# IOWN ACCELERATION —Imagination and Creation—

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**Abstract**

This article introduces NTT research and development (R&D) efforts from two perspectives: the "product-out" approach and the "market-in" approach. It is based on the keynote speech given by Sachiko Oonishi, executive vice president, head of Research and Development Market Strategy of NTT Corporation, at the "NTT R&D FORUM 2023 — IOWN ACCELERATION" held from November 14th to 17th, 2023.

*Keywords: IOWN, R&D, food, health, humanity*

## 1. Introduction

The Research and Development Market Strategy Division in NTT Corporation was inaugurated in June 2023. Our mission is to create new value by fusing our traditional "product-out" research and development (R&D) approach with marketing. This article introduces our R&D work from two perspectives: the product-out approach and the "market-in" approach.

The Innovative Optical and Wireless Network (IOWN) has grown out of exploring and exploiting technologies that connect people, which originated from the telephone. It is the result of the product-out approach to R&D. There is also the market-in approach, in which we create a vision of people, society, and the planet and of how we can create a future that is sustainable yet also exciting to live in then push forward the kind of R&D we need to make this vision a reality.

A technology truly takes its first breath when it is implemented as part of society. Four years since the announcement of IOWN, I hope that you can now feel this idea coming to life and can create in your minds a mental picture of the exciting future that will ultimately make it possible.

## 2. NTT's R&D from the product-out perspective

### 2.1 The starting point of technologies that connect people

**Figure 1** shows the very first telephone (in Japan) back in 1890, 133 years ago. This is the starting point of technologies that "connect people." When you telephoned someone in those days, how long did it take before you could actually start talking? You couldn't dial these early phones; after lifting the receiver, you had to connect to an operator. It worked as follows: in the morning, say, you'd tell the operator "Can I speak to Ms. A, please?" and in the evening, 6 hours and 7 minutes later, you'd finally get to talk to Ms. A. You could also pay double the fee for an "urgent" connection, which took only 2 hours and 26 minutes.

Following this first phase of telephone development, the Electrical Communication Laboratory under the Ministry of Communications was inaugurated 75 years ago. In 1966, our research into optical technology and optical fibers began. These technologies that connected people have ultimately made it possible to connect people and information, people and objects, and the real and virtual domains, and to

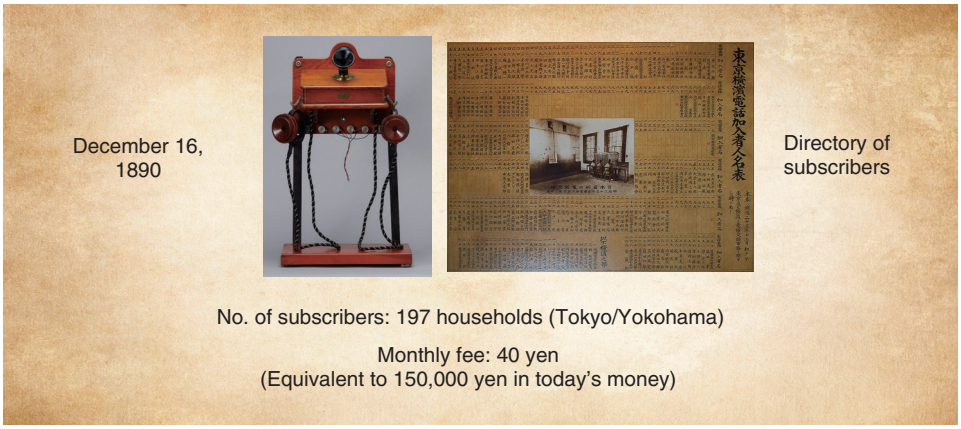
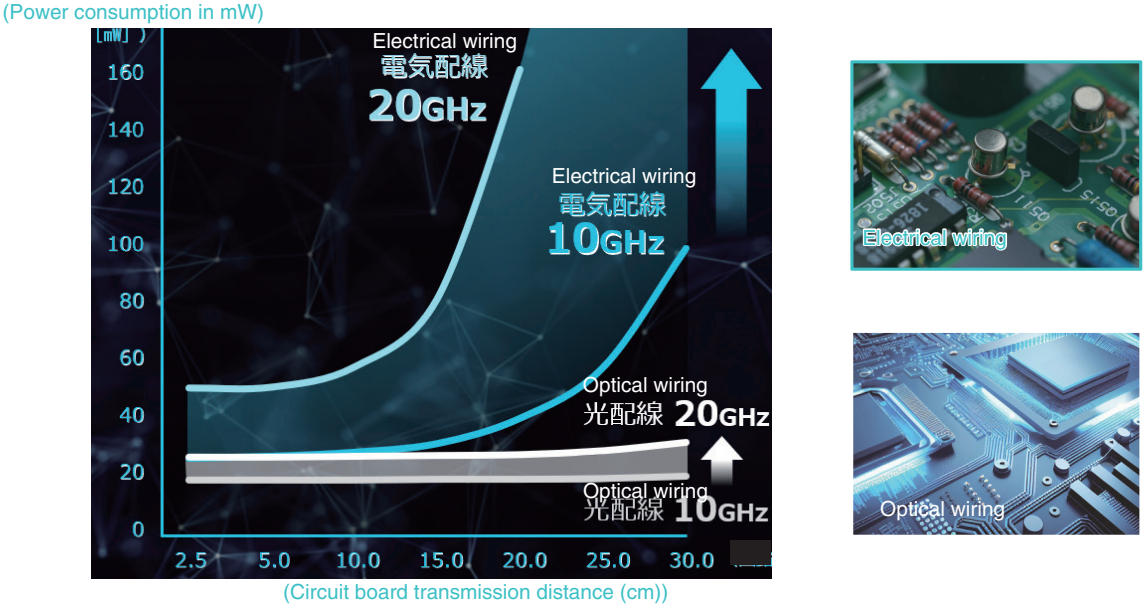



Fig. 1. The very first telephone in Japan.




Source: NEDO, Material of International Symposium on Photonics and Electronics Convergence (2015.6.16).

Fig. 2. Difference between electrical and optical technologies.

transmit not just sounds but images, data, skills, experience, and spaces.

Our 50 years of research into optical technology have now culminated in the concept of IOWN. This concept is about using light not just for conveying information but also in processing layers. Let us look at the differences between electronics and optical technology. As **Fig. 2** shows, with electronics, power consumption increases dramatically as transmission distance over circuits grows [1]. Moreover, as processing speeds increase, higher operating frequencies are also required, further increasing power consumption. However, with optical technology, even as the transmission distance grows longer and operating frequency increases, power consumption does not increase. This feature means power consumption can be reduced further by using optical technology not just for transmitting information but also in the information-processing layer.

By bringing optical technology into all layers from

the network to data-terminal processing, IOWN not only lets us reduce power consumption but also improve transmission capacity, quality, and latency. For example, the All-Photonics Network (APN) features optical technology end-to-end without the traditional switching between electronic and optical technologies, enabling latency-free speed and streamlined power usage. Let us use transport as an analogy. If you have to change trains several times to get to your destination, you are certain to arrive later. The APN works like taking the bullet train all the way to your destination, with no changes required.

At the Japan World Exposition, Osaka, 1970, the first cordless phone was exhibited, connecting people by transmitting sound. At this time, fixed landline phones were still the norm. Following the first-ever exhibition of cordless phones, pagers then cordless phones and smartphones quickly came into widespread use. At the Expo 2025 Osaka, Kansai, Japan, the IOWN APN will be used to transmit spaces in real time, by connecting NTT's datacenter (DC) with the NTT Pavilion venue. Using artificial intelligence (AI) to analyze the NTT Pavilion at the DC, we intend to virtually recreate the Pavilion, letting users experience the dynamically changing and exciting atmosphere of the real live venue.

### 2.2 Start of IOWN1.0

From the development of the first telephone, it took around 90 years for landline phones to become near-universal in Japan. With cars, it took 30 years for the penetration rate to exceed 80%, shrinking to 15 years for the Internet, and just 5 years for smartphones [2]. The household-penetration rate for services that have grown out of technological innovations is increasing faster and faster.

The growth of IOWN is also gathering speed. Our IOWN APN1.0 service was launched in March 2023, four years after the initial vision. As new services permeate people's lifestyles at an accelerating rate due to technological innovation, the power volume required for this is also growing faster and faster. Once generative AI is added as well, it is anticipated that by 2030 data volumes will have increased 16 times and power consumption 13 times from 2018 levels [3].

With demand for DCs continuing to grow as a result of this, demand forecasts at DCs already anticipate supply shortages [4]. Power consumption at DCs in the Netherlands and Singapore now account for a large proportion of the total power consumption, creating a very difficult environment. There are even moves to block or limit construction of new DCs [5–8].

The IOWN APN is a way to break through this barrier. By creating distributed networks of DCs linked through low-latency connections using the APN, we can operate the networks like a single large DC. We believe that by creating distributed networks of small/medium DCs in available spaces, putting DCs in places where there is slack in the power demand or where local-energy-for-local-consumption is possible, and connecting these DCs using APN technology, we can reduce power shortages at DCs.

Whereas the maximum distance between DCs to avoid latency was previously limited to 60 km, the APN allows DCs to be placed up to 100 km apart. In the UK, verification testing of DCs in London and Dagenham (around 100 km away) connected by the APN is underway. As shown on the left of **Fig. 3**, there is a lack of space for establishing DCs within a 60-km range of London due to high land prices; thus, expanding the range to a 100-km radius should bring in lower land prices, enabling potential sites to be found.

IOWN, which has grown out of the exploration of connection technologies and product-out research outcomes, uses technological innovation to make the new digital information society more energy-efficient and sustainable, enabling a 100-fold increase in energy efficiency and 125-fold increase in transmission capacity.

## 3. NTT's R&D from the market-in perspective

I would like to talk about NTT's R&D from the market-in perspective. As the communication domain has grown to include not only sound but images, data, the sense of touch, and spaces, R&D's job is to discuss how these concepts can function in our lifestyles, in society, and across the planet, and how R&D can use these to resolve social challenges and build an exciting future. How will these concepts change our lifestyles regarding a specific sense; the food, clothing and shelter we use; our health; entertainment; energy; and ultimately humanity itself? I'm going to talk about three of these areas below.

### 3.1 Food

As we are all aware, we face growing risks to the stability of our food supply. Effects on our diet are already becoming apparent. With prices of processed foods and condiments increasing by 20% on average and grocery bills by 150 or 200% in one year, people

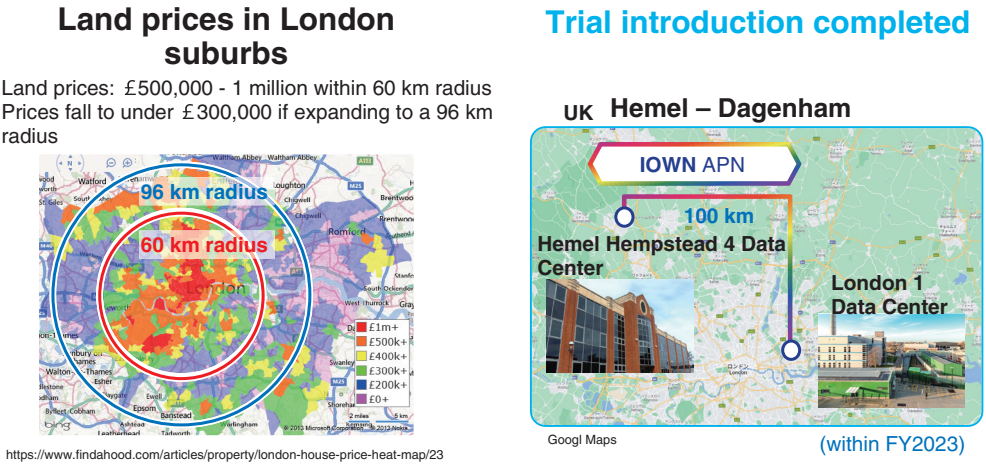



Fig. 3. Connecting DCs in London and Dagenham (around 100 km away) using the APN.

are now really feeling the pinch [9–12]. As you may know, Japan's food self-sufficiency rate is just 38%, 12th among the 13 major economies [13].

Japan's agricultural workforce has fallen to just over 70% of the number in 2000. The average age has increased to 68 [14]. Abandoned land has increased to 420,000 hectares, twice the size of Tokyo and 1.7 times the 1995 figure [15]. Yet in spite of population decline and challenging land and climate conditions, some countries are boosting their food self-sufficiency through innovation. The Netherlands is an agricultural superpower, yet 20% of its land is below sea level, and its agricultural land is just 40% that of Japan. Nevertheless, through widespread deployment of large-scale protected horticulture enabled through technological innovation, it has become the world's second-largest agricultural exporter. Although the UK's agricultural workforce has also declined, it has brought its food self-sufficiency rate up to 70% by developing agricultural science.

On the basis of technologies and solutions delivered by our R&D, NTT Group aims to create innovations in the food-value chain including breeding, agricultural production, livestock, fisheries, and distribution to create a stable supply of food. I will talk about three of these areas today.

### 3.1.1 Agricultural production and protected horticulture

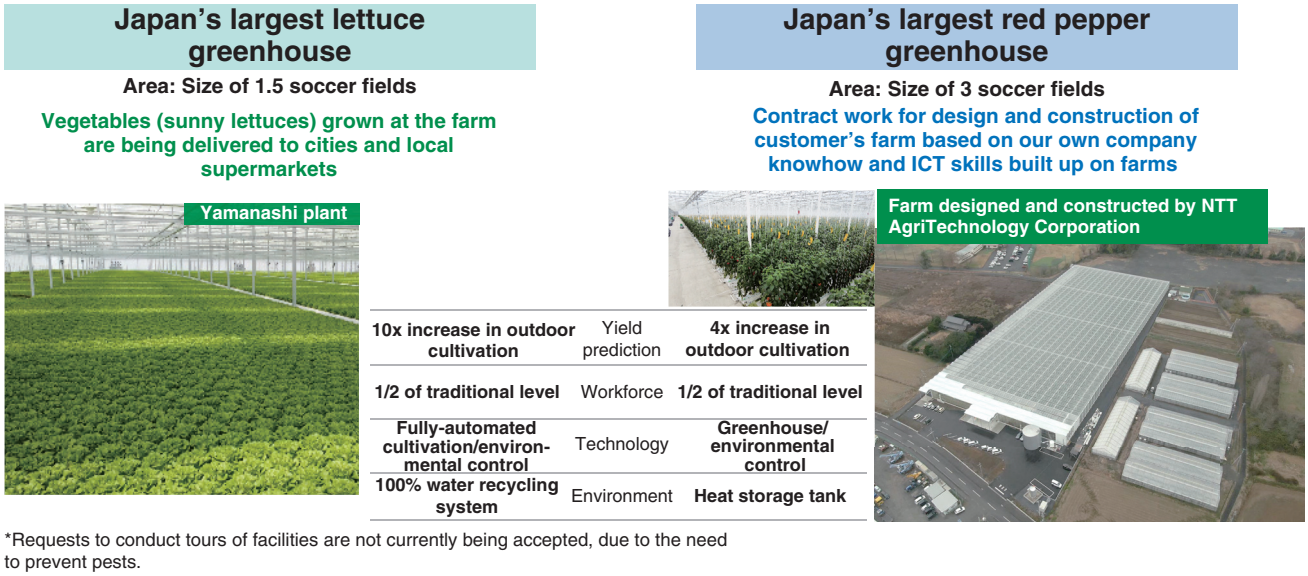
NTT AgriTechnology has set up Japan's largest lettuce greenhouse, the size of 1.5 soccer fields, for protected horticulture. We have succeeded in increasing yields more than 10-fold with half the traditional workforce. The expertise we have demonstrated has brought in inquiries from inside and outside Japan. The right photo in **Fig. 4** shows a farm we designed and constructed on contract after inquiries from a customer. This capsicum farm is the size of three soccer fields. The customer tells us that yields have increased four-fold with half the traditional labor. We are enabling both larger-scale agriculture and reduced labor needs and combining higher yields with a reduced environmental footprint.

We are also providing remote business support from our automation labs using high-definition video transmission and robotics, enabling those even with no cultivation experience to get started. By delivering agricultural support remotely, this system enables a single expert to provide assistance to several producers.

### 3.1.2 Produce distribution

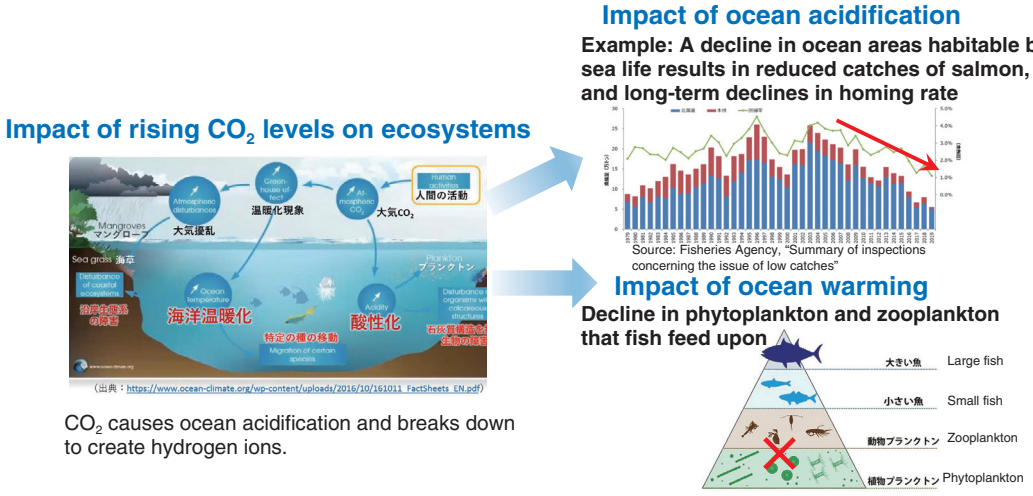
With prices undetermined, producers ship all produce to large markets where it is likely to be sold for high prices. Such produce is often taken a long way on all-day truck journeys, rather than going to markets closer to the places it was produced. Produce gathered together which remains unsold may then be sent on to another place, or in the last few years may even be thrown away because of failure to find enough trucks for distribution.

Using IOWN to enable more environmentally friendly produce distribution by analyzing and forecasting demand information for produce gathered in markets, we hope to ensure that produce will be sent to consumers in a higher state of freshness and only in the necessary amounts, reducing food losses and carbon dioxide ($CO_2$) emission. In our vision for the




*Requests to conduct tours of facilities are not currently being accepted, due to the need to prevent pests.

Fig. 4. Reduced environmental footprint due to 100% water recycling system.




$CO_2$ causes ocean acidification and breaks down to create hydrogen ions.

Fig. 5. Impact of rising $CO_2$ levels on ecosystems.

near future, we will help people enjoy better-tasting food with peace of mind by connecting experts with producers, operators with the actual places where produce is produced and sold, and producers with virtual markets, using IOWN to bring consumers fresh produce they will want to eat and which is better for the planet while also improving Japan's self-sufficiency rate in food.

### 3.1.3 Fisheries

Rising levels of $CO_2$ are causing the warming and acidification of the oceans [16]. With ocean warming reducing areas that are habitable by sea life, we are seeing long-term declines in, for example, catches of salmon, as shown in the graph on the upper right of **Fig. 5** [17]. The acidification of the ocean is causing declines in numbers of the phytoplankton and zooplankton that fish feed upon. In spite of this, the production volumes from fisheries worldwide have doubled since 2000. While catches of fish have remained more or less flat, aquaculture has been

making up the shortfall. As we can see from the center graph, while global aquaculture production has doubled, Japan's production is actually on the decline. Therefore, having been ranked No. 1 worldwide for aquaculture in 1980, Japan has now fallen to No. 11 as of 2021 [18, 19]. In July 2023, NTT Green & Food was established as a joint venture between NTT and Regional Fish Institute to resolve issues of fishing industry decline, food, and the environment.

One aspect that we are working on is quality-improvement technology for the creation of sustainable foods. One example of sustainable foods is sea bream with an edible portion that is 1.6 times that of regular sea bream, while the algae it feeds upon is given extra-activated photosynthesis, resulting in faster growth, and the ability to fix higher-than-normal levels of $CO_2$ inside its cells.

Another aspect is sustainable land-based aquaculture plants. Atmospheric $CO_2$ is absorbed by the ocean, and the modified algae absorb larger-than-normal amounts of it within their cells; the fish eat the algae, absorbing and fixing this $CO_2$ in their bones and other parts, creating a sustainable production mechanism. We are currently constructing Japan's largest land-based aquaculture plant in terms of production scale in Iwata (Shizuoka Prefecture), as of October 2023. The plan for the plant is to produce whiteleg shrimp as a fully domestic production system using a rare variety of Japanese seedling.

### 3.2 Health, healthcare, and medical care

Which raises blood sugar levels more: a banana or a cookie? The glycemic index (GI) for food gives relative values for how high blood sugar rises after eating certain foods, with glucose given a baseline value of 100. According to this index, a cookie has a higher GI value at 77 compared with 58 for a banana. The correct answer is not straightforward. The correct answer varies from individual to individual. Among a group of people with pre-diabetes, 'patients' blood sugar values were measured after they had consumed bananas or cookies. For 445 patients, blood sugar rose after eating bananas and remained largely unchanged after eating cookies. For 644 patients, however, the exact opposite was the case [20].

We can see from this that changes in blood sugar are different for different individuals. The number of people with diabetes worldwide has increased 3.6-fold over the last 20 years [21]. Rapid rises and falls in blood-sugar levels increase the risk of cardiovascular disease as well as diabetes. Chronically high blood sugar damages blood vessels throughout the body, causing various health issues. Stabilizing blood sugar after meals is believed to reduce heart disease and cancer risks. In other words, blood sugar has a major impact on bodily health [22].

NTT's "wearable blood glucose sensor" is a technology that enables the user to measure their blood-sugar levels at any time, helping them understand what foods raise their blood-sugar levels. Blood glucose has traditionally been measured by drawing blood or using pinpricks, as shown in the lower left photo of **Fig. 6**. The round object attached to the person's arm contains a needle that is piercing the skin and measuring the blood glucose level. This means that continuous, real-time measurement is very difficult. Now, the user can measure their level simply by wearing NTT's wearable blood glucose sensor next to their skin. The version presented at R&D Forum 2022 was quite large, as shown in the central photograph of Fig. 6. However, its size was reduced in 2023 to that of a watch, as shown on the right. The watch-sized sensor directs electrical waves under the skin's surface. These are then bounced back to the sensor, creating signals that are analyzed using the technology measuring changes in the concentration of glucose under the skin (which enters the skin from the blood vessels). Therefore, the user wearing the device is able to obtain their blood-sugar levels in real time. By enabling users to measure their blood-sugar levels easily and in real time, this technology can ensure that patients classified as pre-diabetic can eat many of their favorite foods while keeping an eye on their levels to ensure they do not go up. Cases are being reported of patients who were able to bring their blood-sugar levels from pre-diabetic to normal within one week by sticking to a diet suited to them while monitoring their levels [23]. This enables people to control their blood-sugar levels on their own. NTT's wearable blood glucose sensor provides a way for patients to enjoy their food rather than having to endure a diet they do not like by thinking about the foods they enjoy and selecting those items that do not affect their blood-sugar level.

Does drinking coffee contract your blood vessels? Or could it actually rejuvenate them? The antioxidants found in coffee are said to rejuvenate the blood vessels, helping to maintain a healthy heart. However, it is also said that caffeine may cause constriction of the blood vessels. Research by Dr. Ahmed El-Sohemy, Toronto University suggests that while coffee-drinking may reduce the risk of myocardial infarction in people with a genotype that rapidly

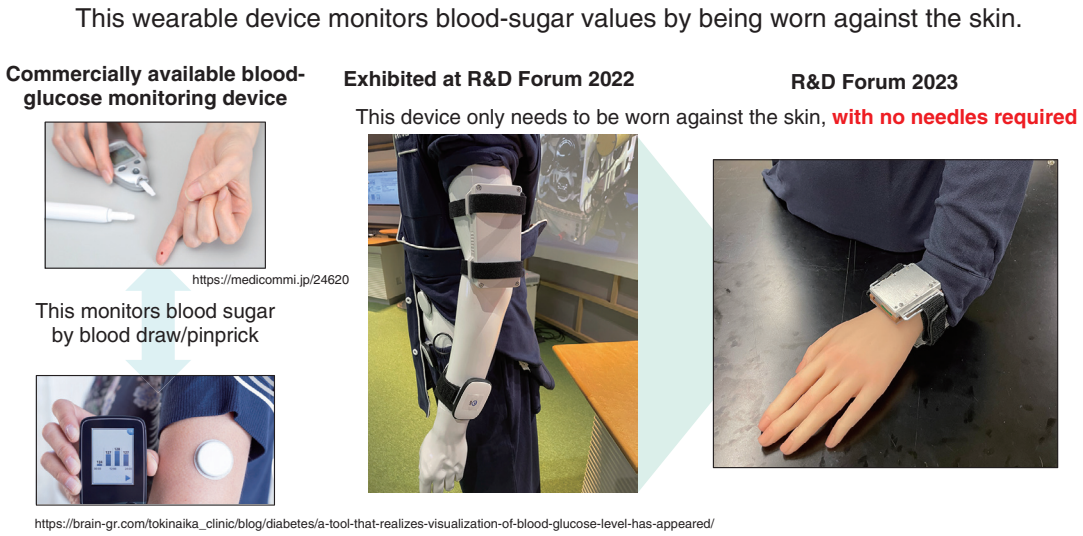



Fig. 6. Blood-sugar monitoring using a biodigital twin.

breaks down caffeine, drinking coffee may put stress on the heart in those whose genes cause them to break down caffeine slowly [24].

The ability to metabolize the components found in medications may also vary among individuals, as with caffeine. Take as an example warfarin, which dissolves clots in blood vessels. For Japanese, the required daily dose of this drug can vary by a factor of 20 from patient to patient, depending on genetic type. In other words, while some individuals can take a single pill daily, others must take 20 pills a day [24].

Analysis of genes and electronic medical records in terms of the ideal dosage of various medications for different people can open up the possibility of tailor-made dosage regimens and preventive medicine adapted to each individual. NTT Life Science is issuing reports analyzing disease risk and individual makeup in terms of alcohol metabolism as part of NTT's big data analysis and its genetic testing services, which use AI.

We are also using NTT's large language model (LLM) "tsuzumi" to automatically construct data, including electronic medical records, and use these data for analyzing individual differences. We believe that by using tsuzumi to analyze people's individual makeup, characteristics, environments, and medical histories, and developing sensors that can obtain various types of vital information through non-stressful sensing methods, it should be possible to personalize in many areas, including diet, medications, and optimized exercise levels. By enabling optimization of care and minimizing losses, this can also create more sustainable, socially responsible, and environmentally friendly healthcare.

### 3.3 Humanity, excitement, and the five senses

#### 3.3.1 Hearing

It was through sound that NTT first brought people together with our first telephones, so this is an area representing over 90 years of NTT research. With certain sound waves, laying two sound waves over each other with a 180-degree offset (antiphase) can cancel out interference. Since the 2020 R&D Forum when we first exhibited our Personalized Sound Zone technology, which uses this principle to deliver high sound quality exclusively to the user's ears while minimizing leakage into the surrounding environment, we have continued to evolve this technology, culminating in the commercialization of our earphones in 2022. We will offer an extensive lineup under the Sonority nwm Earphones brand. As these open earphones do not block the ears or leak sound, they are ideal for use when running, cycling, and in construction environments. In fact, Sonority nwm Earphones transceivers were used by the R&D Forum 2023 Secretariat to run the event.

#### 3.3.2 Touch

In addition to hearing and sight, we can also use touch to create sensations that feel a step closer to the real world. When the stethoscope shown in **Fig. 7** is placed on someone's chest, the heartbeat that you can hear is communicated via electric waves to the ball,

We created a connection between the United Nations (UN) Headquarters in New York (the venue) and NTT headquarters in Tokyo 6800 miles away, to bring the sound of the heartbeats of children in Tokyo to children listening at the venue.

**Children's Conference of the Future in support of the UN: A project announcement event in New York**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**July 19, 2023: Disarmament, Demobilization and Reintegration (DDR) at the UN Headquarters**

**The heartbeats sound as though they were close by**, despite being on the other side of the world

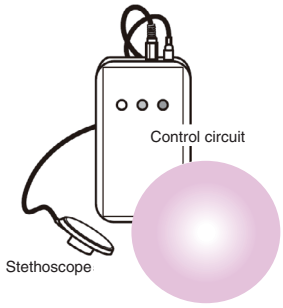


Fig. 7. The sensation of a heartbeat transmitted from Japan to the UN.

making it vibrate. At the Children's Conference of the Future held in July 2023, we connected Tokyo and the United Nation's New York headquarters in this way. A boy in Tokyo (shown on the projector displayed in the central photograph) had his heartbeat detected with a stethoscope. It was relayed via the Internet to the ball set up in New York, which vibrated in synchrony with the real heartbeat. "It feels like it's right there in front of me!" exclaimed the girl touching the vibrating ball.

We believe that conveying something through the sense of touch like this delivers not only instrumental value, such as "what we can do through this," in the same manner as communication through screens using the senses of sight and hearing but also intrinsic value—the value of feeling as though a person or object is right there in front of you. Although society has been returning to real-life experiences following the COVID-19 pandemic, we hope to develop technologies that can convey the sense of touch in this way, making the real world feel close by in a way we all want to experience.

Next, I'd like to talk about technology that makes the user feel as though they have been sent though space and time to a completely different location. By recording the vibration sounds of a real-world bike race and the bumps and depressions of the race track surface and converting all this into data, we can recreate these sensations for a user riding a bike in the metaverse, including the way the vibrations change with the different road surfaces and speeds.

### 3.3.3 Human augmentation

Moving beyond hearing, sight, and touch, the world of human augmentation enables us to experience abilities that go beyond our natural capacity. As we have explored and exploited the technologies that connect people together, the scope of what we are able to communicate to other people has grown over time. By digitalizing various phenomena, converting them into information and data, and using AI to analyze them efficiently and at low cost thanks to IOWN, we can deliver not only visualization, optimization, and energy-saving but also personalization as values. Our hope is to bring these values back to the notions of humanity and the five human senses in the context of social activities including food, shelter, and clothing; healthcare; and entertainment, while using these values to build a future centered on individual well-being and social well-being that cares for the planet.

AI can set out information systematically and present us with options; however, deciding how we feel about these options and what kind of future we want to have are tasks that require the powers of imagination and conceptualization using the five senses that humans possess.

We want our R&D to be about imagining and creating the sustainable yet exciting future that is coming together in our minds as we use our imaginations to create a vision of people, society, and the planet.

## 4. Concluding remarks

Four years since the announcement of IOWN, I truly hope that you can now feel this idea coming to life and imagine the exciting future that will ultimately make it possible.

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