Research & Development

R&D that helps to enhance corporate value

We will continue to advance research and development so that the fruits produced by IOWN can be quickly delivered far and wide to everyone.

Executive Vice President,
Head of Research and Development Planning
Atsuko Oka

ICT is making remarkable progress, developing a wide range of services and leading various transformations. ICT is also changing styles of living and working, creating a new common sense. Individuals can now easily send out information, and diverse values are spreading. At the heart of these changes is DATA (information). The world is transforming into a data centric society where data create values and all activities are decided in a data-driven approach.

Due to this, the volume of data continues to expand rapidly. To process data, large amounts of computing resources are being deployed. As a result, power consumption is dramatically increasing. It is expected that the amount of data will continue to grow in the future. Efforts to reduce power consumption are being made in various areas, but we are approaching to the limits.

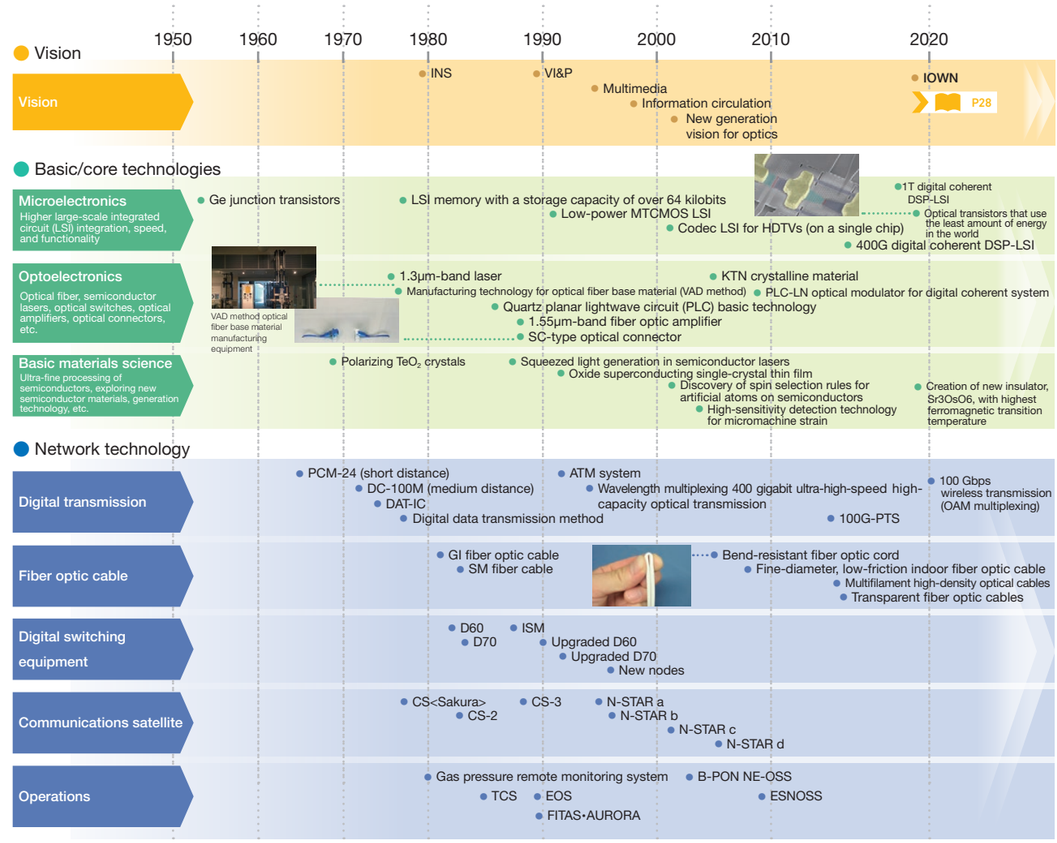
To address this issue, NTT announced the IOWN initiative in 2019. This is an initiative for creating a next-generation communication infrastructure characterized by ultra-high capacity, ultra-low latency, and ultra-low power consumption, utilizing innovative optical technologies. Optical technologies have been widely used in the field of communications, so-called optical fiber. Compared to electricity, optical technologies consume very little power regardless of the communication distance and speed (frequency). The IOWN initiative brings about changes in computing as well as communication by utilizing optical technologies.

IOWN will create a wide variety of services and new value not only in the telecommunications field, but also in transportation, medicine, finance, education, and many other fields. Collaboration with partners in each field is imperative for the realization of IOWN. It is also essential to make IOWN products available to the public as quickly as possible. To achieve this, NTT will soon provide the IOWN testing environment, jointly develop IOWN-compatible services with partners and aim to commercially deploy these services. At the 2025 World Exposition in Osaka, Kansai, we will showcase a unique experience, the beginning of the new era powered by IOWN, to the people around the world. I hope you will look forward to the progress of IOWN initiatives which paves the way to the next generation.

NTT R&D: History and Initiatives

At NTT, approximately 2,300 researchers have conducted a broad, diverse range of research, from basic research to R&D that underpins business development, giving rise to world-leading technologies and services and contributing to the development of society, industry, and academia. Beginning with the creation of networks to support telephone services that connect people, we have brought about an evolution in networks to create high-speed broadband optical and wireless networks that connect people to information, and this culminated in the information-based society of today.

Creation of new networks is also supported by the fruits of research and the development of basic and core technologies such as optoelectronics, microelectronics, and basic materials science, which transcend the limits of conventional signal speeds and transmission capacity.

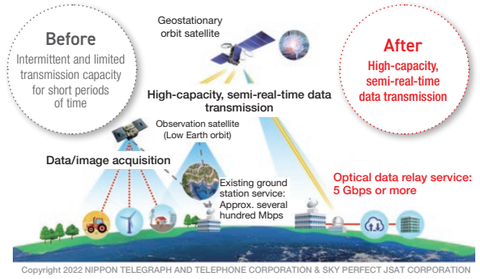


The results we have achieved in research and development in various fields, such as the communications technology and basic technology that we have cultivated, have developed into photoelectric merging technology, among others, which has culminated in IOWN.

Space integrated computing network

To establish sustainable economic and social activities, it will become ever more important to effectively maximize the use of stratospheric and near-Earth space as an ICT infrastructure platform in a diverse array of fields such as energy, environment and climate change, disaster prevention, marine infrastructure, and security.

Based on the "Space Integrated Computing Network Concept," NTT will take on the challenge of building new infrastructure, beginning with an optical wireless communication network to be constructed in space and a mobile network to be constructed in the stratosphere.



Research & Development －R&D that helps to enhance corporate value

The Bible of IOWN

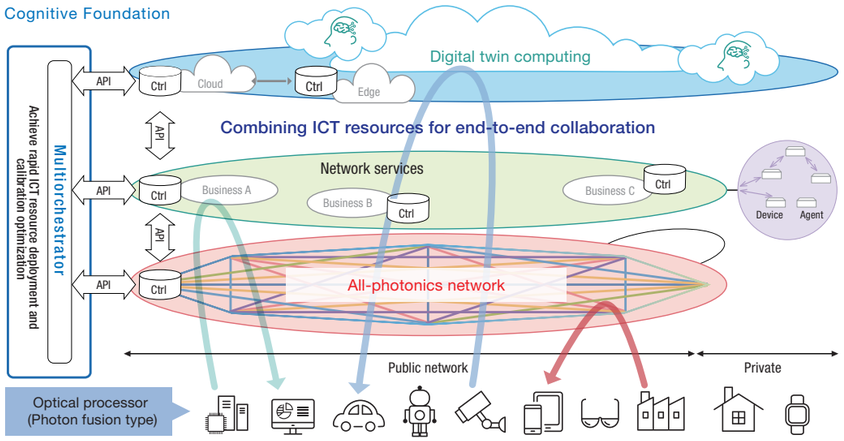
An in-depth analysis of IOWN! I will answer the questions we have received from our shareholders and investors!

Head of NTT IOWN Integrated Innovation Center
Hidehiro Tsukano

Our next-generation communication platform concept being developed with the goal of practical application in 2030

IOWN (Innovative Optical and Wireless Network)

Framework involving devices, networks and information processing infrastructure built on optical and other innovative technologies, to deliver high-speed and high-capacity communications, and vast computing resources. IOWN consists of three main components: an All-Photonics Network (APN), which applies optical technology; a Digital Twin Computing (DTC), which enables advanced, real-time interaction between objects and people in cyberspace; and a Cognitive Foundation (CF), which deploys various ICT resources efficiently, including the aforementioned.



Low power consumption	High quality and high capacity	Low latency
Power efficiency: **100 times higher***	Transmission capacity: **125 times higher***	End-to-end delay: **1/200***
Transmission media: Optical fiber cables Transmission systems: Light (wavelength) throughout Information processing platform: Photonics-electrics convergence devices	●Wavelength (optical signal) Independent Light → Light → Light Light/Light Wavelengths Optical fiber 1000	●Transmission per wavelength ●No queueing ●No data compression Wavelengths A: High-capacity video (uncompressed) No latency Wavelengths B: Speech
Various information communication services are provided using 1/100th of power consumption	In an instant (0.3 sec), 10,000 two-hour movies can be downloaded (with 5G, one movie can be downloaded in three seconds)	Video is transmitted in real-time without the latency experienced with digital TV or satellite broadcast

* Target power efficiency for the photonics part

*Target transmission capacity per fiber optic cable

* Latency target value in video traffic not requiring compression in the same prefecture

Q1 Why is IOWN necessary? What benefits does it offer?

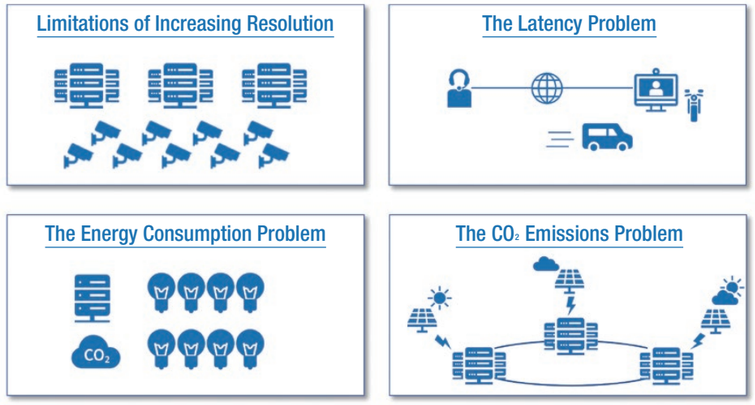
The development of digital technology has brought about a number of technological innovations, such as ultra-high definition images, but we believe that we must change our mindset to achieve further evolution. With IOWN, we believe it is important to try to grasp phenomena and information as they are through a more diverse set of values and perceptions, as opposed to filtering them through human-only values. Dr. Jakob von Uexküll, a German biologist, proposed the concept of the "self-centered world" ("Umwelt" in German), which states that all living things have a species-specific perceptual system, and that each has a world based on its own species-specific perception and acts as its own subject. The IOWN concept is based on the idea that different subjects see things in different ways, and that the information being conveyed and the processing method will vary according to the values of each subject. Thus, it aims to convey and process every bit of information in accordance with the values of each subject.

While dramatically low latency, enormous bandwidth, and very small latency fluctuations are required to make these new ideas a reality, the current internet is reaching its limits in terms of both transmission and processing power. Furthermore, power consumption continues to increase in tandem with the enormous amount of information being processed, and the increase in CO_2 emissions has become a serious global issue.

A flower as seen by a human (left)/A flower as seen by a bee (right)

NTT Group's vision of a high-capacity, low-latency, low-power-consumption infrastructure that can handle information as-is requires an end-to-end, full-stack redesign and optimization that breaks away from individually designed layers, from networking to computing.

The key to this is "photoelectric merging" technology. Conventionally, optical signals and electronic signals have had their roles completely separated into "transmission" and "processing," respectively, and the task of converting the two types of signals is inefficient and consumes a lot of power. If we tightly integrate optics and electronics, we can apply optical technology to the entire system, down to the processor level, and we can rethink the architecture (structure) from a full stack perspective.



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Q2 What are the areas in which NTT is particularly strong or enjoys an advantage?

I think the optics-related knowledge that NTT has accumulated over the years is a big advantage. What everyone is probably most familiar with is internet connection services using fiber optic cables, but NTT has long been researching the possibility of not only using fiber optic cables as a transmission medium, but using optics as a basis for transmission equipment and information processing. The results of these research projects are being put on a development track that brings them closer to commercialization, with the goal being practical applications.

In terms of recent achievements, the core of “photoelectric merging technology" is the ability to perform optical-electrical and electrical-optical conversion at ultra-high speeds and with ultra-low power consumption. In LSI, the input/output (I/O) consumes the most electricity, and the impact of replacing this with light is quite significant. Moreover, with electricity, power consumption increases rapidly as the distance over which signals are transmitted increases, but with light, power consumption does not increase very quickly. Thus, by utilizing light through photoelectric merging technology, it is possible to achieve not only ultra-high speeds, an original characteristic of light, but also ultra-low power consumption.

A typical example is the optical transistor developed by NTT in 2019, the first in the world to combine ultra-high speeds with ultra-low power consumption. A transistor is a conversion device that can output an electrical signal in its proper form by providing it with a control signal. Converting signals is called switching. Conventional light-switching devices are huge and cost several hundred billion yen, but now that optical transistors have been created, they have been reduced to the size of a piece of chewing gum.

In addition, the research and development of optical transistors involves not only signal processing technology, but also the creation of optical modulators. This requires know-how regarding stabilization at high accuracy so as not to disturb the spectrum of a certain wavelength, which is an analog technology that is part of a cottage industry. The fact that we are now able to connect long distances with light is largely due to utilization of our technology.

To cope with the increase in data volume and power consumption, a structural evolution from electronic processing to optical transmission is essential, and the breakthrough in the technology supporting this structural evolution hinges on the higher precision, smaller size, and lower cost of optical transistors. Therein lies NTT’s advantage.

Q3 How will IOWN technology be implemented? What sorts of business models can you envision?

IOWN will be available in a variety of domains, but here are two easy-to-understand scenarios.

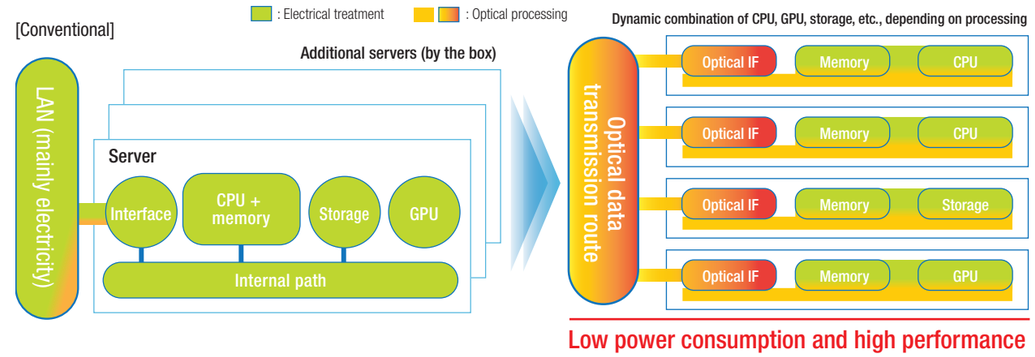
First, let’s consider the interior of a data center, disaggregated computing. A personal computer has a similar structure, but a server has an interface, a CPU, memory, and storage. The current trend is for the CPU to issue instructions, temporarily store information in memory, and then store the information resulting from its calculations in storage. The CPUs used to be run by electrical signals, but by directly connecting accelerators such as GPUs and DPUs via light and linking them with different wavelengths, it is no longer necessary for each server to have its own CPUs and memory. CPUs are located in one chassis and memory in another, and connecting them via light makes it possible to create a situation in which it appears as if a very large amount of CPUs and memory are installed on a single server. This allows for a scalable computing infrastructure with ultra-low power consumption, high-speed processing, and the ability to add as many parts as required.

One potential business model in this case would involve selling optical transistors. In addition to the optical transistors themselves, products that incorporate photoelectric merging technology and optical modulators into computer motherboards and semiconductor packages are also a possibility. Essentially, we would be selling key components.

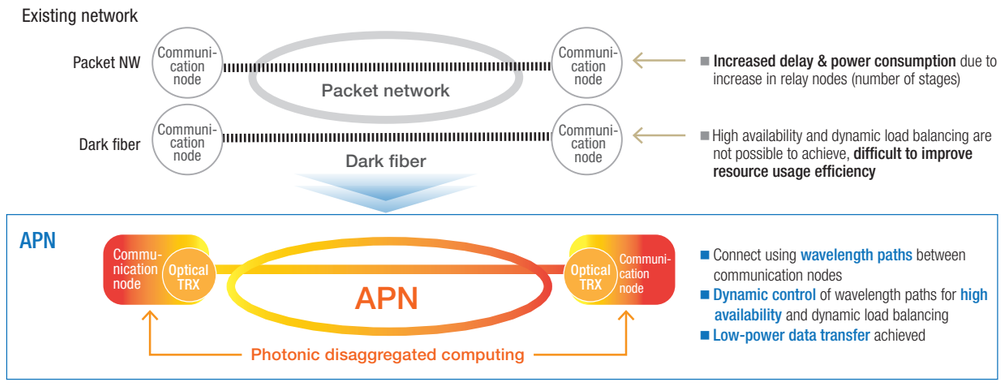
Next, we will expand the scope somewhat to include all-photonics networks, which utilize light between networks, and areas outside the data center. Optical transmission technology used in the core of relay systems that connect cities and in metro networks that extend throughout cities can be expanded to the end user's neighborhood, which would allow for flexible configuration of ultra-high-capacity optical paths, such as a “one wavelength per person” model, for each application. It would be like having a dedicated, on-demand, one-to-one optical line with no video compression and almost no delay in transmission and reception.

APNs could be used for the mobile fronthaul portion that links base stations and mobile antennas. In urban areas, the population changes depending on whether it is day or night, so traffic volumes will inevitably vary. For this reason, load balancing, which dynamically constructs optical paths, can be used to reduce power consumption.

● Photonic disaggregated computing

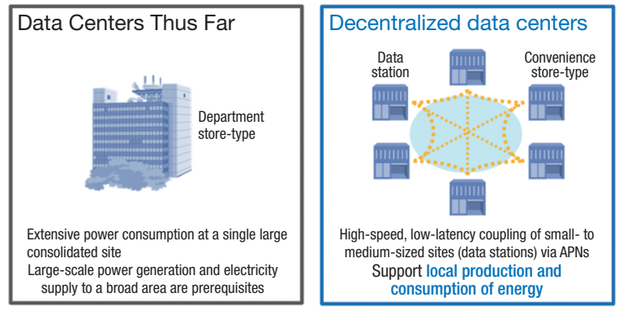


● All-photonics network (APN) characteristics



APNs can also be used as lines linking data centers. These days, it is difficult to set up large data centers that require enormous amounts of power. In the future, small- and medium-sized data centers will be dispersed over a broad area, and it will be necessary to connect these distributed data centers using light so that they can operate at a level comparable to that of large-scale data centers. Large-scale data centers require enormous amounts of electricity, but if spread out, they can also make use of renewable energy generated close to their locations, thus enabling local production for local consumption of energy.

Potential business models for cases in which APNs are provided include: acting as an infrastructure service provider, such as providing mobile fronthaul and networks between data centers; a data center business that provides distributed data centers connected by APNs; and a product business selling optical transceivers to be installed in data centers edges.



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The Bible of IOWN

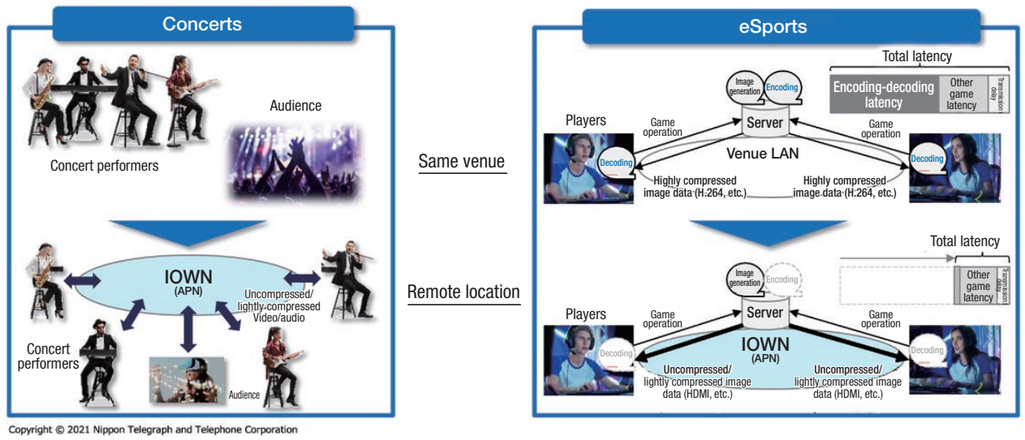
Q4 What are some use cases you currently have in mind?

While (1) providing interconnect solutions for data center operators and (2) providing mobile networks for mobile operators have already been introduced, (3) providing networks for events (live broadcasts, cloud-based e-sports broadcasts) is another potential use case.

We have already conducted demonstration tests for cloud-based e-sports event broadcasts. Competitive games via the cloud are fought in real time, and it will be essential to exchange large amounts of 8k video data with a delay of less than 20 ms. A delay of a few milliseconds compared to a delay 10 times that amount will result in a different attack timing. It is impossible to fight within a game in an environment where the timing of attacks is off due to delay. The delay in the demonstration test was 20 ms, but we are making efforts to lower this to a few milliseconds, and we are currently developing a system that can control the delay in 1-μs increments to enable synchronization.

● Virtual reproduction of real life (concerts, eSports)

- Reproduction of events offering two-way exchange of high-definition video and audio within a virtual space
- Low-latency data exchange allows for those at remote locations to have the same experience as those at the venue



IOWN GLOBAL FORUM Linking Companies and Academic Institutions Across the Globe

In response to the interest from such organizations, we established IOWN Global Forum, Inc., a new industry forum based in the United States, together with Intel Corporation and Sony Corporation in January 2020. This forum has grown to boast membership by 101 organizations as of August 2022.

IOWN Global Forum's objective is to accelerate the adoption of a new communication infrastructure that will bring together an all-photonic network infrastructure including silicon photonics, edge computing, and wireless distributed computing to meet our future data and computing requirements through the development of new technologies, frameworks, specifications, and reference designs.

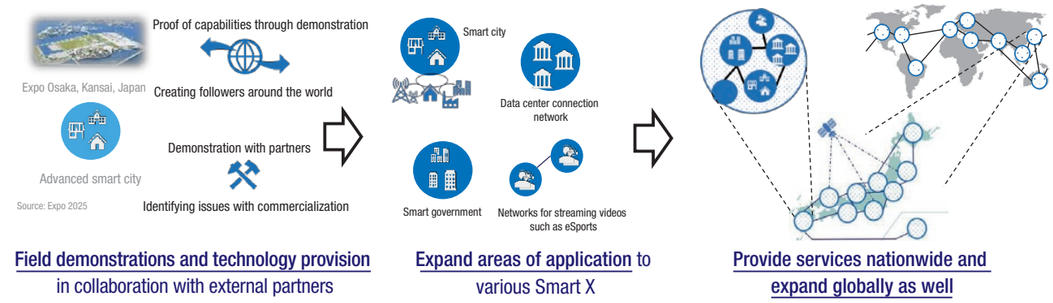
IOWN GLOBAL FORUM™

Q5 What are your schedule and milestones going forward?

We hope to conduct early demonstrations of the aforementioned use cases, receive feedback from customers, and further refine the IOWN technology. Then, starting around 2024, we will proceed with field demonstrations and limited introductions to users and areas that have a need for advanced services, such as smart cities and critical infrastructure. Around 2026, we will expand the scope of application, though it will still be limited to specific uses and areas. After 2030, we will expand the service nationwide and even globally by connecting areas where it has already been implemented.

Also, an important event coming up in the near future is the Osaka Kansai Expo 2025. We hope to convey a part of our IOWN-based worldview in an easy-to-understand manner, combining some of the IOWN technologies we have mentioned thus far with existing technologies as well. In doing so, we hope to present a new kind of value through partnerships with various companies and organizations, which will lead to these technologies subsequently being implemented throughout society.

● IOWN Expansion Roadmap



Field demonstrations and technology provision in collaboration with external partners

Expand areas of application to various Smart X

Provide services nationwide and expand globally as well

IOWN is a very broad concept, and many of its aspects may be difficult to understand. IOWN is an innovative concept based on light that communicates and processes things as-is and helps to create a new smart society with low energy consumption and sustainability that is not possible with our current internet. Of course, there are still a great many issues to be resolved, but we are determined to work hard and show everyone the results of our efforts.

Research & Development －R&D that helps to enhance corporate value

Providing security and safety for NTT Group's businesses and supporting their growth

Intellectual property strategy

We believe that for NTT Group to both grow and contribute to society, it is essential to protect the results of our intellectual property investments properly and utilize them while respecting the intellectual property of others.

NTT Intellectual Property Center Activity Policy

NTT Group, which engages in research and development, from basic to applied, in a wide range of technological fields, has accumulated intellectual property investments (R&D investments) over the years as a telecommunications operator that are unparalleled around the globe.

The NTT Intellectual Property Center has established an Activity Policy to provide security and safety to NTT Group's businesses, which is on the verge of expanding globally under the slogan of “Your Value Partner,” and to support its growth. The Center formulates intellectual property strategies, provides appropriate protection for the results obtained through intellectual property investments, and promotes the use of intellectual property while respecting that of others.

IOWN, which is generating significant expectations and interest both at home and abroad, is not something that NTT Group can achieve on its own. Through an array of activities in line with our Activity Policy, we will support collaboration with our partners to address various social issues from a global perspective.

Formulating and Advancing Our Intellectual Property Strategy

The NTT Intellectual Property Center is NTT Group’s core organization for managing intellectual property. The Center aims to secure competitive advantages by proactively and appropriately protecting and managing intellectual property rights (i.e., patents), or internal expertise, from the results of R&D, the source of all business activities.

NTT aims to share the benefits of its R&D by broadly licensing out its technologies that help advance industry and technologies can be standardized and used throughout society. When deploying the results of R&D in their operations, each company in NTT Group respects the intellectual property rights of other companies.

With our intellectual property strategy as the basis of these activities, we take a three-pronged approach to formulating and advancing our business strategies and R&D strategy, based on our medium-term business strategy and vision: (1) develop strategic intellectual property rights, (2) manage risks, and (3) deploy the intellectual property we own.

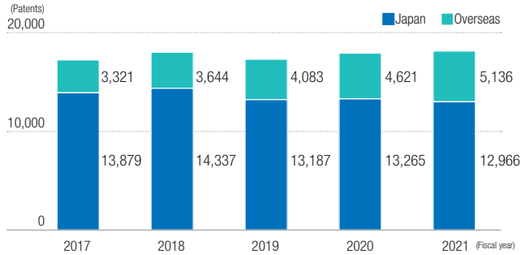
① Strengthening our competitiveness with strategic rights creation (build an intellectual property portfolio)	• Build an intellectual property portfolio through the strategic development of intellectual property rights from fruits of R&D activities, based on technologies and anticipated business models
② Risk management that protects our intellectual property rights and respects the rights of others	• When Group companies deploy the results of R&D in their operations, we examine the intellectual property rights of others inside and outside Japan up until the stage where R&D results are applied in order to avoid infringing on the rights of third parties • Reduce business risk and comply with laws and regulations related to intellectual property rights, by sharing among Group companies information about intellectual property trends and their impact, such as revisions to systems around the world, cases of conflict and court decisions
③ Develop business and partners through broad deployment of intellectual property rights	• Deploy intellectual property in business to help our customers and society, and to secure competitive advantages in business • Proactively engage in activities to standardize intellectual property

Intellectual Property Portfolio

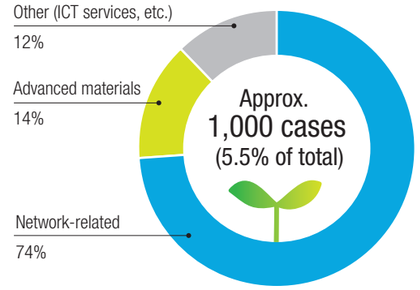
The results of R&D, which plays a major role in the creation of intellectual property for NTT Group, has translated into ownership of approximately 18,000 patents around the world.

The NTT Intellectual Property Center is not only responding to NTT Group's global business by strengthening overseas patent applications, but also working to obtain rights to a wide range of energy reduction technologies, such as photonics-electronics convergence technologies that will advance carbon neutrality, which IOWN aims to achieve by FY2040.

● Number of NTT patents held



● Number of patents held by NTT in energy reduction-related technologies



Open & Closed Strategy (Initiatives related to Standard Essential Patents)

IOWN will not be achieved via a limited number of companies whose core business is information and communications technology. In fact, companies and organizations in various fields active around the world have gathered at the IOWN Global Forum to discuss use cases and technical specifications for making IOWN a reality. In these discussions, it is important to clarify open (cooperative) and closed (competitive) areas while working toward the same goal. In open areas, for example, it is essential to define technology standards to achieve stable communication between devices from different vendors (standardization).

While NTT laboratories play a central role in proposing NTT technologies as standards, the NTT Intellectual Property Center is working to enhance its Standard Essential Patents (SEP) in coordination with these activities. SEPs are patents that must be used in the manufacture and sale of products and provision of services that conform to certain standards. The NTT Intellectual Property Center provides a secure platform for handling standardized technology rights by participating in and establishing patent pools, whereby companies and organizations in collective possession of SEPs manage patent royalties and other conditions, thereby maintaining relationships of trust with other companies and contributing to the safe and secure business operations of NTT Group.

● Open & Closed Strategy Summary