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NICT REPORT

National Institute of Information and Communications Technology

2019

Phased array weather radar

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

As Japan's sole public research institute specializing in the field of information and communications technology (ICT), the National Institute of Information and Communications Technology (NICT) has as its mission, to find solutions to social issues and to create new value by advancing ICT. To realize this mission, every day we engage in research and development on leading-edge technologies, and drive efforts to advance open innovation, expanding and implementing these technologies in society.

In our fourth Medium- to Long-Term Plan that started in April 2016 (FY2016 to FY2020), we identified five foundations:

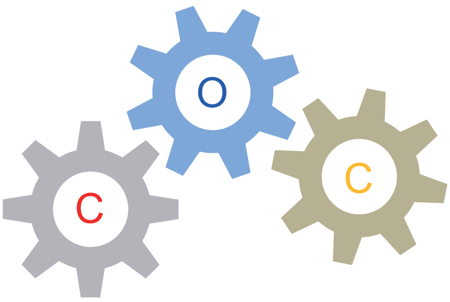
1. Sensing fundamentals, to "Watch" the real world through ICT.
2. Integrated ICT, to "Connect" society through wireless and optical communications technologies.
3. Data utilization and analytics platforms, to "Create" new value through data utilization.
4. Cybersecurity, to "Protect" society from increasingly complex and sophisticated cyberattacks.
5. Frontier research, to "Develop" new horizons in information and communications.

To promote basic and foundational R&D and also to maximize R&D results while using limited resources, we have initiatives to create innovation, by enhancing cooperation within the institute, and to accelerate innovation, by organically linking internal and external capabilities through an open environment. We are consolidating systems and strongly promoting these initiatives.

In order to advance world-leading research and development, NICT is conducting R&D with three management concepts. The first is "Collaboration" beyond just our own research, with various stakeholders in industry, academia, government, and research institutes in Japan and abroad. The second is "Open Mind and Open Innovation," to establish an innovation ecosystem of technical and social innovation through activities based at these various stakeholders. And the third is to always maintain a "Challenger Spirit," in our activities, to make NICT the premier ICT research institute in the world.

It is my hope that this report will help provide a better understanding of NICT's activities and will be used to promote still greater collaboration with NICT. We look forward to your continuing support and cooperation in these endeavors in the future.

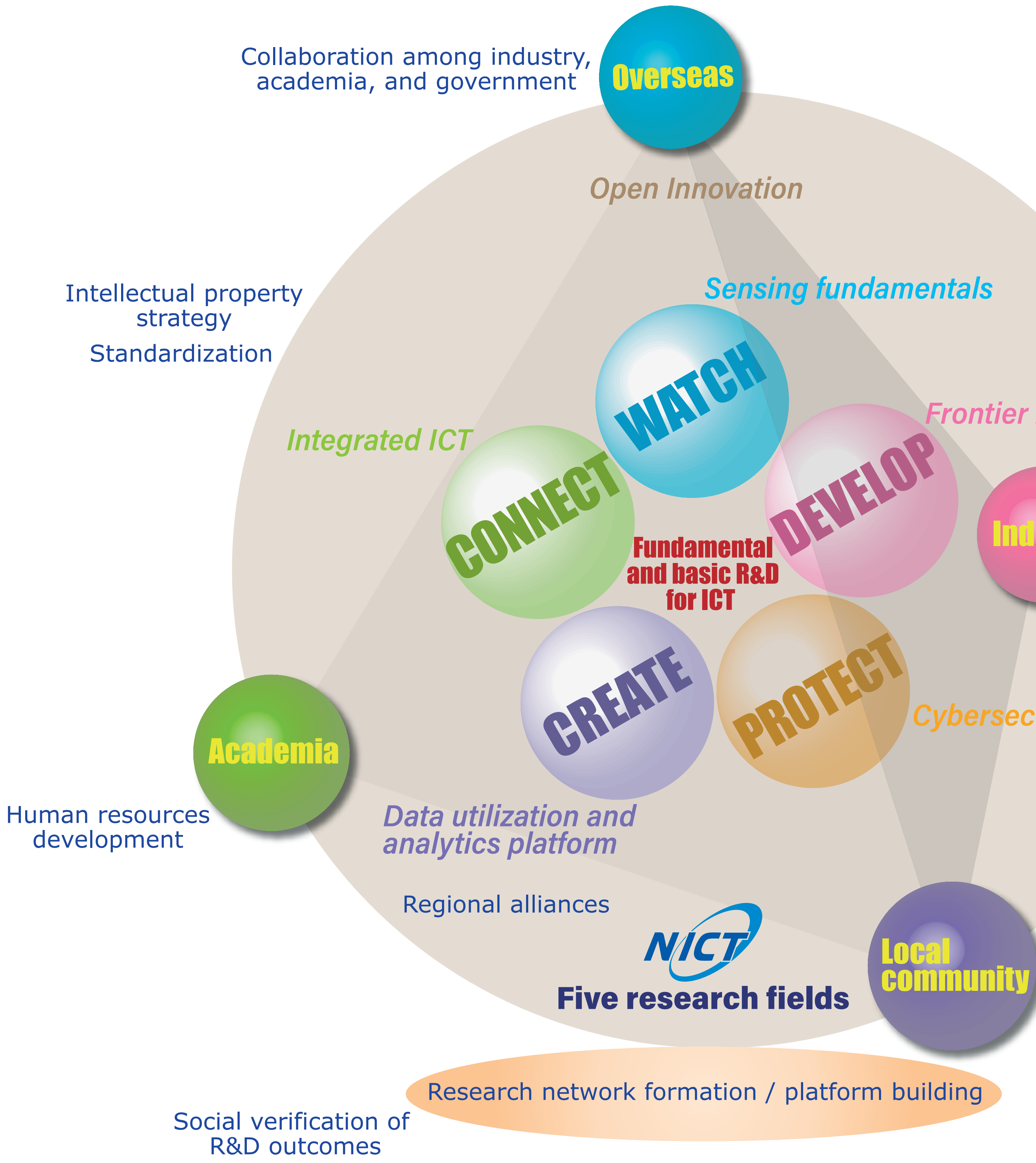
Leading the World Regarding Three Concepts
- Collaboration
- Open mind and open innovation
- Challenger spirit



President of the National Institute of Information and Communications Technology

Dr. Hideyuki TOKUDA

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

NICT Charter

1 Message from the President

2 Pioneering Future Society with Cutting-Edge ICT

6 Research and Development

6	Applied Electromagnetic Research Institute	Sensing fundamentals	WATCH
8	Network System Research Institute		
10	Wireless Networks Research Center	Integrated ICT	CONNECT
12	Universal Communication Research Institute		
14	Center for Information and Neural Networks		
16	Advanced Speech Translation Research and Development Promotion Center	Data utilization and analytics platform	CREATE
18	Cybersecurity Research Institute	Cybersecurity	PROTECT
20	Advanced ICT Research Institute	Frontier research	DEVELOP
22	ICT Testbed Research and Development Promotion Center		
24	National Cyber Training Center		
26	AI Science Research and Development Promotion Center		
28	Resilient ICT Research Center		
30	Big Data Integration Research Center		
32	Terahertz Technology Research Center		
34	Innovation Promotion Department		
36	Global Alliance Department		
38	ICT Deployment and Industry Promotion Department	Open innovation	

40 Research Highlights

42 New cryptographic technology for the quantum computer age
43 NICTER Analysis Report 2017
44 Hybrid approach for more accurate "one-second"
46 When people are happy, they can find things faster
47 Uninterrupted communication for users moving at 500km/h
49 Enhancing the energy controllability using strong interaction with photons
50 Toward autonomous transport infrastructure utilizing 5G ultra-low latency
52 High-precision chromatic aberration correction method for super-resolution microscopy
53 Generation of JST is now multiplexed
55 Aiming for further translation accuracy in the medical field
56 Multimode/multicore fiber system for practical optical communication infrastructure

58 Organization and Fact Data

58 Budget and Work Force
59 History

60 NICT Primary Facilities

Sensing fundamentals

Applied Electromagnetic Research Institute

Director General　Kazumasa Taira

In order to create new value for humans through the use of ICT, we must obtain information by observing various phenomena and situations in our environment. The mission of the Applied Electromagnetic Research Institute in NICT is to fulfill this requirement through the use of electromagnetic waves. We aim to realize more accurate electromagnetic-based measurements in order to protect the activity of society and deliver new scientific value by observing what has previously been impossible to see. Such efforts may result in novel applications of electromagnetic waves, particularly by collaborating with industry and academia.

Specifically, we are conducting research and development using electromagnetic waves in four main areas: Remote sensing technology and Space environment measurement technology for the acquisition, collection, and visualization of diverse information from diverse objects that surround us, Space-time standards technology that forms the basis for the generation, dissemination, and utilization of high-quality time and frequency signals, and Electromagnetic environment technology that provides a platform for ensuring the electromagnetic compatibility of equipment and systems in order to maintain a safe and secure electromagnetic environment for future diversification in the usage of electromagnetic waves. Some of our research and development themes are introduced below.

The world's first practical multi-parameter phased array weather radar (MP-PAWR)

As part of a Cross-ministerial Strategic Innovation Promotion Program (SIP) for the research and development of resilient technology to prevent and mitigate disasters and predict localized heavy rainfall (cloudbursts) and tornadoes, we have developed a Multi-Parameter Phased Array Weather Radar (MP-PAWR) that combines a phased array weather radar capable of performing high-speed three-dimensional observations of clouds over time scales ranging from 30 seconds to one minute, and a multiparameter (dual phase) radar that can measure rainfall with high accuracy and predict torrential rainfall up to 30 minutes in advance. The installation of this radar at Saitama University was completed in November 2017, and in March 2018 we acquired a radio station license and began evaluating the radar performance. (Fig.1)

R&D for the numerical prediction of solar flares that have a large impact on society

In collaboration with the Advanced Speech Translation Research and Development Promotion Center, we have devel-

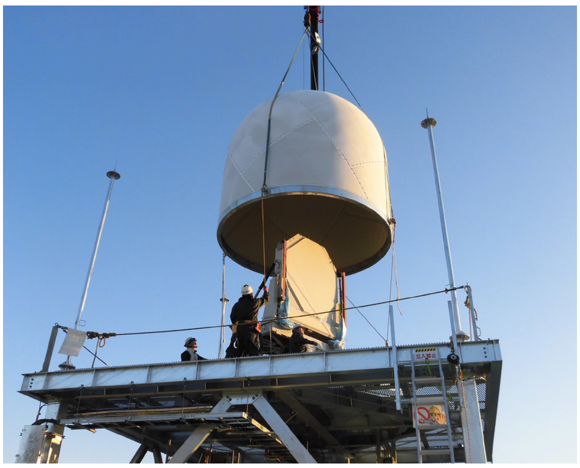


Fig.1 : Multi-Parameter Phased Array Weather Radar installed at Saitama University

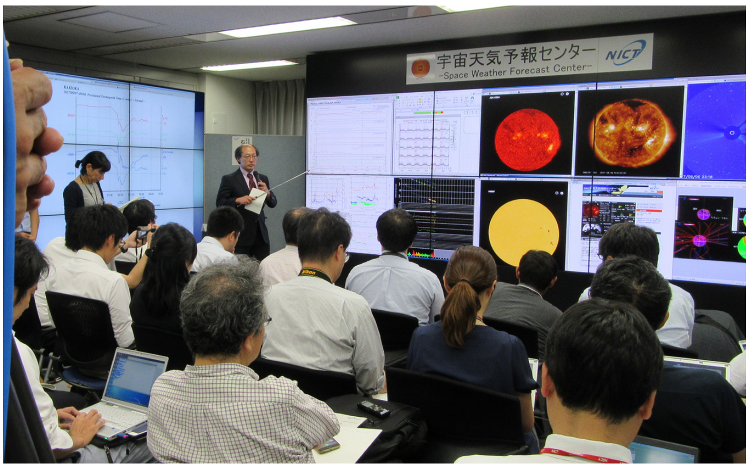


Fig.2 : Solar flare press conference

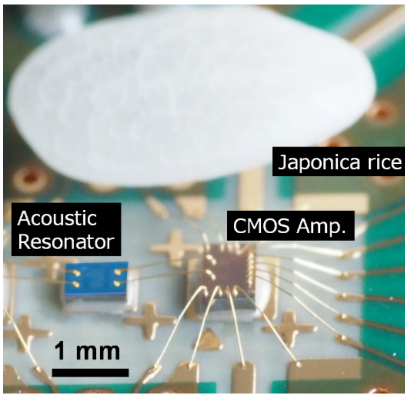


Fig.3 : 3.4 GHz FBAR oscillator for use in chip-scale atomic clocks

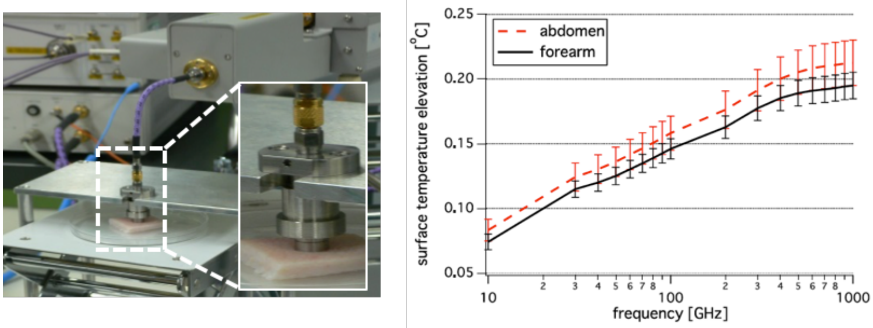


Fig.4 : Measurements of the dielectric constants of biological tissues in the millimeter-wave frequency band (left), and the results of a numerical analysis of the increase in temperature at the surface of the body due to exposure to electromagnetic waves up to the terahertz band (right)

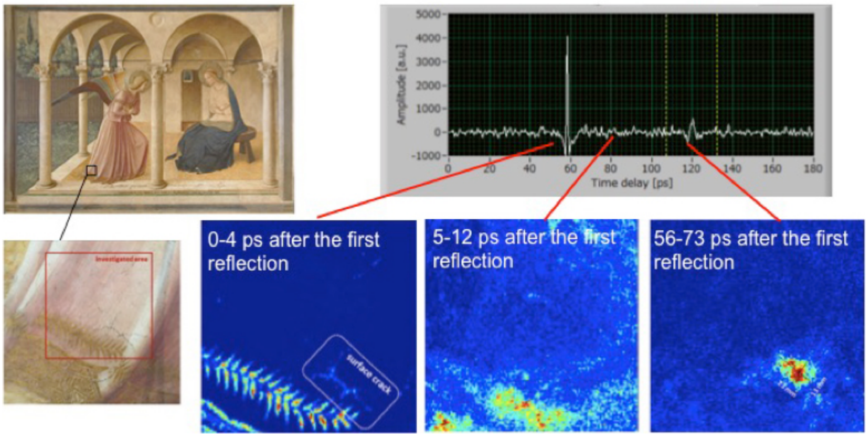


Fig.5: Analysis of the mortar condition beneath The Annunciation — a typical renaissance-era fresco, painted by Fra Angelico

oped a solar flare prediction model that uses deep learning to predict the occurrence of large solar flares that can have a large effect on our satellites and communication/broadcasting infrastructure. This work has now reached the stage of putting this model into actual operation.

When a large solar flare was detected in September 2017, the NICT issued a press release and held a press conference to warn of its possible effects on society, resulting in widespread media coverage (271 newspaper articles, 60 television programs, and 779 Web news items) (Fig.2). The NICT Space Weather Forecast website received 1.8 million hits in two days.

R&D of ultra-precise atomic clocks

The transition frequencies of the strontium optical lattice clock and the indium ion clock were accurately measured in NICT, leading to the adoption of these technologies in the Consultative Committee for Time and Frequency at the International Committee for Weights and Measures. The committee was held in June 2016, and we made a large contribution to the revision of recommended frequencies.

Our success in generating a time scale using a strontium lattice clock was published not only in an original paper but also in a press release (Research Highlight p.44).

For chip-scale atomic clocks that we hope will be installed in mobile phones or IoT devices, we have developed a 3.4 GHz oscillator using a film bulk acoustic resonator (FBAR) (Fig.3), resulting in an atomic clock with better short-term frequency stability than commercial products.

R&D of electromagnetic compatibility (EMC)

Regarding calibration techniques for high-frequency power measuring instruments up to the terahertz band, we have developed a calorimeter for the 220-330 GHz band in collaboration with the National Institute of Advanced Industrial Science and Technology. By establishing the traceability to the national standard and assessing the uncertainty of the results, we started a calibration service from FY2018.

The results of a study that accurately evaluated human exposure based on measurements of the dielectric constants of biological tissues up to the terahertz band was published by the UK Institute of Physics in the journal Physics in Medicine and Biology (Fig.4), and was adopted as the basis of the next revision to the international guidelines on RF safety that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the IEEE have been developing and will publish in the near future.

Various social advances in electromagnetic wave technology

We are actively involved in various efforts to utilize electromagnetic wave in real society. For example, we are collaborating with a general conductor to develop short-distance positioning technology for the use in construction sites. It is based on wireless two-way time comparison (WiWi) technique. We are also contributing at an international level by working with foreign museums on the use of electromagnetic waves in non-destructive sensing technology for the study of social infrastructure and cultural properties (Fig.5). Furthermore, our wavefront printing technique is expected to be used in various applications such as automotive or in-vehicle display devices, because it enables the fabrication of very complex optical components on a lightweight holographic film.

Integrated ICT

Network System Research Institute

Director General　Naoya Wada

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.

The Photonic Network System Laboratory performs research into ultrahigh-capacity multi-core fiber transmission technologies and optical integrated network technologies to meet the increased demand for data services, which is predicted to increase by three orders of magnitude beyond current levels.

The Network Science and Convergence Device Technology Laboratory performs research into (i) automation of dynamic, on-demand network configuration and control technology, and (ii) information dissemination and sharing based on information-centric networking concepts. In addition, its laboratory studies are geared towards realizing the seamless convergence of core networks, optical access and wireless, to provide end users with high-capacity communications.

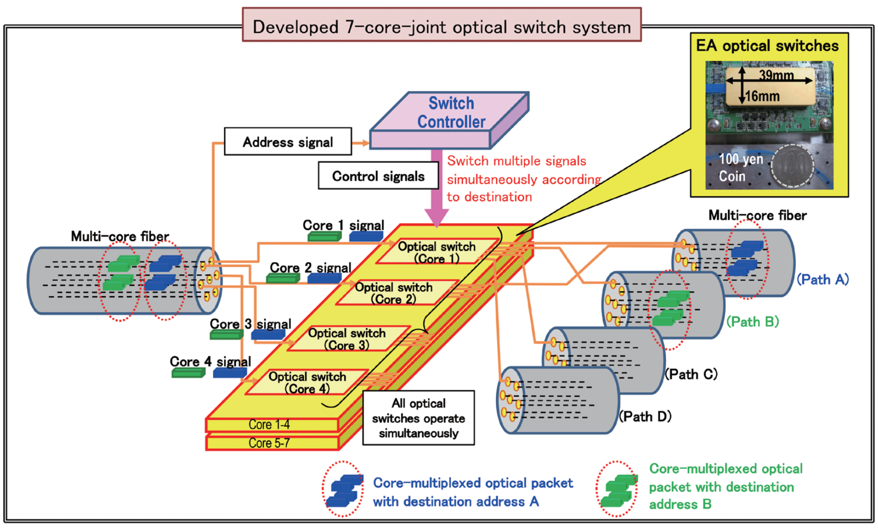


Fig.1 : Developed 7-core-joint optical switch system

83.3 Tbit/s: a new world record in optical switching

Regarding the research and development of multi-core all-optical switching technologies, we have developed a high-speed parallel switching system equipped with a controller that simultaneously drives multiple elements according to the destination signals (Fig.1), enabled by a parallel configuration of high-speed electro-absorption (EA) optical switches with a switching speed on the order of nanoseconds. Using this testbed, we have successfully tested 7-core-multiplexed optical packet switching with a world record switching capacity of 53.3 Tbit/s. This result was chosen for a special session of outstanding papers (commonly referred to as Post-deadline Papers) at the European Conference and Exhibition on Optical Communication (ECOC2017), the top conference in the field of optical communications. Later on, we made further improvements to this technology and achieved a new record switching capacity of 83.3 Tbit/s, which is 6.5 times higher than the previous record set just three years ago.

159 Tbit/s Transmission over 1,045 km using standard diameter multimode optical fiber

We successfully demonstrated transmission of 159 Tbit/s data over 1,045 km using a 3-mode optical fiber with a standard cladding diameter (0.125 mm) that is compatible with standard optical fiber infrastructure (Fig.2). Using the common metric of the product of transmission capacity and distance, this experiment gives a value of 166 Pbit/s·km (petabit kilometers), which is approximately double the existing world record for standard diameter optical fibers for spatial multiplexing. This result was selected for the Post-deadline special session of the Optical Fiber Communication Conference (OFC2018), which is the top conference in the field of optical communications.

Highly integrated two-dimensional photodetector array

We have developed a highly integrated photodetector device (Fig.3) that can detect and convert a large number of high-speed optical signals to the electrical signals simultaneously. This device integrates 32 photodetector units in an area of ap-

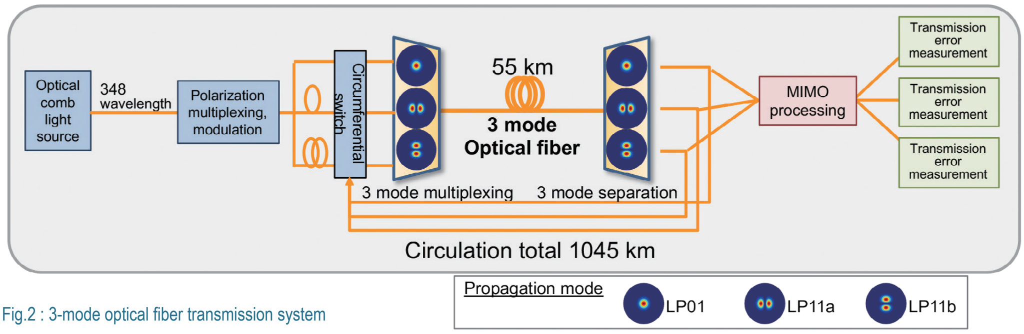


Fig.2 : 3-mode optical fiber transmission system

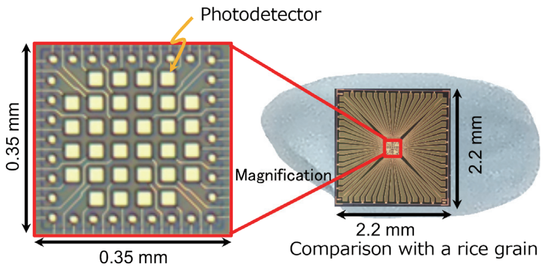


Fig.3 : Ultra-compact, highly integrated two-dimensional photodetector array

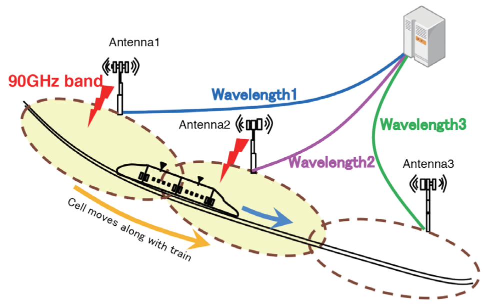


Fig.4 : "Uninterrupted" fiber-wireless communication technology for high-speed railways

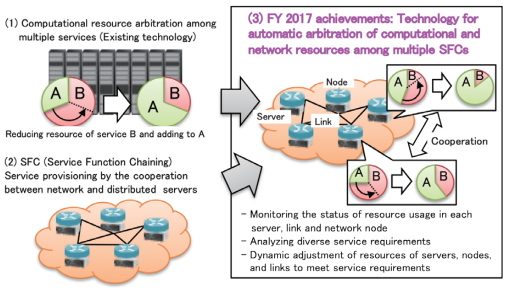


Fig.5 : Automatic Resource Arbitration among Multiple Service Function Chains

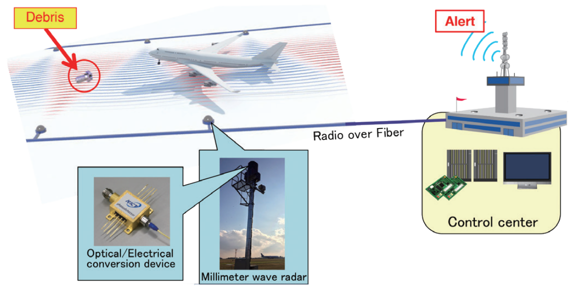


Fig.6 : Foreign Object Debris Detection System

proximately 0.1 mm², allowing it to simultaneously receive multi-channel optical signals and convert each of them into a high-speed electrical signal of 10 GHz or higher. The development of this device has made it possible to concentrate a large number of photodetectors into a small area, resulting in a drastic reduction of the size and power consumption of large-capacity optical communication devices. This result was selected for ECOC2017.

Automatic virtual network configuration and control technology

In the 5G era and beyond, networks will have the capability of instantly configuring virtual network slices with enough network and computing resources for different types of network services. For the agile provisioning of network services and their adaptation to traffic fluctuations, we need technology for the automatic configuration and control of virtual network slices. Meanwhile, service function chaining (SFC) is an innovative approach to in-network processing of traffic, which enables flexible deployment of network service functions on each slice(Fig.5). We have been researching and developing technologies to automate the dynamic arbitration and migration of computational resources among multiple service function chains deployed on multiple virtual network slices. These technologies can mitigate the service degradation caused by CPU-saturation and/or switching of communication paths. We have designed a mechanism for autonomic computational resource control to satisfy diverse quality-of-service requirements in response to network traffic fluctuations, and we have verified that our mechanism can reduce CPU-saturation in all service function chains by at least 90% compared with the conventional fixed resource allocation approach, thereby contributing to the enhancement of service quality. These results were presented at IEEE/IFIP Network Operations and Management Symposium (NOMS2018), which is a prominent international conference in the field of network operations and management.

Efforts leading to social implementation

Using the radio-over-fiber technology and optical and electrical high-frequency convergent device technology, we are continuing with a verification trial of an airport runway monitoring radar system (Fig.6) at Narita Airport, and we are collecting radar observation data for future commercial development. We have also promoted this system with the aim of creating new business and have contributed to the start of testing at Kuala Lumpur Airport in Malaysia.

Integrated ICT

Wireless Networks Research Center

Director General Kiyoshi Hamaguchi

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.

The Wireless Networks Research Center conducts comprehensive research and development centered about two research laboratories distinguished by their research themes with the aim of expanding the field of wireless communications. The following research on wireless network platform technologies and satellite communications technologies is being performed in conformance with the Fourth Medium- to Long-Term Plan of NICT.

Wireless network management technology

We built prototypes of privately operated microcell radio equipment for the millimeter-wave band (28 GHz) and constructed a simulation environment including management equipment and base stations. We used this environment to demonstrate the feasibility of a proposed system that could be used by multiple operators in Intelligent Transport Systems (ITS) and other real-world systems (Fig.1 (a)). Additionally, using a system for reporting the operating information (position, frequency, etc.) of microcell base stations from multiple cellular operators based on control-plane/user-plane separation, we demonstrated the possibility of integrating such “private microcells” with 5G mobile communications and proposed the necessary architecture to the 3rd Generation Partnership Project (3GPP), where it was subsequently adopted.

Next, envisioning application in environments such as emergency-supply warehouses and smart offices, we successfully conducted an indoor experiment on massive connectivity assuming 20,000 5G radio terminals. In this way, we demonstrated the feasibility of using this technology in 5G systems under massive connections on the order of 1,000,000 devices/km^2 (Fig.1 (b)).

Furthermore, as a technology contributing to efficient frequency utilization, we conducted a basic experiment on massive connectivity under the conditions of five simultaneously connected terminals and a latency time of 5 milliseconds (ms) or less. We submitted a portion of these experimental results to 3GPP RAN 1 as a draft contribution. We also proposed a control system to enable high-density rollout of microcells and submitted a partial system as a draft contribution toward the next-generation wireless LAN standard (IEEE802.11ax). This contribution was accepted and is now under discussion. In addition, we proposed an extended Multipath TCP (MPTCP) system to the Internet Engineering Task Force (IETF). The purpose of this system is to individual applications to operate at desired transmission speed and latency in combination with deep packet inspection technology while simultaneously connecting multiple cellular operators and enabling the sharing of resources on the transport layer.

Wireless network customization technology

Among network structures consisting of multiple units of radio equipment (wireless grid), the high-reliability mesh network is laying the foundation for new application fields. For this type of network, we studied the modeling of various wireless adaptation formats for in-factory use and successfully obtained data in a real-world environment in conformance with wireless applications (some 130 types) that we analyzed and categorized last fiscal year. We are working to deploy this technology in society by proposing it to a working group of the IEEE 802.1 standard committee and promoting its reflection in a

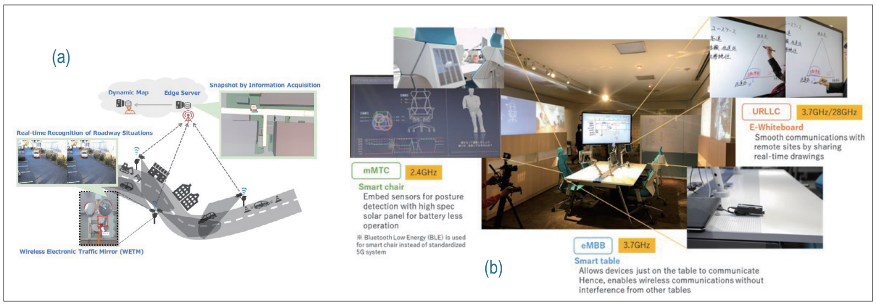


Fig.1 : Wireless network management technology: (a) demonstration of ITS using privately operated microcells, (b) demonstration of a smart office using 5G wireless terminals

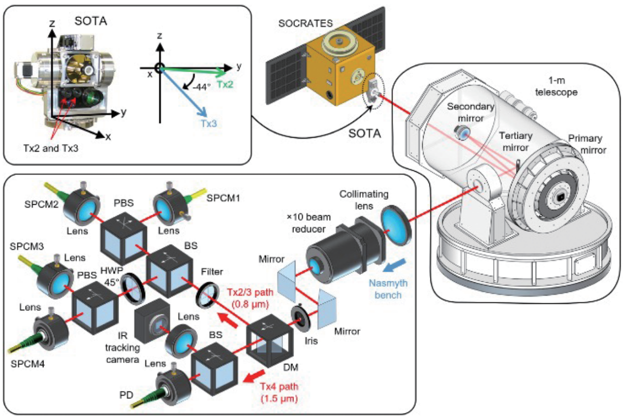


Fig.2 : World's first satellite-to-ground, quantum-cryptography basic experiment using SOTA

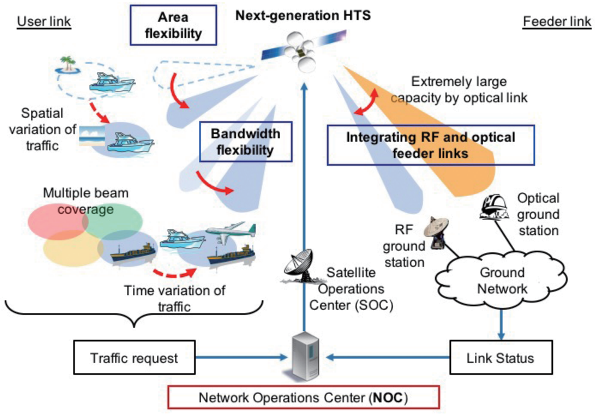


Fig.4 : Conceptual model of high-efficiency control system

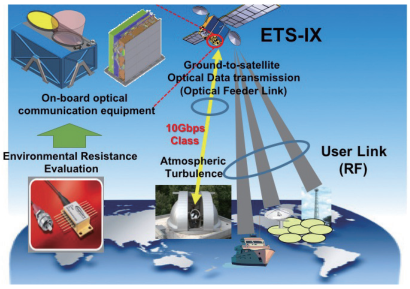


Fig.3 : Basic configuration of optical feeder link experiment using ETS-9

white paper. Additionally, for large-capacity data collection networks consisting of a large-scale mesh of many wireless terminals, we extended the Layer 2 Routing (L2R) specification as an IEEE 802.15.10 recommended practice in fiscal year 2016 and successfully demonstrated data concatenation, virtualization, and other functional enhancements. Then, as an agricultural application of an ultra-low-energy network using battery-driven wireless terminals, we successfully demonstrated low-energy wireless operation for both data collection and control in a real agricultural field.

Wireless network reinforcement technology

We proposed a PHY/MAC system for distributed inter-terminal communications and took a leading role in formulating the IEEE 802.15.8 standard. We also developed an impulse-radio ultra-wideband (IR-UWB) positioning system and promoted system verification trials in Southeast Asia. In addition, we studied latency-guaranteed wireless network technology (maximum allowed latency: 20 ms) for transmitting on-vehicle sensor data for application to the IEEE 802.15.8 UWB system. Furthermore, in relation to latency-guaranteed, multi-hop relay control communication systems for ensuring the safe operation of non-line-of-sight robots or drones, we designed and developed a frequency-redundant-type system using a new robot band and successfully performed a verification experiment targeting the flying of drones. We also conducted joint research with a major power infrastructure operator toward practical deployment of this technology.

Global optical satellite communications network technology

We performed optical satellite communications experiments between a low-orbit satellite and a ground station using an on-board laser communication terminal called Small Optical TrAnsponder (SOTA), and successfully performed the world's first basic quantum-communications experiment for a 50-kg-class micro-satellite (Fig.2). This achievement was published in Nature Photonics and turned out to be more successful than expected.

Next, with a view to performing space communication demonstrations using Engineering Test Satellite IX (ETS-IX), we completed the preliminary design for the on-board equipment of ultra-high-speed optical communication equipment called HIgh speed Communication with Advanced Laser Instrument (HICALI) for achieving 10-Gbps-class transmission speeds between a stationary satellite and ground station as a world's first (Fig.3). Additionally, after working on the development of ultra-high-speed optical satellite communication devices for on-board use in the form of consigned research, we use the results of this work to establish a screening process for space-environment tolerance tests for commercial off-the-shelf (COTS) optical communication devices.

We also participated in standardization activities for space laser communications in the Consultative Committee for Space Data Systems (CCSDS) founded by major space agencies around the world and contributed to the first official report for space laser communications.

Space/ocean broadband satellite communications network technology

The Wireless Networks Research Center led the drafting of overall requirements for ETS-IX communication missions, promoted R&D of flexible satellite traffic control technology and on-board fixed multi-beam communication equipment as the representative research institution, and completed a preliminary design. Additionally, with regard to high-efficiency operation and control technology for a non-conventional RF/optical hybrid satellite communication system proposed by NICT for ETS-9 demonstrations, we studied a basic model in fiscal year 2016 and designed a conceptual model of a control system in which a Network Operation Center (NOC) manages frequency and beam variation and RF/optical feeder link switching (Fig.4). We also fabricated the basic components of a simulator for testing these functions. In addition to the above, we performed a series of measurements of mobile-terminal propagation characteristics in the Ka-band using the WINDS satellite.

In the area of international standardization, we participated in the standardization of an integrated Mobile Satellite Services (MSS) system within the Asia-Pacific Telecommunity (APT) as part of the APT Wireless Group (AWG) and contributed to the completion of a new report reflecting NICT proposals.

Data utilization and analytics platform
Universal Communication Research Institute

Director General Yutaka Kidawara

We are conducting R&D to contribute to increasing convenience for people and building a rich and secure society through human-friendly communication technology and intelligent advanced technology. In particular, we are conducting R&D on technology that uses big data, incorporating the vast amount of knowledge and information circulating in society (social knowledge) as a source of information, and makes specialist knowledge available easily, even to non-specialists. This is done by generating useful questions and automatically providing answers to those questions, and by providing knowledge that helps users in making decisions. We also engage in joint R&D with the Resilient ICT Research Center, on platform technology that will organize the social knowledge on the Internet regarding disasters in real time, integrate it with various types of observation data, and to provide it to users in an easy to understand form. To optimize and increase the efficiency of various social systems, we are also conducting R&D on an image analysis technology providing advanced recognition of circumstances and support for taking action. We aim to create new ICT that will realize human-friendly and society-friendly communication and be useful for the lifestyles and well-being of people.

Application and use of DISAANA/D-SUMM (Joint development with the Resilient ICT Research Center)

Details regarding DISAANA and D-SUMM will be described in the section on the Resilient ICT Research Center.

Next-generation conversation technology R&D

To use social knowledge effectively, we are promoting development of the WEKDA next-generation dialog system. WEKDA, or WEb-based Knowledge Disseminating dialog Agent, uses the large volume of knowledge on the Web to conduct conversation on a wide range of topics (Fig.1). Rather than conversing based on rules and scenarios, as with other conversation technologies, it uses questions and answers based on the vast information on the Web. There is demand in society for this sort of advanced next generation artificial intelligence technology. Underlying WEKDA is WISDOM X, a system that analyzes the information on some four billion Web pages to present answers to questions. When given an input phrase (e.g.: "iPS cells are amazing, aren't they?"), it uses deep learning to ask a question about what to show the user (e.g.: "What would you like to see about iPS cells?). When WISDOM X is given this question, the system generates a response from the results of searching for an answer (e.g.: "A possible treatment for cardiomyopathy using iPS cells has been found."). An outline of this mechanism was developed in FY2016, and in FY2017, we implemented a deep learning mechanism to rank the results from the answer search and also functionality to generate an appropriate response from the search results, using a deep learning method similar to machine translation. These enabled the system to generate more appropriate responses from the results of the answer search. The architecture of WEKDA is shown in Fig.2. The dialog system was implemented by combining multiple deep-learning modules, including those just mentioned. Questions can be input directly to WISDOM X and the answer will be presented.

Fig.1 : Conversation with the WEKDA next-generation dialog system

Currently, WEKDA is limited to handling "What" questions that can be answered with

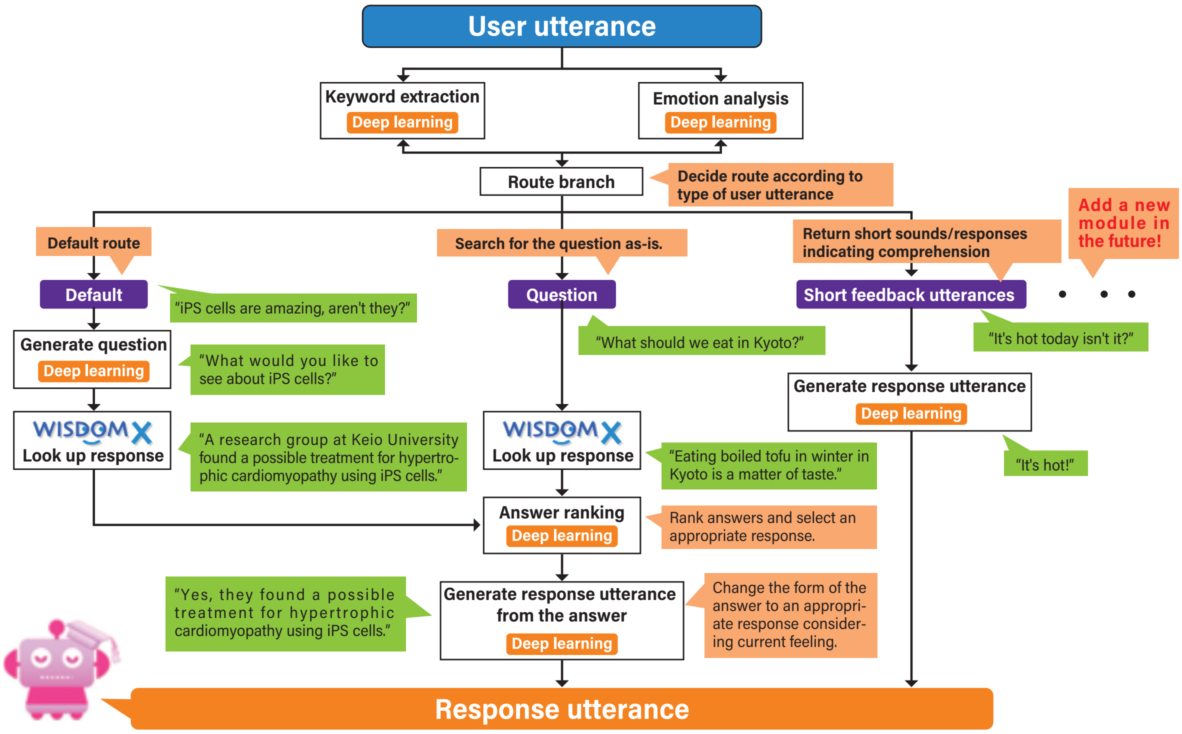


Fig.2 : WEKDA dialog system architecture

a noun, such as "What can be done to solve global warming?" and "What if" questions such as "What if global warming continues?" However, WISDOM X can also answer "Why" questions to find reasons for things, such as "Why has Japan fallen into deflation?" The responses to such questions were relatively long; however, and not suitable as answers. In FY2017, we developed a deep learning technology that summarizes such long responses, enabling shorter answers to be given, such as "Because society is continuing to age" for the question above.

As a computing platform supporting this technical development, we have integrated a deep learning framework into the RaSC middleware. RaSC was developed at this center and has been used in the past to run large scale software such as WISDOM X on a large scale cluster in parallel and at high speed. This has enabled us to run WEKDA, which is an amalgamation of deep learning technology, at low cost and high speed. While conducting this research, we also developed a new batch scheduler to improve utilization of GPGPUs, and were able to improve efficiency of GPGPU use in the Institute.

Image analysis technology R&D

We have developed a method for clustering large volumes of tourism photographs collected from SNS according to structure, as a technology to automatically build a tourism-support image corpus. The method is implemented by performing clustering on a graph with vertices for each image, connected by comparing local feature points (a match graph)(Fig.3). Earlier clustering methods had the disadvantage of not being able to detect small clusters, so to solve this problem, we developed a new clustering method using a random walk technique. This method was presented at the IEEE International Conference on Image Processing (ICIP) 2017. In the proposed method, the accuracy of clustering would be negatively affected by making too many steps in the random walk, so we also developed a method to prevent taking too many steps, and conducted tests to confirm that it is effective.

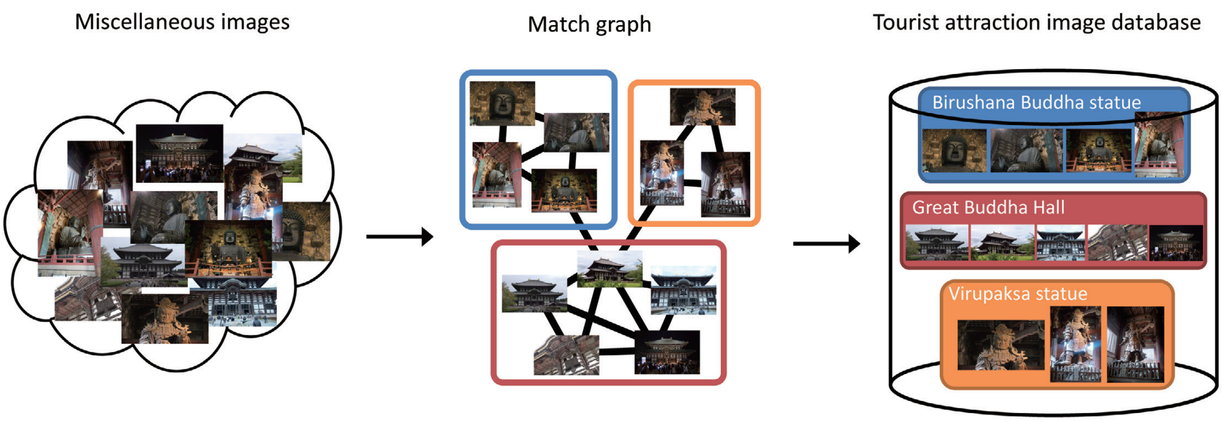


Fig.3 : Technology to build an image corpus to support tourism automatically

Data utilization and analytics platform

Center for Information and Neural Networks

Director General　Toshio Yanagida

The Center for Information and Neural Networks (CiNet) conducts fundamental research integrating neuroscience and information and communications technology (ICT). It operates around a core of NICT, Osaka University, and the Advanced Telecommunications Research Institute (ATR), and engages in widespread collaboration with other universities, research institutes, and enterprises.

The human brain is the most complex information and communication apparatus known to man. In our fourth Medium- to Long-Term Plan, we have set a goal of establishing technology able to measure brain activity related to cognition, perception, and movement, and to encode and decode it efficiently. Our ultimate goal is to create a new generation of ICT that will help improve health and welfare. To achieve this, we are analyzing high-order brain information processing and applying it to tasks such as designing information processing architectures and discovering biomarkers. We are also promoting R&D on technologies to improve the physical, sensory, and social capabilities of individuals. We are also conducting basic research to evaluate appropriateness and safety based on brain information technologies, and promoting basic technologies to infer human emotion and cognition, based on human responses to multi-sensory fluctuations and changes in brain data.

Brain information decoding technologies

Brain information decoding technologies read details of perception and cognition from brain activity. We expect that basic technologies like the brain-machine interface will play an important role, but to make such technologies practical, it is necessary to read the complex and varied content of perception produced in the real world. In earlier research, technologies to identify what is being viewed, or to infer the content of dreams, from brain activity have been developed, but they have not been able to visualize more than an extremely small subset of the complex and varied perceptions arising from the real world. This research has focused on language itself as a means of expressing varied perceptions, and we have conceived a technology that decodes perception details from brain activity by incorporating feature spaces of language in a brain-information decoder. We used this approach to analyze brain activity while watching advertisement videos, and were successful in inferring details of perception and cognition induced by the video, in the form of objects (nouns), actions (verbs), and impressions (adjectives), using a vocabulary of several tens of thousands of words (Fig.1).

Movie contents

Perceptual contents decoded from brain activity

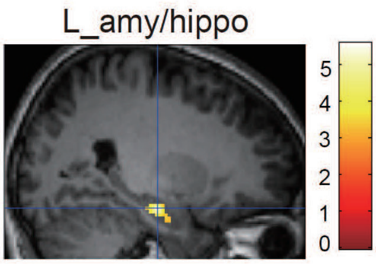
noun	verb	adjective
hair	wear	cute
blond hair	talk	close
hairdo	like	friendly
face	divulge	young
appearance	play	wanted
woman	socialize	scary

↑ Likelihood

Fig.1 : Decoding brain activity while watching video and estimating perception content

Technology to predict depression using fMRI

We have established a technology able to predict tendencies toward depression, current and in the following year, from patterns of activity in the amygdala, which responds to comparison of one's situation relative to another (social value orientation). This has been reported in the journal Nature Human Behaviour. Specifically, 94 subjects performed the Beck Depression Inventory II, which is a test for depressive tendencies, and were then given a task called the Ultimatum Game while undergoing an MRI scan. In the Ultimatum Game, one person has the role of proposer, and proposes a way to distribute a sum of



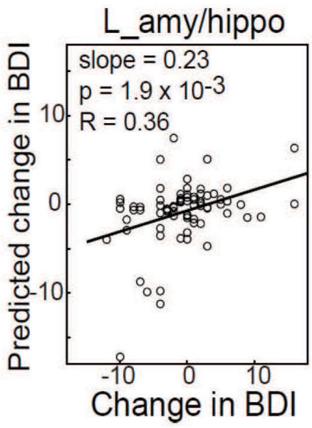


Fig.2 : (Left) Part of the brain related to economic inequity. (Right) Relationship between changes in depression tendencies one year later and values predicted from brain activity patterns.

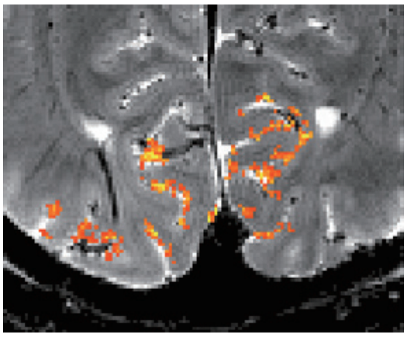


Fig.4 : Ultra-high-resolution fMRI under visual stimulation with 0.6 mm voxels (capturing the brain activity localized in the visual cortical structure)

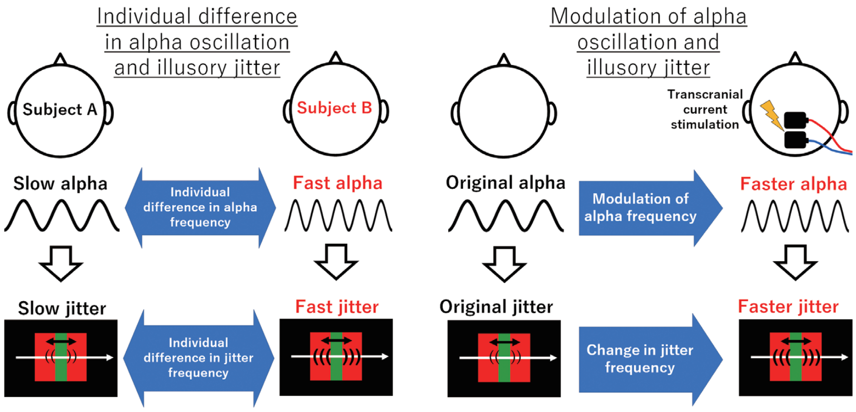


Fig.3 : When alpha waves are changed by electrical stimulation, the rhythm of illusory jitter also changes

money (500 yen in this case), while our subject decides whether to accept or reject the proposal. If the proposal is accepted, the money is distributed according to the proposal, but if it is rejected, both parties receive nothing. Earlier research has shown that most people would reject a proposal if their allocated portion was 20% or less. In this research, subjects made 56 decisions for differing proposers and proposals. Subjects also repeated the Beck Depression Inventory II one year later to study their depressive tendencies. We attempted to predict depressive tendencies, current and one year later, based on patterns of activity in the amygdala and hippocampus arising from differences when a proposal was offered, using Bayesian sparse regression with a kernel function (which is a machine learning method). We observed a significant positive correlation between the predicted and measured values (Fig.2). This positive correlation between predicted and measured values shows the potential for prediction. This result also hints at the importance to a person's mental state, of comparisons with other people (disparity), and shows that information processing in the amygdale and hippocampus is an underlying factor.

Explaining brain function and next generation ICT research issues

In this research, we focused on a phenomenon called illusory jitter, in which objects that are not actually moving appear to shake with a frequency of approximately 10 cycles per second. We first confirmed that differences among subjects in the rhythm of the perceived jitter reflect differences in the rhythm of their alpha brain waves. In other words, people with faster alpha wave rhythm tended to perceive faster jitter, while people with slower alpha wave rhythm perceived slower jitter. We also developed a technology able to artificially change the rhythm of alpha waves by applying weak, non-harming electrical stimulation to the back of the subject's head (transcranial stimulation). When this technology was used to change the rhythm of alpha waves, the illusory jitter perceived by the subjects also changed similarly (Fig.3). These results verify that the rhythm of alpha waves contribute to perception of illusory jitter, and suggest that the timing for synthesis of information about shape and movement, which are processed in different locations in the brain, is determined by alpha waves.

Brain function measurement technologies

Generally, the signals originating from brain activity that can be observed using fMRI are extremely weak, so the accuracy of the data is usually increased statistically by taking repeated measurements with an imaging technique called single-shot EPI, that has excellent time resolution. However, 7T-fMRI can produce stronger signals than earlier technologies, so we changed from the conventional approach of prioritizing time resolution, and used multi-shot EPI, which increases the accuracy of the signals collected themselves. We also increased the efficiency of measurements by rearranging how the tasks were given, and by capturing structured images, which have excellent histological contrast, we built an fMRI test system able to make detailed comparisons of structure and function. As a result, we were able to collect fMRI data with spatial resolution of 0.6 mm (Fig.4).

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

Director General　Yutaka　Kidawara

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 is based on Japan's Global Communication Plan (GCP), 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. We aim to accelerate open innovation using multilingual speech translation technology to realize an advanced ICT-based society where language barriers do not exist. In FY2017, we continued to make efforts 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 also reflected these capabilities in our multilingual speech translation app VoiceTra, and conducted field experiments in collaboration with organizations and private companies from various fields such as disaster prevention, rail travel, shopping, taxi services, medicine, emergency and rescue, and policing. Some of these experiments have yielded new commercial services.

R&D of multilingual speech recognition technology

As the basis of our speech recognition technology, we built a speech corpus consisting of a total of 2,265 hours of recorded speech: 500 hours of Korean, 542 hours of Thai, and 516 hours of Myanmar, To improve the accuracy of speech translation in fields related to travel and daily life, we increased the size of the Japanese-English bilingual dictionary from 100,000 words to 300,000 words, and we also increased the size of the Japanese-Chinese and Japanese-Korean dictionaries from 100,000 words to 210,000 words, respectively. We added 60,000 new words of translation for Thai, Vietnamese, Indonesian, Myanmar, Spanish, and French, respectively. The improvements made to our speech recognition models significantly increased the recognition accuracy for Japanese, Thai, Vietnamese, Indonesian, and Myanmar, with a reduction of between 28% and 42% in word error rates. These improved models have been incorporated into the VoiceTra field trial system and have been made available to the public.

R&D of multilingual speech synthesis technology

To improve the practicality of our Korean and Vietnamese speech synthesis systems, we increased the scale of the speech corpus used to train the acoustic model for each language to 15,000–20,000 utterances (15–20 hours) for both male and female speakers, corresponding to 2–5 times the size of the original corpus. This resulted in a highly accurate acoustic model and better speech synthesis quality. We also improved the pronunciation accuracy of each language by introducing a new text normalization process that transforms non-phonetic characters like numerals and symbols into strings of phonetic characters that are more suitable for reading. The new and improved speech synthesis system has been incorporated into VoiceTra and made available to the public.

As in the speech recognition field, deep learning approaches have also been introduced to the speech synthesis field in recent years, and have resulted in a higher quality of synthesized speech compared with conventional methods based on hidden Markov models (HMMs). At ASTREC, we have been conducting research on deep learning since 2015 and have developed a new speech synthesis system that utilizes deep neural networks (DNNs). Figure 1 compares the new system with a conventional HMM system, and Fig.2 shows the results of speech synthesis listening tests performed using a DNN acoustic model of a Japanese female speaker that we developed. The speech quality of the DNN system was clearly better, achieving an average opinion score 0.6 points higher than that of the conventional system. The Japanese female voice DNN synthesis system has been made publicly available on VoiceTra.

R&D of machine translation technology

Our translation corpus of spoken language in ten different languages for multiple fields including medicine has been expanded far beyond the original target of one million sentences. By using this translation corpus, we have confirmed that our translation system has made steady improvements in accuracy for all languages. In this way, we were able to surpass our original goal in building the translation corpus (which was to provide the foun-

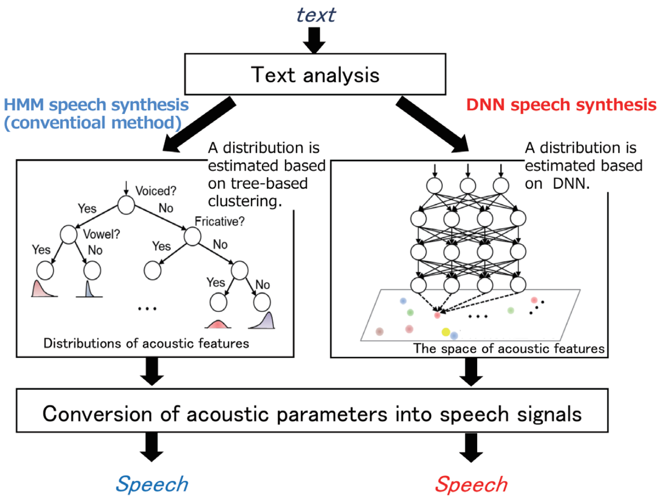


Fig.1 : The outlines of speech synthesis methods

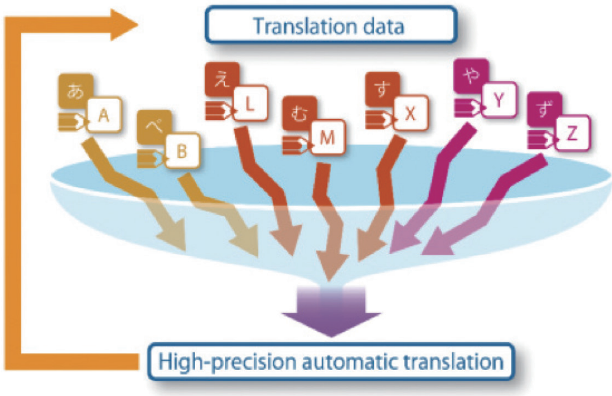


Fig.3 : The "Hon'yaku Bank" concept

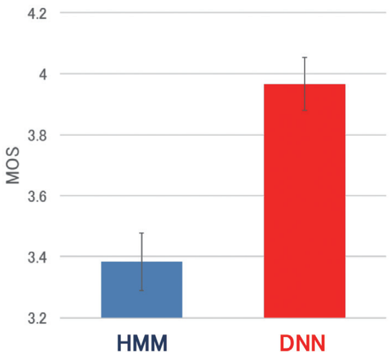


Fig.2 : Results of perceptual evaluation of synthetic speech based on MOS (Mean Opinion Score)

dations needed for the development of multilingual translation services), and made a significant contribution to accelerating the implementation of speech translation technology in society.

In cooperation with the Ministry of Internal Affairs and Communications, we have also introduced a "Hon'yaku (Translation) Bank" scheme whereby NICT can collect translation corpora from diverse sources scattered throughout Japan. This scheme uses various means (including uploads via the Web) to efficiently collect multilingual translations in multiple fields from around the country, and is expected to achieve greater precision in general-purpose machine translation (Fig.3). This Hon'yaku Bank scheme can be described as a new donation-based collection method.

R&D of a simultaneous language interpretation platform

We have developed a prototype one-shot speech translation system as the first stage of our research and development aimed for completion in 2020. In its current system, VoiceTra must send a series of four requests to the server in order to process one translation—one to perform speech recognition, another to perform text translation, one more to perform reverse translation, and a final request to perform speech synthesis. With a one-shot speech translation system, the input speech is sent to the server as a speech translation request, the server performs all the necessary processing during this one single request, and then sends back the speech recognition, translation, reverse translation, and speech synthesis results in sequence as a single response. This results in a faster response speed than the current system where four round trips of requests and responses are required. In a comparative evaluation we performed in Europe, the current method had a reaction speed of about 6 seconds, while the one-shot speech translation method had a reaction speed of about 2 seconds. In Japan, the reaction speed increased from about 2 seconds to about 1.5 seconds. In the future, we will incorporate the one-shot speech translation method into VoiceTra. We also plan to expand this system to work with continuous speech input, which would enable the development of a system that can perform simultaneous interpretation of lectures and the like, and to provide a research platform for simultaneous interpretation.

NICT team won awards at the World Robot Summit 2018

The NICT Team formed by Dr. Komei Sugiura, Dr. Aly Magassouba, and others from the Advanced Speech Technology Laboratory of ASTREC, won the "1st Place (METI*1 Minister's Award)" and the "JSAI*2 Award" in the Partner Robot Challenge Virtual Space at the World Robot Summit (WRS) 2018. WRS 2018 was held from Oct. 17 - 21 at Tokyo Big Sight and was sponsored by METI and NEDO*3 . In this challenge, seven domestic/international teams competed with each other and they were judged based on the achievement rates of the following 3 tasks: 1) multimodal language understanding task—how accurate can the service robot in virtual space understand users' commands using non-linguistic information such as images; 2) gesture recognition task in the same virtual environment; and 3) multimodal language generation task. The NICT Team marked the best achievement rates in all 3 tasks leading themselves to their victory.

The NICT Team being awarded the "METI Minister's Award" by Parliamentary Vice-Minister of Economy, Trade and Industry, Mr. Akimasa Ishikawa

*1 Ministry of Economy, Trade and Industry
*2 The Japanese Society for Artificial Intelligence
*3 New Energy and Industrial Technology Development Organization

Cybersecurity

Cybersecurity Research Institute

Director General　Tetsuya Miyazaki

In the Internet of Things (IoT) era, many sensors and other devices will be deployed in our surroundings and connected to networks. They will allow us to lead more convenient and 'smart' lives. However, security measures for guaranteeing the safety of such devices are becoming a pressing issue behind the scenes. The scope that cybersecurity should cover is expanding daily; in particular, it must be able to protect people from information leaks and privacy violations when big data collected from such IoT devices is utilized. The Cybersecurity Research Institute conducts research and development (R&D) on how to deal with the latest pressing concerns and emergent issues in our information society.

The Cybersecurity Research Institute consists of the Cybersecurity Laboratory and Security Fundamentals Laboratory. The Cybersecurity Laboratory conducts R&D on advanced cybersecurity technologies and security testbed development and operations technology, while the Security Fundamentals Laboratory conducts R&D on cryptographic technologies.

Advanced cybersecurity technologies

We conduct R&D on monitoring cyberattacks and analyzing the increasingly sophisticated and evolved cyberattacks against government and other important infrastructure. We also engage in research that involves collecting and analyzing huge amounts of data from these diverse attacks in order to develop automatic countermeasures. We strive for the quick deployment of our R&D outcomes by verifying them on NICT's own cyber incident response system. In order to reinforce the capability of responding to cyberattacks against governments or critical infrastructure, we carry out R&D on visualization-driven security operation techniques and machine-learning-based

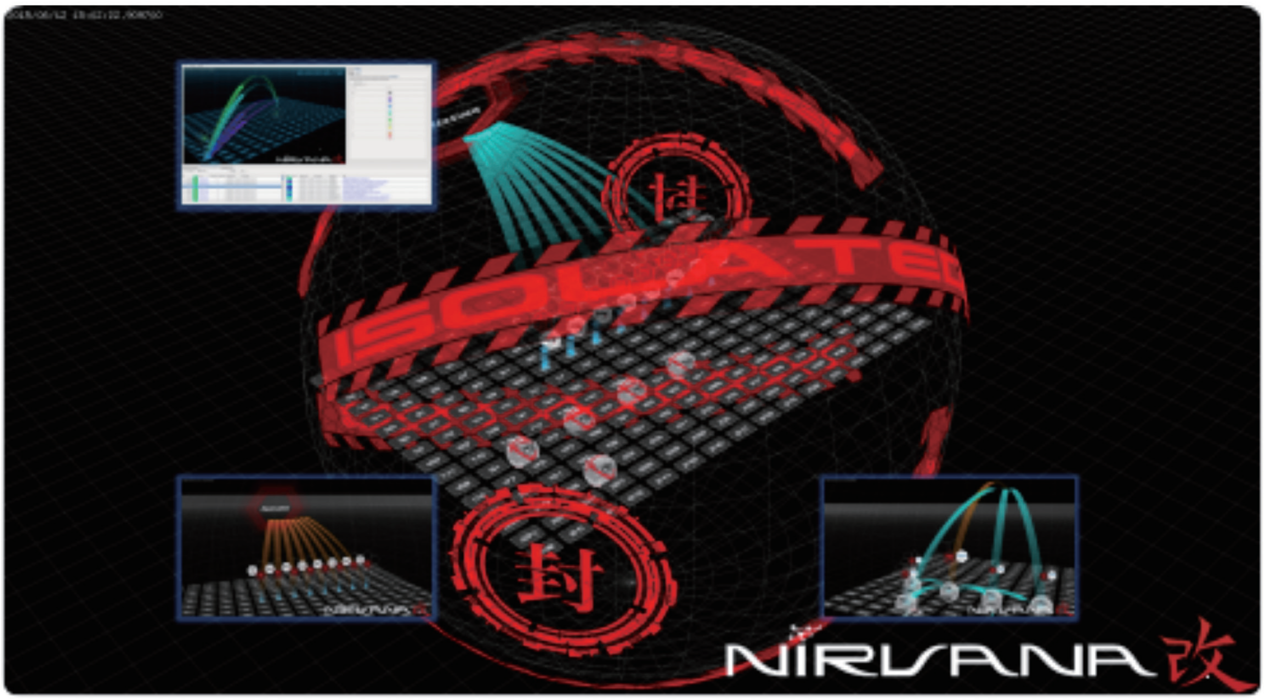


Fig.1 : NIRVANA-KAI
Visualization of defensive actuation in NIRVANA-KAI to isolate an infected class C address.

analysis. NIRVANA-KAI (NICTER Real-network Visual Analyzer KAI) is a security platform against advanced persistent threats (APTs). It collects and analyzes security alerts provided by various security appliances and end hosts, and it automatically deploys new controls to the appliances to prevent APTs (Fig.1). This security platform, in combination with other security appliances, visualizes security-related events (e.g., cyberattacks) in real time and thus facilitates the implementation of prompt and adequate measures. We have been successfully transferring the technology of NIRVANA-KAI to Japanese industry since 2015.

Security testbed development and operations technology

We oversee R&D on technologies for emulating cyberattacks in a safe environment. In particular, we are developing a security verification platform for verifying new protection technologies and countermeasures in an emulation environment. In this security testbed development, we are investigating a large-scale deception framework called STARDUST for luring human adversaries with the aim of attributing sophisticated cyberattacks such as APTs (Fig.2). STARDUST can quickly and flexibly build mimetic enterprise networks called 'parallel networks.' In a parallel network, APT malware can be executed and observed in a highly stealthy manner. A wormhole connects parallel and real networks so that the parallel-world network can pretend to have the same IP addresses as the real-world network. STARDUST enables us to stealthily observe adversaries' activities on parallel networks and to feed-forward the findings of the observation to APT countermeasures such as NIRVANA-KAI to promote their evolution.

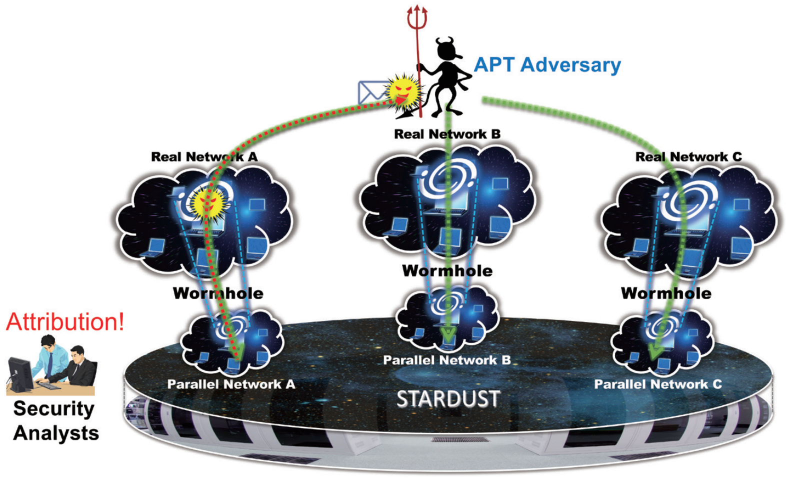


Fig.2 : STARDUST
A 'parallel network' imitating an organization network can be built on the STARDUST platform to attract attackers. It can observe the behavior of an attack on the network.

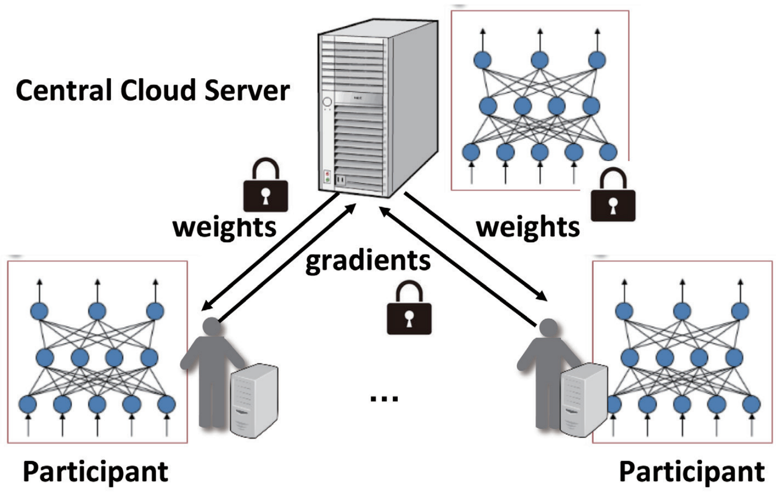


Fig.3 : Privacy-preserving deep learning
Many learning participants perform neural-network-based deep learning on a combined dataset of all participants without revealing the local data of individual participants.

Cryptographic technologies

Our R&D on functional cryptographic technologies provides new functionalities to meet the evolving social needs accompanying the growth of IoT and to evaluate cryptographic technologies. We are contributing to the standardization of new cryptographic technologies and to the construction of safe and secure ICT systems. We also engage in R&D on privacy-enhancing technologies aimed at the safe utilization of personal data and technical support for appropriate privacy measures. Recently, deep learning has gained considerable attention in both industry and academia. Although the collection of massive amounts of data is vital for deep learning, it raises the issue of privacy. To resolve this issue, we are building a privacy-preserving deep learning system, where many learning participants perform neural-network-based deep learning over a combined dataset of all participants without revealing the participants' local data (Fig.3). This privacy-preserving deep learning system allows us to integrate isolated and hidden small data as big data. One of our promising technologies for realizing the system is 'homomorphic encryption,' which allows computations to be carried out on encrypted data without decryption. We are investigating the application of this system to a broad range of fields, such as medical genetics and illegal remittance detection, in a privacy-preserving manner.

Frontier research

Advanced ICT Research Institute

Director General Iwao Hosako

The Advanced ICT Research Institute is engaged in research and development toward innovative information and communications technology (ICT) for future society, that cannot be achieved by improving existing technologies. To achieve this, we are exploring to create new concepts, new technologies, and new materials that can produce fundamental technologies for ICT in the future. Specific technologies targeted for R&D include high-functionality ICT device technology explore the epoch-making fundamental technology as the core of various ICT devices by developing and creating high-functional elements and groundbreaking fabrication technologies with extreme precision, quantum ICT technologies to create reliable and robust communication technologies based on the ultimate scientific principle of quantum mechanics, ultra-high-frequency terahertz (THz) technologies toward pioneer ultra-high-speed wireless communications and sensing technologies that surpass existing technologies, and fundamental Bio-ICT technologies to produce new ICT paradigm by investigating and applying the superior functions and efficient mechanisms of living things. And besides, to promote the social adoption of the results produced by these basic and fundamental research projects, we have established three technology development centers in the institute: Quantum ICT Advanced Development Center, Green ICT Device Advanced Development Center, and DUV ICT Device Advanced Development Center, focusing our research and development efforts on near-future implementation of our research establishments from a needs-oriented point of view.

The following introduces major research results to date.

High-functionality ICT device technology

In our research on small, ultra-fast optical modulators for practical use, we succeeded in filling a silicon slot waveguide with an organic electro-optic (EO) polymer with no voids with the aim of achieving 400-Gbps-plus optical interconnects. We also verified the optical-propagation properties of this waveguide thereby obtaining technology that can achieve hybrid optical modulators based on an organic-EO-polymer/Si-slot waveguide. Furthermore, in ever-expanding interdisciplinary research toward THz-class ultra-high-frequency applications, we succeeded in fabricating an organic-EO-polymer ridge waveguide clad in THz low-absorption material and verified high-efficiency THz-wave generation by a novel waveguide structure the first of its kind in the world (Fig.1).

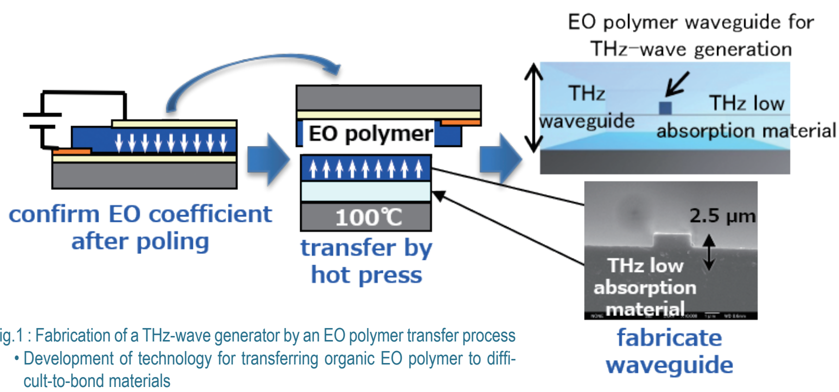


Fig.1 : Fabrication of a THz-wave generator by an EO polymer transfer process
- Development of technology for transferring organic EO polymer to difficult-to-bond materials
- World's first THz-wave high-efficiency generator from a ridge waveguide

Next, in our R&D efforts aimed at broadening the application field of superconducting single photon detectors (SSPDs), we demonstrated high-speed response seven times that of our conventional SSPDs in a new device structure called the superconducting nanowire avalanche photodetector (SNAP). We fabricated a multi-pixel (32×32) SSPD prototype and developed cryogenic signal processing using a single-flux-quantum (SFQ) circuit operating with a time accuracy below 10 ps for a high-speed SSPD system. In the development of feromagnetic Josephson junctions for application to superconducting qubits, we succeeded in observing the π state for the first time in the world in a magnetic Josephson junction made of a nitride superconductor (Fig.2), which is an important fundamental technology for realizing superconducting qubits with superior coherence.

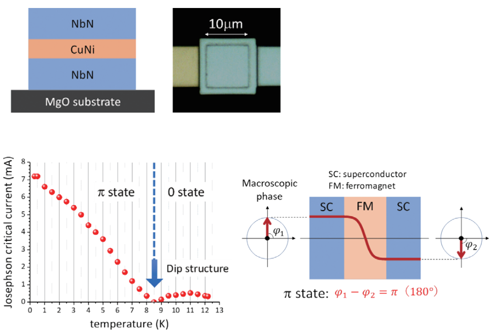


Fig.2 : Upper: Device structure and micrograph of magnetic Josephson junction
Lower: Temperature dependence of Josephson critical current and observation of π state

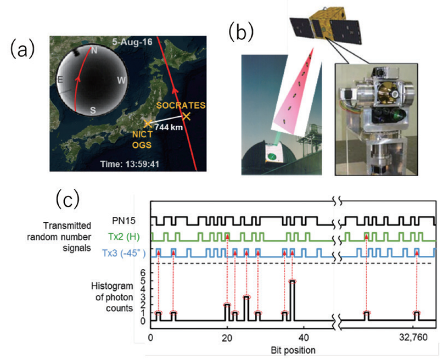


Fig.3 : Upper left: NICT optical ground station (OGS) and microsatellite (SOCRATES) orbit (red line)
Upper right: Photo of satellite, OGS, and SOTA
Bottom: Transmitted random-sequence signal and received signal at OGS

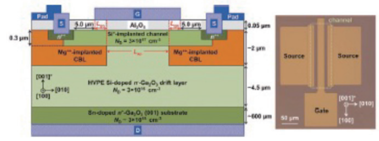


Fig.4 : Cross sectional diagram (left) and optical micrograph (right) of vertical D-mode Ga_2O_3 MOSFET

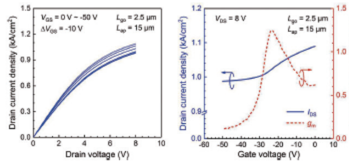


Fig.5 : DC current versus voltage output characteristics (left) and transfer characteristics (right) of vertical D-mode Ga_2O_3 MOSFET

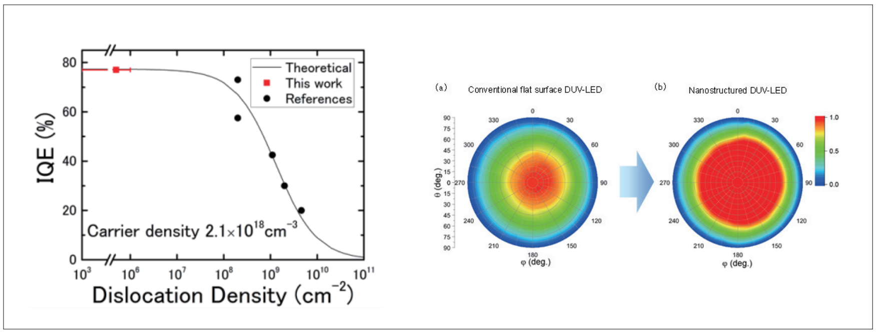


Fig.6 : Internal quantum efficiencies (left) and 3D far-field radiation patterns (right) of DUV-LEDs

High-frequency terahertz fundamental technologies

We achieved a 300-GHz silicon-CMOS receiver integrated circuit and combined it with a transmitter circuit implemented in FY2016. In this way, we achieved 300-GHz operation for both transmission and reception on a silicon integrated circuit. This achievement won a best-paper award for the second time at the IEEE International Symposium on Radio-Frequency Integration Technology (RFIT, August 2017) following an award received in FY2015.

BioICT fundamental technologies

We succeeded in producing new molecular devices having promising functions by combining biological molecular modules existing in nature. In this way, we have obtained a foothold toward achieving biomimetic devices having some of the superior features of living things. This achievement appeared in the Current Opinion in Biotechnology journal highlighted on its cover page.

Quantum cryptography and physical-layer security technology

Taking photon-signal discrimination technology developed as a quantum technology for free-space transmission, we applied it to a quantum-communication receiver for satellite/ground-station free-space optical communications using a Small Optical TrAnsponder (SOTA) mounted on a 50-kg-class microsatellite (SOCRATES) and performed a basic quantum-communication experiment. The Space Communications Laboratory of the Wireless Networks Research Center at NICT developed this SOTA terminal. In this experiment, we succeeded in receiving very weak signals with an average of 0.14 photons/pulse from this microsatellite at a ground station and performed time synchronization, polarization axis alignment, and photon-stream bit-pattern decoding against these signals (Fig.3). This was the world's first experimental demonstration of quantum communication using a microsatellite.

Quantum node technology

In the field of quantum metrology, we developed a new indium-ion cooling method (joint cooling) and improved the accuracy of indium-ion optical frequency standards by 1/10 compared with the current worldwide maximum value in collaboration with the Space-Time Standards Laboratory of the Applied Electromagnetic Research Institute at NICT.

Development of a vertical Ga_2O_3 transistor

We fabricated a prototype version of a vertical depletion mode (D-mode) Ga_2O_3 metal-oxide-semiconductor field-effect transistor (MOSFET) and evaluated device characteristics. Figure 4 shows a cross sectional diagram and an optical micrograph of a vertical D-mode Ga_2O_3 MOSFET fabricated in FY2017. Figure 5 shows DC current versus voltage output characteristics and transfer characteristics of this device. With this prototype, we achieved the world's first operation demonstration of a genuine vertical Ga_2O_3 transistor.

DUV optical device technology

We have developed a new method to determine the internal quantum efficiency and current injection efficiency of deep ultraviolet (DUV) light-emitting diodes (LEDs) during current injection. As a result, we have demonstrated, for the first time, an extremely high value of 77% for internal quantum efficiency in a DUV-LED during current injection (Fig.6, left). This result was published in Optics Express as a highlighted paper representing an outstanding achievement of excellent scientific quality in this field. We also greatly improved light-extraction characteristics and droop characteristics using DUV-LEDs incorporating newly developed aluminum-nitride (AlN) nanophotonic/nanofin structures (Fig.6, right), and successfully demonstrated the world's highest continuous-wave output power in excess of 200 mW in a single-chip DUV-LED at a peak emission wavelength of 265 nm.

Open Innovation

ICT Testbed Research and Development Promotion Center

Director General Hiroaki Harai

At the ICT Testbed Research and Development Promotion Center, we are building and operating an integrated testbed that is compatible with various IoT demonstration experiments, including an ultra high speed R&D network testbed (JGN), a wide area SDN testbed (RISE), a large scale emulation facility (StarBED), and a large scale sensor and cloud facility (JOSE).

We are also researching and developing infrastructure technology for the implementation of a large scale actual infrastructure testbed for highly realistic technical verification of cutting-edge ICT deployed on actual infrastructure, and a large scale emulation infrastructure testbed for performing technical verification in diverse environments partially combined with simulated infrastructure.

Construction of NICT's integrated testbed

At the ICT Testbed Coordination and Planning Office, we are integrating multiple testbeds and developing services for an NICT integrated testbed. As a result, we are constructing and operating a testbed that supports diverse IoT demonstration experiments including both emulated and real infrastructure. In FY2017, with the aim of increasing the number of users, we started on new initiatives including a caravan testbed (a set of portable communication equipment that supports the last mile of IoT), and an LPWA testbed (a demonstration field where it is possible to test and verify multiple LPWA communication schemes). In collaboration with the ICT Testbed Research, Development and Operations Laboratory, we are developing and verifying the underlying technologies of each testbed, installing these technologies in testbeds, and offering them to users. Figure 1 shows an outline of the NICT integrated testbed.

Cooperation with external organizations

In November 2017, NICT constructed Asia's first wide-area international demonstration environment in collaboration with SingAREN and NSCC based on a 100 Gbps line between Tokyo, Hong Kong, and Singapore. In the following month, NICT and SingAREN formed a project with the other five organizations, including SINET and Internet2, and entered into a Memorandum of Understanding for cooperation on a 100 Gbps network for research and education use across the Asia-Pacific region. At SC17 held in Denver, USA, an international demonstration environment was constructed using three 100 Gbps international routes between Japan and the United States, and we successfully conducted ultra high speed data transmission tests at rates of up to 270 Gbps in cooperation with the National Institute of Informatics. We also established an international demonstration environment at the Sapporo Snow Festival with two 100 Gbps lines between Japan and Singapore, and collaborated with some 50 organizations from industry, academia, and government to conduct successful multicast distribution of uncompressed 8K video streams. Furthermore, the Himawari satellite real-time imaging Web site, whose technology was transferred to domestic weather agencies in FY2017, is now serving 400,000-page views per year (a 25% increase) to clients outside Japan. To improve the usability and convenience of this service, a mirror site has been set up at NECTEC in Bangkok. In

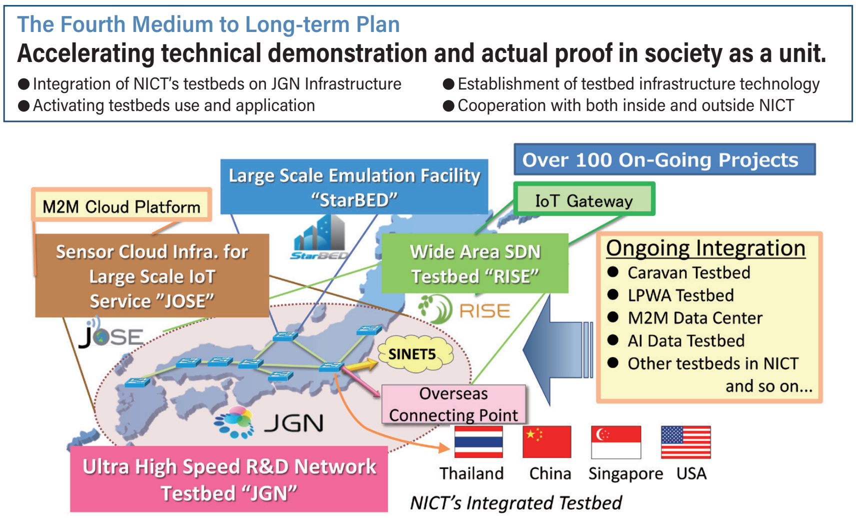


Fig.1 : NICT's integrated testbed

FY2017, we transferred technology to domestic corporations by using a high-speed file transfer tool based on the HpFP protocol developed prior to FY2016, and we also used this tool to transfer data to the mirror sites. As a result, we were able to transmit files at up to 700 Mbps on JGN/APAN.

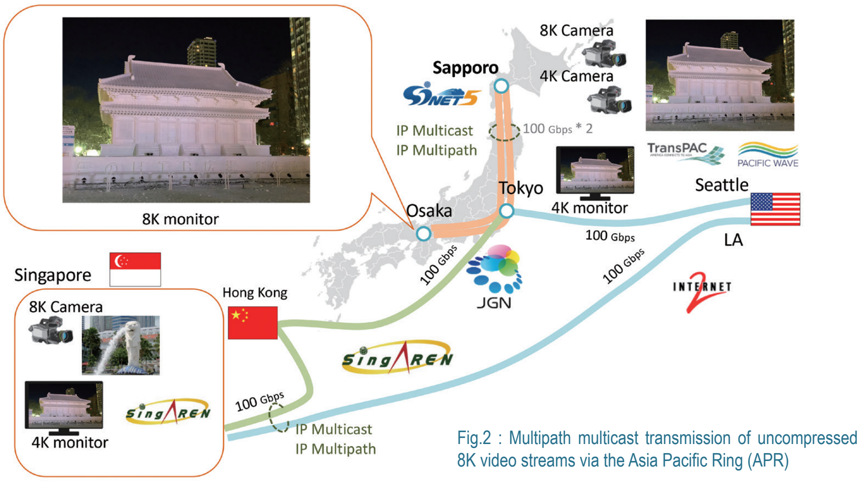


Fig.2 : Multipath multicast transmission of uncompressed 8K video streams via the Asia Pacific Ring (APR)

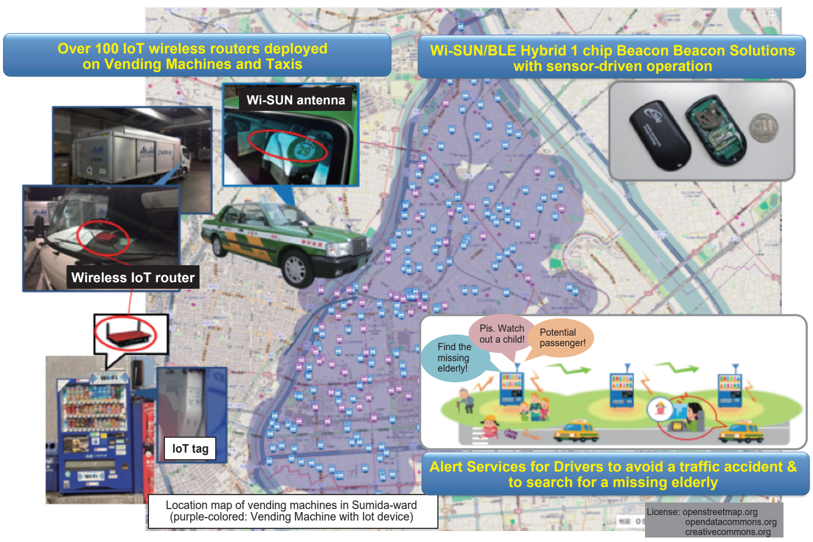
Demonstration of ultra wide-band network applications

In addition to R&D on testbed infrastructure, we have also been working on demonstrations of ultra wideband network applications on the JGN ultra high speed network testbed. In particular, with a view to the forthcoming era of 8K broadcasting, we have been conducting experimental long-distance transmission of uncompressed 8K video streams, which will be required for content creation systems. During the Sapporo Snow Festival in FY2017, we built an extremely large multipath network using the Asia Pacific Ring (APR), which consisted of the JGN Asia 100 Gbps line and the 100 Gbps lines of other organizations in the Pacific Rim region. On this network, we successfully performed multicast transmission of uncompressed 8K video streams (Fig.2). This experiment was performed with the cooperation of 53 organizations, including the National Institute of Informatics, the WIDE Project, Kanagawa Institute of Technology, TransPAC, Pacific Wave, Internet2 and other national and overseas research institutes and network equipment vendors.

Verifying the operation of virtual IoT devices

At StarBED, we have been promoting R&D of wireless emulation technology to model the characteristics of wireless networks in wired networks and validate software used for wireless environments. In FY2017, we expanded the range of cases that can be verified by building a new Bluetooth Low Energy (BLE) emulation platform called BluMoon to provide compatibility with the BLE system used by IoT devices.

Demonstration of community-based IoT service infrastructure using vending machines and taxis in Tokyo



The creation of a unique community-based IoT service infrastructure, which functions as a cost-effective local information sharing network, has been challenged in Tokyo area since June 2017, utilizing NICT's large scale sensor and cloud facility "JOSE." The infrastructure can help with sharing socially-valuable data among the community in a cost-effective way based on a technology combining the multi-hop communications and the opportunistic network principle using multiple unlicensed-band wireless interfaces such as Wi-Fi, Bluetooth, and Wi-SUN. We have achieved to deploy more than 100 wireless IoT routers on vending machines and taxis that are actually operating in Tokyo by the end of October in 2018, and we have performed the proof-of-concept of some applications that would be effective as the use cases for the IoT service infrastructure; such as an alert system for car drivers to avoid a traffic accident, a support system to search for a missing elderly, and a support system for taxi drivers to effectively find new passengers.

Open Innovation

National Cyber Training Center

Director General　Michio Sonoda

At the National Cyber Training Center, we are working on training security operators and security innovators for positions in cybersecurity and ICT, and we are also conducting research and development in these fields (Fig.1).

In the training of security operators, we are targeting our efforts at information system managers and other cybersecurity professionals by implementing two types of exercise — CYDER (Cyber Defense Exercise with Recurrence) and Cyber Colosseo — as practical cyber defense exercises using real systems for the purpose of equipping people with incident response skills so they can respond promptly to emergencies where affiliated organizations are subjected to severe cyberattacks.

Security operator training

(a) Overview of CYDER (Fig.2)

In order to address an urgent need for the training of security experts, the National Cyber Training Center conducts cybersecurity human resource development projects based on the Act on the National Institute of Information and Communications Technology (Article 14 part 1 clause 7) by utilizing our technical knowledge of cybersecurity research, together with the NICT's large-scale network environment (StarBED), which can simulate massive practical network environments. As part of our human resource development projects, CYDER provides short-term practical training courses based on the latest cybersecurity threats. This sort of practical cybersecurity training is now being implemented and deployed nationwide.

Trainees in the courses conducted throughout Japan play the role of IT system administrators of large virtual organizations by experiencing intensive programs covering the entire process of incident response from attack detection to countermeasures and reporting in a single day.

(b) The achievements of CYDER

In FY2017, in order to secure more learning opportunities while preparing exercise scenarios suited to the trainees, we set up a beginner-level course (A-course) in addition to the conventional intermediate-level course (B-course) aimed at local public bodies, government agencies, and the like. As a result of implementing this training program on a larger scale than in previous years, we ran a total of 100 train-

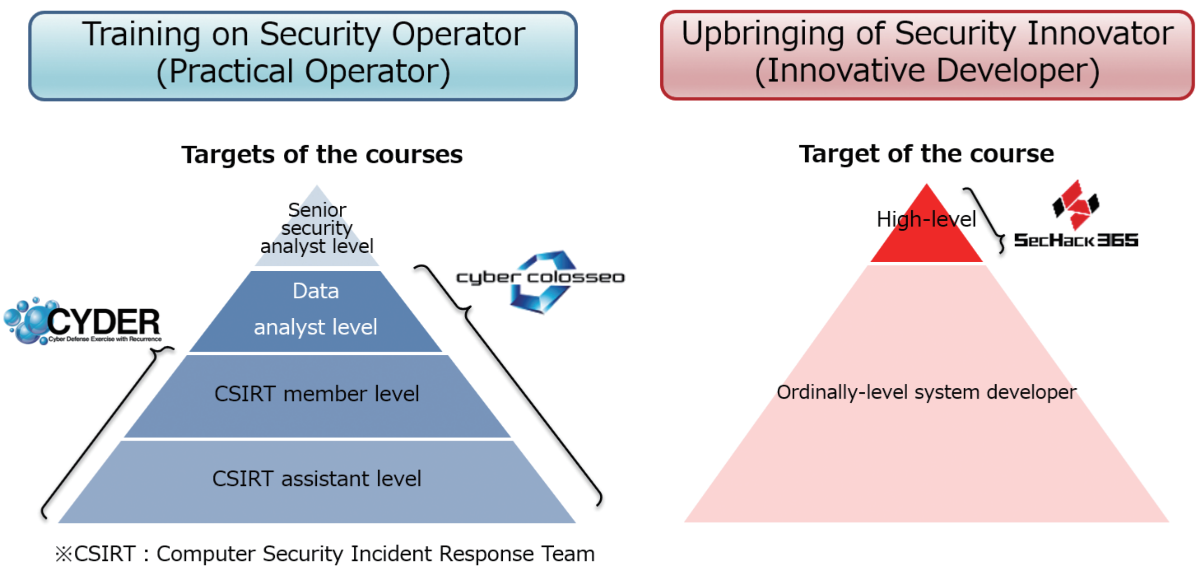


Fig.1 : National Cyber Training Center program overview

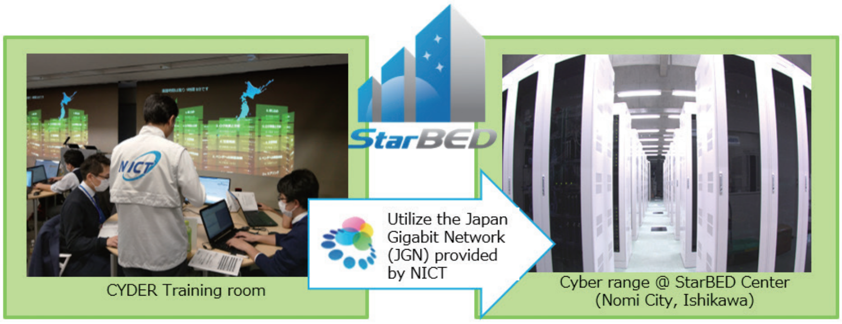


Fig.2 : Virtual network environment for CYDER training

Fig.3 : Battle-oriented cyber training concept

ing sessions in all 47 Japanese prefectures, which were attended by 3,009 trainees (approximately twice the number trained in the previous year). CYDER has thus become Japan's largest training program of this sort.

(c) Overview and achievements of Cyber Colosseo (Fig.3)

Since 2017, with the aim of providing phased and systematic training of people with the necessary skills in the run-up to the Tokyo 2020 Olympic and Paralympic Games (which are now less than two years away), we have been providing security personnel from organizations involved in the Olympic and Paralympic Games with training in advanced practical content such as offensive and defensive battles, in addition to the fundamental CYDER knowledge. This culminated in the Cyber Colosseo training program where real systems are used to train people with even more advanced skills. In the first year of this program, we trained 74 security personnel from organizations involved in the Games.

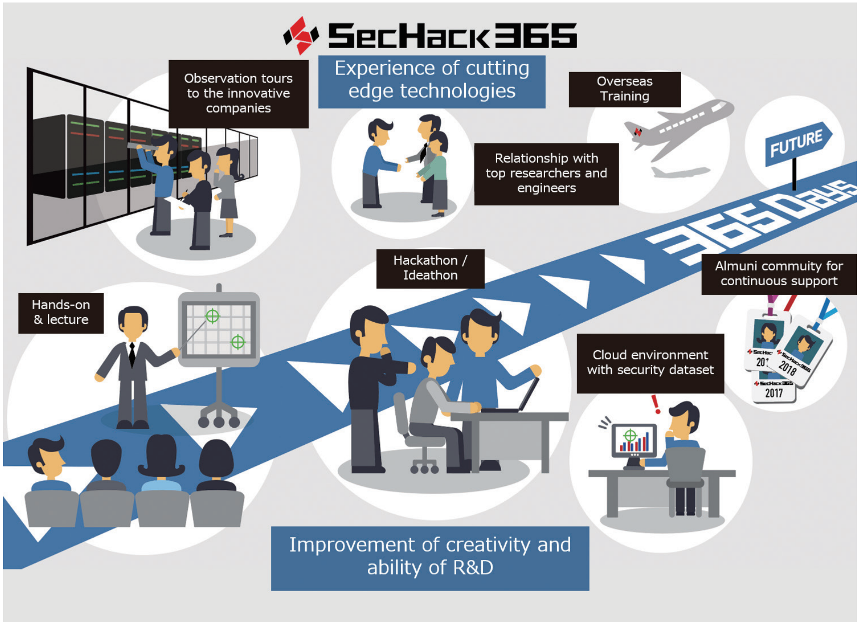


Fig.4 : SecHack365 program overview

Security innovator training program

(a) Overview of SecHack365 (Fig.4)

In order to provide practical training for the research and development of innovative security software and the like, it is necessary to obtain technical guidance and support based on the experience and achievements of leading researchers and engineers in addition to data related to cyberattacks, such as malware samples and traffic data obtained from them, and R&D environments in which it is possible to conduct research and development using this data safely. At the National Cyber Training Center, by using NICT's NONSTOP remote development environment and R&D knowledge, we are now offering a comprehensive skills development program based on a year-long combination of an ideathon, a hackathon, remote R&D, and exercises (SecHack365).

(b) The achievements of SecHack365

In the first period (FY2017) of SecHack365, we received 358 applications and conducted cybersecurity R&D training for 47 successful candidates (trainees). These 47 trainees were trained in a total of five group training meetings held throughout Japan in parallel with the remote guidance from trainers and the provision of a remote R&D environment, and presented the results of their research and development at a final presentation meeting. The final presentation and the achievements of each trainee were also publicized in newspaper reports and other media, and drew a lot of attention in Japan as a new solution to the issue of training young ICT professionals by government agencies. In addition, four trainees who had achieved excellent scores were sent to Austin, Texas to take part in the SXSW (South by Southwest) Hackathon (the world's largest creative event of its kind) as foreign observers. Their achievement was judged to be the most creative and was awarded a prize from Cloudinary, one of the companies sponsoring the event. In the future, we aim to employ research assistants with superior grades in order to guide their research and development efforts, and if we find promising research achievements, we plan to follow them up by such means as applying for research and development at NICT. In this way, we aim to maximize the development of human resources by ensuring that this program provides continuity and development potential.

Open Innovation

AI Science Research and Development Promotion Center

Director General Yutaka Kidawara

As a center for the promotion of efforts to create open innovation in the field of artificial intelligence (AI), as mentioned in the NICT's 4th Medium- to Long-Term Plan, and to implement the government's plan for economic growth based on the R&D and commercialization of AI technology, we need a central organization that can promote external links. Based on these trends, the AI Science Research and Development Promotion Center (AIS) was founded in April 2017. Since then, we have also been working to promote the development of systems and raise awareness (including the creation of an AIS logo and PR activities via the NICT public relations magazine).

At AIS, we aim to set up an R&D environment that is accessible to industry, academia, and government for the use of data collected by NICT, and to provide a one-stop service with a view to social implementation (Fig.1).

Our priority R&D tasks for FY2017 are as follows:

・Constructing an AI data testbed

We have started building an advanced AI testbed that allows various forms of AI data collected in NICT's previous R&D efforts to be used on a nationwide scale via the Japan Gigabit Network (JGN) in order to accelerate the pace of AI-related R&D and demonstration trials.

・Promoting open innovation research projects

We are promoting open innovation research projects by strengthening our AI-related research ties with industry, academia, and government agencies.

Here are the main topics of activities at AIS:

Constructing and maintaining an AI data testbed

Our AI data testbed is a platform aimed at the development of new AI technology and innovative creations based on this technology by applying and verifying the latest machine learning technology and the like to various forms of data collected and stored during previous R&D work at NICT. In FY2017, in collaboration with the ICT Testbed Research and Development Promotion Center, we set up systems including a large-scale storage system for AI data, and a GPGPU processing server for large-scale machine learning.

Fig.1 : Logo of the AI Science Research and Development Promotion Center (AIS)

Maintaining AI-related data

In addition to organizing basic ideas for the sharing of data with third parties and rules for the use of data (Fig.2), we are also compiling lists of AI data and related applications that are available for sharing (language resources,

・Prohibited uses

(a) Uses that contravene any laws, regulations or ordinances, or are contrary to public order and morals

(b) Uses that pose a threat to national security, or the security of individual citizens

(c) Uses that place undue load on the Web server

・Warning re infringement of third party rights

When data is covered by copyrights and other rights of third parties other than NICT, it is the user's responsibility to ensure that these third parties have given their permission for use of the data unless it is clear that these rights have already been processed.

Also, content acquired by, for example, cooperating with the APIs of external databases or the like should be handled according to the provider's terms of use.

・Disclaimers

Disclaimers regarding all acts performed using the data (including the use of information such as editing or processing data), Public data not guaranteed to be complete, accurate, comprehensive or fit for any particular purpose, Data liable to be changed, moved, deleted etc. without prior notice.

・Source description

State the source when using data, and include additional notes to show when the data has been edited, augmented, etc.

・Individual terms of use

Parts of the data may be subject to additional individual constraints (fees, physical/organizational access limitations, corporate status of user, usage methods, etc.), which must be complied with when specified.

・Governing law and jurisdiction by agreement

These rules of use are to be interpreted based on Japanese law. The use of data according to these rules and any disputes concerning these rules shall be dealt with in the first instance by the exclusive jurisdiction of the Tokyo District Court.

・Other considerations

Fig.2 : Overview of the AI data sharing rules

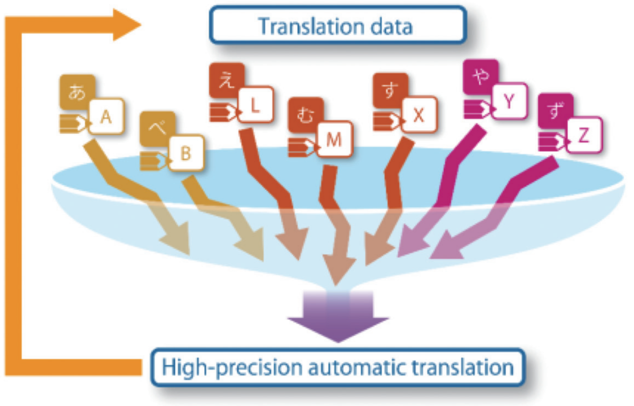


Fig.3 : Our translation bank concept (Hon'yaku Bank)

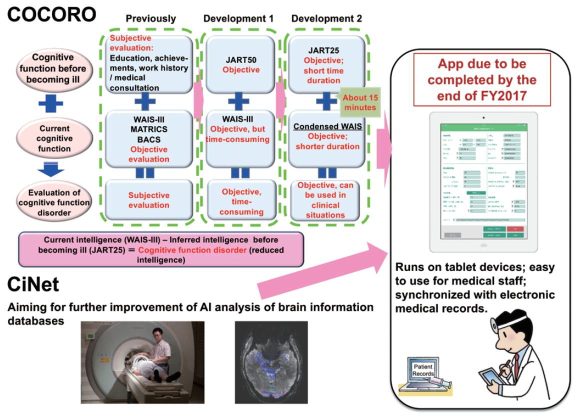


Fig.4 : Development of software for measuring cognitive function with a shorter test

voice resources, bio-related data, brain-related data) and publishing them on the AIS website. We have also conducted a wide range of surveys for user evaluation in NICT and to extract very scarce data.

Neural big data infrastructure

In the neural big data infrastructure project, we are collaborating with the Center for Information and Neural Networks to prepare an R&D system where the large-scale collection of fMRI/MEG brain activity data and AI technology such as machine learning are used to implement next-generation AI systems for the analysis and simulation of brain activity, including brain biomarkers (Fig.4), brain information decoding, an electroencephalogram testbed, and brain & sports/wellness.

Accelerating the study of neural translation dedicated to patent documentation

By entering into an agreement with the National Institute of Advanced Industrial Science and Technology on promoting collaboration and cooperation in the information communication field, we have started a joint study based on this agreement on the subject of neural machine translation dedicated to patent translation and a system structure that makes this possible. We conducted research on the use of multiple GPUs to perform parallel acceleration of neural machine translation training, and achieved speeds approximately four times faster than were possible with a single GPU.

Operating a translation bank

At NICT, we are researching and developing neural machine translation as part of a Global Communication Plan aimed at providing society with multilingual speech translation technology by 2020. Improvements to the algorithms of neural networks can be an effective way of improving the accuracy of neural machine translation, but it is vitally important to securing large quantities of translation data from various fields.

For this reason, in September 2017, we started operating a nationwide translation bank system (Hon'yaku Bank) to collect translation data in collaboration with the Ministry of Internal Affairs and Communications. We launched a website to raise awareness and improve people's understanding of this service, and in order to offer some merit for providing this system with translation data, we prepared a system whereby, when calculating the user license fees for NICT's machine translation technology, the charges are reduced in consideration of the estimated amount of translation data provided by a user. In the future, it is expected that Japan's translation technology will become more accurate and cover a wider range of fields due to the use of translation data collected by NICT via this translation bank (Fig.3).

During the period of roughly six months following the launch of the translation bank, over 50 companies have signed up to participate in the project.

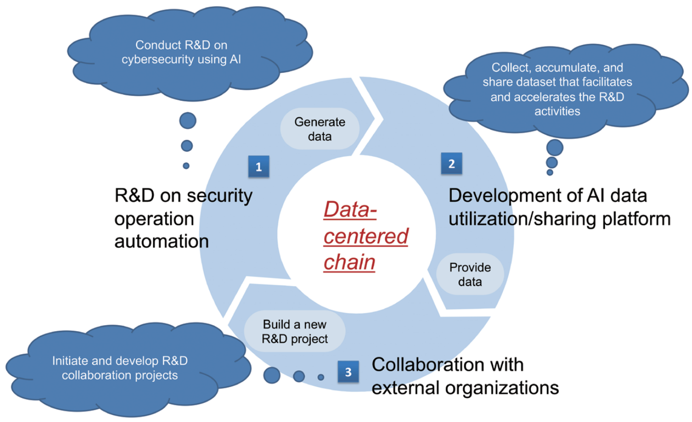


Fig.5 : Overview of AIS cybersecurity project

AI × security

In recent years, cyberattacks have posed new threats due to the accelerated use of AI and automation based on machine learning and the like, and there is an urgent need for more automation and AI in the security operations that deal with these attacks. For this reason, we launched the AI × security project in cooperation with the Cybersecurity Research Institute, and in FY2017 we identified specific tasks and built a research and development system (Fig.5).

Participating in discussions on AI-related policy proposals, etc.

We are cooperating with external organizations by taking part in discussions of AI-related policy proposals at COCN (Council on Competitiveness–Nippon) and DiTT (Digital Textbook and Teaching), among others.

Open Innovation
Resilient ICT Research Center

Director General Yoichi Suzuki

The Resilient ICT Research Center is working in two main purposes: the research of basic technology, infrastructure and applications for disaster-resilient ICT, and the promotion of social implementations aimed at maximizing the benefits of research and development. In addition to performing research, the laboratories of the Center are also involved in developing social implementations of the results of this research, and the Planning and Collaboration Promotion Office is actively planning and executing demonstration tests using the results of laboratory research, and is actively involved in external cooperation and local coordination efforts. With the aim of maximizing the benefits of research, we will work on social implementations of the results of research related to disaster resilient ICT.

The activities of the Resilient ICT Research Center are as follows. First, we have been steadily promoting research and development for disaster resilient ICT, and have played a role as a research center. And the other one, we are promoting industry-academia-government collaboration activities relating to disaster resilient ICT; the collaboration with external research organizations including universities and research institutes; forming a network to link industry, government, and academia (including local public organizations); collecting, accumulating, and exchanging knowledge; transfer of technology to companies; ascertaining the needs of users; and the council activity. Furthermore, we are promoting the social implementation of R&D results related to disaster resilient ICT by performing demonstration trials using the results, and disaster training performed by regional public bodies.

Our research is taking place in two laboratories, which are working on the following three projects:

Disaster-Resilient Optical Network Technology

(a) Resilient optical switching infrastructure technology

To enable the instantaneous dynamic optical network control, we are conducting the fundamental research and development of optical network subsystems including both optical signal monitoring subsystems and control subsystems. In particular, we employ burst mode optical amplifiers to mitigate the power fluctuations of the optical signals owing to the dynamic behavior of optical paths along the time axis and wavelength axis especially in the event of a link failure. Specifically, we have made it possible to reconfigure the optical network much faster by reducing the time taken to switch the wavelength paths, for instance, reconfigure four wavelength lightpaths from 36 seconds (needed by the conventional technique) to 0.2 seconds (Fig.1). This is the first time that the ultra-fast switching of optical paths is experimentally validated.

(b) Basic emergency recovery technology for optical networks

We have been investigating and developing the emergency recovery resources and technologies to achieve the quick and low-cost recovery of optical networks. For example, an emergency disaster-recovery first-aid unit and the corresponding recovery schemes are proposed for the recovery of Control & Management-plane, and optical Data-plane, as shown in Fig.2. To enable the collaboration between carriers, we have also been investing an approach: "emergency exchange points of carrier collaboration (EPOC)" which avoids the leakage of the carriers' confidential topology information. EPOC-based emergency

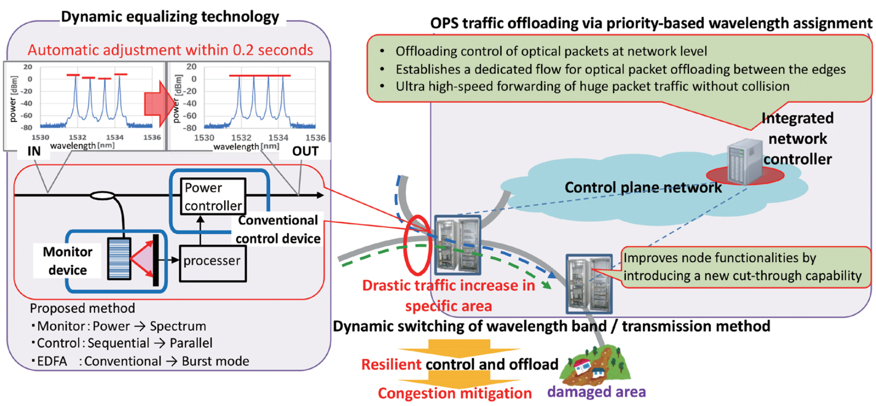


Fig.1 : Principle achievements in flexibly optical switching platform technology. Left: High-speed wavelength switching, Right: Optical packet offloading

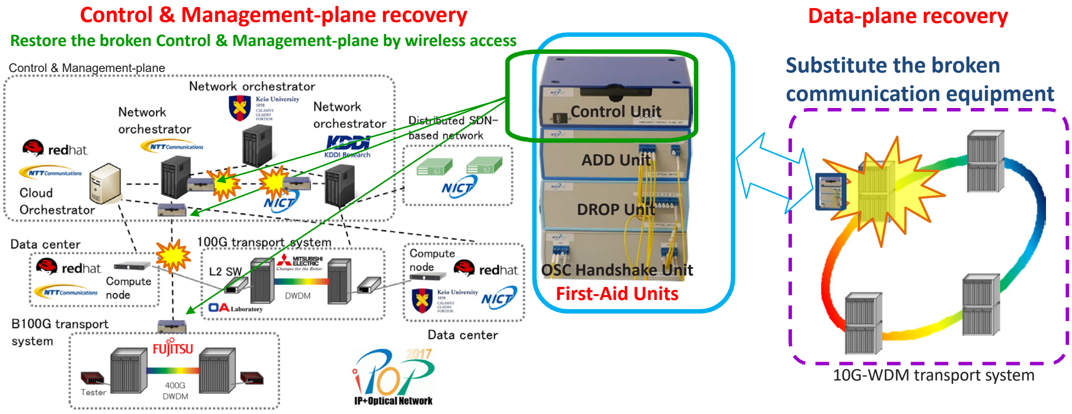


Fig.2 : Demonstrations of optical network quick recovery with the first-aid units.

packet transport capability can be quickly created via the cooperation between carriers and a third-party organization which efficiently and smoothly interconnects both the surviving optical network resources and various types of packet network resources. We first time demonstrated the principles and successfully validated the feasibility of these technologies for disaster recovery with experiments.

Disaster-resilient wireless communication technology

(a) Technology for enhancing regional networks

In a conventional system, the load is concentrated on VPN servers and it is not possible to establish multi-stage connections. To improve on this, we need mesh gateway functions to facilitate load distribution through the use of a mesh configuration for direct communication, improved reliability through redundancy, and improved security for IoT devices and the like in local independent networks. To implement such functions, we have developed new technology for the construction of logical independent networks in a mesh configuration using an L2 overlay network via a completely new wide-area network that combines mesh network technology, software switching technology, and multi-layer SSL-VPN connection technology that we have already developed (Fig.3).

(b) Agile network configuration technology

In order to keep network functions available for as long as possible using limited terminal batteries in the event of a disaster or the like, we are developing a smartphone app that can control multiple wireless devices installed in a smartphone to allow neighboring smartphones to work cooperatively. According to a computer simulation, the use of this app can be expected to result in an overall reduction in power consumption of about 30%. Also, in the development of a seismic observation system that can be immediately deployed across a wide area, we have built a prototype LoRa system that can remotely alter setting parameters. By measuring the actual file transfer speeds, we have confirmed that this system is fast enough for transferring data in the event of an earthquake.

(c) Social demonstration and social implementation

In training for the support of people who have difficulty in returning home in Tokyo's Chuo ward, and preparatory training for the establishment of a central Cabinet Office Disaster management headquarters in the Tachikawa district where there is a large-scale backup disaster management facility, we have contributed to training through use of the NerveNet system that we developed as a means of ensuring communications between disaster management centers if the public telecommunications network is disabled. Also, in the R&D project aimed at the early detection of disasters by a network of acoustic and electromagnetic sensors that we are working on as a SCOPE research project for the Ministry of Internal Affairs and Communications, we have partnered up with Tohoku University to develop an infrasound sensor device that combines a MEMS sensor with a Raspberry Pi. This device costs approximately a hundred times less than conventional equipment. In field tests, we successfully observed the infrasound waveforms accompanying a volcanic eruption.

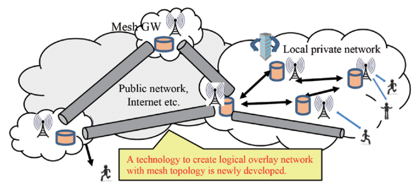


Fig.3 : Development of mesh-like logic overlay network

Real-time analysis of disaster information from social knowledge

During real disasters such as extreme rainfall in the northern part of Kyushu, people were able to make effective use of our disaster information analyzer system (DISAANA), which uses deep semantic analysis to analyze information posted to Twitter during a disaster, and our disaster summarizer system (D-SUMM), which makes it easy to understand the disaster status of specified local authorities. These systems were also used in map-based disaster prevention drills in Oita Prefecture and Tokyo, and for civic protection training in Iwate Prefecture.

In order to provide information of greater accuracy by analyzing not only Twitter tweets (the original target of these systems), but also real-world observation data, we have developed a framework that crawls websites that provide weather forecasts and traffic information, and integrally analyzes this information in DISAANA and D-SUMM together with Twitter contributions.

Open Innovation

Big Data Integration Research Center

Director General Koji Zettsu

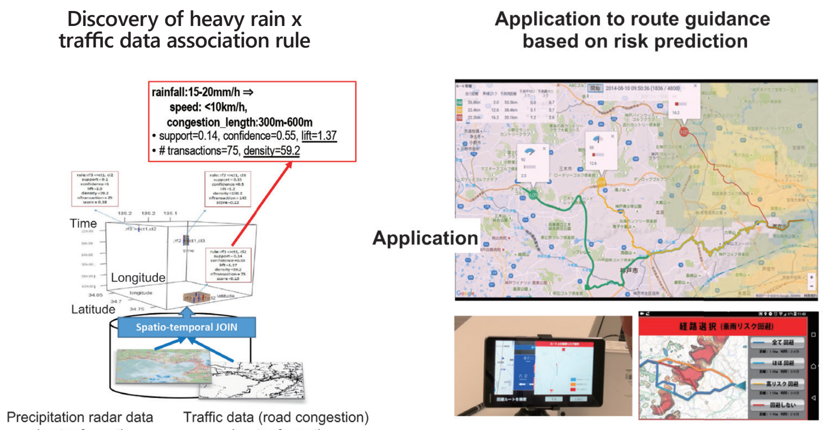
The Big Data Integration Research Center conducts research and development of data collection and analysis aimed at making effective use of real-space information obtained from the environment and human society. We are also developing data mining technology that will integrate advanced environmental data with social data to analyze their cross-domain associations. This will facilitate model case studies of environmental influences on social systems such as transportation. We are also conducting R&D on methods that feedback the analysis results to sensors and devices in real space, and on sensor technologies that provide efficient and effective feedback. This will allow us to create, develop, and verify platform technology for implementing mechanisms capable of advanced situation recognition and behavior support, with the goal of optimizing social systems.

R&D of fundamental technology for cross-domain data collaborations

We are developing a data analytics platform for cross-domain data collaborations in order to exploit various forms of social big data and data acquired by various forms of sensing technology. We are also developing smart services for a smart sustainable society and constructing a data utilization testbed to support this development, and we are engaged in open innovation promotion activities involving regional demonstrations.

So far, we have developed a method for discovering localized association patterns from heterogeneous urban sensing data through the mutual optimization of association rule extraction and spatiotemporal clustering, and we have applied this method to the prediction of traffic risks in the times of torrential rain based on rainfall data (XRAIN, phased array weather radar), traffic data (congestion, accidents), and social media data (Twitter). In an evaluation experiment, we achieved an improvement of about 60-80% in accuracy compared with a conventional method (Apriori) for association rule extraction alone, and we demonstrated the efficacy of our method for association analysis of spatiotemporally-skewed sensing data such as data related to natural disasters. Also, to develop support for transportation and mobility, we prototyped an application system for risk-adaptive map-based navigation where routes are searched according to the user's risk tolerance level based on traffic risks estimated from rainfall data. The results of an evaluation performed using a drive simulator with 30 test users showed that approximately 86% of users select alternative routes to avoid risks when presented with information about risk severity and driving costs (distance and time) (Fig.1).

On the other hand, we are also conducting R&D on the use of atmospheric environment data. In collaborative research with Nagoya University, we have developed a portable sensor that acquires data on personal exposure to air pollution (PM2.5), and we have developed a method for predicting personal exposure based on lasso regression analysis. In preliminary tests conducted from March through May 2017, we confirmed that it is capable of predicting personal exposure to PM2.5 with 80% accuracy (with an error range of ±15 μg/m3). We have also built a field demonstration system on the NICT integrated



Prototype based on a commercial route guide service.

Fig.1 : Mobility support based on a association analysis of heavy rain and traffic data

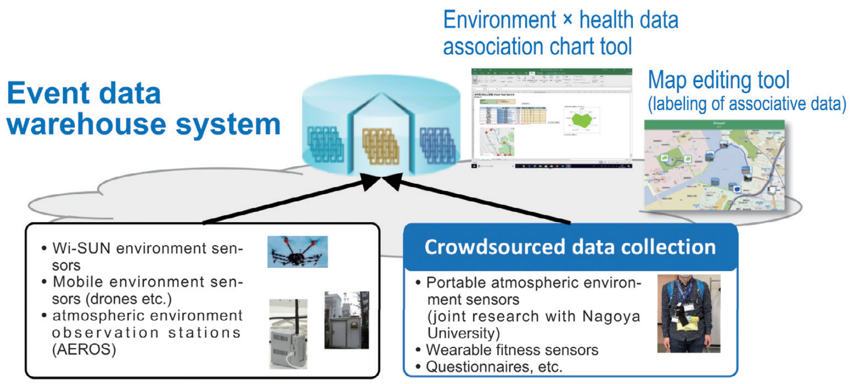
testbed that collects atmospheric environment data (PM2.5 levels, temperature and humidity, etc.) and health data (heart rate, autonomic nervous balance, etc.) and prepares digital maps including charts and comments showing how they are associated. A field demonstration trial with the participation of local residents aimed at finding healthy air was held in Fukuoka City between March 10 and April 8, 2018. A total of 69 people took part in this trial, including members of a running club, a regional open innovation group (One Japan in Kyushu), local students, and an IT volunteer group (Code for Fukuoka). The results of a questionnaire survey showed that most of them found the study very interesting, and included positive comments such as "It was a good opportunity to consider how my own vital data is affected by the environment," "It was interesting to see data about what I feel every day," and "It was fun using the latest sensor technology and learning about NICT's work."

R&D of social big data analysis infrastructure

In the R&D of large-scale information integrated visualization technology, we are working on a 3D visualization method that facilitates understanding of the effects of day-to-day events in the real world, and how these effects spread across space and time. By focusing on position-related expressions in micro-blogging streams (of which Twitter is a prime example), our system associates tweets with location coordinates (either directly attached to the tweet or based on words such as the names of places or establishments). It then produces a multi-layered 3D visualization by checking for local events and wide-area events, using animation to show how this information changes over time. We are currently working on applying this system to the analysis and visualization of heavy rain risk by integrating it with rainfall data obtained by a weather radar (Fig.3).

Also, in the research and development of data mining technology targeting non-textual data, we have developed a new algorithm that recursively searches tree-structured data converted from a time-series database based on periodic-frequency indicators that measure the temporal periodicity of item sets, and efficiently discovers all the item sets with partial periodicity. On the other hand, in large-scale graph data analysis technology, we have confirmed that the cost of communication can be reduced by 12% on average by running GraphSlice (an efficient distributed processing framework for social graphs) on Apache Spark in order to develop a scalable distributed graph database engine suitable for cloud environments.

Furthermore, in the R&D of human behavior analysis using social media data, we have succeeded in detecting tweets that strongly influence purchasing behavior with high accuracy (F-value of 0.53) based on multiple clues such as the relevance of the tweet contents, the proximity of tweet posting times, and the degree of closeness between users.



A scene at the Datathon held in Fukuoka in March to April 2018

Fig.2 : Experimental demonstration of smart IoT for an environment and health monitoring system aimed at improving air quality

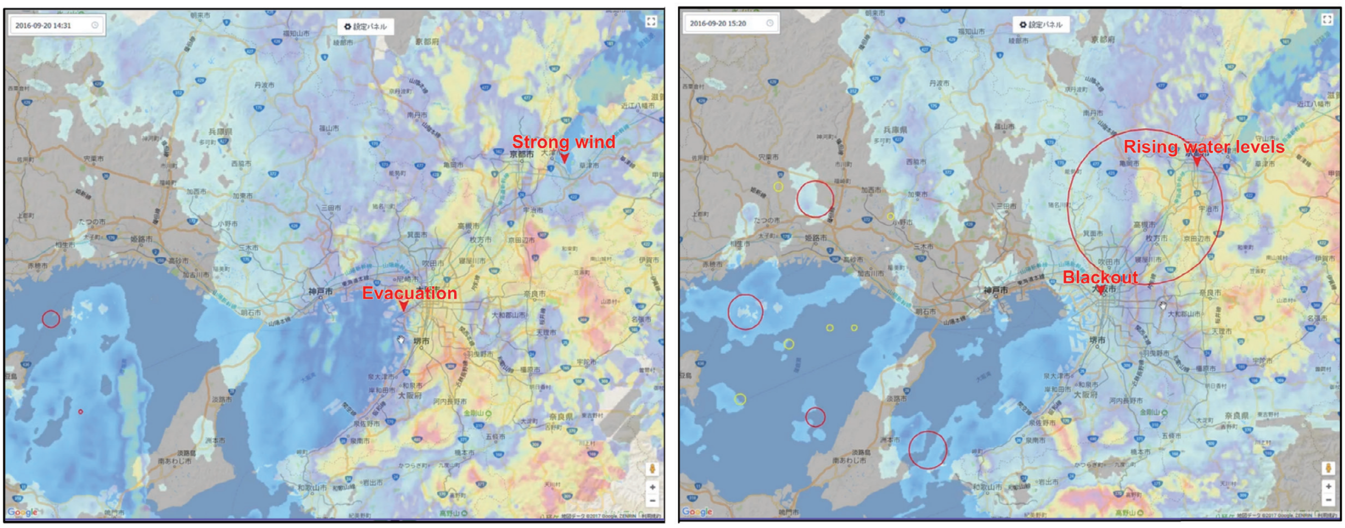


Fig.3 : Integrated visualization of heavy rain data (PANDA, XRAIN) and geospatial word-clouds based on social big data

Open Innovation
Terahertz Technology Research Center

Director General Iwao Hosako

The terahertz band refers to electromagnetic waves at frequencies ranging from roughly 100 GHz to 10 THz (3 mm to 30 μm in wavelength), 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. However, due to trends such as the recent growth in demand for high capacity communication between wireless terminals, coupled with the increasing competition for microwave frequency resources that are already in use, there is a rapidly growing need for technology that can exploit new frequencies in the terahertz band. This situation has led to a rapid acceleration in the research and development of devices capable of operating in the terahertz band, as well as advances in basic measurement technology. Researchers are now starting to consider how this frequency band can be used for "active services" involving the generation of terahertz signals. To accelerate this trend, the Terahertz Technology Research Center has leveraged NICT's diverse capabilities 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 with a capacity of the order of 100 Gbit/s. In addition, by working with organizations such as the Terahertz Systems Consortium, we will promote joint studies with industry and academia and take part in discussions about standardization aimed at improving the environment so that the terahertz band can be used effectively (Fig.1).

Core technology for terahertz radio test bed

In FY2007, we examined a method for generating optical frequency comb signals with low phase noise and high purity with the aim of generating terahertz signals with high spectral efficiency. Figure 2 shows an outline of an optoelectronic oscillator incorporating an optical frequency comb oscillator built using this method. By using a highly pure microwave signal produced by self-excitation of an optoelectronic resonator structure to directly generate an optical frequency comb, we have

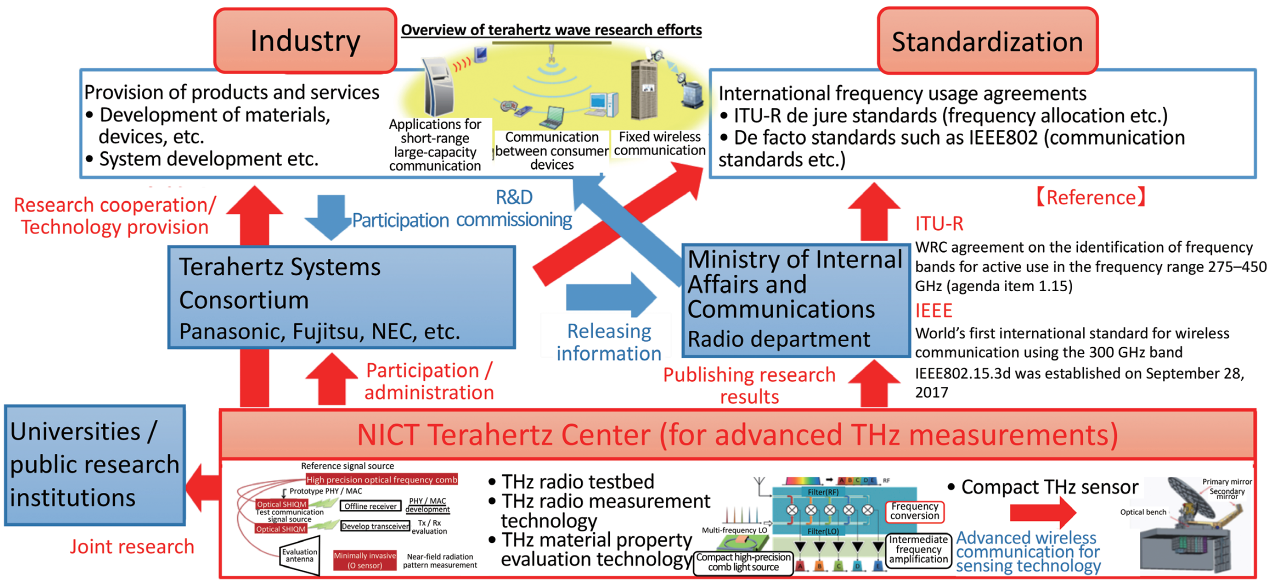


Fig.1 : Overview of the Terahertz Center

successfully generated an optical frequency comb signal with high frequency stability and a 300 GHz bandwidth.

Fundamental technologies for terahertz spectrum measurements

In FY2007, we designed, prototyped and evaluated a 400 GHz band mixer that can input frequency bands equally divided by a filter bank and simultaneously downconvert them to an intermediate frequency (IF). By making this mixer's IF band as wide as possible, we were able to reduce the number of filter banks needed to cover the measurement frequency band. By reducing the number of mixers, we ended up with a simpler system. In a conventional mixer, an isolator is used to eliminate the impedance mismatch with the IF amplifier connected to the mixer, but this restricts the IF band. In our study, as shown in Fig.3(a), we integrated a 3–21 GHz band IF amplifier into a 400 GHz band mixer block, and we coupled the mixer chip and a monolithic microwave integrated circuit (MMIC) with a wideband matching circuit. Figure 3 (b) shows the results of measuring how the mixer's noise temperature and gain vary across the IF band, together with the simulated results obtained from an equivalent circuit model. We successfully achieved a bandwidth much broader than the 4–12 GHz band caused by the limitations of conventional isolators, and the device performance also matched the simulated behavior very closely.

International standardization

In WP5A (Land mobile service) and WP5C (Fixed wireless systems), two new reports have been completed on technical operation characteristics and spectrum requirements of LMS and FS systems operating at 275–450 GHz, and these reports have been published as Report ITU-R M.2417-0 and Report ITU-R F.2416-0. In WP3K (Point-to-area propagation), a revision of Recommendation P.1238 has been proposed regarding terrestrial mobile input to 300 GHz band terrestrial mobile application systems. Meanwhile, at an APT preparatory meeting for WRC-19 (APG19-3), an NICT official was put in charge of the DG (drafting group) for agenda item 1.15, and compiled an APT draft provisional opinion on this item.

Furthermore, the IEEE (Institute of Electrical and Electronic Engineers) standardization task group 802.15.3d has been studying the standardization of 300 GHz band short-range WPAN (Wireless Personal Area Network) systems, and Director General Iwao Hosako of the Terahertz Technology Research Center has taken part as vice chairperson of the working group. Due to the strong leadership of the standardization study, the study of this group is way ahead of schedule, and on September 28, 2017, its system specifications received final approval and were published as IEEE std 802.15.3d-2017.

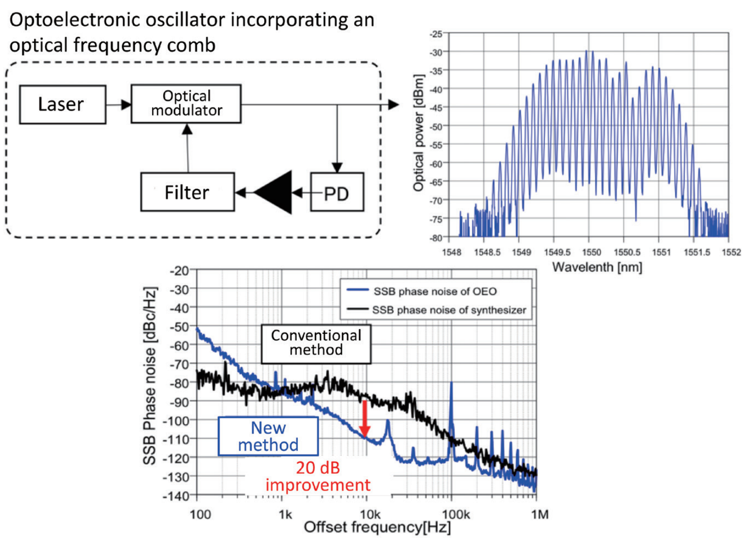


Fig.2 : Improvement of oscillation and phase noise characteristics of an optoelectronic oscillator incorporating an optical frequency comb oscillator

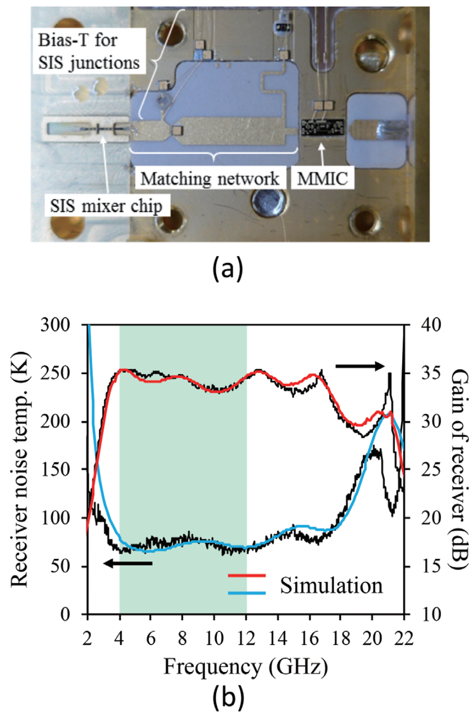


Fig.3 : (a) Photograph of the integrated parts of the mixer chip and IF amplifier, (b) Comparison of simulated and measured noise / gain characteristics

Open Innovation

Innovation Promotion Department

Executive Director Takaharu Koide

The Innovation Promotion Department cooperates with related departments in the Open Innovation Promotion Headquarters under 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 with the aim of contributing to enhancing collaboration among government, industry, and academia.***
- ***Promote open innovation by implementing R&D achievements in society through appropriate securing and effective use of intellectual property and effective standardization activities in collaboration with government, industry, and academia.***

Promotion of collaborative research with companies, universities, public research institutions, etc.

In addition to ordinary collaborative research, NICT promotes "funded collaborative research" in which NICT accepts the provision of research expenses from the collaborator. NICT also contributes to enhancing collaboration among government, industry, and academia through research based on external research funding such as competitive funds.

Promotion of researcher exchanges with outside institutions

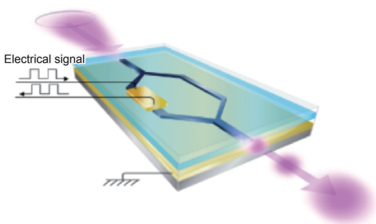
NICT promotes researcher exchanges for mutual cooperation with universities and other institutions in diverse areas in the information and communication field.

Tabletop Glasses-free 3D Display

Type: Researcher/corporate collaboration
Technology transfer: To electronics manufacturers
Summary: Development of a glasses-free 3D display for displaying three-dimensional images on a curved screen. Enables more realistic 3D display by increasing light beam density by 3.5 times and enhancing the floating sensation. This glasses-free 3D display enables 360-degree viewing of 3D images by multiple users from each viewpoint.

Organic EO Polymer Material

Type: Researcher/corporate collaboration
Technology transfer: To chemical manufacturers
Summary: Organic EO polymer material is a promising material for achieving new optical devices featuring both high-speed and low-power-consumption properties. To promote the development of optical devices using this material and create a supply of polymers for organic EO compounds whose technology has already been transferred, the technology for this organic EO polymer material was transferred to two chemical manufacturers.



Multilingual Translation

Type: Researcher/corporate collaboration
Technology transfer: To translation technology development companies
Summary: NICT' s high-accuracy speech recognition, translation, and speech synthesis technologies can be used in diverse areas including tourism, commercial complexes, and healthcare as an app on smartphones and other devices. The number of supported languages is being expanded to 31. Applicable to companies needing a translation system, patent/document translation companies, etc.

VoiceTra screenshot

Language selection screen

Fig.1 : Examples of technology transfers in FY2017

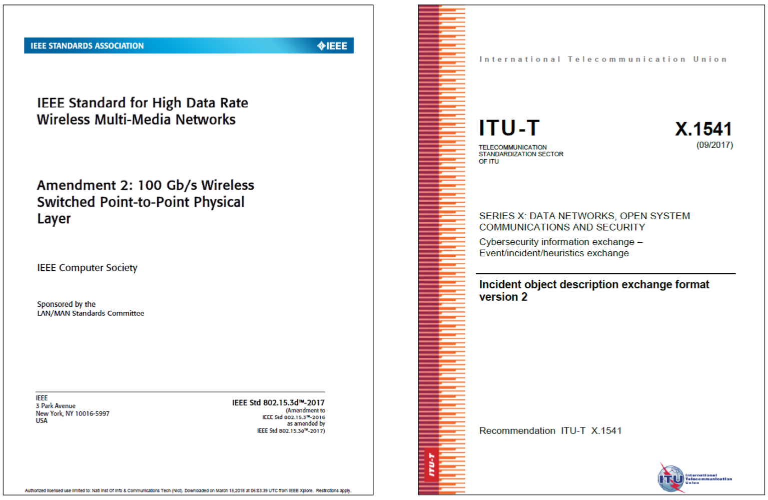


Fig.2 : Examples of international standards established in FY2017
IEEE Std 802.15.3d-2017: 100 Gb/s Wireless Switched Point-to-Point Physical Layer (left)
ITU-T X.1541 IODEF version 2: Incident object description exchange format (right)

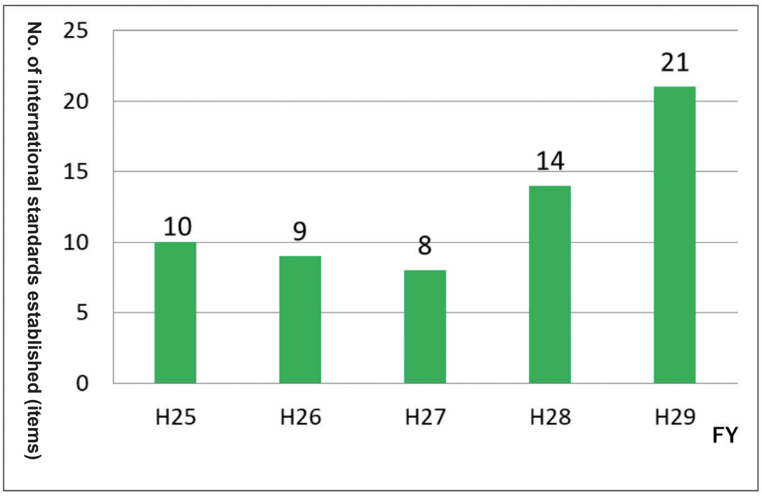


Fig.3 : Change in number of international standards established

NICT also promotes research exchanges with academia, e.g., by concluding agreements with graduate schools based on the Joint Graduate School Program, and provides research opportunities with guidance by NICT researchers for graduate students.

Promotion of efficient and fruitful commissioned R&D by effective use of external research resources

In addition to continuous strengthening of collaboration with its own research, NICT has been promoting commissioned R&D by making use of the research capabilities of industry and academia.

In fiscal year 2017, NICT worked on 20 themes continuing from previous years resulting in 467 papers, 599 oral presentations, 17 proposals to standardization organizations, and 111 industrial property right applications. As for standardization activities, nine recommendations in total have been adopted, one by IEC (International Electrotechnical Commission), seven by oneM2M (Standards for M2M and the Internet of Things), and one by OSGi (Open Services Gateway initiative) Alliance.

Effective promotion of technology transfer

NICT promotes appropriate securing and use of intellectual property by providing end-to-end intellectual property services from the time of an invention to technology transfer thereby helping to expand its own revenues and foster open innovation. Specific examples include the licensing of a tabletop glasses-free 3D display and organic EO polymer material (Fig.1), which contributed to the implementation of NICT research results in society.

Promotion of standardization activities

Under close coordination with government, industry, and domestic and international standardization organizations and bodies, NICT promotes effective standardization activities based on its specialized knowledge and R&D results and contributes to open innovation.

(1) To reflect its R&D results in international standards, NICT actively participates in meetings and other gatherings at various international standardization organizations. In FY2017, NICT submitted a total of 208 contributions based on R&D results. In the same year, a total of 39 individuals served as chairpersons, editors, etc. in various committees involved with standardization and meetings of international standardization organizations.

(2) NICT continued to maintain its membership qualifications in international standardization organizations and bodies such as ITU-R/T/D, APT, ETSI, and 3GPP.

(3) As a result of these activities, NICT contributed to the establishment of 21 international standards in FY2017 reflecting its R&D results including IEEE Standard 802.15.3d-2017 (Fig.2) titled "100 Gb/s Wireless Switched Point-to-Point Physical Layer" (the world's first terahertz-wave radio communications international standard) and other standards in fields such as wireless networks, optical access infrastructures, space weather, standard time, electromagnetic environment, and security. Change over time in the number of international standards established is shown in Fig.3.

Open Innovation

Global Alliance Department

Executive Director　Etsuko Nakanishi

As economic and social globalization progresses, international strategy regarding R&D on information and communications technology, and development of the results of that R&D, is being viewed as more important than ever for promoting open innovation and international development and strengthening international competitiveness from a global perspective.

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

Promotion of international research collaboration

We have established 21 Memoranda of Understanding (MOU) with 20 foreign organizations in 12 countries and regions, including the German Research Center for Artificial Intelligence (DFKI), the Fraunhofer Heinrich Hertz Institute, Karlsruhe Institute of Technology (Germany), and the Ho Chi Minh City Department of Information and Communication (Vietnam), and are working proactively to promote international research collaboration and international development of NICT research results (Fig.1).

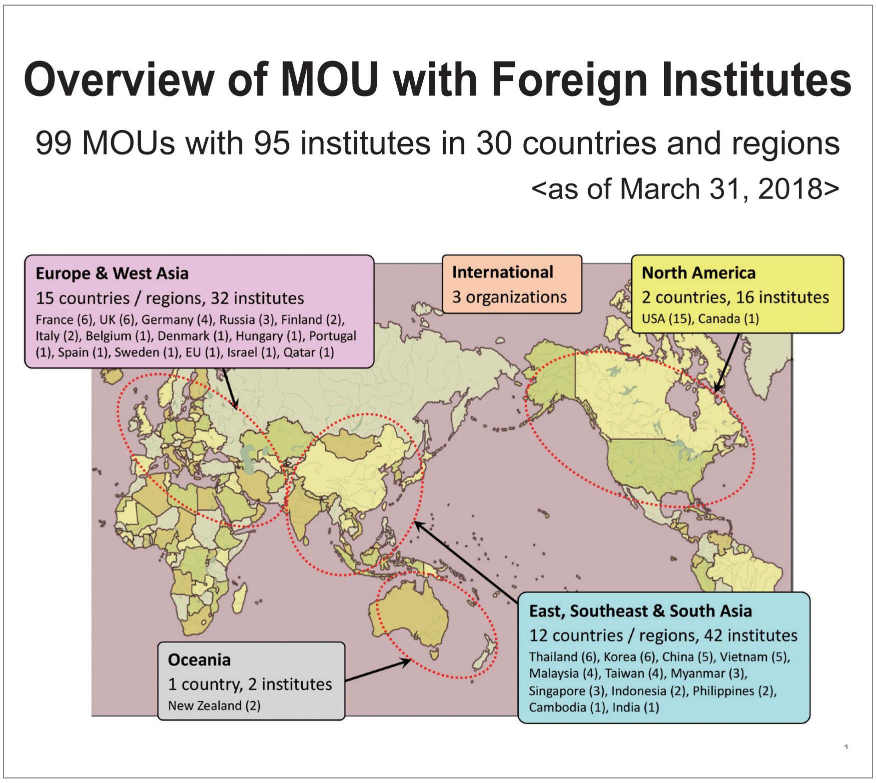


Fig.1 : Universities and research institutes with which we have a Memorandum of Understanding (MOU) (as of end of FY2017)

Promotion of projects in cooperation with foreign governments

We have conducted research in collaboration with Thailand's National Electronics and Computer Technology Center (NECTEC) and others on a disaster resilience dam monitoring network. This was proposed by the Thailand Ministry of Digital Economy and Society in response to an Asia-Pacific Telecommunity (APT) solicitation for international collaborative research and was adopted during FY2016 (Fig.2). Research on a landslide early warning system proposed through the Sri Lanka Telecommunication Regulation Commission was also selected in the same APT solicitation. It was performed in collaboration with the Sri Lanka Disaster Management Centre, etc., and involved a study of the feasibility of applying our disaster-resilient network technology (NerveNet).

Promotion of international joint research with the USA

With the National Science Foundation (NSF) of the USA, we decided on research topics of joint research in the network domain for the Japan-US Network Opportunity (JUNO2) program, and in the computational neuroscience domain for the Collaborative Research in Computational Neuroscience (CRCNS) project. We also conducted solicitation and selection of proposals for these.

Promotion of international joint research with Europe

In collaboration with the European Commission and the Ministry of Internal Affairs and Communications, we conducted the final review of the second round of International Joint Research and the first review of the third round International Joint Research, and also decided the topics and conducted solicitation and selection of proposals for the fourth round International Joint Research planned to start in FY2018.

Participation in international conferences and trade shows

In addition to participating proactively in international conferences and forums, presenting research results at events such as Global City Teams Challenge (GCTC) Expo 2017 (August, USA), we also held our own international seminars and exhibited at international trade shows, including a workshop that we held jointly with Thailand's National Electronics and Computer Technology Center (September, Thailand), and exhibits at the ASEAN IVO Forum 2017 (November, Brunei) and CSTB Telecom & Media 2018 (January, Russia).

International personnel exchange

As part of our international personnel exchange in FY2017, we accepted 26 internship students from 22 institutes in 14 countries and regions, including Indonesia, France, China, the Netherlands, the USA, Canada, Belgium, Thailand, South Korea, the UK, Malaysia, Cyprus, Cambodia, and Portugal (in order of acceptance). The trends for number of internship students accepted and number of institutes in the last five years are shown in Table 1. We also supported researchers from overseas by holding Japanese language training

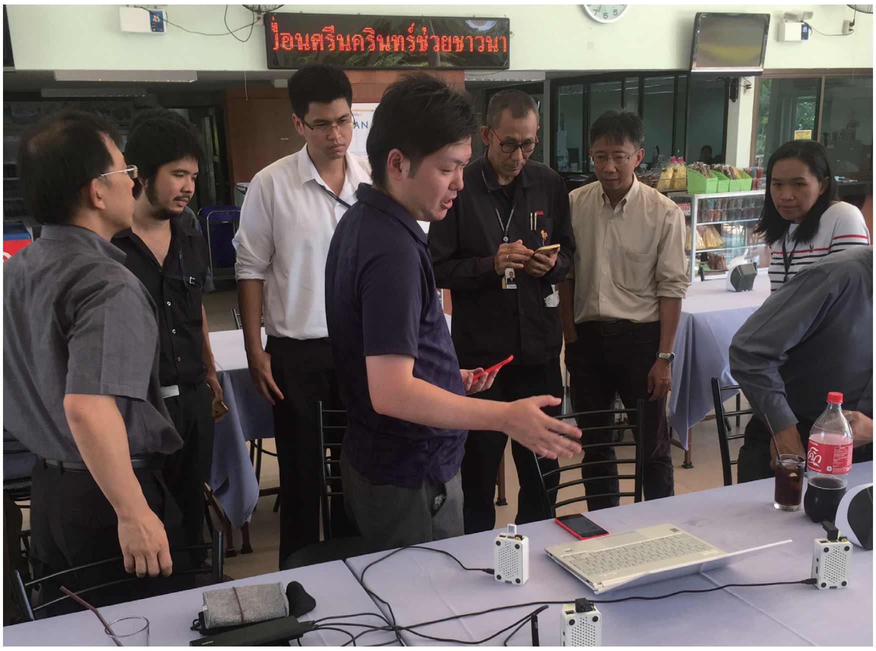


Fig.2 : Demonstrating the dynamic state of the disaster resilience network technology (NerveNet) with power company staff at the dam site (Sept. 12, 2017 in Kanchanaburi Province, Thailand)

	2013	2014	2015	2016	2017
Number of institutes	14	21	20	16	22
Number of internship students	19	25	22	19	26

Table 1 : Five-year internship trends

and translating various materials into English.

Overseas Center activities

The NICT Overseas Centers gather regional information as needed based on NICT internal requests, collecting and analyzing the latest R&D information from a global perspective, and providing feedback to the relevant personnel within NICT. In FY2017, we also conducted systematic surveys of R&D trends in brain-information related technologies, interactive and adaptive machine translation, space weather forecasting, and other topics, to provide support to R&D activities.

We have also conducted our own initiatives, mainly through the Overseas Centers, toward international development of R&D results, such as exhibiting at Black Hat USA 2017 (July, USA), the Thailand National Science and Technology Fair (August 2017, Thailand), and Digital Thailand Big Bang (September 2017, Thailand). We conduct studies based on requests from laboratories and other departments within NICT to strengthen collaboration within NICT and have also worked on disseminating information regarding NICT R&D and promoting research exchange and collaboration between NICT and overseas institutes, with efforts such as exhibiting at the Jiji Press London Top Seminar on multilingual speech translation.

Open Innovation
ICT Deployment and Industry Promotion Department

Executive Director Mitsuhiro Hishida

Information communication provides the infrastructure for social and economic activity. We are currently engaged in many activities in this field, such as promoting the commercialization of initiatives such as ventures 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 people's social and economic activities, we are promoting the following initiatives in the field of information communication to efficiently and effectively implement various promotion activities.

Inviting overseas researchers and providing support for the hosting of international research conferences

Through NICT's own International Exchange Program and the privately funded Japan Trust International Research Cooperation Program, we are working to invite overseas researchers to research institutes other than the NICT, and we are providing support for the hosting of international research conferences as part of our International Exchange Program.

(a) Foreign Researcher Invitation Program

In FY2017, our International Exchange Program placed eleven researchers at domestic institutes including Kyushu University and the University of Tokyo (although one dropped out after being placed).

(b) Japan Trust International Research Cooperation Program*

In FY2017, two overseas researchers were invited to the KDDI Research, Inc. and Fujitsu Laboratories Ltd. as part of the Japan Trust International Research Cooperation Program.

(c) International Conference Support Program

In FY2017, we supported twelve international research conferences including the International Conference on Light and Photonics 2017 and the 15th MST Radar Workshop.

* The Japan Trust International Research Cooperation Program is operated as a joint effort of NICT together with the New Energy and Industrial Technology Development Organization (NEDO). NICT invites researchers in the fields of communication and broadcasting, and NEDO invites researchers in fields related to the mining and manufacturing industries.

Supporting ICT startups

We support the efforts of ICT entrepreneurs to start up and commercialize their businesses from a strategic viewpoint aimed at strengthening Japan's medium- to long-term industrial competitiveness in the field of information communication.

(a) Providing ICT startups with information and exchange opportunities

We aim to provide opportunities for people to present and exchange information by holding real-life events and hosting an online ICT startup support center (http://www.nict.go.jp/venture/), and to provide entrepreneurs with matching opportunities to promote the commercialization of their businesses.

(b) Investing in information communication ventures, etc.

We manage companies in which the TAO (a previous incarnation of the NICT) directly invested.

(c) Providing grants and loan guarantees to information communication ventures and the like

We provide grants and loan guarantees to businesses that use new technology development facilities, and to businesses that share area-specific telecommunication facilities.

(d) Discovering and nurturing ICT startups

To discover and train promising ICT startups and young entrepreneurs, we have contributed to regional collaboration events by organizing activities such as kick-off seminars and brush-up seminars in cooperation with regional entrepreneur support groups. Also, to impart a global mindset to people planning to take part in NICT's Kigyouka Koshien entrepreneur competition, we implemented a Silicon Valley Boot Camp that included exchang-

Fig.1 : Silicon Valley Boot Camp

es with local ICT ventures at the west coast of the US (Silicon Valley) and lectures from locally active venture entrepreneurs and the like (Fig.1).

Supporting the spread of information communication infrastructure

We want Japan to be the world's most advanced ICT nation, and support the spread of information communication infrastructure in this country.

(a) Supporting regional communications and broadcast development projects

We are supporting businesses that contribute to the enhancement of telecommunications (e.g., by improving CATV or setting up relay stations for terrestrial digital TV broadcasting) in areas other than large cities by subsidizing their interest payments on loans from banks and other financial institutions.

Supporting people with insufficient access to information

We support the development of environments where everyone has equal access to communication and broadcasting services.

(a) Promoting the production of programs with subtitles, sign language, and audio description.

For people with audio-visual impairments, we partially subsidize the production of programs with subtitles, audio descriptions and sign language interpreting, sign language translation video to be displayed together with broadcast programs, and equipment that checks the subtitles of commercial programs.

(b) Promoting the development of communication and broadcasting services for challenged users

We provide partial subsidies for people who provide and develop communication and broadcasting services that are more accessible to people with physical disabilities who have difficulty in using communication and broadcasting services.

(c) Supporting barrier-free information delivery

Through our website on barrier-free information delivery, we are providing information that makes it easier for elderly and challenged users to make use of communication and broadcasting services.

Fig.2 : A scene at the NICT exhibition booth in TechCrunch DISRUPT SF held in Sept. 2018

Promoting private-sector research on communication and broadcasting technology

・Commissioning private organizations to research basic technologies

We promote the strategic and efficient research of fundamental technology by the private sector in the field of information communication.


RESEAR
VISION

Research Highlights

42 New cryptographic technology for the quantum computer age

43 NICTER Analysis Report 2017

44 Hybrid approach for more accurate "one-second"

46 When people are happy, they can find things faster

47 Uninterrupted communication for users moving at 500km/h

49 Enhancing the energy controllability using strong interaction with photons

50 Toward autonomous transport infrastructure utilizing 5G ultra-low latency

52 High-precision chromatic aberration correction method for super-resolution microscopy

53 Generation of JST is now multiplexed

55 Aiming for further translation accuracy in the medical field

56 Multimode/multicore fiber system for practical optical communication infrastructure

PROTECT

New cryptographic technology for the quantum computer age

Proposal of Public Key Encryption based on Lattices for International Standardization

It has been known that a quantum computer of sufficient performance is capable of breaking RSA and discrete logarithm problems, which are currently used to secure communications over the Internet. At the same time, the commercialization of quantum computers and their availability as a free-of-charge cloud service in recent years reflect the progress made in their performance and penetration. It is therefore possible that current public key encryption will be unable to provide secure communications sometime in the future (Fig.1).

To protect the communication of information in the age of quantum computers, the Cybersecurity Research Institute of NICT developed LOTUS (Learning with errOrs based encryption with chosen ciphertexT secUrity for poSt quantum era) as a new cryptosystem that aims to satisfy the following conditions:

(1) Quantum-resistant: Must be difficult to break even by quantum computers
(2) Versatile: Must be applicable to browsers, databases, and many communication, transportation, and industrial systems.

"A base cryptosystem is added with functionality"

LOTUS is a lattice-based cryptosystem*1 based, in particular, on the LWE problem*2, which has been intensively studied of late. The LOTUS team at Security Fundamentals Laboratory explains the design rationale of LOTUS as follows: "It is achieved by first configuring a base cryptosystem and then adding functionality for checking the structure of ciphertext at the time of decryption."

This cryptographic technology is a first-round candidate in the PQC standardization process held by the National Institute of Standards and Technology (NIST) of the United States. All submitted candidates, including LOTUS, are being analyzed by experts in this field for a period of three years or more that started at the end of 2017 to choose a new standard for the future.

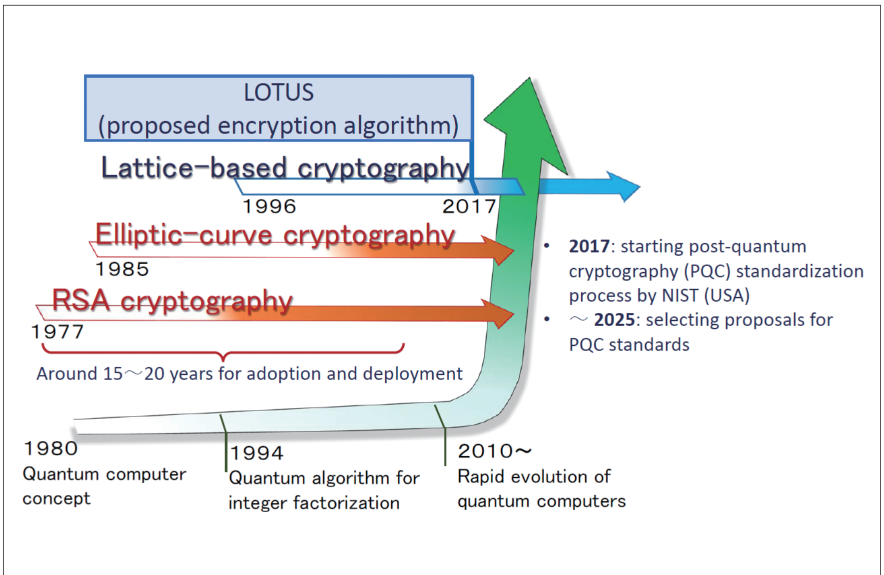


Fig.1 : Transition of public key encryption

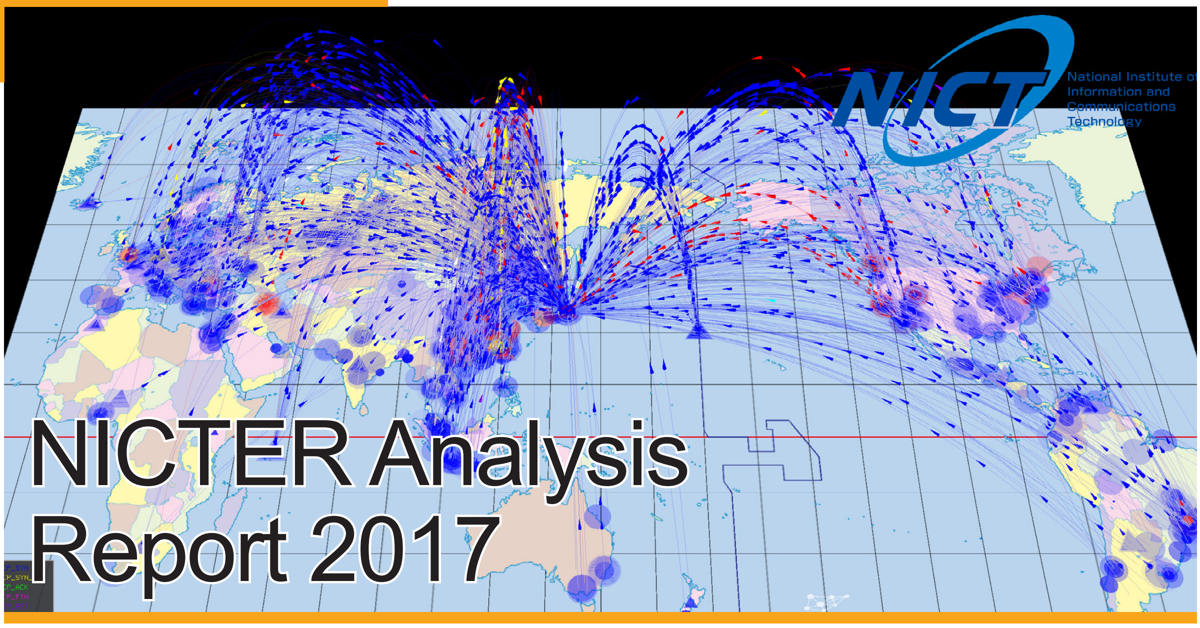
Footnote

***1 Lattice-based cryptosystem**
A set of points arranged in a regular way in space is called a lattice and a cipher that ensures safety by using the mathematical properties of a lattice is called a lattice-based cryptosystem. Here, expressing the property of regular arrangement as a matrix enables encryption and decryption processing to be performed in parallel, ensuring efficient implementations.

***2 LWE problem**
Short for Learning with Errors problem. Given a set of simultaneous linear equations in which the number of equations is greater than the number of variables, this problem consists of finding an integer solution such that the difference between the left side and right side of each equation becomes small. It has been shown that this problem is as hard as the lattice shortest vector problem depending on parameters, which indicates that finding a solution would take an extremely large amount of time even for a quantum computer.

PROTECT

NICTER Analysis Report 2017



The NICT Cybersecurity Research Institute has been operating a large-scale cyberattack monitoring network (darknet monitoring) as part of the NICTER*1 project and has been monitoring cyberattack-related network packets*2 since 2005. The monitoring and analysis results of the NICTER project for 2017 (released in February 2018) are summarized below.

Cyberattack-related network packets observed in 2017 on the NICTER darknet monitoring network (about 300,000 IP addresses) rose to a total of 150.4 billion, which is about 560,000 packets per IP address per year (Fig.1).

The total number of packets per year represents only the number of packets arriving within the range of the darknet monitored by NICTER and should not be interpreted as the number of attacks mounted throughout Japan or against government institutions.

The total number of observed packets per IP address per year keeps increasing each year (Fig.2) and from 2016 to 2017, this number increased by 1,2 times.

Year	Total packets (billion)	# of darknet IP addresses	Packets received per IP address
2005	0.31	16,000	19,066
2006	0.81	100,000	17,231
2007	1.99	100,000	19,118
2008	2.29	120,000	22,710
2009	3.57	120,000	36,190
2010	5.65	120,000	50,128
2011	4.54	120,000	40,654
2012	7.78	190,000	53,085
2013	12.88	210,000	63,655
2014	25.66	240,000	115,323
2015	54.51	280,000	213,523
2016	128.1	300,000	469,104
2017	150.4	300,000	559,125

Fig.1 : NICTER darknet monitoring statistics

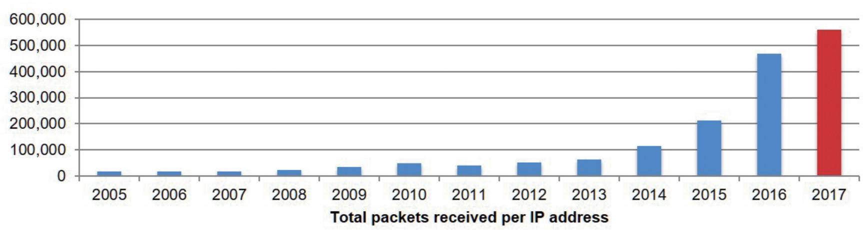


Fig.2 : Total number of observed packets per IP address per year

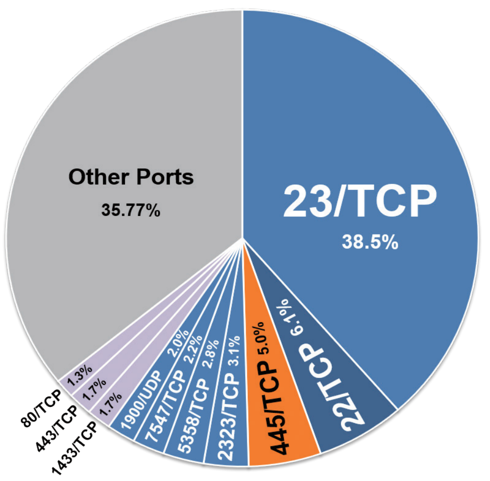
"We raise our awareness of the need for applying security measures to IoT devices too."

Figure 3 shows the top 10 attack targets (destination port numbers) observed by NICTER in 2017. The blue portions of this pie chart, which constitute more than half of the total, correspond to attacks targeting vulnerabilities inherent to specific type of IoT devices such as mobile routers and home routers. These results reflect the increasing sophistication of attacks toward IoT devices.

Director Daisuke Inoue and Executive Technical Researcher Masaki Kubo of the Cybersecurity Laboratory have stated, "It is important that we raise our awareness of the need for applying security measures to IoT devices too, such as by accurately determining what IoT devices are used in the home or workplace and appropriately configuring and updating them as needed."

NICT is committed to enhancing the use of NICTER monitoring and analysis results and researching and developing security measures for IoT devices to improve security in Japan.

NICTER Analysis Report 2017 (detailed versions):
Web version: http://www.nict.go.jp/cyber/report.html
PDF version: https://www.nict.go.jp/cyber/report/NICTER_report_2017.pdf



Port	Target
23/TCP	IoT（WebCam）
22/TCP	IoT（Mobile Router） SSH
445/TCP	Windows（Server Service）
2323/TCP	IoT (WebCam, etc)
5358/TCP	IoT (WebCam, etc)
7547/TCP	IoT（WebCam, etc）
1900/UDP	IoT（Broadband router）
1433/TCP	Database server（SQL）
443/TCP	Web server（SSL/TLS）
80/TCP	Web server（HTTP）

Fig.1 : Percentage breakdown of packets by destination port number
Port number 22/TCP, which ranks second in number of packets, includes scan packets to ordinary authentication servers (Secure Shell (SSH) protocol) that are not mobile routers. "Other Ports" in the pie chart also include many packets targeting IoT devices.

Footnote

***1 NICTER (Network Incident analysis Center for Tactical Emergency Response)**
NICTER is an integrated system for rapidly grasping various types of threats to information security over a wide area and deriving effective countermeasures. It has functions for performing correlation analysis of information obtained by observing cyberattacks and collecting malware and for investigating the root causes of security threats.

***2 Cyberattack-related network packets**
This is the generic term for packets arriving at the darknet. These include scan packets from malware-infected devices searching for the next target to infect on the Internet and backscatter packets from servers under denial-of-service (DoS) attacks.

WATCH

Hybrid approach for more accurate "one-second"

Synergy between optical and microwave clocks, achieving a months-long time scale with high precision

National standard times are maintained to be synchronized with Coordinated Universal Time (UTC). Since the radiation frequency associated with the cesium hyperfine transition defines the length of "one-second," maintaining accurate Cs clocks is straightforward to keep time. Optical clocks, on the other hand, have been making rapid progress recently and now have much less systematic uncertainty than microwave standards. Nevertheless, nobody has so far generated the real-time signal of a time scale using optical clocks because it is still difficult to operate an optical clock continuously for one month or longer.

Researchers at the NICT Space-Time Standards Laboratory including atomic physicists and time-composing experts have demonstrated a novel time scale called the "optical-microwave hybrid time scale" that combines an optical lattice clock with a hydrogen maser (HM). The ^{87}Sr lattice clock, as a standard for pace adjustment, is sparsely operated for three hours once a week. This operation calibrates the frequency of the HM, and the measurements over the latest 25 days allow them to predict how the HM ticking rate will change. Then, they can adjust the HM frequency for the following week in advance to compensate for the predicted frequency drift.

"The method demonstrated here brings the benefit of optical frequency standards to time keeping."

The signal generated in this optical-microwave hybrid system continued for half a year without interruption. The resultant "one-second" was more accurate than that of UTC on that date, and the time deviated by 0.8 ns in half a year relative to TT(BIPM), which is the most accurate time scale post-processed by the International Bureau of Weights and Measures (BIPM). This demonstration shows it is possible to keep time with respect to the future optical definition of the second, which may come into play in the next decade.

Tetsuya Ido, director of NICT Space-Time Standards Laboratory, states "We serve the society by providing time endlessly without interruptions. The optical-microwave hybrid method demonstrated here brings the benefit of optical frequency standards to time keeping."

NICT, which generates Japan Standard Time (JST), aims to apply this hybrid method to the JST generation system step by step. The next step would be establishing a redundancy of optical frequency references. Another optical lattice clock or single-ion clock will work. They may utilize those in other laboratories by forming connections via optical fiber network or satellite-based frequency transfer.

Dr. Ido has also said "Highly precise optical clocks are expected to be geodetic sensors to detect the variation of gravitational environment. Such applications demand a reference that remains unchanged. Highly accurate and stable national time scale may play this role that is available in 24h/7d as an infrastructure."

Reference

Hidekazu Hachisu, Fumimaru Nakagawa, Yuko Hanado, and Tetsuya Ido, "Months-long real-time generation of a time scale based on an optical clock," Scientific Reports 8:4243 (2018).
DOI: 10.1038/s41598-018-22423-5
URL: http://www.nature.com/articles/s41598-018-22423-5

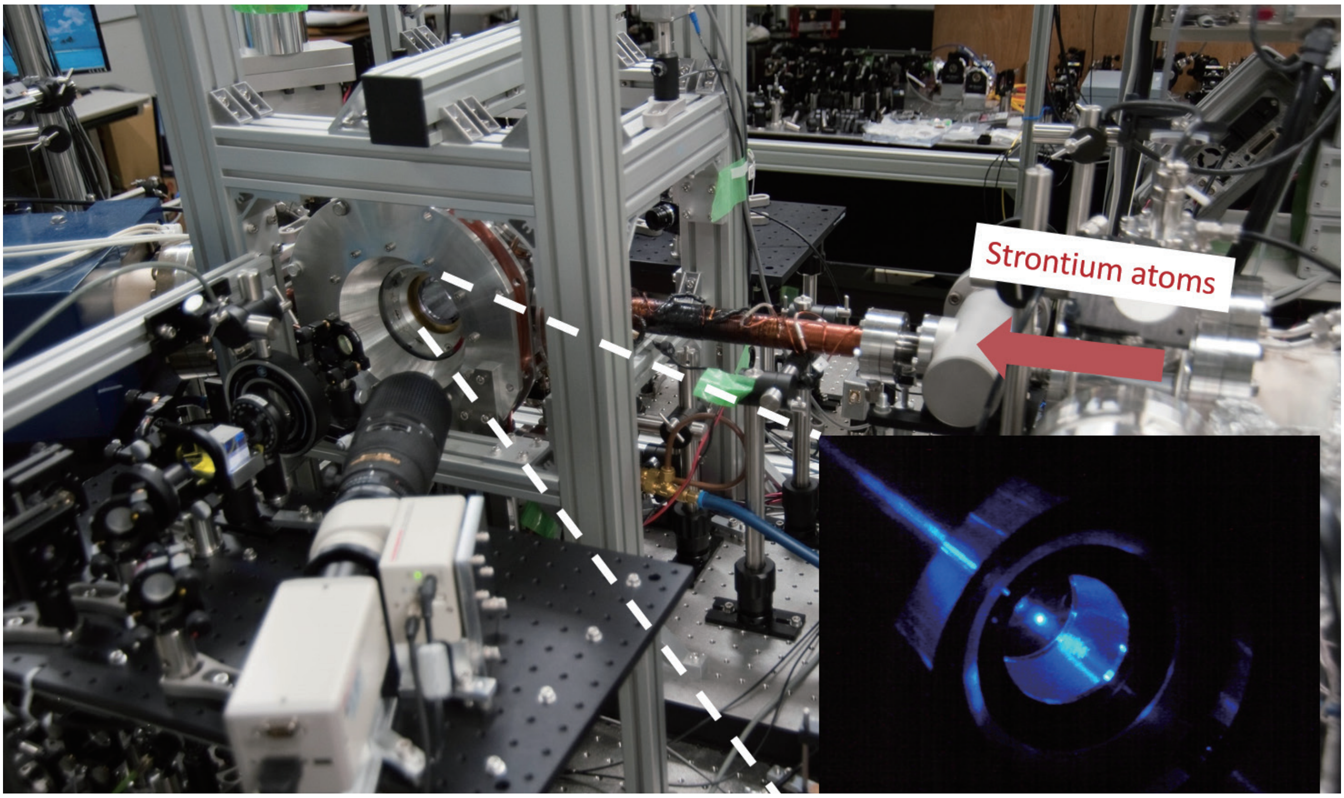


Fig.1 : ^{87}Sr optical lattice clock

CREATE

When people are happy, they can find things faster

Everyday changes of mood were found to affect the performance of visual search

A wide range of social psychology studies support the premise that people are more creative when they are happy, and are more sociable when they are able to engage with many things and people. However, the effect of mood on people's ability to perform basic tasks such as noticing or finding things has not been clarified.

A team led by Noriko Yamagishi, a senior researcher at the CiNet Brain Networks and Communication Laboratory, has developed a smartphone app to record variations in people's level of happiness during their everyday lives, and by having them perform visual search tasks at the same time, it was revealed that a person's level of happiness affects their speed in visual search task (Fig.1).

"A person's degree of happiness is not a constant attribute like personality."

Thirty-three research participants worked on tasks for about 5 minutes each time three times a day (morning, noon, and night) for two weeks (Fig.2). The results showed that a person's degree of happiness is not a constant attribute like personality, but changes from one moment to the next. When a person's happiness level is higher, he/she can locate more quickly a target object set among obstacles.

According to Dr. Yamagishi, "The results of this study suggest that it is possible to estimate how happy someone is by using a smartphone app to monitor their performance in visual search tasks. This could lead to the development of methods for visualizing the early stages of mental disorders such as depression."

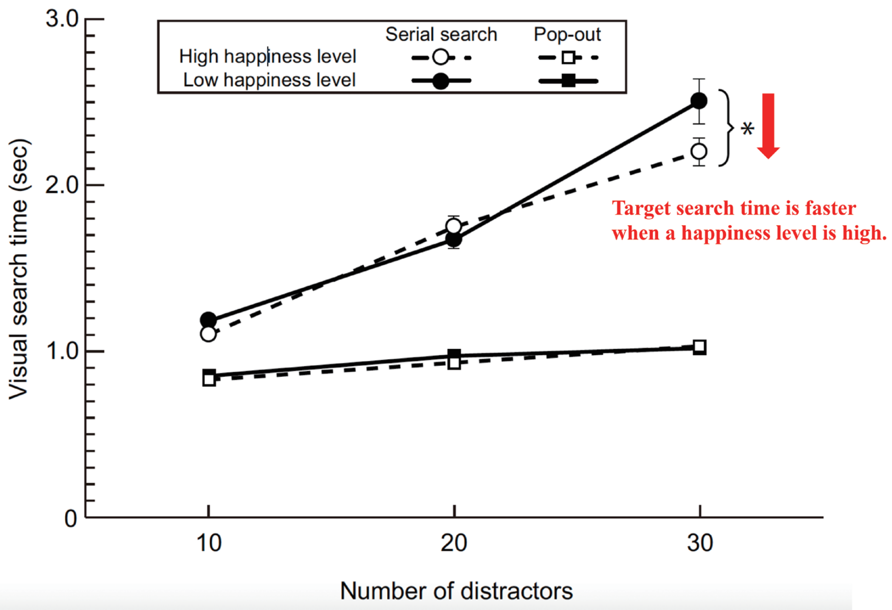


Fig.1 : Effect of happiness level on visual search times

Reference

PLOS ONE
URL: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0195865
DOI: 10.1371/journal.pone.0195865
The effect of mood state on visual search times for detecting a target in noise:
An application of smartphone technology
Maekawa, T., Anderson, S. J., de Brecht, M., Yamagishi, N.

Collaboration Research Members
NICT : Toru Maekawa Matthew de Brecht Noriko Yamagishi
Aston University(http://www.aston.ac.uk/) : Stephen J. Anderson

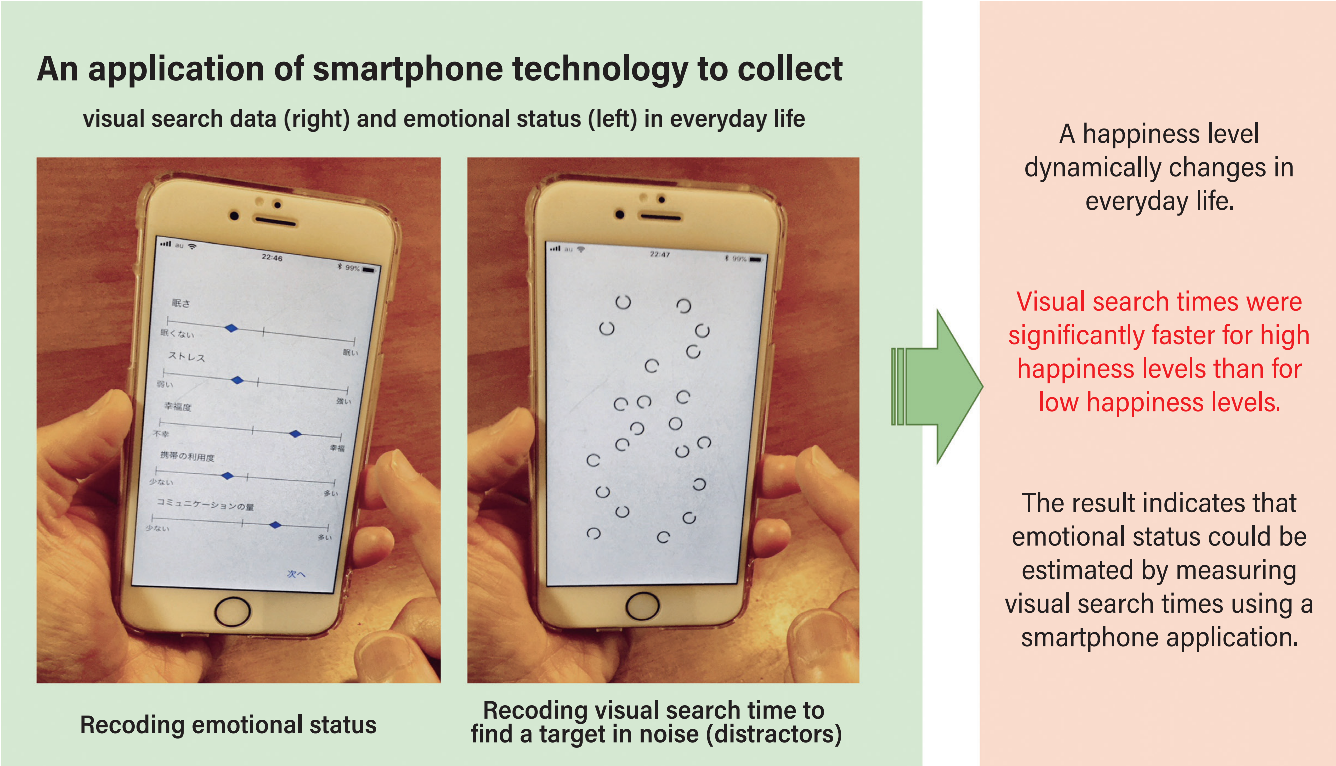


Fig.2 : Smartphone application to collect emotional status and visual performance in everyday life

CONNECT

Uninterrupted communication for users moving at 500km/h

Proof of concept demonstration of high-capacity seamless communication for high-speed railways

The demands for high-speed and smooth communications are rapidly increasing, including from users who are on rapidly moving vehicles such as high-speed trains, because of the explosive popularization of smartphones and other personal multimedia devices. In current cellular networks, however, connections to Internet networks during high-speed movement are frequently interrupted because of radio station switching (handover).

NICT Network System Research Institute (NSRI) researchers performed a proof-of-concept demonstration of an uninterrupted communication system for high-speed trains by combining a linear cell network configuration, a high-speed seamless fiber-wireless system in the millimeter-wave (mmWave) band, and an ultra-fast optical-path switching technique. This work was conducted as part of a project titled “Research and development of millimeter-wave backhaul technology for high-speed vehicles” funded by the Ministry of Internal Affairs and Communications (MIC), Japan (Research representative: Hitachi Kokusai Electric Inc.).

In this work, the NICT researchers developed a technology to transmit approximately 20-Gbit/s radio signals (16-QAM, carrier frequency of 7 GHz and sampling rate of 6 GHz) in the 90-GHz band from a central station to 50 remote radio stations using a switchable wavelength-division-multiplexing radio-over-fiber and mmWave wireless network. The switching of the remote radio stations in accordance with the movement of trains can be controlled from the central station, and a switching time of less than 10 μs was achieved using high-speed wavelength-tunable lasers.

"We demonstrated that the signal distribution to radio stations can be switched in less than 10 μs."

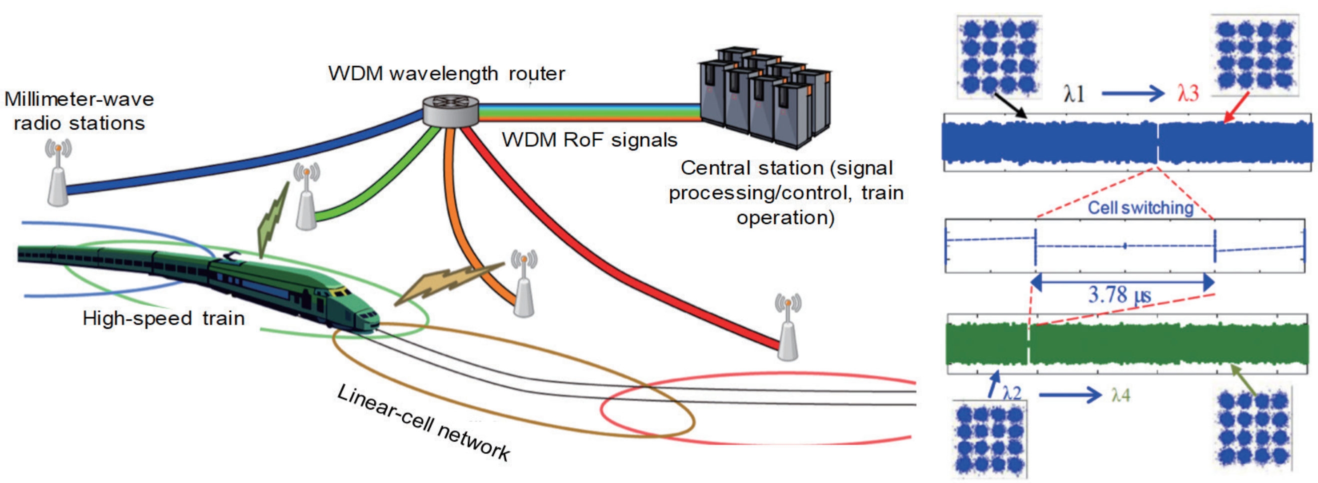
In high-speed railways, the radio stations that the trains are approaching can be precisely predicted using train information such as train location and velocity, which is available at the train operation center. Thus, appropriate signal distribution to the corresponding radio stations can be performed by means of high-speed optical switching technologies, such as high-speed wavelength-tunable lasers. Naokatsu Yamamoto, Director of the NSRI Network Science and Convergence Device Technology Laboratory, stated, "We demonstrated that the signal distribution to radio stations can be switched in less than 10 μs. This indicates that an uninterrupted communication system for high-speed railways can be constructed, even for trains moving at 500 km/h or faster."

Handover-free communication has faced a significant challenge in terms of avoiding significant degradation of the throughput of high-mobility users, which includes users on high-speed trains, due to the frequently interrupted connections with radio stations. With this network configuration, the development of an uninterrupted network for high-mobility users can be implemented in an easier way than in standard cellular networks because the necessary control signals are available at central stations.

Dr. Yamamoto further said, "In the future, in collaboration with Hitachi Kokusai Electric Inc., the Railway Technology Research Institute, the Electronic Navigation Research Institute (part of the National Institute of Maritime, Port and Aviation Technology Institute), and other related parties in the aforementioned MIC-funded project, we will implement field test demonstrations on actual railway lines."

Reference

Pham Tien Dat, Atsushi Kanno, Keizo Inagaki, Toshimasa Umezawa, Fançoir Rottenberg, Jérome Louveaux, Naokatsu Yamamoto, and Tetsuya Kawanishi, "High-Speed and Handover-Free Communications for High-Speed Trains Using Switched WDM Fiber–Wireless System," in Proc. 41st Optical Fiber Communication Conference and Exhibition (OFC), March 2018, paper Th4D. 2.



Conceptual diagram of the proposed communication system for high-speed railways (left) and radio station switching and performance of 16-QAM signals (right).

DEVELOP

Enhancing the energy controllability using strong interaction with photons

Observed huge Lamb shift shows potential of utilizing vacuum fluctuation in designing quantum circuit

The physics of extremely strong interaction between light and matter has not been well understood due to the lack of suitable experimental means. To find and understand new phenomena in this unexplored regime, a research group comprising Senior Researcher Fumiki Yoshihara, Senior Researcher Tomoko Fuse, and Executive Researcher Kouichi Semba of the NICT Advanced ICT Research Institute has been working on superconducting artificial atoms*1 that can interact very strongly with an electromagnetic field mode in a resonator circuit. In 2016, they successfully implemented a new regime of very strong interactions between light and matter (deep-strong-coupling (DSC) regime), and became the first to demonstrate the existence of stable states molecule-like consisting of photons and artificial atoms.

In the DSC regime, interactions with just a single photon can cause tremendous changes in the energy levels of an artificial atom. Until now, there have been no reports of systematic experiments to explore phenomena (Lamb shift, Stark effect) in this regime.

In collaboration with NTT Corporation, Qatar Environment & Energy Research Institute, Tokyo Medical and Dental University, and Waseda University, this research group has become the first to successfully generate a very large energy change (optical shift) in artificial atoms interacting with photons. This experiment was conducted using the superconducting circuit shown in Fig.1. The superconducting artificial atoms (outlined in red) were prepared using microfabrication techniques. Artificial atoms have quantum properties equivalent to atoms, and can confine photons in the superconducting resonator circuit. New experiments using double resonance spectroscopy showed that the observable energy range became wider, and the team succeeded in observing a huge relative light shift about 100 times larger than in conventional experiments (Fig.2).

“The relative shift we observed is 6 orders of magnitude larger than that initially observed in the hydrogen atom.”

The Lamb shift is caused by interactions with the vacuum electromagnetic field in resonator circuits. The effect was first discovered as a difference in the fine energy levels of hydrogen atoms. Since then, it has brought dramatic developments in quantum electrodynamics, and plays a key role in the sophisticated electronics technology supporting modern society. In the words of Kouichi Semba (Executive Researcher at the Frontier Research Laboratory), “The huge Lamb shift we observed this time is 6 orders of magnitude larger than the energy shift initially observed in the hydrogen atom, due to the effect of the zero point fluctuation current in the superconducting circuit. In this way, quantum technology using superconducting artificial atoms has lead to an era when it is necessary to change the idea in circuit design, to make use of the quantum fluctuation which was only a very small correction term in the past in a leading role”

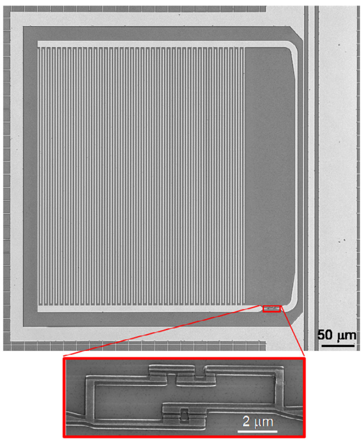


Fig.1 : The deep-strong-coupling circuit used in the experiments, consisting of an aluminum superconducting artificial atom (outlined in red) and an LC resonator circuit

It is expected that DSC physics could be exploited to control artificial atoms at high speed and to minimize the back action of quantum measurements, thus contributing to the progress of quantum technology.

This study was partly funded by the Japan Science and Technology Agency JST-CREST, a grant-in-aid for scientific research from the Japan Society for the Promotion of Science in basic research (S and C), and Waseda University's Graduate Program for Embodiment Informatics.

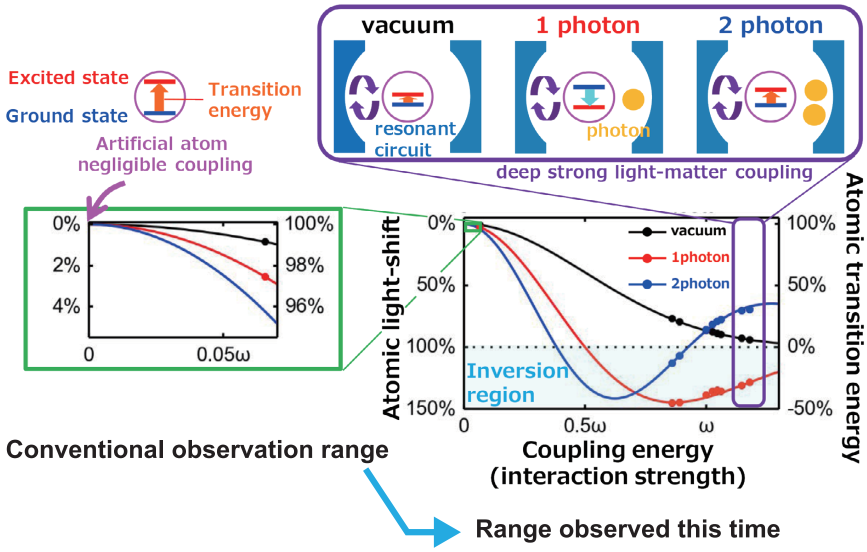


Fig.2 : Transition energy of an artificial atom with 0, 1, or 2 photons in the LC resonator circuit

Footnote

***1 Superconducting artificial atom:** A quantum circuit made from a superconductor with discrete energy levels that resemble the line spectrum of a natural atom.

Reference

Physical Review Letters
DOI: https://doi.org/10.1103/PhysRevLett.120.183601
URL: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.120.183601
Inversion of qubit energy levels in qubit-oscillator circuits in the deep-strong-coupling regime
F. Yoshihara, T. Fuse, Z. Ao, S. Ashhab, K. Kakuyanagi, S. Saito, T. Aoki, K. Koshino, and K. Semba

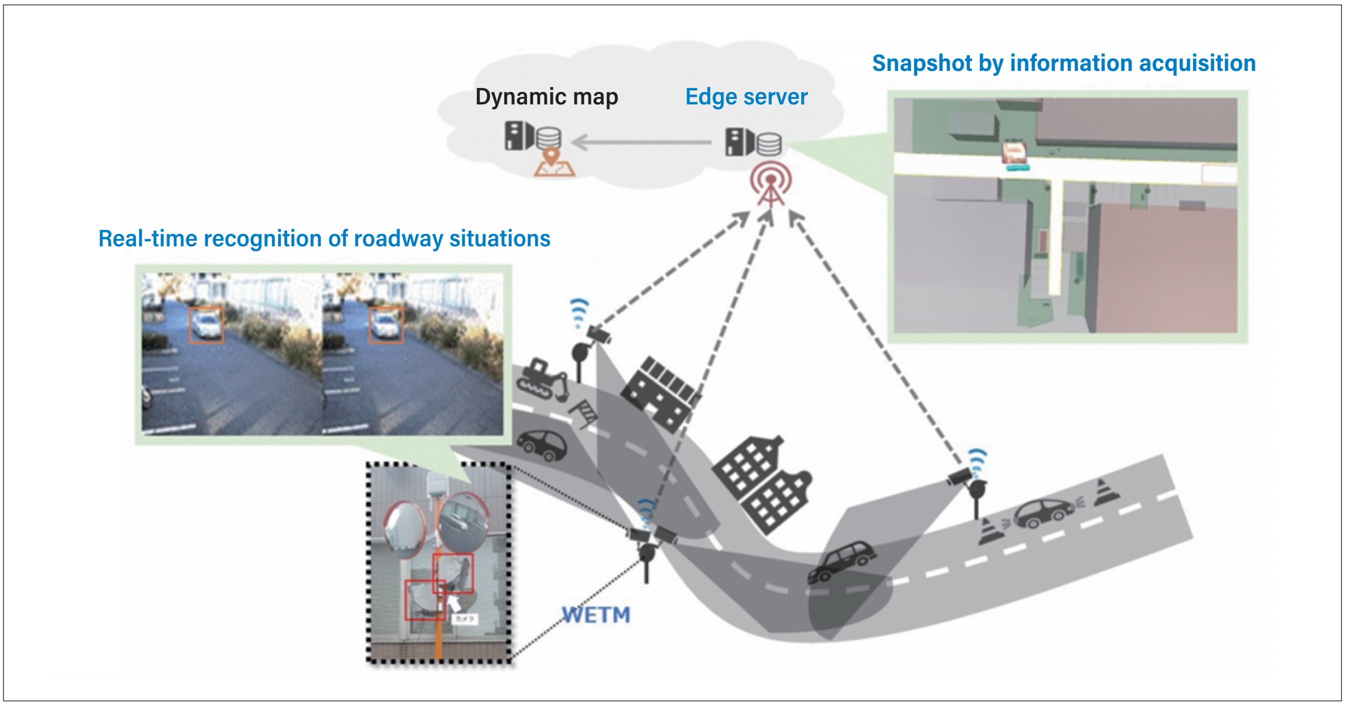
Collaboration Research Members
NICT: Kouichi SEMBA, Fumiki YOSHIHARA, Tomoko FUSE
NTT: Shiro SAITO, Kousuke KAKUYANAGI
QEERI: Sahel ASHHAB
Tokyo Medical and Dental University: Kazuki KOSHINO
Waseda University: Takao AOKI, Ziqiao AO

CONNECT

Toward autonomous transport infrastructure utilizing 5G ultra-low latency

Real-time recognition of roadway situations by Wireless Electronic Traffic Mirror (WETM) built-in sensors

In the near future, the diverse autonomous mobilities of vehicles, drones, tractors, etc. are expected to become more popular, and a highly reliable intelligent transport infrastructure will be required to support safe autonomous movement. In addition, various mobilities may autonomously move in different road situations with combinations of congestion, construction, potential collisions, and so on. In order to achieve an autonomous transport system, the roadway situations need to be accurately grasped in real time. This necessitates the establishment of a roadway acquisition technology by which a large number of sensors with wireless communications can collect the road information



An overview of intelligent transport infrastructure.

and place it on a dynamic map to maintain the road information.

For the establishment of a roadway acquisition technology, NICT Wireless System Research Center (WSRC) researchers built a test-bed intelligent transport infrastructure in Yokosuka Research Park (YRP) utilizing the 5th generation wireless communication system (5G) ultra-low latency to support autonomous mobility in the roadway environment as in the intersections.

“Under the test-bed infrastructure, we have confirmed that it is possible to grasp the roadway situations in real time.”

In addition, they developed a Wireless Electronic Traffic Mirror (WETM) built-in camera and location measuring sensors that enable the collection of information on a variety of roadway situations such as road construction and vehicle congestion. This information is then reflected on a dynamic map (DM), which is a database maintaining the roadway information, and is transmitted to the autonomously moving vehicles, pedestrians, and so on.

Kentaro Ishizu, research manager of the WSRC Wireless System Laboratory, stated, “Under the test-bed infrastructure, we have confirmed that it is possible to grasp the roadway situations in real time, especially an area in the vicinity of an intersection with poor visibility. From these achievements, we expect to construct an intelligent transport infrastructure to avoid mobility collisions and to predict movement.”

In the future, they will implement the 5G wireless communication system on the test-bed infrastructure and evaluate its performance with various wireless systems in different roadway conditions such as when a large number of moving objects is located on a roadway and the moving speed of each is different or the area is wide. Dr. Ishizu also said, “We will confirm the functional requirements to be aimed at establishing the technology to realize a more advanced autonomous transport system.”

An apprearance of WETM

DEVELOP

High-precision chromatic aberration correction method for super-resolution microscopy

The software developed in this study can be downloaded

The fluorescence microscope is a basic tool of biotechnology research, and the development of a new form of microscopy is an important key step to advance research in this field. For example, the development of super resolution microscopy* (awarded the 2014 Nobel Prize in Chemistry) has dramatically improved the resolution of fluorescence microscopes (Fig.1). However, this has in turn given rise to problems caused by chromatic aberration (misregistration of different light wavelengths) which had hitherto been negligible.

Researchers at the NICT Advanced ICT Research Institute have developed a method that can measure and correct chromatic aberration caused not only by the lenses and other components of a microscope, but also by biological samples being viewed under the microscope. Using this method, the chromatic aberration of super resolution microscopy can be improved approximately tenfold compared with conventional apparatus.

“With this technique we can achieve a chromatic aberration correction accuracy of about 15 nm in three dimensions.”

With the development of image acquisition and computation methods, it was possible to acquire images with color shifts caused by chromatic aberration in the sample being observed by means of multiple methods such as multi-color staining of the same objects in similar samples, or observation of samples in the fluorescent spectra that are normally cut off (Fig.2).

According to Senior Researcher Atsushi Matsuda of the Frontier Research Laboratory, “with this technique we can achieve a chromatic aberration correction accuracy of about 15 nm in three dimensions, allowing accurate interpretation of images obtained by super-resolution microscopy.” As a result, it is now possible to use fluorescence microscopes to perform measurements that could previously only be made using an electron microscope.

The high-precision chromatic aberration correction software developed in this study can be downloaded free of charge.

https://github.com/macronucleus/Chromagnon/blob/master/README.md

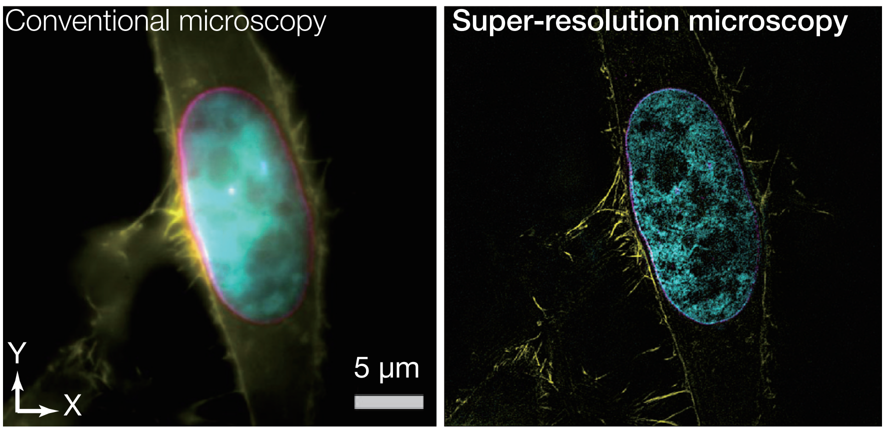


Fig.1 : Example of multicolor observations with a fluorescence microscope

Footnote

*** Super-resolution microscopy**
A type of fluorescence microscopy that allows samples to be observed at higher resolution than in conventional optical microscopes. The spatial resolution limit of a conventional microscope is about 250 nm horizontally and about 600 nm vertically, while that of a super-resolution microscope is about 15–150 nm horizontally and about 5–300 nm vertically.

Reference

Atsushi Matsuda, Lothar Schermelleh, Yasuhiro Hirano, Tokuko Haraguchi, and Yasushi Hiraoka,
"Accurate and fiducial-marker-free correction for three-dimensional chromatic shift in biological fluorescence microscopy," Scientific Reports
DOI: 10.1038/s41598-018-25922-7
URL: https://www.nature.com/articles/s41598-018-25922-7

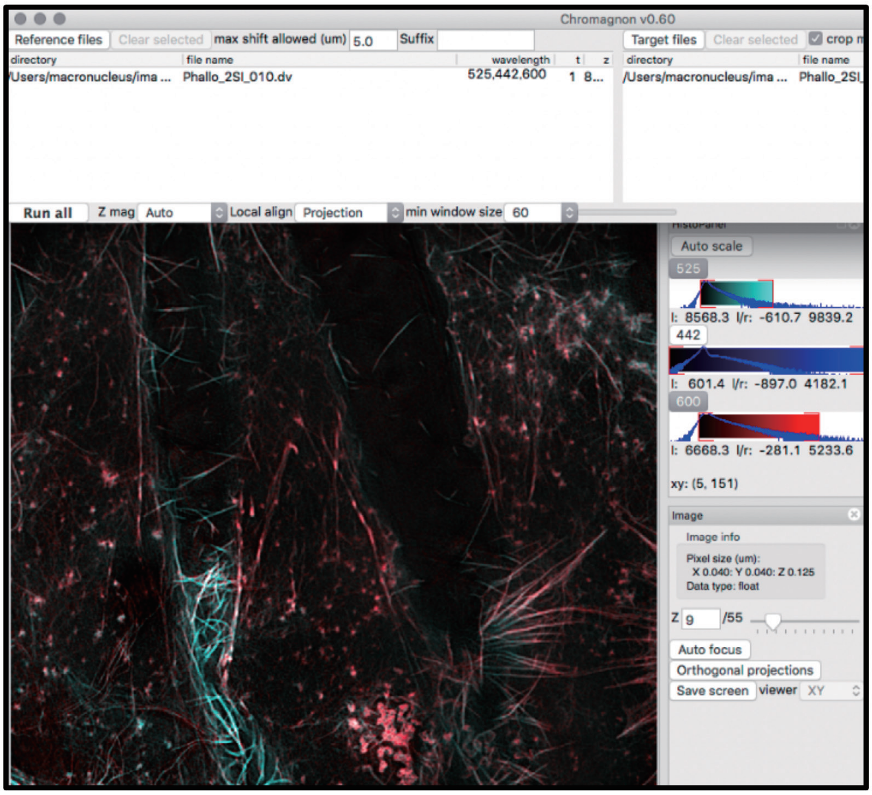


Fig.2 : Screenshot of the chromatic aberration correction software developed in this study

WATCH

Generation of JST is now multiplexed

Kobe branch begins routine supply of Japan Standard Time

Based on the Act on the National Institute of Information and Communications Technology, NICT has been working on the generation, maintenance, and dissemination of Japan Standard Time (JST). On June 10, 2018, NICT began to operate JST sub-station at Kobe in order to strengthen ability to cope with emergencies.

Japan Standard Time has hitherto been generated by a set of atomic clocks running at the NICT headquarters (in Koganei City, Tokyo). However, since these clocks are all concentrated at one location, a worst-case natural disaster at the NICT headquarters could bring the generation and provision of Japan Standard Time to a halt. To mitigate this risk, the Space-Time Standards Laboratory at the Applied Electromagnetic Research Institute has been working on the distributed synthesis of Japan Standard Time. The idea is to generate Japan Standard Time by distributing multiple atomic clocks across multiple regional centers (including LF standard time and frequency transmission stations) and synthesizing the resulting data by sharing it via satellite links.

"Parallel generation of standard time"

The JST sub-station at Kobe is one of these distributed stations and can function as a replacement for the JST station at NICT headquarters in an emergency(Fig.3). It is equipped with essential functions necessary for generation of Japan Standard Time, including five cesium atomic clocks (CS), two hydrogen masers, and a high-precision time comparison system via satellites, and as a result, it always generates synthetic atomic time in parallel with JST station at NICT headquarters. Besides, we have set up an NTP server and an optical telephone JJY system for use in the event of the supply services at NICT going offline.

The launch of this JST sub-station at Kobe means that the generation of Japan Standard Time is now multiplexed, making it much more reliable.

Fig.1 : The Japan Standard Time system at the JST sub-station at Kobe(left: Antenna of satellite time comparison system, right: Measurement system)

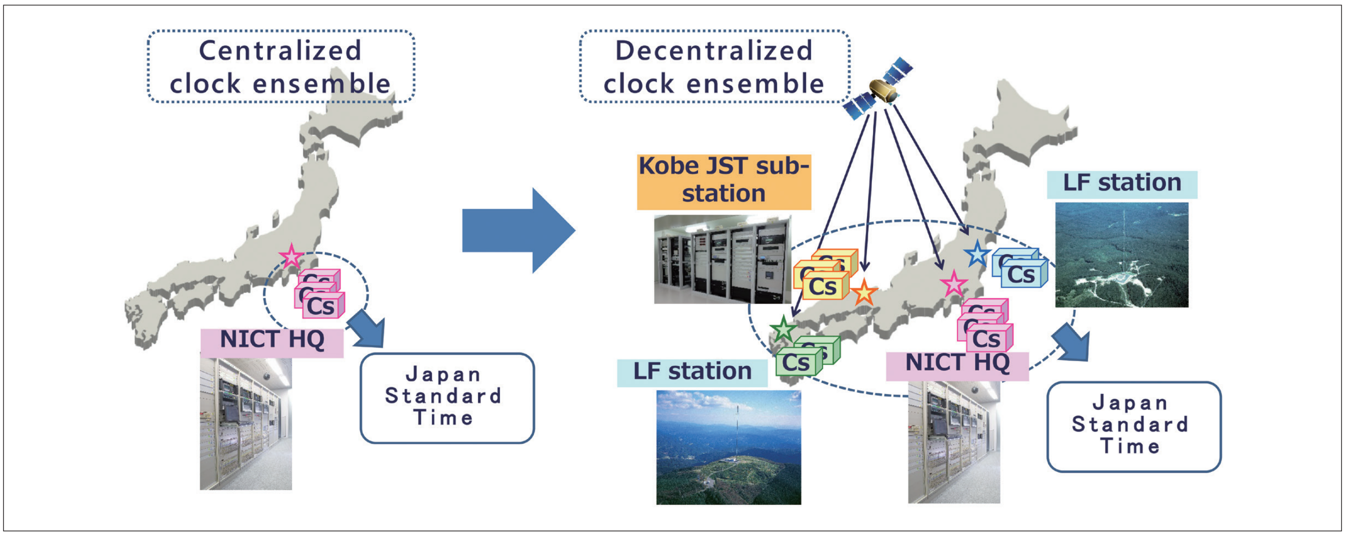


Fig.2 The distributed synthesis of Japan standard Time

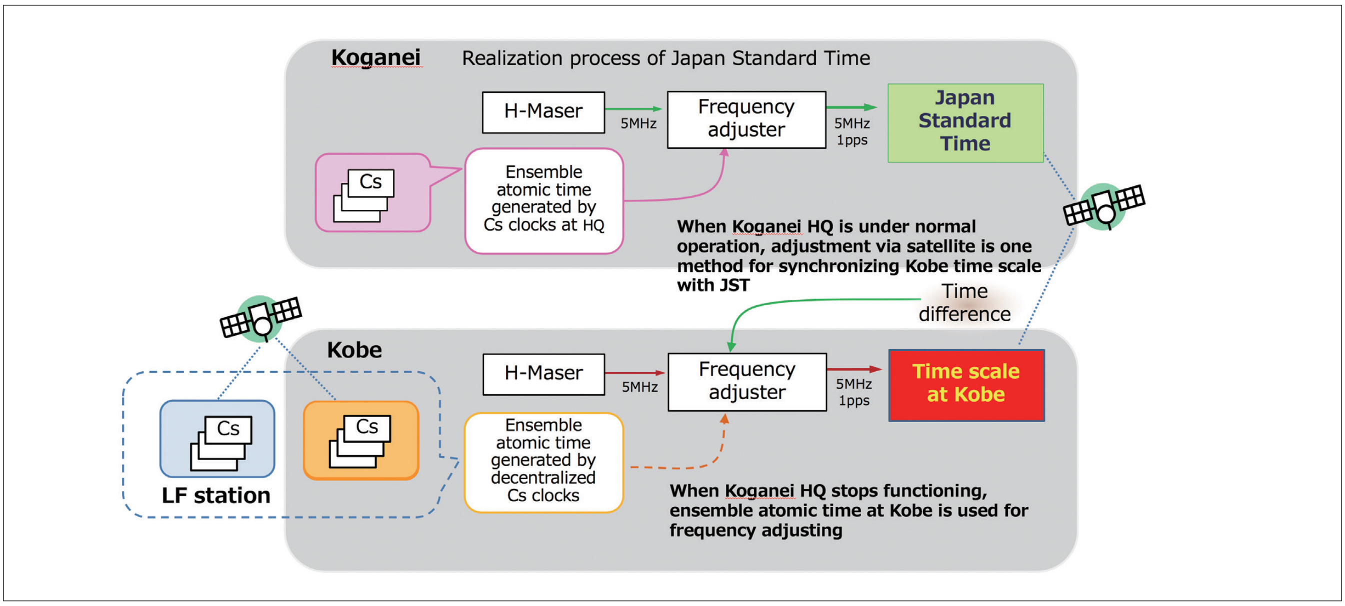


Fig.3 : The operation scheme of Japan Standard Time

CREATE

Aiming for further translation accuracy in the medical field

Augmenting VoiceTra with translation data from the MSD Manual (medical dictionary)

Eiichiro Sumita: Advanced Speech Translation Research and Development Promotion Center

In recent years, the use of artificial intelligence (AI) in speech translation technology has been actively researched, and products and services based on this research have also started to appear on the market. The VoiceTra*1 system figure developed by NICT uses AI to provide highly accurate multilingual speech translations on various themes such as tourism, healthcare, and shopping. Nowadays, the number of foreign visitors to Japan is growing year by year, and there is a growing need for medical translation services when these visitors fall ill during their stay. There is consequently a need for multilingual data covering a wide range of medical conditions in order to provide more robust translations in the medical field where precision is particularly important.

Under these circumstances, NICT and the pharmaceutical company MSD K.K. (based in Chiyoda-ku, Tokyo) have agreed to provide data in ten languages from MSD's digital medical dictionary (MSD Manual Consumer Version)*2 for use in Translation Bank (a translation data collection initiative being undertaken by the Ministry of Internal Affairs and Communications and NICT), and to cooperate in the strengthening of the AI speech translation engine. Through this joint effort, the quantity of medical translation data in VoiceTra has been increased by a factor of 3 or 4, and we can expect a substantial improvement in translation accuracy.

"We can expect to make great progress overcoming language barriers in the medical field."

In the words of Dr. Eiichiro Sumita, a NICT Fellow who has been researching speech translation at NICT for many years,

"As part of the global communications plan of the Ministry of Internal Affairs and Communications, NICT is promoting speech translation technology that is more precise and supports more languages and disciplines. By training a voice translation system with the MSD manual, which has been collecting the latest medical information in multiple languages for 120 years, we can expect to make great progress overcoming language barriers in the medical field."

An updated version of VoiceTra reflecting the MSD manual data is scheduled to be made available in the fall of 2018.

Footnote

***1 VoiceTra:**
A multilingual speech translation app developed by NICT. Provides highly accurate speech translation in 31 languages for free. http://voicetra.nict.go.jp/

***2 MSD Manual:**
A comprehensive medical dictionary provided by MSD for the benefit of society. Widely used throughout the world, and has been translated into 10 languages. https://www.msdmanuals.com/en-jp (Note: MSD is a trade name of Merck & Co., Inc., with headquarters in Kenilworth, N.J., U.S.A.)

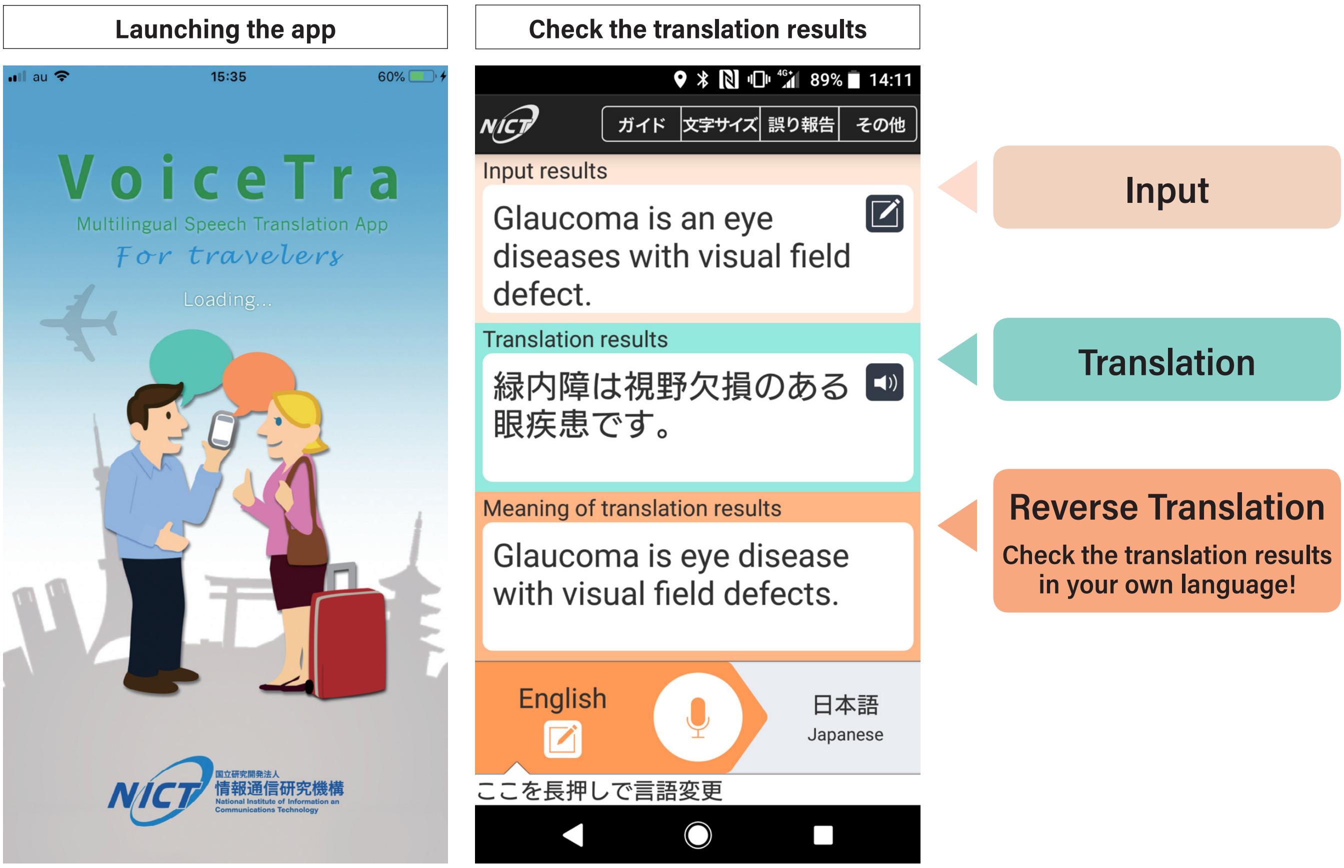


Fig. : "VoiceTra" translates your spoken words into different languages.

CONNECT

Multimode/multicore fiber system for practical optical communication infrastructure

World-record, 1.2Pb/s transmission through <0.2mm three-mode/four-core fiber was demonstrated

In order to cope with ever-increasing communication traffic, research on large-scale optical transmission using new types of optical fibers that allow exceeding the limit of conventional optical fibers and their application are actively conducted all over the world. The main new types of optical fibers studied are multicore fibers, in which multiple passages (cores) are arranged in an optical fiber, and multimode fibers that support multiple propagation modes in a single core with a larger core diameter. Ultimate throughputs of several

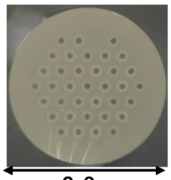
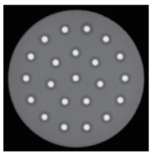
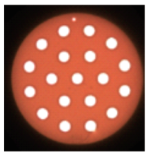
	Previous hybrid fibers			This report	SSMF
	2015, Mar.	2015, Sep.	2017, Sep.	2018, Sep.	
Throughput (bps)		2.15P	10.16P	1.2P	0.15P
Core/mode	36core/3mode	22core/1mode	19core/3mode	4core/3mode	1core/1mode
Cladding diameter	 0.3mm	 0.26mm	 0.267mm	 0.16mm	 0.125mm
Coating diameter				0.25mm	0.235~0.265mm

Fig. : Comparison of 3-mode/4-core fiber with previous fibers

Peta-b/s have been achieved by using hybrid of multimode/multicore fibers. However, such fibers were required to have much larger cladding diameter than standard single-mode fiber. To achieve practical implementation, the fiber cladding diameter must be reduced to less than 0.2mm to ensure the necessary reliability standards, mainly regarding mechanical strength.

NICT Network System Research Institute (NSRI), Fujikura Ltd. (Fujikura, President: Masahiko Ito) , Hokkaido Univ. (President: Toyoharu Nawa), and Macquarie Univ. MQ Photonics Research Centre (MQ)developed a three-mode four-core optical fiber, capable of wide-band wavelength multiplexing transmission with 0.16 mm cladding diameter (coating diameter: 0.25 mm) that can be easily cabled with existing equipment. They have successfully demonstrated a transmission experiment with a data-rate of 1.2 Peta-b/s. This is the world record throughput with an optical fiber with a cladding diameter below 0.2mm.

Thinner fibers have several advantages such as volume productivity from same size of preform, less failure probability and loss in fusion splicing, in addition to mechanical strength. Also, the core number of four has an affinity to data center communications.

In order to achieve the transmission capacity of 1.2 Peta-b/s, mode and core multiplexing in a single optical coupler was used in combination with 256-QAM (quadrature-amplitude modulation), which is a high-end practical high-density multilevel modulation optical signal, for a total of 368 wavelengths. Digital MIMO (multiple-input and multiple-output) enabled unscrambling the mixed modal signals for each individual core. This showed that multimode/multicore fiber which have compatible diameter with SMF can provide Peta-b/s transmission capability.

"This is promising for commercialization inter/ intra-data center applications"

Yoshinari Awaji and Hideaki Furukawa, both Research manager of the NSRI Photonic Network System Laboratory have stated: "We succeeded in Peta-b/s transmission with much thinner fiber than before. When laying of standard outer diameter optical fibers takes place, the existing equipment for cabling can be used and the practical use at an early stage is promising. Such kind of transmission system can be applied to inter-/intra- data center applications earlier, then the transmission distance will be extended toward metro-area applications in the future if combined with brand-new fiber fabrication technology, which is researched by NICT through Industry-University-Government Cooperation."

The demonstration shows that SMF-compatible-diameter multimode/multicore fibers can increase the capacity potential for eight times within same cable accommodation space. They say, "We will continue to research and develop future optical communication infrastructure technologies which can smoothly accommodate traffic such as big data and 5G services and beyond."

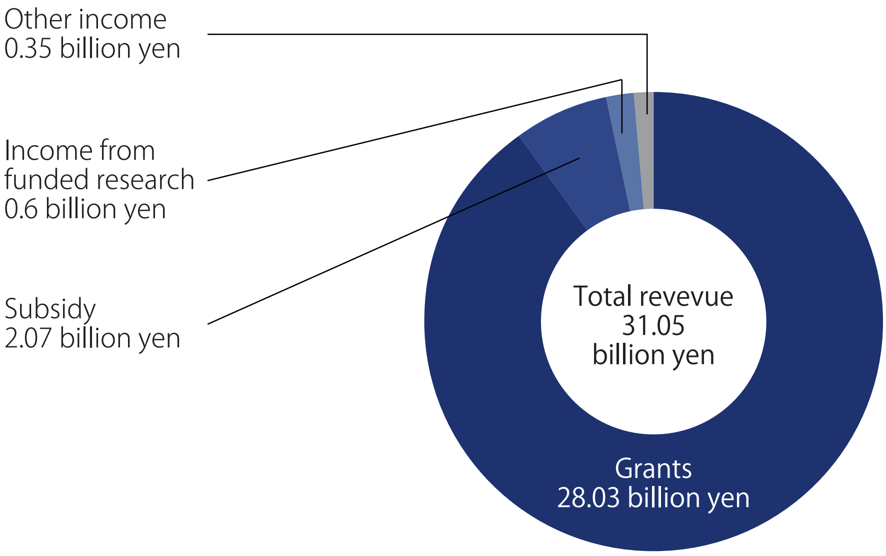
Reference

Ruben S. Luís, Georg Rademacher, Benjamin J. Puttnam, Tobias A. Eriksson, Hideaki Furukawa, Andrew Ross-Adams, Simon Gross, Michael Withford, Nicolas Riesen, Yusuke Sasaki, Kunimasa Saitoh, Kazuhiko Aikawa, Yoshinari Awaji, and Naoya Wada, "1.2 Pb/s Transmission Over a 160 μm Cladding, 4-Core, 3-Mode Fiber, Using 368 C+L band PDM-256-QAM Channels," in Proc. 44th European Conference on Optical Communication (ECOC), September 2018, paper Th3B.3.

Budget

The original budget for FY2018

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



Total expenditure for FY2017 was 51.78 billion yen in a reported basis.

Yen-dollar conversion ratio: 107.6yen/dollar (Aplil 2018)

Work Force

1093 (as of April 1, 2018)
(Including fixed term enployees)

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
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

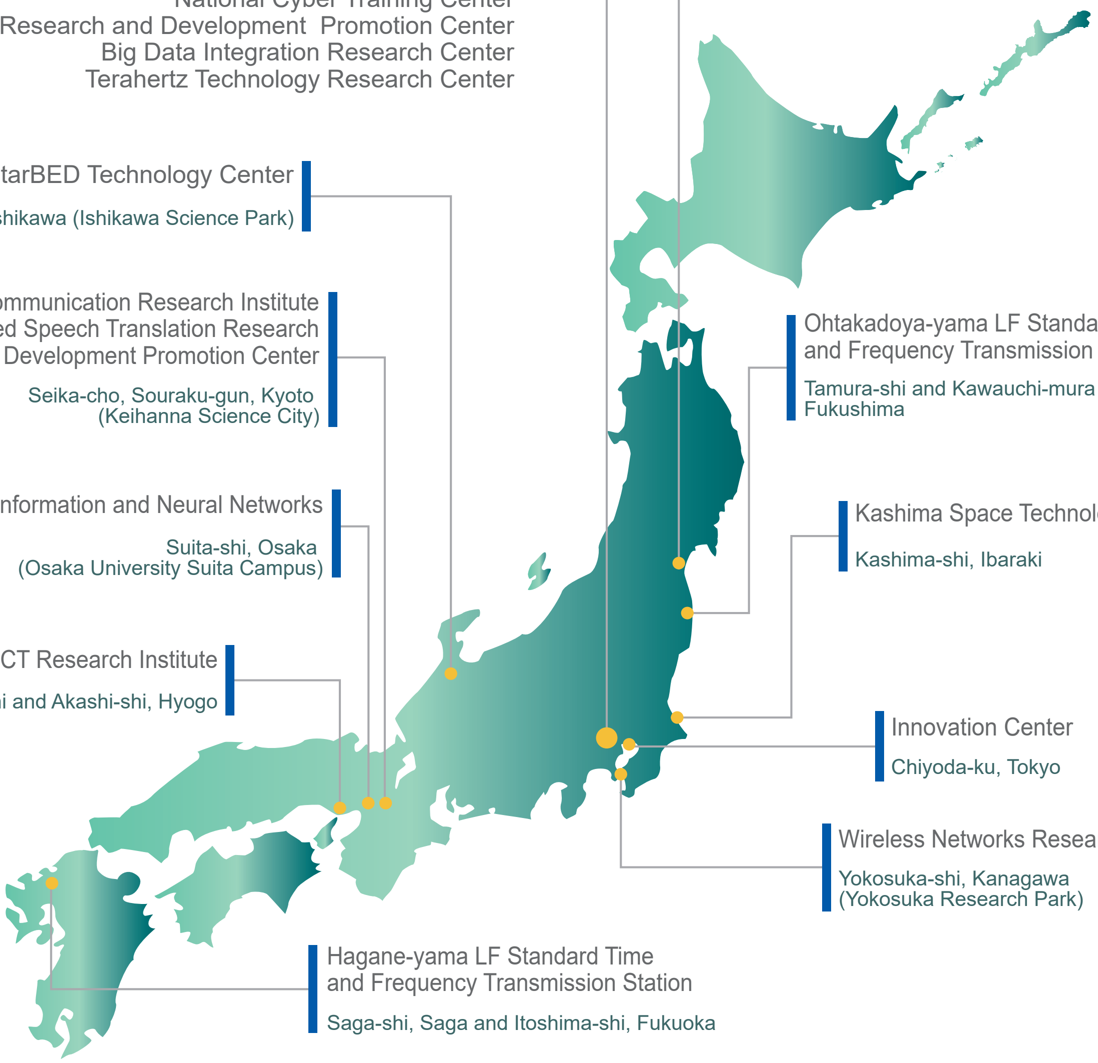
Kobe-shi and Akashi-shi, Hyogo

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 Centers

Asia Center
North-America Center
Europe Center

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

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