Initiatives toward Access Network Technology for the Beyond-5G Era

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Abstract

We have been researching future end-user lifestyles and business transformations for carriers and other telecommunications providers that will be driven by changes in social contexts, particularly by changes in mobile, video, and Internet of Things related markets. From these changes, we identified necessary technologies to provide information and communication technology services that are expected to proliferate in the future. We present in this article our findings that examine future directions in the development of access network technology designed to realize the next-generation social infrastructure.

Keywords: access networks, future vision, advanced functionality

1. Social context changes driving lifestyle transformations

Numerous changes are occurring in society as technology advances, and they are leading to various transformations in lifestyles. In this section, we explore the background and expected outcome of these changes.

1.1 Background

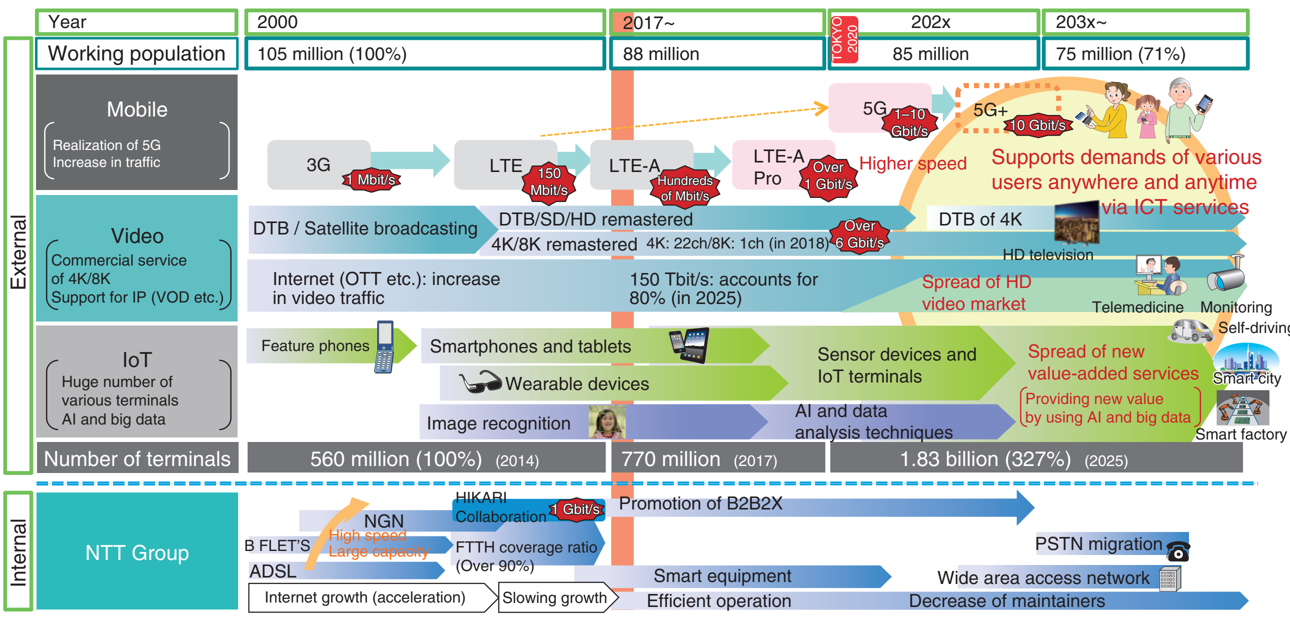
Technological advances and changes in the social context that have occurred and are expected to occur between 2000 and 203x are illustrated in **Fig. 1**. The time period from 2000 to the present has been the Internet technology growth period, as the number of Internet users increased with the introduction of high-speed and large-capacity services. The fifth-generation (5G) service is anticipated to arrive in the mobile market by 2020, which will boost transmission speeds a hundred-fold. By 202x, the 5G service area will have expanded, making 5G the foundational platform for information and communication technology (ICT) applications.

In the video content market, progress in practical 4K/8K applications is expected to heat up demand for retransmission of 4K/8K video over Internet protocol (IP) networks. In the worldwide Internet of Things (IoT) market, smartphones and tablets are the current growth drivers, but in the coming years, various types of IoT devices will be deployed such as smartwatches, smart glasses, and other wearables, as well as numerous types of sensors and imaging devices such as live cameras.

By 203x, we foresee enhanced broadband mobile communications with an expanding coverage area and the increasing use of multiple services. Additionally, the scope of the video content market will be expanded to not only broadcast and video content but also monitoring, remote medicine diagnosis, and other high-definition video applications. Furthermore, big data and artificial intelligence (AI) technologies will evolve and be used in more real-world applications. This is expected to transform lifestyles so that ICT services with multiple quality levels will be accessible everywhere in the form of advanced urban functions, which includes infrastructure, energy, traffic, and other areas.

1.2 Future ICT usage scenarios

Three ICT usage scenarios envisioned for 203x are



5G: fifth-generation
AI: artificial intelligence
ADSL: asymmetric digital subscriber line
B2B2X: business to business to X
DTB: digital terrestrial broadcasting
FTTH: fiber to the home
HD: high definition
HIKARI Collaboration: NTT's initiative for wholesale of fiber-optic services
ICT: information and communication technology
IoT: Internet of Things
IP: Internet protocol
LTE: Long-Term Evolution
LTE-A: LTE-Advanced
NGN: Next Generation Network
OTT: over-the-top
PSTN: public switched telephone network
SD: standard definition
VOD: video on demand

Fig. 1. Direction of ICT progress toward an abundant future society.

depicted in **Fig. 2**.

(1) Seamless connectivity

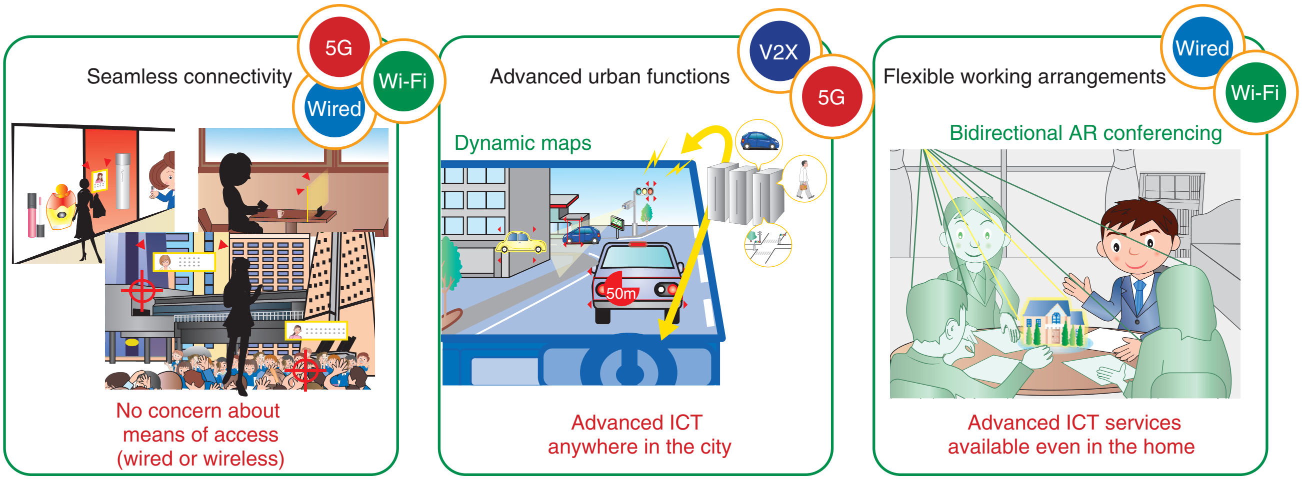
In the first scenario, users will be able to enjoy ICT services at all kinds of locations without needing to think about the access connection or device. As one possible service in this scenario, a person talking on the phone while walking down the street might decide to enter a coffee shop, where the call can be seamlessly continued as a video call on a display in the shop. Realizing this usage scenario will require the functionality to continue communications seamlessly even when the network connection points or devices change, as well as the functionality to guarantee end-to-end communication quality, which will maintain the high-level user experience, from the server providing the service to the user's device independent of the transmission media (e.g., wireless or wired) or the method of network connection.

(2) Advanced urban functions

In the second scenario, ICT will advance as urban functions providing greater added value. One possible example is the use of dynamic maps, which will be generated on servers based on a multitude of information sources from intelligent transport systems such as sensors, video or camera images, and traffic lights deployed throughout a city. The dynamic map information will then be sent to cars and other vehicles to provide advanced onboard functions such as hazard prediction. Implementing this usage scenario will require the functionality to collect a lot of data from many sources in real time and calculate useful information using networked computing resources, and the functionality to distribute this information from networked computing resources to large numbers of devices (cars) simultaneously and with low latency.

(3) Flexible working arrangements

In the third scenario, we expect to see a need for advanced ICT services to facilitate remote access working environments and flexible working arrangements, enabling people to work from home or from a shared office, for example. One possible working arrangement involves colleagues in remote locations carrying out group work via augmented reality conferencing available in each person's home. This working arrangement necessitates the assurance of low-latency broadband communication paths between multiple locations for the duration of the conference,



AR: augmented reality
V2X: vehicle-to-everything

Fig. 2. Usage scenarios for high added-value public ICT services.

as well as advanced network authentication functionality that determines whether to permit the connection between multiple sites.

1.3 Trends for telecommunications carriers

We believe the telecommunications carriers of the future will have to provide flexible network services to both users and service operators. Flexible network services involve three things: (1) customization that permits users and applications to use only the bandwidth, latency, computing resources, and other resources they need just when they need them; (2) instantaneous configurations and connections to enable instant real-time service usage; and (3) automatic selection of the optimum network without the user having to choose one. Furthermore, to enable users to conveniently access the services they subscribe to anywhere at any time, the capability for telecommunications carriers to perform centralized, end-to-end management is needed. Additionally, to provide these services inexpensively and continuously, we believe further work-process automation and reduction will be necessary through extensive application of AI and robotic technologies in operations, administration, and maintenance. Automation and reduction of work processes will also offset the future decline in maintenance personnel precipitated by a reduction in the working population in Japan.

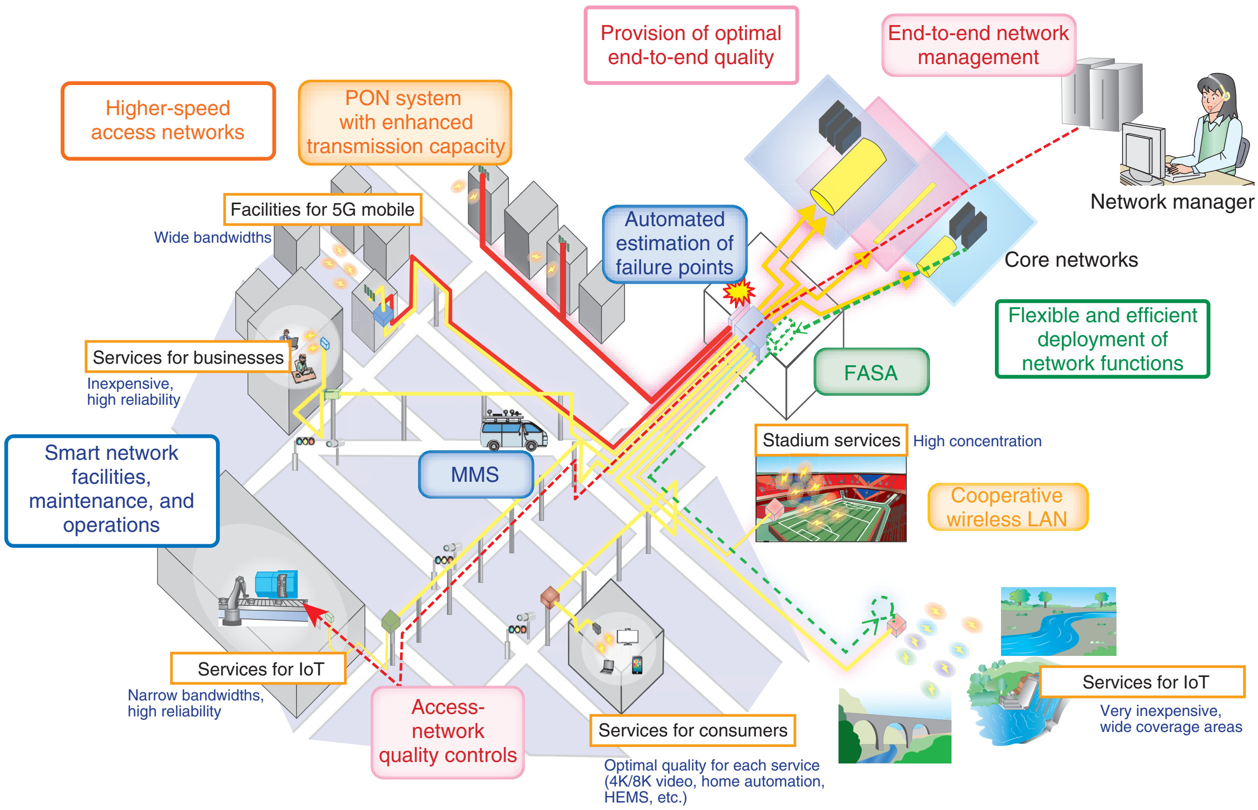
2. Access network systems technologies for the era of 5G deployment

To realize the future vision described above, NTT Access Network Service Systems Laboratories (AS Labs) aims to advance access network functionality with four research and development (R&D) initiatives, as shown in **Fig. 3**. In addition to continuing initiatives toward (1) realization of higher-speed access networks, and (2) smart network facilities, maintenance, and operations that utilize existing facilities, we are pursuing R&D projects focusing on (3) the provision of optimal end-to-end quality that goes beyond the scope of conventional quality management and also on (4) flexible and efficient deployment of network functions to address a variety of communication quality requirements. These initiatives are outlined in the following subsections.

2.1 Realization of higher-speed access network

Our R&D efforts in the area of passive optical network (PON) architectures for the construction of low-cost optical access services have furthered the development of broadband-PON (B-PON) and gigabit Ethernet-PON (GE-PON). We have also contributed to the standardization of ITU-T[*1] G.983 (2003) and IEEE[*2] 802.3ah (2004), which are for B-PON and

*1 ITU-T: International Telecommunication Union - Telecommunication Standardization Sector
*2 IEEE: Institute of Electrical and Electronics Engineers



FASA: Flexible Access System Architecture
HEMS: home energy management systems
MMS: mobile mapping system

Fig. 3. Image of future access networks.

GE-PON, respectively. In addition, we promoted the development of faster technologies that led first to the standardization of 10-Gbit/s-capable Ethernet PON (10G-EPON, IEEE 802.3av, 2009) and later, of 40-Gbit/s-capable Next Generation-PON2 (NG-PON2, ITU-T G.989, 2015) [1], which expanded transmission capacities and improved extensibility based on 10-Gbit/s-capable PON systems. These high-speed access technologies are expected to be crucial for the accommodation of mobile base stations for 5G and beyond, and for 4K/8K video content distribution. Current standardization efforts in PON systems are focused on even higher speeds, and a standard for 100-Gbit/s-capable 100G-EPON [2] is expected to be completed in 2019.

In the wireless access field, wireless local area networks (LANs) have achieved widespread proliferation, but the underlying standard, IEEE 802.11, was first established back in 1997 when the maximum transmission speed was just 2 Mbit/s. Demand for higher wireless LAN speeds has continued to grow since this time, with the spread of laptops, tablets, and other wireless devices. To address this demand, R&D progress has been made in orthogonal frequency division multiplexing and multiple-input and multiple-output technologies, paving the way for the most recent iteration of the standard, IEEE 802.11ac, which realizes physical speeds up to 6.9 Gbit/s. With this new standard, transmission speeds have now increased more than 1000 times in less than 20 years.

Further diversification of wireless devices is expected to bring even better wireless environments. One problem, however, is reduced throughput due to radio interference in highly concentrated usage environments such as sports stadiums. Standardization efforts to improve throughput in such conditions are now underway as IEEE 802.11ax. AS Labs is also studying cooperative wireless LAN technology [3] that will improve frequency usage efficiency and achieve higher speeds.

2.2 Smart network facilities, maintenance, and operations for access networks

To date, the main focus in access networks has been on deploying network equipment and optical fiber efficiently in order to deliver the optical fiber network to homes. In the future, however, access network facilities will have to cope with many diverse requirements to support the 5G and IoT telecommunications infrastructures. For example, they will have to efficiently accommodate the increasing number of mobile base stations or IoT devices over wide coverage areas. Consequently, we are looking into how to optimize the deployment of access network facilities while maximizing the use of existing ones.

Another area of focus involves achieving smarter maintenance and operations for access networks. The number of workers involved in maintenance and operation of the network is expected to decrease in the future. Therefore, it is necessary to be able to operate and maintain the network with a smaller number of workers by achieving smarter maintenance and operations. For example, we are working to improve the efficiency of equipment inspections by utilizing a mobile mapping system [4] and to reduce the burden of routine work in network operations or service reception tasks and to simplify tasks that require advanced skills by utilizing navigation technologies [5]. We are also striving to make network-fault detection operations more advanced and efficient using automatic failure points estimation technology [6] and to enable comprehensive management and operation of diverse networks through the use of network resource management technology [7].

In the coming years, we will pursue R&D of advanced automation of network operations by AI and machine learning and remote maintenance using sensors, robots, and other devices, while aggressively systemizing routine operation tasks.

2.3 Provision of optimal end-to-end quality

Future networks will have to provide services with optimal end-to-end communication quality from the service provider network to the end user devices. Networks will need the functionality to automatically guarantee required bandwidth for consumers just for the duration a video service is used, for example, as well as to permanently allocate a narrow bandwidth for IoT devices. Access networks to date have generally provided best-effort transmission. However, we are researching functions that will recognize the services users are accessing and provide quality accordingly. As mentioned previously, communications do not exclusively use NTT networks but pass through the networks of other communication carriers and ultimately traverse the user's own network. A requirement in providing end-to-end quality, then, is to coordinate our networks with these other networks. Consequently, we are studying network technologies and operation systems technologies that enable quality coordination and cooperation between networks.

2.4 Flexible and efficient deployment of network functions

Network functions virtualization, a network architecture concept involving the virtualization of many different network node functions in core networks, is gradually being rolled out. In contrast, access network systems development has been conducted separately for each provided service and function, which has stymied the deployment of generic network functions.

AS Labs, therefore, is engaged in researching Flexible Access System Architecture (FASA) [8], which segments the functions provided by access networks into components and allows the flexible combination of those components. For example, FASA turns bandwidth management functions, maintenance functions, and multicast processing functions into (software) components, making it possible to add on functions just for users that need that function or combination of functions. This, in turn, is anticipated to facilitate not only rapid provision of a variety of services but also reductions in capital expenditures through the use of general-purpose hardware, reductions in operating expenses by communalizing maintenance operations, and service continuity assurance by eliminating equipment end-of-life issues with the use of general-purpose hardware.

AS Labs has issued a FASA white paper describing a common application programming interface enabling the addition and replacement of software components and has proposed its standardization at the Broadband Forum (BBF). We are also active in the open implementation of the FASA platform in cooperation with the Open Networking Foundation (ONF) and other open-source software communities.

3. Future development

In addition to our previous studies on technology for high-speed and high-capacity networks, AS Labs is pushing forward with R&D in advanced access network functionality. We are also studying how to provide optimal end-to-end quality and flexible deployment of network functions, as well as investigating efficient base-station accommodation and new cabling applications.

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