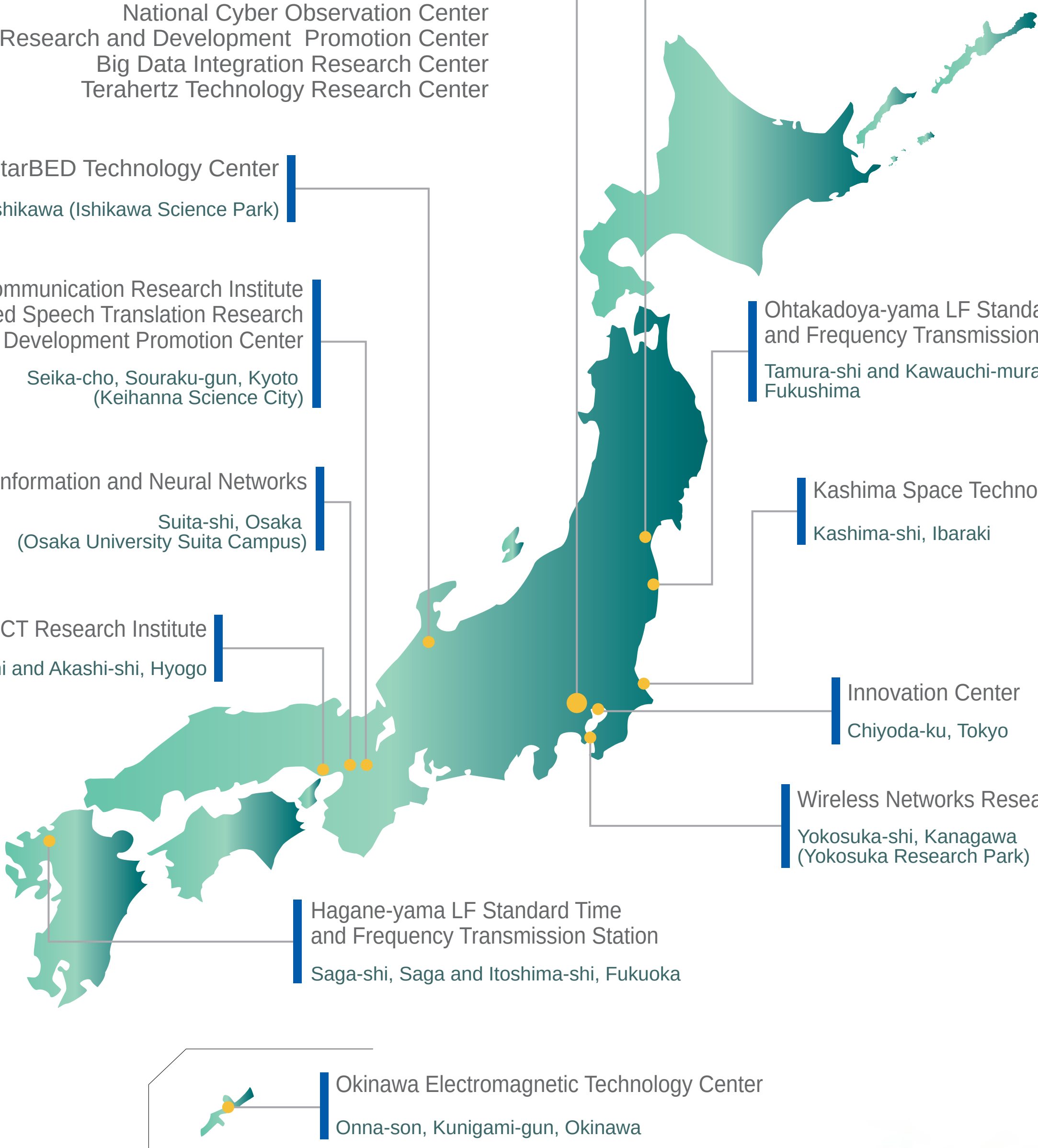
Center for Information and Neural Networks
Suita-shi, Osaka
(Osaka University Suita Campus)

Kashima Space Technology Center
Kashima-shi, Ibaraki

Advanced ICT Research Institute
Kobe-shi and Akashi-shi, Hyogo

Innovation Center
Chiyoda-ku, Tokyo

Wireless Networks Research Center
Yokosuka-shi, Kanagawa
(Yokosuka Research Park)



Hagane-yama LF Standard Time and Frequency Transmission Station
Saga-shi, Saga and Itoshima-shi, Fukuoka

Okinawa Electromagnetic Technology Center
Onna-son, Kunigami-gun, Okinawa

Overseas bases

Asia Center
North-America Center
Europe Center

https://www.nict.go.jp/en/global/overseas_centers/overseas_centers.html

NICT REPORT 2021

Published：Jan. 2021

National Institute of
Information and Communications Technology

Public Relations Department
4-2-1, Nukui-Kitamachi, Koganei, Tokyo 184-8795, Japan
Tel：+81-42-327-5392
e-mail：publicity@nict.go.jp
URL：https://www.nict.go.jp/en/

National Institute of Information and Communications Technology