R&D Activities to Implement an Access Network for the IOWN Era

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Abstract

NTT Access Network Service Systems Laboratories is conducting research and development to support access networks in the fields of optical fiber access, infrastructure, access system, wireless access, and operation technologies. To advance the Innovative Optical and Wireless Network (IOWN) from concept to implementation by 2030, we introduce our vision of a future access network and our efforts to implement it.

Keywords: future access network, advanced maintenance and operations, IOWN

1. Directions in access network research and development

NTT has proposed the Innovative Optical and Wireless Network (IOWN) concept and is working toward its implementation. We at NTT Access Network Service Systems Laboratories assume the following changes in the environment and requirements for an access network in the IOWN era.

We assume that the demand for network coverage will expand from residential and commercial areas to places where industry needs it, such as in the ocean and mountainous areas, i.e., "anywhere." The need for one-way and low-resolution communication, mainly for downloading, will change to the demand for seamless real-time and bidirectional communication such as high reality and extended reality (XR), i.e., "seamless." The user had to choose the network, but this has been reversed and the network needs to be changed to automatically adapt to the user's usage, i.e., "anytime and immediately." Connection should not be disconnected in normal times, and this will be extended to in the event of a disaster, i.e., "not being disconnected." It is necessary to raise the level of implementation to further advance digitalization from the stage of merely proceeding with digital transformation (DX) to compensating for the decrease in the quantity and quality of the labor force and achieving automation, i.e., "smart operations" of business and facilities.

In addition to strengthening our efforts to improve the basic performance and operability of telecommunications networks, we believe that it is necessary to address new needs by using our extensive optical-fiber and equipment-inspection technology and expertise beyond the utilization of facilities in the telecommunications field, so that we can explore new business by taking into account recent trends in our operating companies. As shown in **Fig. 1**, we have established three research and development (R&D) policies to respond to these changing needs. Policy (1) is "achieve extreme requirements and support diversification of services," Policy (2) is "improve operations to be smarter," and Policy (3) is "use assets for new business areas." To promote these policies, we consider robust networks, reduction in environmental impact, and on-site safety as strengthening points taking into account the recent issues regarding our operating companies and society.

2. Envisioned access network in the IOWN era and its implementation technologies

In the near future, we envisage a world where wireless access networks will accommodate not only conventional mobile terminals but also diverse

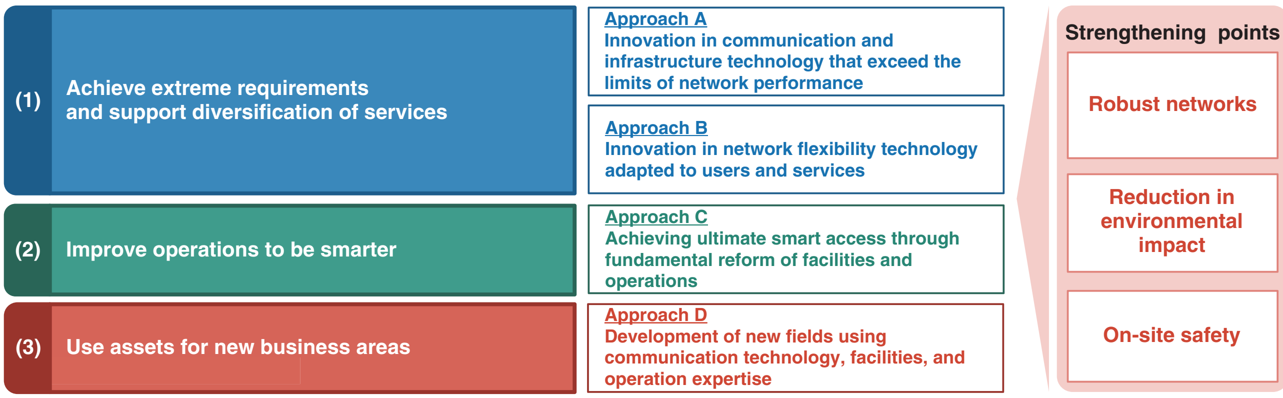

Fig. 1. R&D policies of NTT Access Network Service Systems Laboratories.

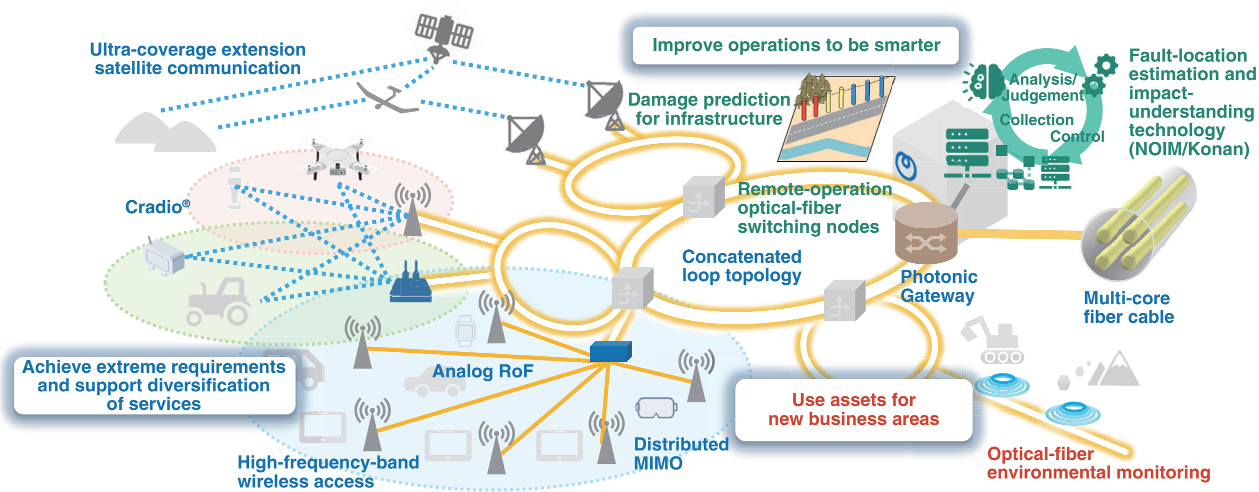

Fig. 2. Future vision of access networks.

objects such as mobility, robots, and sensor devices. We assume that the environment will change so that we can receive information and services with large capacity and low latency even when we are outside or on the move. At the same time, wired access networks are expected to be used in industrial applications such as distributed datacenters; mission-critical applications, such as telemedicine; and entertainment and education.

To achieve high speed and large capacity in wireless access networks, the utilization of radio waves of higher frequency bands than the 5th-generation mobile communication system (5G) has been discussed. However, such radio waves are too linear to pass into shadows and are vulnerable to shielding. Therefore, we are studying an architecture in which a large number of antennas are distributed so that even if the radio wave from one antenna is blocked by an obstacle, it can continue to be connected with other antennas and maintain high-speed communication. Antennas will be placed on the exterior walls of buildings, beside traffic lights, smart poles, and other places on which antennas had never been installed. To achieve this, it is necessary to simplify each antenna as much as possible and develop a technology to control multiple antennas in a coordinated manner.

Figure 2 shows the future vision of the access network based on these factors.

Analog radio-over-fiber (RoF) technology involves modulating the intensity of optical signals with radio signals in their original waveforms and transmitting them through optical fibers as analog signals. By concentrating the signal-processing units such as digital-to-analog conversion and beamforming on the central-station side, it is expected to reduce the size, power consumption, and simplification of the base station and enable cost-effective installation of the base station.

The distributed multiple input multiple output (MIMO) technology selects and controls beams from multiple distributed antennas to enable stable large-capacity communications while reducing interference between antennas and users. In addition to the technology to achieve high-speed wireless communication, technology to use wireless communication more flexibly will be required. Therefore, we are working on providing a natural communication environment that does not require the user to be aware of the wireless network by using Multi-radio Proactive Control Technology (Cradio®), which links the three technologies of understanding, prediction, and control of various information in the wireless network. There are many benefits and use scenes of Cradio®. The first use scene is the basic design of wireless network services. On the basis of the three dimensional (3D) structure of a building and the radio-wave-propagation characteristics of each frequency, it is possible to design and control the installation of antennas using public 5G, private 5G, Wi-Fi, and radio-relay devices, such as a reconfigurable intelligent surface, in a non-skilled manner to efficiently construct the wireless environment desired by the customer.

The second use scene is operation and maintenance. We are developing wireless-network quality-prediction technology, i.e., providing a wireless access network to a connected car on the basis of information, such as the radio-wave strength on the driving route learned in advance and the radio information just before, the quality of communication is predicted several seconds ahead, and the switching of the wireless network as necessary without interruption is controlled to ensure optimum operating conditions. The application of wireless sensing/visualization technology is a new application of Cradio®. Focusing on understanding changes in radio-wave conditions, we use the fact that radio waves transmitted from an antenna are blocked or reflected by people or objects to detect objects such as passing people or opening and closing doors. We are also developing a sensing technology for scenes in which the location of terminals placed in a room is automatically determined.

Radio antennas deployed in more diverse locations will need to be accommodated in optical fiber networks. Regarding the deployment of such a network to the access network, since optical facilities have been constructed mainly for fiber-to-the-home services, the service area has been developed mainly for residential areas such as houses. This will continue, but future access networks will also need to reach wireless base stations installed in various locations. It will also be necessary to provide communication lines to datacenters that require higher speed and reliability rather than best-effort IP services such as FLET'S HIKARI, which will make it difficult to predict planned demand and require mission-critical quality. To respond to such changes, we developed a configuration technology that enables us to provide flexible, reliable, and concatenated loop topology by overlaying existing access networks or constructing them using existing cables. To install base stations on signal poles and streetlights, we are developing a construction technology for cabling in grooves formed on road surfaces in situations where it is impossible to pull cables from underground pipelines or overhead lines.

Each line housed in an optical fiber cable is accommodated in an NTT building (telecom central office). In the IOWN era, an NTT building is expected to handle not only Internet signals but also uncompressed video signals, such as High-Definition Multimedia Interface (HDMI), radio analog signals, and optical signals for optical fiber sensing. It is also necessary to respond to needs by providing an end-to-end optical path that connects arbitrary points, including the turnaround point at an NTT building. To meet this requirement, we are conducting R&D on new photonic nodes, such as Photonic Gateway, which will not depend on the signal format. By providing the optical path to any point, it will become possible to provide it quickly with flexible control and efficiently accommodate various optical services. We are also developing technologies for multi-core fiber cables to achieve ultra-large-capacity transmission for a heavily trafficked network.

We are also developing technologies to improve the maintenance and operation of our services. We are constructing robust networks by using damage-prediction technology for communication facilities. By combining past disaster and weather data with data on the aging and characteristics of individual NTT facilities, we can predict areas with a high probability

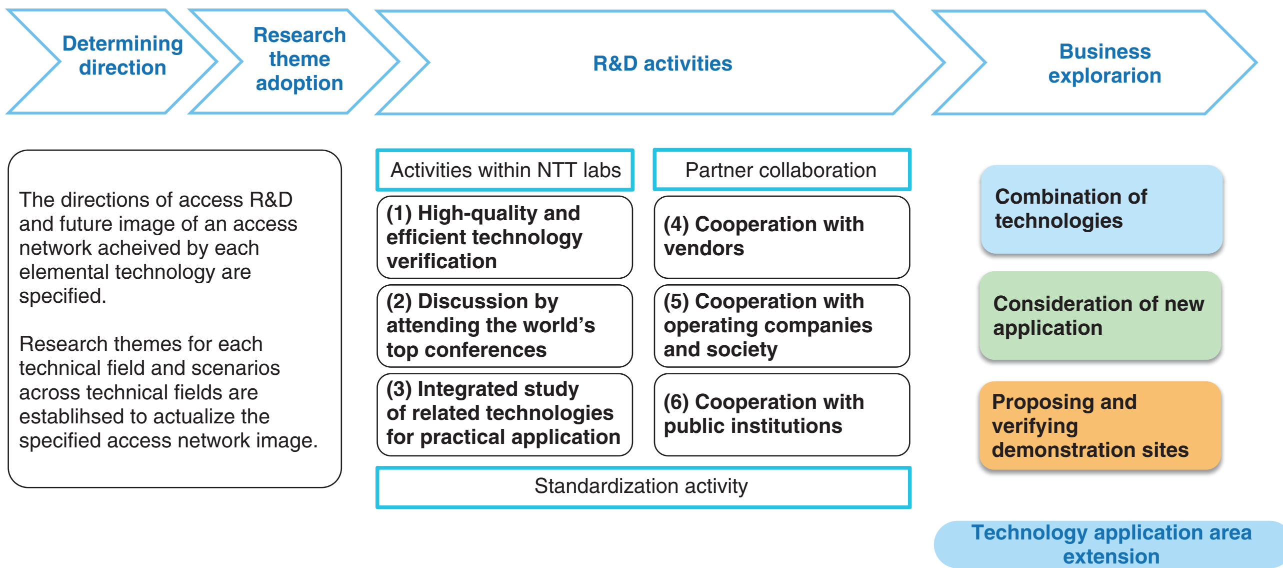

Fig. 3. Approach of R&D activities.

of damage during a disaster and take measures, such as strengthening the resistance of facilities, in advance. We are developing technology to predict damage to various communication infrastructures due to various factors such as damage to utility poles caused by heavy rain, damage to bridge-attachment facilities caused by rising river water, and damage to underground pipeline facilities caused by earthquakes.

For the response after a disaster or a large-scale network failure, Konan (Knowledge-based autonomous failure-event analysis technology for network) is used to estimate the location of the failure on the basis of the status of the alarm from the affected communication equipment. We are also developing a model called NOIM (Network Operation Injected Model), which is a data model of the entire network equipment configuration, including the service, transmission and physical layers, to understand the impact of failure and speed up the subsequent dissemination of information and planning of countermeasures.

3. Activity from technology development to social implementation

Figure 3 shows the approach of R&D activities in our laboratories.

3.1 Determining the R&D direction

From the initial determination of the R&D direction to research-theme adoption, as explained at the beginning of this article, we are devising research themes that are based on technological trends and strengths in optical fiber access, infrastructure, access system, wireless access, and operation technology.

3.2 Activities at NTT laboratories

The activities in the third phase of R&D at our laboratories are presented. In the R&D phase for social implementation, we are (1) conducting high-quality and efficient technology verification, (2) promoting discussion by attending the world's top conferences, and (3) conducting an integrated study of related technologies for practical application. A specific example of (1) is the construction of a verification environment for wireless technology [1]. To reproduce the environment we are aiming for as a future-use environment and use scene, we have built a dedicated experimental facility in Yokosuka. By having a dedicated environment, we can efficiently conduct verification with higher accuracy with more freedom in the experimental setup and fewer restrictions on use. Regarding (2), we have been actively disseminating information at international conferences and journals in optical access, such as ECOC (the European Conference on Optical Communication) and OFC (Optical Fiber Communications Conference and Exhibition), where the world's top-level researchers in the field gather, to enhance technological advancement and superiority and the appropriateness of problem setting. An example of (3) is activities in optical fiber systems. In addition to the design of the fiber structure, we are also conducting a set of verifications, such as cabling, constructability in an actual field environment, connectivity, and transmission characteristics, to improve our capabilities as a communications facility [2].

3.3 Partner collaboration

We are also promoting efforts to obtain better research results by using the schemes for collaboration with various partners such as (4) venders, (5) operating companies and society, and (6) public institutions.

Regarding (4), we are devising a scheme regarding 6G for demonstration cooperation with major vendors in Japan and overseas and advancing research [3]. To ensure that the creation of functions does not become separated from product implementation, we will promote feasibility studies, taking into account the implementation issues of the functions. Regarding (5), this approach is aimed at actively developing use cases from the research stage and establishing the necessary functions and technologies at the required level. In the robot-delivery experiment in the Shinagawa-Konan area, we are participating in an experiment from the standpoint of radio technology in cooperation with NTT Group companies investigating intelligent control in buildings [4]. Regarding (6), we are investigating technologies related to the All-Photonics Network (APN) in cooperation with public institutions. We will aim to devise research themes with a high degree of public importance and spillover potential by using national project schemes [5].

We are also promoting technology deployment through standardization activities. In the fields of radio, optical access, optical fiber, and operation, NTT has been leading discussions by submitting contributions toward the standardization of new NTT technologies and obtaining positions in standards organizations and organizations such as "de jure" and forums. Standardization activities of functions, methods, products, etc. will be carried out from the core R&D phase to promote standardization of rules and regulations that enable functions and interconnections necessary for product implementation. Through the standardization process, we are promoting initiatives for securing quality and interoperability, reducing costs, and creating business opportunities by enabling the industry and related parties to understand the content of NTT technologies and promoting the formation of partnerships.

3.4 Business exploration

Finally, we discuss an initiative in the business phase to leverage the advantages of technology. Activities are being made to expand the application use cases of technology, such as finding new value by combining multiple technologies across technology fields, examining the possibility of applying technology to areas other than traditional access areas, and creating value through demonstration experiments matched with servicers. As an example of such activities, we have applied our image-recognition artificial-intelligence technology for telecommunications infrastructures to detect and evaluate equipment, e.g., to automatically detect rust on signs and guardrails managed by local governments for facility inspections [6]. The APN's low-latency optical transmission technology was also combined with ultra-low-latency split-screen-processing technology to demonstrate remote ensemble and chorus performances at a music event in collaboration with an NTT Group company [7].

4. Summary

We introduced the vision and technology of the future access network of our laboratories and the challenges to implementation. By setting the direction and policy of R&D to meet the changing needs of the IOWN era; promoting the development of technologies related to wireless, optical transmission, and optical fibers to achieve a high-speed, high-capacity, low-latency, and highly reliable communication environment, as well as technologies to enable advanced infrastructure maintenance and operations; and refining technologies by cooperating with partners, using demonstration sites, and improving the quality of research activities, we will develop an access network for the IOWN era around 2030.

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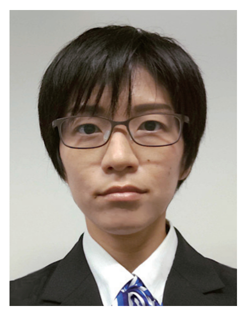

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