Creating New Value: Access Networks to Support a Sustainable Society

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Abstract

NTT Access Network Service Systems Laboratories is undertaking research and development (R&D) on access networks, which link customers to NTT central offices. Amid these efforts, we are producing cutting-edge access network technologies that accelerate the implementation of IOWN (the Innovative Optical and Wireless Network) to create new value and promote sustainability. Our R&D on access network technologies is also leading to the diversification of service, smarter operations, and the development of new business areas. This article introduces these latest technologies.

Keywords: access networks, IOWN, R&D

1. Introduction

NTT Access Network Service Systems Laboratories (AS Lab) was established in July 1972 as the Construction Technology Development Office. For over 50 years, AS Lab has been responsible for the research and development (R&D) of access network technologies in the NTT Group [1]. In today's information and telecommunications market, cloud services and fifth-generation mobile communication systems (5G) technologies are growing, and technologies such as artificial intelligence (AI) and digital twins are making rapid progress. To support these developments from their foundations, a high-throughput, high-capacity, low-latency network infrastructure is required. Expectations for 6G, the successor to 5G, are also increasing, and stronger measures against natural disasters, which have been occurring frequently, and against network failures are in demand. At the same time, we must contribute to the reduction of the environmental burden. These trends underscore the critical importance of access network technologies.

To meet these needs, NTT has steadily advanced the R&D of the Innovative Optical and Wireless Network (IOWN) since it proposed the concept in 2019. In March 2023, NTT launched the All-Photonics Network (APN) IOWN1.0 commercial service. NTT aims to be a creator of new value and accelerator of a global sustainable society [2]. Working together as one with the rest of the NTT Group, AS Lab is moving forward with all its might to develop IOWN from its concept to implementation through R&D.

Figure 1 shows the direction of AS Lab's R&D efforts. AS Lab's mission is "taking on the challenge of creating new value through research and commercialization of cutting-edge access network technologies and contributing to building a sustainable society." As we strengthen our efforts to achieve robust networks, environmental load reduction, and a healthy and safe workplace environment, we are taking into account global perspectives and improvement in employee experience (EX). We are conducting R&D of cutting-edge elemental technologies in five areas (optical-fiber access technology, infrastructure technology, access system technology, wireless access technology, and operation technology). We use these core competences in carrying out the following three R&D policies: (1) R&D to meet extreme requirements and support diversification of services, (2) R&D to dramatically make operations smarter, and (3) R&D to use assets for new business

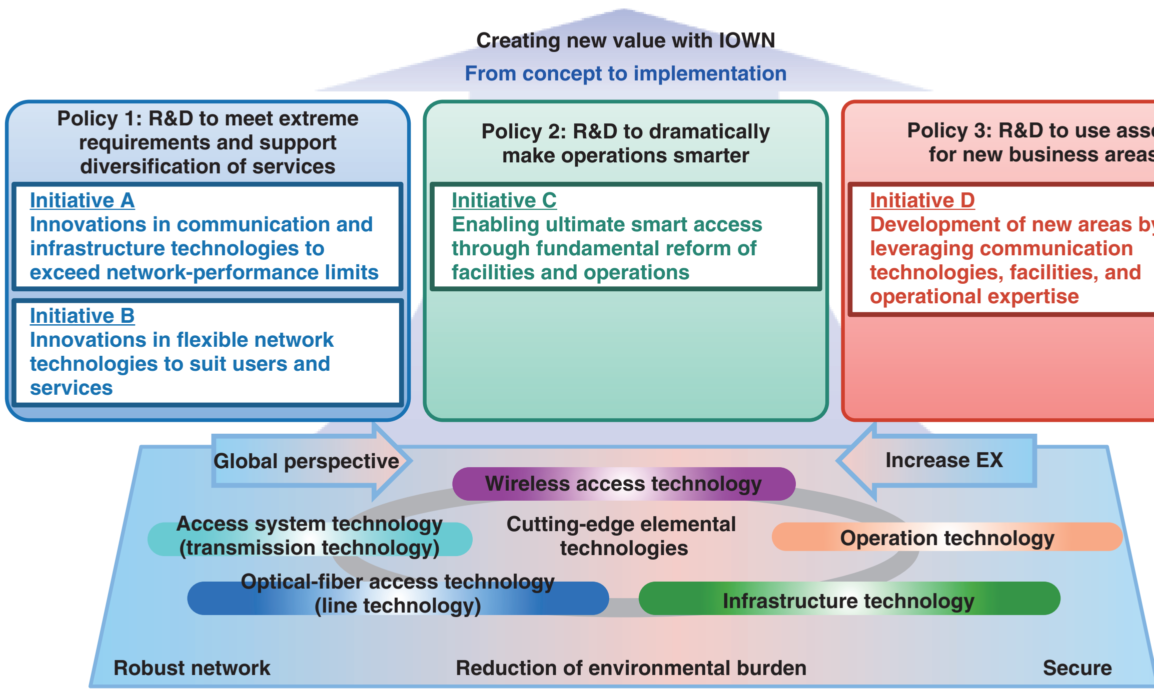


Fig. 1. Direction of R&D.

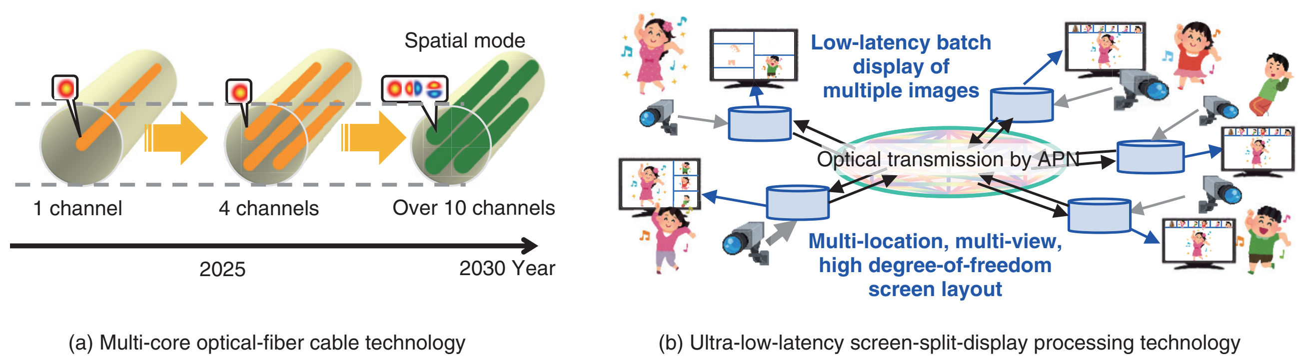


Fig. 2. Initiative A: Innovations in communication and infrastructure technologies to exceed network-performance limits.

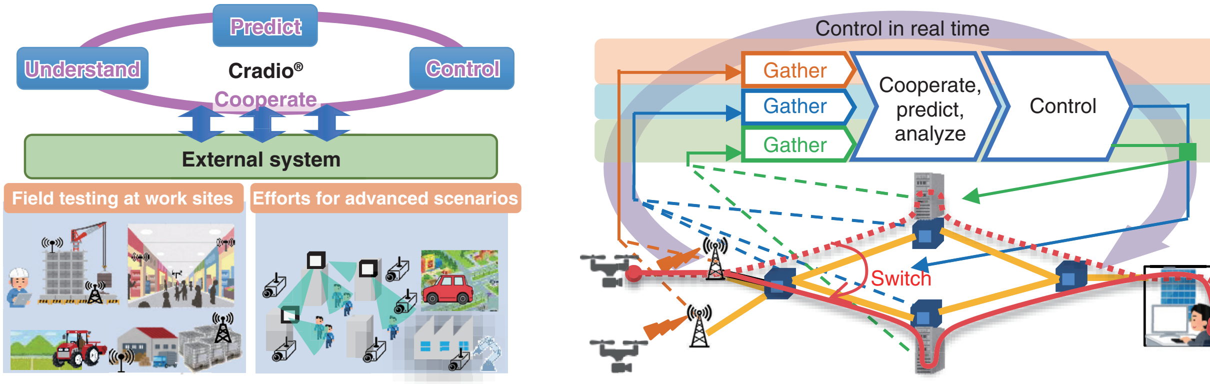
areas. The following initiatives support these three policies: Initiative A: Innovations in communication and infrastructure technologies to exceed network-performance limits, Initiative B: Innovations in flexible network technologies to suit users and services, Initiative C: Enabling ultimate smart access through fundamental reform of facilities and operations, and Initiative D: Development of new areas by leveraging communication technologies, facilities, and operational expertise.

2. Policy 1: R&D to meet extreme requirements and support diversification of services

Policy 1 is supported by Initiatives A and B.

Initiative A: Innovations in communication and infrastructure technologies to exceed network-performance limits

As shown in **Fig. 2**, Initiative A is aimed at increasing the throughput and capacity, reducing latency, and expanding the coverage of optical and wireless



(a) Cradio®

(b) Low-latency FDN technology

Fig. 3. Initiative B: Innovations in flexible network technologies to suit users and services.

communications.

The multi-core optical-fiber cable technology shown in Fig. 2(a) delivers high-capacity light through both land and sea in an eco-friendly manner. It creates optical paths at the petabit level, which is ultra-high-capacity transmission. As the demand for optical fibers in submarine and terrestrial networks expands dramatically, transmission capacity within existing facility space must be continually expanded. Using the same 125-µm cladding, this technology maintains compatibility with existing optical fibers while achieving 4x efficiency in space utilization. Taking into consideration simultaneous optimum design of fibers and cables, this initiative makes effective use of existing technologies and optical facilities, such as optical cables, and achieves high capacity and multi-core fibers between submarine networks and datacenters while also reducing facility construction costs. It also reduces the environmental burden by reducing the power consumption of transmission paths.

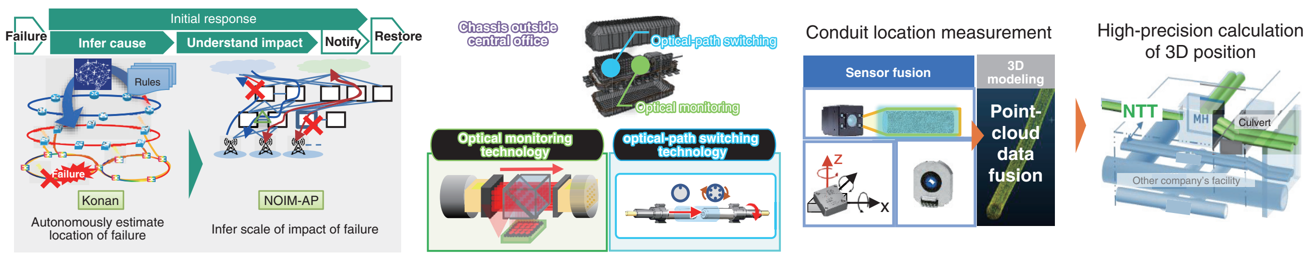
As shown in Fig. 2(b), NTT's ultra-low-latency screen-split-display processing technology enables remote lessons without time lag to be offered. By using the APN to provide multiple video and audio streams remotely without delay, the technology serves as a platform for remote ensemble performances by, for example, orchestral ensembles and dance groups. When multiple sites and perspectives are required, to keep the latency between the display of multiple sites to under 20 ms, the technology begins video display without first waiting for the videos from all the sites to be assembled together. It applies distributed processing to achieve screen layout with a high degree of freedom. The combination of the APN and this technology makes remote music and dance performances; telemedicine, such as remote surgery, remote operations and remote maneuvering; and other remote activities at multiple sites possible.

Initiative B: Innovations in flexible network technologies to suit users and services

As shown in **Fig. 3**, Initiative B is aimed at implementing networks that continuously and flexibly maintain connectivity to suit users and services.

As shown in Fig. 3(a), multi-radio proactive control technologies (Cradio®) maintain continuous connectivity through three technology groups: understanding, prediction, and control. As an era of great changes is beginning with the establishment of new wireless standards, these wireless technologies bring great promise in diverse use cases for industrial digital transformation (DX). Through field testing at business sites, Cradio® is bringing about advanced technologies to meet demand. The scope of its prediction, understanding, and control technologies are being expanded to meet the needs of use cases with diverse demands and requirements. These include high-throughput, high-capacity, and low-latency communication and the elimination of coverage holes. By providing advanced combinations of multiple wireless access technologies including Cradio®, AS Lab is working to support cutting-edge efforts such as smart cities and smart factories.

As shown in Fig. 3(b), AS Lab's low-latency function-dedicated network (FDN) technology brings about smooth remote control in locations where it is



(a) Konan/NOIM

(b) Remote optical-path switching node

(c) Technology for obtaining highly precise locations of buried conduits

Fig. 4. Initiative C: Enabling ultimate smart access through fundamental reform of facilities and operations.

difficult to work onsite. To achieve remote control, it is important to stably maintain end-to-end communication that is low latency and low jitter. For optical paths, the IOWN APN can provide low-latency and low-jitter communication. Radio paths used by wireless systems, however, are easily affected by external factors, making quality control a challenge. The FDN technology collects real-time information on optical paths, servers, and wireless systems for cooperative control, predicts end-to-end quality, selects the optimal optical path and servers, and switches to the selected optical path and servers before degradation occurs. This technology makes it possible to achieve advanced remote control for locations where working onsite is difficult. Use cases include remote facility inspection using drones and image processing.

AS Lab is working to achieve DX in factories by advancing Cradio® and the FDN technology's optical-wireless cooperative control. Real-time cooperative control has been field tested, as reported in a May 2024 press release [3].

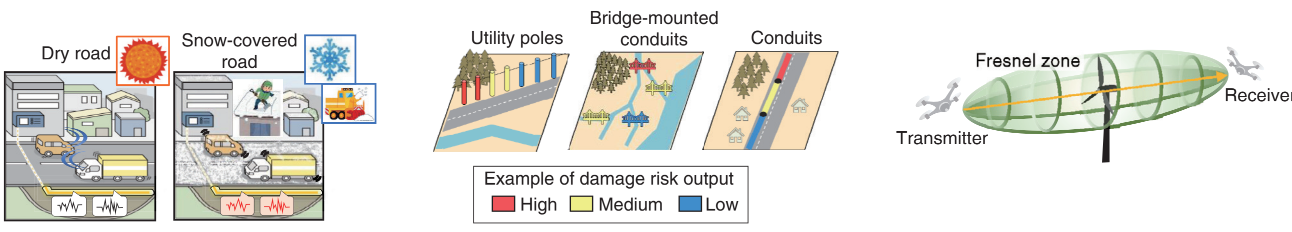
3. Policy 2: R&D to dramatically make operations smarter

Initiative C: Enabling ultimate smart access through fundamental reform of facilities and operations

Initiative C, shown in **Fig. 4**, is aimed at enabling ultimate smart access.

As shown in Fig. 4(a), AS Lab's Konan (Knowledge-based Autonomous Failure-Event Analysis Technology for Networks)/NOIM (Network Operation Injected Model) estimates and understands the location of failure and its impact when a large-scale system failure occurs. This technology makes it possible to quickly understand the cause of a network failure and its complex effects, which have become major issues for communications providers. The impact of network failures on society has grown larger, and prompt recovery is necessary to achieve robust communication networks. However, the time required for estimating cause and analyzing impact presents a hurdle. Konan/NOIM deploys a common data model for cause estimation and impact analysis. It normalizes in a simple manner the connection relationships between resources that make up a network. It also extracts custom alarms for failures from multilayer alarms, autonomously estimates the area of failure using generated rules, and infers the scale of impact of the failure on fixed-line and mobile services from multiple perspectives. Therefore, the cause of failure and its complex impact can be rapidly understood. Planning/construction support systems can be also expanded at reduced costs by using a common data model.

Figure 4(b) shows AS Lab's remote optical-path switching node technology. It enables remote onsite work on optical facilities through switching of optical fibers without the need to dispatch workers to the site, solving the issue of the lack of field workers. There is a shortage of workers for fiber-optic facilities outside of communication central offices; however, there are also expectations for the facility business to bring new revenue sources. As a technological feature for achieving these goals, we are designing the structure of outdoor chassis to enable expansion of remote operations while being easy to maintain and waterproof. Optical monitoring technology is also applied to enable batch measurements of optical cables, and optical-path switching technology is applied to maintain communication paths even during power outages. Thus, we seek to expand remote operations for outdoor facility work and develop new services and



(a) Optical-fiber environmental monitoring

(b) Prediction of social infrastructure damage

(c) Extremely low-power radio transmission/reception technology

Fig. 5. Initiative D: Development of new areas by leveraging communication technologies, facilities, and operational expertise.

add value by using optical monitoring and optical-path switching technologies.

Figure 4(c) shows AS Lab's latest DX technology for improving the efficiency of outdoor facility maintenance and operation. This technology obtains highly accurate location information for buried conduits by three-dimensional (3D) modelling of the conduits' shapes, enabling buried conduits to be located without physical digging. To advance the digitization of managing underground facilities, accurate 3D location information of the facilities must be acquired.

Techniques for acquiring underground facility location information include radar measurement, but this technique is difficult to apply to deeply buried conduits and congested areas. AS Lab's technology scans inside a conduit using a measurement device equipped with multiple sensors and integrates the acquired data to calculate locations with high precision. It also calculates the absolute coordinates of the ends of conduits (ducts) through highly precise measurements of maintenance hole locations using satellite-positioning data. With this technology, it is possible to comprehensively obtain highly precise locations of buried conduits, contributing to increased efficiency of underground facility maintenance and management (design, construction, and maintenance and disaster recovery). A press release of this technology's contribution toward the creation of digital twins of social infrastructures was issued in May 2024 [4].

4. Policy 3: R&D to use assets to develop new business areas

Initiative D: Development of new areas by leveraging communication technologies, facilities, and operational expertise

As shown in **Fig. 5**, Initiative D is aimed at developing new business areas by applying AS Lab's leading advanced network technologies to non-communication fields.

Figure 5(a) shows AS Lab's optical-fiber environmental monitoring technology. This technology addresses regional issues through networks and sensing. It uses environmental vibration data collected from installed optical fibers from the surface. For example, this technology provides support for snow removal decisions in heavy snowfall regions. Because of labor shortages in the snow removal business, the transition to a sustainable model is necessary. This optical-fiber sensing technology collects and analyzes the speed and vibration frequency characteristics of passing vehicles and uses a supervised machine learning model to estimate whether snow removal is necessary. We conducted a field trial in Aomori City, and compared with the results of onsite surveys, our technology yielded a 90% correct response rate. A press release of this trial, the world's first, was issued in November 2023 [5]. We seek to continue to expand the application of DX to the snow removal business with this technology and grow NTT's facility business.

Figure 5(b) shows AS Lab's technology for predicting infrastructure damage from disasters and eliminating the unexpected through visualization of the risk of infrastructure damage. The technology learns damage trends on the basis of public data and facility data owned by NTT to visualize damage risks throughout Japan when a disaster occurs. When a disaster strikes, maintaining lifeline functions, including telecommunications, is critical. Proactive responses to predicted damage throughout society are needed. This technology uses public data and NTT facility data at a minimum 10-m mesh to enable high-precision quantitative evaluation of damage risk anywhere and at any time. By analyzing the disaster mechanism, factors effective for predicting damage risk can be identified and used. By learning damage trends in association with the disaster mechanism, disaster risk at the facility level can be visualized. A press release of this technology was issued in April 2024 [6].

Figure 5(c) shows AS Lab's technology for non-stop inspection of wind turbines. Extremely low-power radio signals are transmitted and received between two drones. This technology enables energy generated by wind turbines to be increased through inspection that does not stop their power generation and poses no harm to turbine blades. Offshore wind power generation is expected to expand to bring about a sustainable society. Because offshore wind turbine blades are larger than land-based ones, measures to prevent suspending operation, which leads to decrease in energy generated, take on greater significance. It is also necessary to prevent cost increases associated with maintenance and operation due to, for example, using ships for offshore work. The key points of this technology include the use of autonomous drones as radio transmitters and receivers and the use of extremely low-power radio without a radio station license. We have designed the technology so that the Fresnel zone, determined by the frequency and transmit/receive distance, can be easily changed and changes in received signal can be detected. Therefore, the technology contributes to carbon neutrality by increasing power generation through extreme low-power radio inspection and reducing maintenance and operational costs through the use of autonomous drones.

5. Conclusion

Taking on the challenge of creating new value and contributing to the sustainability of the Earth, the direction of AS Lab's R&D of access networks and major technologies in our R&D initiatives were presented. We will continue to conduct R&D of IOWN toward its practical implementation.

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