Access Network Technologies to Implement IOWN

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Abstract

NTT Access Network Service Systems Laboratories is engaged in research and development (R&D) on access networks that link customers to NTT central offices, supporting the world's communication infrastructure technology with the world's most advanced and cutting-edge R&D. In this article, we introduce our R&D initiatives for the improvement of network functions, smarter operations, and the creation of new value through using our assets to implement the Innovative Optical and Wireless Network (IOWN).

Keywords: access network, IOWN, R&D

1. Introduction

NTT Access Network Service Systems Laboratories (AS Lab) was established in July 1972 as the Construction Technology Development Office. Its current name was adopted in January 1999 after several reorganizations and the merger with departments in Makuhari (Chiba prefecture) and Yokosuka (Kanagawa prefecture). In 2014, a department of AS Lab was set up in Musashino (Tokyo Metropolitan Capital region), and in July 2021, following the reorganization of NTT laboratories in conjunction with the establishment of NTT Innovative Optical and Wireless Network (IOWN) Integrated Innovation Center, AS Lab's development work was transferred to NTT Network Innovation Center. In July 2022, AS Lab marked 50 years since its establishment.

At the time of its establishment, we worked on the research and development (R&D) of outdoor communication facilities and the development and popularization of technologies to construct and maintain them in an efficient, safe, and secure manner. To economically achieve high-speed data-communication services in the period of popularization and expansion of Internet connection services, we have conducted R&D on access networks, including optical access systems, operation systems to support the spread of optical services for quick installation and efficient maintenance, wireless systems for the provision of seamless access, and infrastructure facilities such as underground conduits and tunnels.

Society 5.0 is currently being studied as a sustainable and resilient society that integrates cyberspace and physical space (cyber-physical system). As a means to achieve this, the Beyond fifth-generation/sixth-generation (5G/6G), which is the next-generation mobile communication system, is being studied for launch around 2030, and the R&D of IOWN is being accelerated toward early implementation in 2030. As the need for fixed-line broadband services continues to be strong due to the increase in remote work caused by the COVID-19 pandemic, expectations for access networks have become even greater.

We are working toward the implementation of IOWN on the basis of five access network elemental technologies, namely, access system technology, wireless access technology, optical fiber access technology, infrastructure technology, and operation technology, to achieve its mission of "achieving a natural and smart society by continuing to create and support services through research and development of leading-edge access network technology." The three core R&D policies to implement IOWN are (1) to meet extreme requirements and support diversification of services, (2) dramatically make operations smarter, and (3) use assets for new business areas

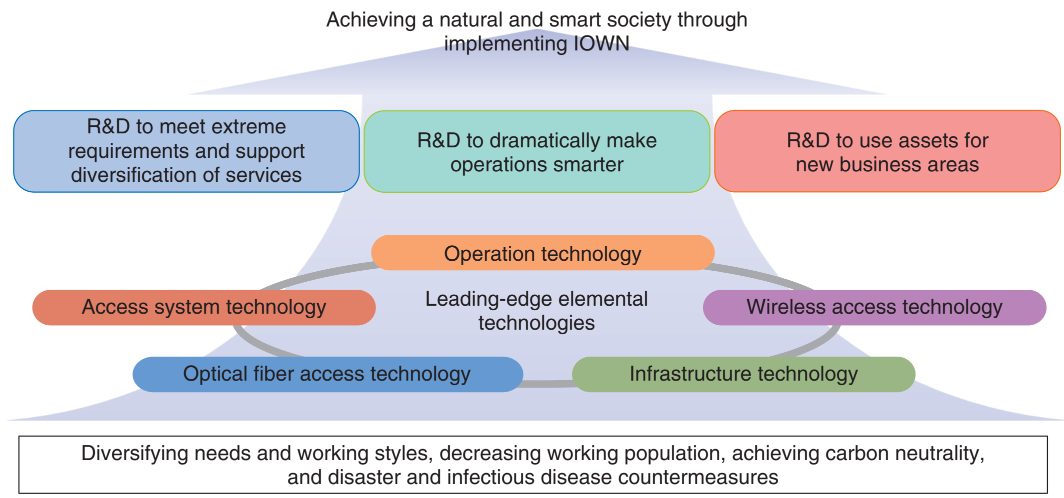


Fig. 1. R&D policies at AS Lab.

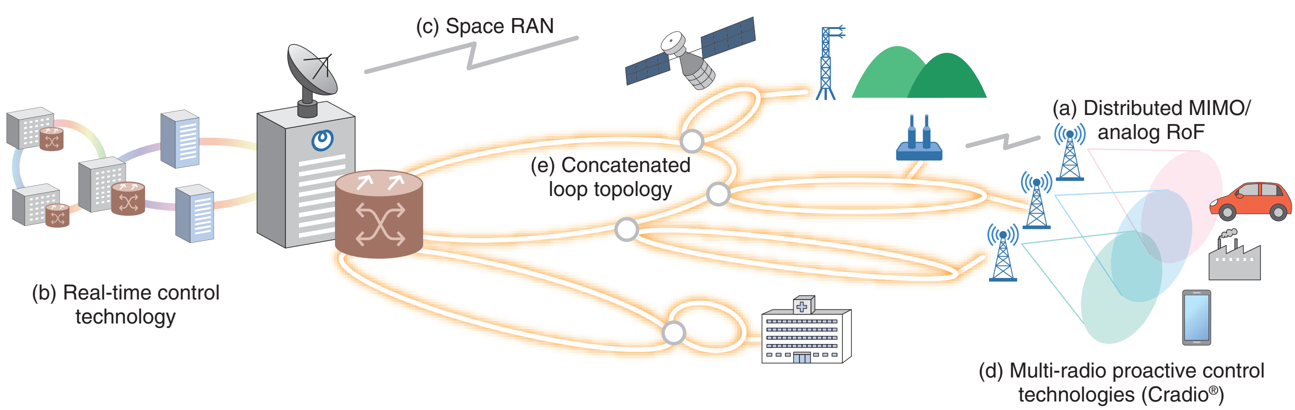


Fig. 2. R&D to meet extreme requirements and support diversification of services.

(**Fig. 1**).

The following sections introduce the main technologies that promote R&D under the above three policies.

2. R&D to meet extreme requirements and support diversification of services

To meet the extreme requirements for the telecom domain and support diversification of services, we are working to innovate communication and infrastructure technologies that will exceed the limits of network performance and innovate flexible network technologies that will meet the needs of users and services (**Fig 2**).

2.1 Innovations in communication and infrastructure technologies to exceed network performance limits

In the area of innovation in communication and infrastructure technologies, we are engaged in R&D on technologies to increase the speed and capacity of wireless and optical communications, reduce the delay of access links, and expand coverage for high-speed access at sea, in mountainous areas, and in the sky.

In the IOWN/6G era, millimeter-wave and sub-terahertz wave bands, which are higher frequencies than those used in current systems, must also be used for higher speed and capacity. However, the higher the frequency band, the smaller the communication area. The distributed multiple-input multiple-output (MIMO) technology achieves stable high-capacity wireless transmission even in a mobile and shielded environment by arranging a large number of antennas (Fig. 2(a)). The area coordination technology with analog radio over fiber (RoF) for the use of high-frequency bands and high-density deployment of remote radio units (RRU) achieves remote beam control by subcarrier multiplexing to send main signals and control signals at one wavelength and reducing signal distortion through level adjustment in multiplexing analog and digital signals. This results in installation and workability improvements through the miniaturization and low power consumption of RRUs and operation and optical fiber cost reductions by reducing the required number of wavelengths.

Both the need for remote operations and demand for performing advanced tasks remotely will increase. Therefore, in addition to end-to-end low latency and low jitter, returning immediately to normal conditions in the event of network congestion or edge overload is required. We are investigating real-time control technology that executes transmission and edge control to switch to optimal optical paths and edge resources, respectively (Fig. 2(b)). By using timely information collection and switching control, it becomes possible to switch immediately even for communication quality change, enabling services to remotely control drones and robots without stress.

To expand coverage, we are studying a space radio access network (RAN) using non-terrestrial network technologies such as geostationary-orbit satellites, low Earth-orbit satellites, and high-altitude platform station (HAPS) (Fig. 2(c)). The provision of a space RAN is expected to support worldwide mobile communications with ultra-wide coverage and improved disaster resistance as well as enhanced 5G and 6G. HAPS platforms can also interconnect to the nearest terrestrial network gateway and extend the reach of existing mobile services directly to end-user devices, providing service options including rural, emergency, and maritime connectivity.

Wireless communication systems will be expanded to use high-frequency radio bands to increase the capacity of communication, but this presents a serious problem in regard to ensuring coverage because radio waves do not extend beyond the line-of-sight range. Therefore, we are researching and developing a technology to control the direction of radio-wave reflection using a reconfigurable intelligent surface. We have confirmed in a demonstration experiment in a world first that the radio-wave-reflection direction from a base station can be dynamically changed in accordance with the movement of a terminal to always form a radio communicable area.

2.2 Innovations in flexible network technologies to suit users and services

As a wireless technology to develop a network that matches user services, we are investigating multi-radio proactive control technologies (Cradio®) that can continuously provide a natural communication environment without users having to be aware of how they are using the wireless network through cooperation with diverse systems and applications (Fig. 2(d)). Cradio® is broadly composed of the following three technology groups: Understanding (wireless sensing/visualization), Prediction (wireless-network-quality prediction and estimation), and Control (wireless-network dynamic design/control). It provides an optimal wireless environment for users by creating a wireless access network suitable for various application requirements amid ever-changing communication quality in wireless channels by implementing these three technology groups in a highly advanced manner, interlocking them, and cooperating with various applications.

To develop an inclusive optical fiber network for diversified services, we are investigating new optical access network designs based on a concatenated loop topology (Fig. 2(e)). The demand for optical fiber communication will change, and the business model will change to B2B2X (business-to-business-to-X). Therefore, the optical access network that supports IOWN must respond to the change in the business model. The concatenated loop topology achieves three goals for the optical access network: reliability (optical path duplexing for supporting ultra-reliable services), tolerance for demand variation (fiber reassignment for meeting uncertain demands), and path selectivity (optional cable routes for directly connecting decentralized base stations) and provides the optical fiber communication services that meet the various needs of service providers.

3. R&D to dramatically make operations smarter

We are conducting R&D on smart engineering and maintenance as an effort to achieve the ultimate smart access network by digitizing facilities and operations (**Fig. 3**).

Smart engineering uses remote-operated optical fiber switching nodes and optical coupling technology

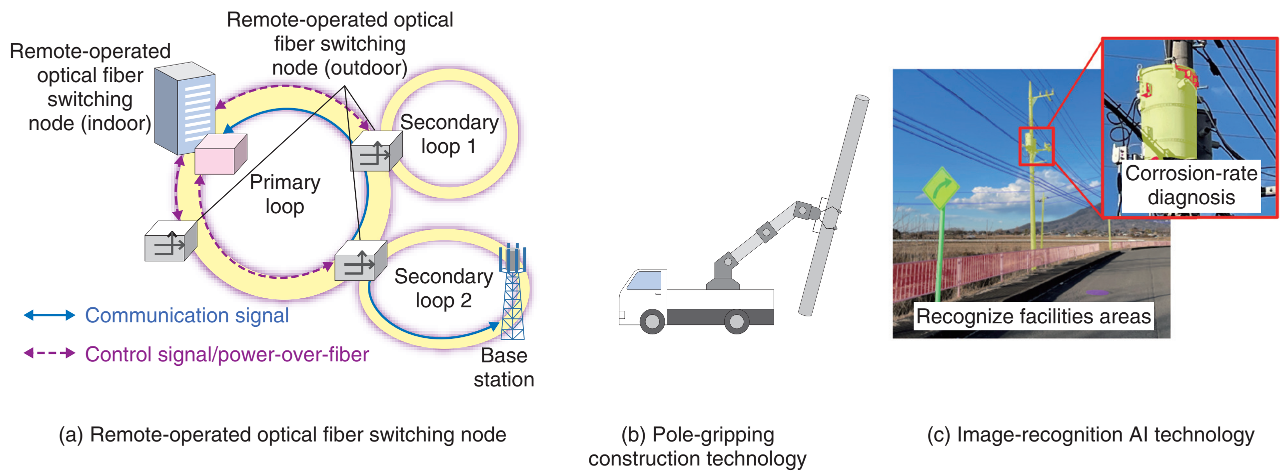


Fig. 3. R&D to dramatically make operations smarter.

(Fig. 3(a)). Optical access networks offering rapid and flexible services will be required to predict the service area and communication capacity, which is challenging. To respond to such demand fluctuations, we are promoting R&D on node technology that remotely switches the outside nodes installed at the connection points between the upper and lower loops of the concatenated loop topology previously introduced and optical coupling technology that arbitrarily branches from existing optical fiber cores.

We are also investigating pole-gripping construction technology to reduce construction burdens and significantly improve safety for on-site contractors (Fig. 3(b)). We aim to achieve this by replacing the traditional role of a human with a machine that controls the gripping force and grip structure without slippage, damage, or breakage, regardless of pole materials and installation conditions.

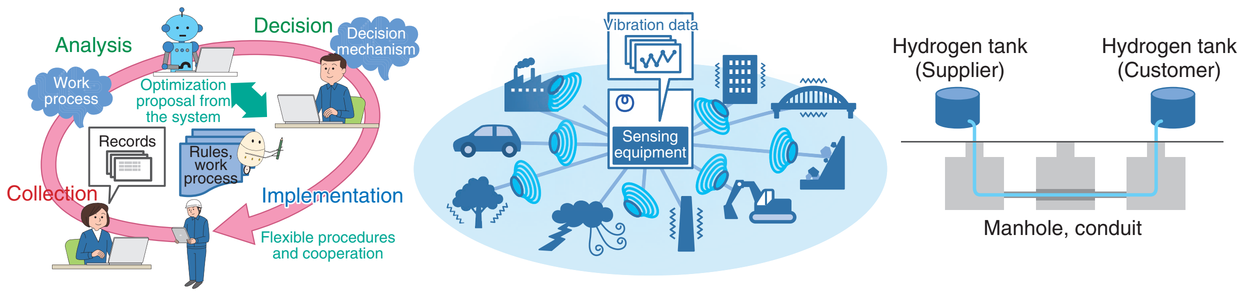
In smart maintenance, we are researching on image-recognition artificial intelligence (AI) technology that can distinguish multiple types of infrastructure facilities from images of roadside facilities taken using a mobile mapping system (MMS) to detect rust that has formed on the facilities (roadside facilities and utility pole-mounted facilities) (Fig. 3(c)). This makes it possible for separate field inspections currently carried out by each infrastructure manager to be consolidated into one MMS run. This is expected to reduce the operational costs of inspections. We are aiming to achieve efficient maintenance of all social infrastructure by using digital information.

4. R&D to use assets for new business areas

We are engaged in R&D to develop new business areas that will become new sources of revenue for NTT, using the assets it has cultivated in the fields of access systems, wireless access, optical fiber access, infrastructure, and operations: operation expertise, communication facilities, and communication technologies (**Fig. 4**).

In operation technologies using operation expertise, we are investigating business design support technology to improve business processes through robotic process automation (RPA) (Fig. 4(a)). Although digital transformation requires an understanding of the current situation based on a highly objective business analysis, analyzing complex business processes requires specialized skills and a significant amount of time, making it difficult to achieve. This technology focuses on the co-occurrence of operation logs and automatically classifies similar operations while absorbing fluctuations in operation procedures. It also extracts frequent operation flows automatically by using sequence alignment. By analyzing and visualizing operation logs, it simplifies the business-process design without requiring any special skills. Users can also edit and output RPA scenario files for automating operations from visualized operation flows, resulting in the continuous evolution of business operations.

In optical fiber environmental monitoring using communication facilities, a deployed optical fiber network is used as a sensor to obtain high-value-added information that can provide various social



(a) Business design support technology to improve business process

(b) Optical fiber environmental monitoring

(c) Hydrogen transportation using communication facilities

Fig. 4. R&D to use assets for new business areas.

services (Fig. 4(b)). Vibrations in the optical fiber network are recorded in real time using highly sensitive measurement technology. IOWN's All-Photonics Network transmits large amounts of high-precision vibration data, and the data-centric infrastructure converts it into environmental information. New business can thus be created with optical fiber networks. As increasing the use of hydrogen energy is expected to achieve carbon neutrality, the challenge is to reduce the transportation cost of hydrogen from the supply areas to demand areas. We are also studying hydrogen-transportation technology using existing communication facilities (Fig. 4(c)).

5. Conclusion

This article presented the direction of R&D on access networks toward IOWN and the main technologies in R&D on the three core policies. We will promote R&D of access network technologies and achieve further sophistication of social systems and the development of new business fields by implementing IOWN in view of the changing circumstances and progress toward a smart world.

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He joined NTT in 1992 and has been engaged in developmental research on optical access network systems. He has been in his current position since July 2019.