Photonic Gateway and Related Optical Access Technologies to Achieve the All-Photonics Network

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Abstract

We, members of Optical Access Systems Project of NTT Access Network Service Systems Laboratories, are engaging in the research and development of the Photonic Gateway to achieve low-latency optical access networks and the All-Photonics Network, an essential component of IOWN (the Innovative Optical and Wireless Network). This article, which is based on a workshop lecture video-streamed on the Tsukuba Forum 2020 ONLINE website in October/November 2020, introduces technologies that use the optical characteristics, such as wavelength management and optical path aggregation, required for high-bandwidth, low-latency networks.

Keywords: IOWN, APN, optical access systems

1. Background of optical access technologies

The communication services provided by optical access can accommodate the traffic created by the triple play of telephony, Internet access and video, and mobile access and Internet of Things. It can be said that these services are mainly intended to support human cognition. It is expected that the bit price will continue to decrease due to improvements in transmission speed, so it will be possible to transfer more information rapidly at low cost. Along with this, the near future is expected to see new communication applications such as cloud access, augmented reality/virtual reality, autonomous driving, and e-sports, which handle a large amount of information and rapid-service responses beyond human cognition. Therefore, optical access systems will be required to offer lower latency while accommodating diversified services more efficiently.

It has been pointed out that the labor population in Japan will continue to decline, with a 40% decrease expected by 2060 [1]. Access systems are distributed to cover a wide area, so reducing operation overheads including business trips and improving operation efficiency are important goals. Considering the impact of the COVID-19 pandemic, it has become critical to develop an optical access system that minimizes operation overheads.

2. Our vision of optical access systems

Current optical access systems were developed for different types of optical access networks, e.g., for business, mobile, and consumer use, and consist of dedicated devices that can efficiently provide specific communication services optimized for transmission speeds at the appropriate release time and area expansion for each use. However, we have to ensure not only adequate transmission speeds but also multiple attributes, such as low latency and efficient operation, to reduce operation overheads and improve flexibility.

To satisfy these requirements, it will be important for optical access systems to support the separation of the basic transmission/transfer functions from

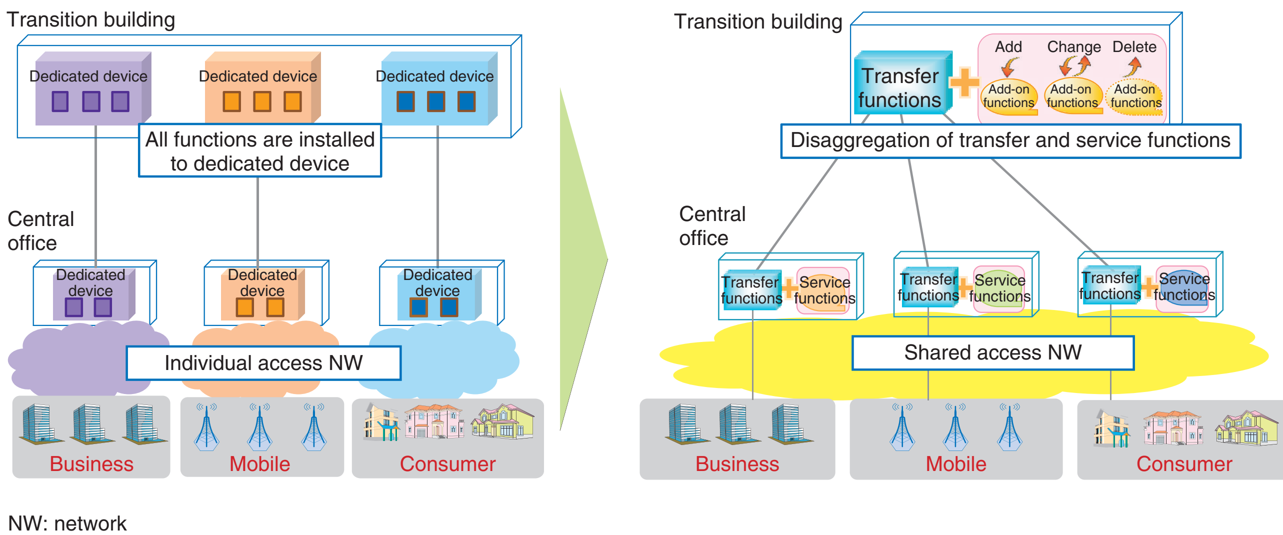

Fig. 1. Our vision of optical access systems.

additional functions. Our aim is to build an optical access system that standardizes and commonizes the basic transmission/transfer functions as much as possible (**Fig. 1**). This separation makes it possible to launch a service quickly with the minimum number of transmission/transfer functions; add or delete additional functions in accordance with various service requirements as they emerge. In addition, by reducing the number of system types, operation tasks can be standardized, and the maintenance process can be made easier and safer. Configuring the transmission/transfer functions in a simple manner makes it possible for services to share the optical access infrastructure, for example, optical fiber, and its devices. We are developing an optical access system for achieving high flexibility, low operation overheads, and infrastructure sharing.

3. The All-Photonics Network and Photonic Gateway for achieving large-capacity, low-latency networks

The Innovative Optical and Wireless Network (IOWN) announced by NTT in 2019 is aimed to promote a smart society with the three elements of the All-Photonics Network (APN), Digital Twin Computing (DTC), and Cognitive Foundation (CF) [2]. The APN targets 100 times greater power efficiency, 125 times greater transfer capacity, and 200 times lower end-to-end delay compared with the current network. Specifically, by using optical device technologies and wavelength division multiplexing, we aim to reduce the transfer delay to the limit by providing full-mesh connection of optical paths end-to-end. We also aim to create a large-capacity network that is protocol agnostic.

To provide end-to-end optical paths, the APN uses the Photonic Exchange (EX) and Photonic Gateway (GW), which together replace electrical-processing functions such as exchange, multiplexing, and switching with optical functions. The Photonic EX can cross-connect large-capacity paths of 1-Pbit/s class on the core in full-mesh manner. The Photonic GW offers the functions of controlling wavelength allocation to terminals and path aggregation on the local full mesh (**Fig. 2**). This makes the best use of the optical characteristics and enables low-latency transmission that is independent of specific protocols. We are researching and developing the Photonic GW.

4. Path aggregation and wavelength management by the Photonic GW

The Photonic GW consists of an optical node that has optical direct-aggregating and add-drop functions and a controller that performs automatic configuration. Specifically, the optical node hosts the following five functions, enabling low-latency path aggregation while minimizing the use of electrical processing (**Fig. 3**).

(1) Remote wavelength control: specifies and controls which wavelength the transceiver of a

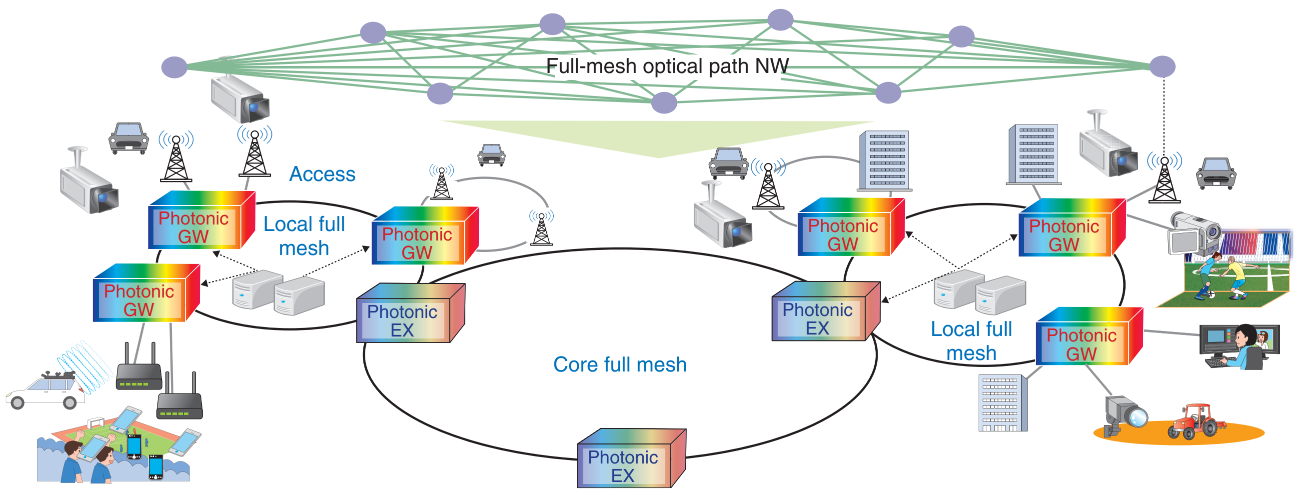

Fig. 2. APN transport and the Photonic GW.

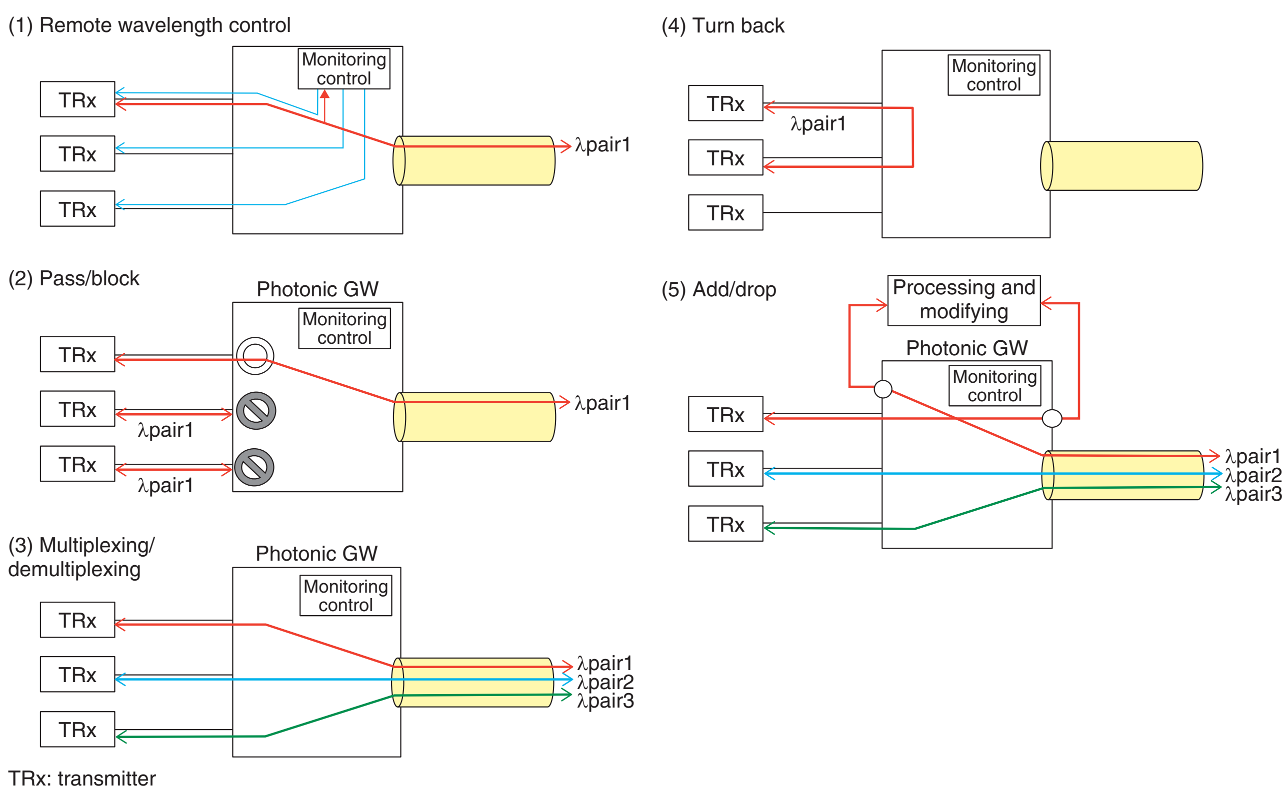

Fig. 3. Five functions in the Photonic GW.

user terminal uses and monitors the wavelength of the signal.

(2) Pass/block: passes signals when the path opens and stops unnecessary signals.

(3) Multiplexing/demultiplexing: aggregates the signals and transfers them to the core network in accordance with the wavelength and distributes the signals transferred from the core

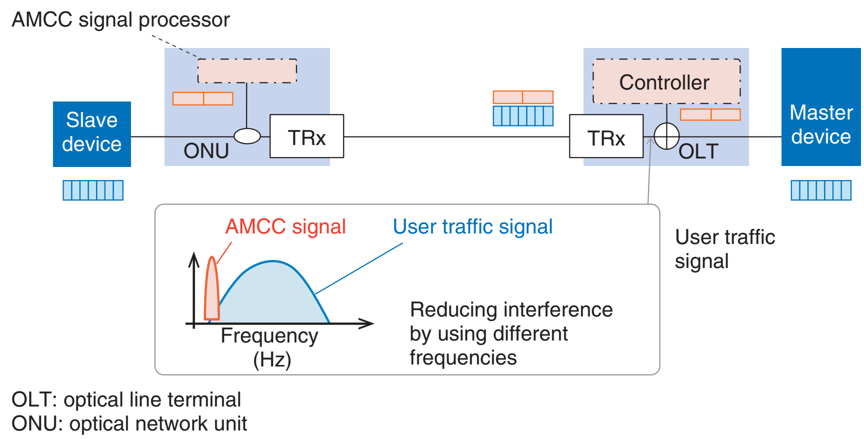

Fig. 4. AMCC mechanism.

network in accordance with wavelength.

(4) Turn back: enables turn back at the Photonic GW, rather than at the Photonic EX, for traffic that requires the shortest route.

(5) Add/drop: enables intermediate processing at the Photonic GW site for optical repeating, wavelength conversion, and electrical processing.

The remote wavelength control function uses the auxiliary management and control channel (AMCC), which is an in-channel control technology (**Fig. 4**). The AMCC is one of the main functions of the Photonic GW for wavelength management. It multiplexes the wavelength control signals with the user signal from the Photonic GW to the user terminal's transceiver. Because the frequency band of the control signal is low, it does not interfere with the user signal. In addition, wavelength control signal multiplexing is achieved with an additional simple circuit. By using the AMCC, it is possible to monitor and control wavelengths independently of the protocol of the user signal or the optical modulation format of the signal and to standardize and commonize the control functions.

5. Example of protocol-free network by the APN

The conventional approach to the transmission of radio frequency (RF) signals, such as television broadcasting service and fixed, mobile wireless services, requires the development and optimization of each transmission specification such as the transmitter, receiver, and relaying system for each licensed frequency. This duplicates the installation, operation, and renewal costs. As a result, the total cost has become excessive. At NTT Access Network Service Systems Laboratories, we put into practice the radio-over-fiber technology, which converts RF signals into optical frequency modulation (FM) signals and transmits them over long distances, as the FM conversion scheme [3]. Using a wideband FM conversion scheme for the APN composed of the Photonic GW makes protocol-free transmission possible in which analog RF signals in various bands are converted and transmitted over long distances. Since this transmission is transparent to the signal format and modulation method of the RF signals, we can provide a *protocol-free* transmission service that flexibly supports many formats such as digital signal formats, e.g., IP (Internet Protocol), Ethernet, or signal speed.

6. Separation of transmission/transfer functions from additional functions

We are also working on technology that allows separation of the transmission/transfer functions from additional functions. In particular, it is important that the transmission/transfer functions of a device are simply configured to make the additional functions easy to add, change, and delete as software and/or at a user terminal.

One of our activities to achieve separation is to promote the open development of access systems at the Open Networking Foundation. In cooperation with AT&T, Deutsche Telekom, and Turkish Telekom, we participated in the SEBA (SDN-Enabled Broadband Access – SDN: software-defined networking) project [4], formulated an optical line terminal function

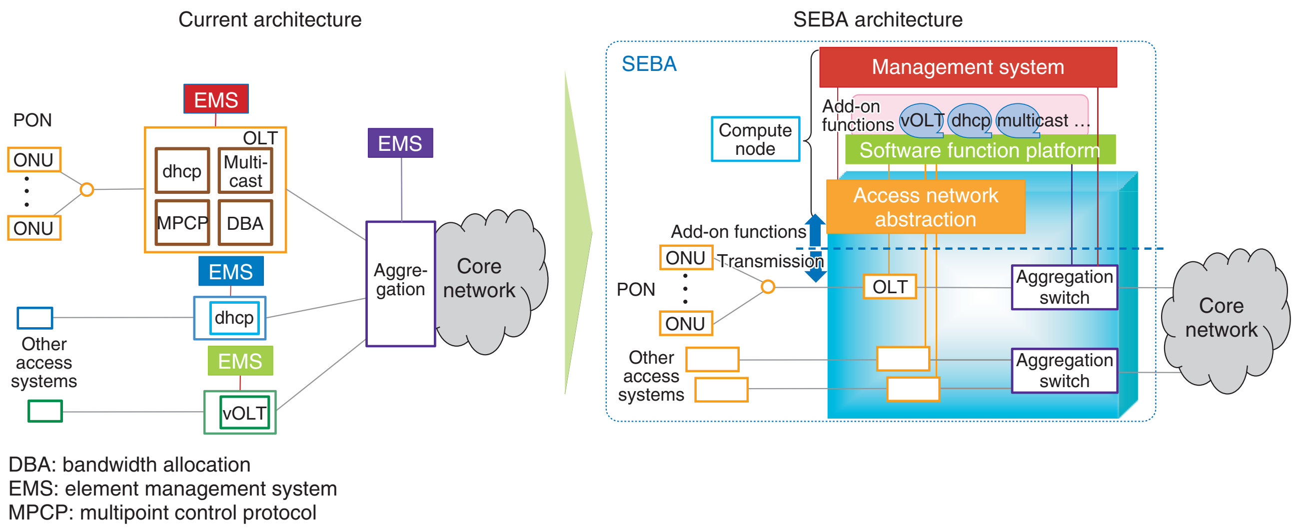

Fig. 5. OLT function disaggregation architecture.

disaggregation architecture, and developed it as open source (**Fig. 5**).

To provide optical access services through various methods, such as point-to-point and passive optical network (PON), dedicated hardware and an optimized element management system have to be used for each type of access system. However, SEBA makes it possible for access systems to implement functions and control schemes on a common software basis and to unify the management system. Since SEBA is open source, anyone can refer to it and freely implement and easily add or delete functions according to the operator's requirements.

As another example of separating the transfer functions from additional functions, we developed an additional function for hitless redundant switching at the edge device when a route failure occurs (**Fig. 6**). Conventionally, when a route failure occurs, a service experiences momentary interruption due to redundant switching, and some packets are discarded. With our technology for separating the transmission/transfer functions from additional functions, hitless redundant-switching devices are installed at both ends of the network, signals are transmitted along both routes, and the signal is selected on the receiving side. This makes it possible to switch routes without interruption. This technology has been in use for a long time, and the unique feature of this technology is that the simple L2 (layer 2) transfer function is used as a network service, and the function for achieving hitless redundant switching is located at the edge device, not the network. Therefore, it is possible to quickly provide hitless redundant switching to those users who need it. Users simply add the hitless redundant-switching device, and no change to the network is needed.

7. Future plans

We will continue our research and development activities on optical access system technology to achieve high bandwidth and low latency networks. We will also promote our technology for separating the basic transmission/transfer functions from additional functions to achieve high flexibility and low operation overheads. These technologies will be strongly leveraged in achieving IOWN and specifically the APN.

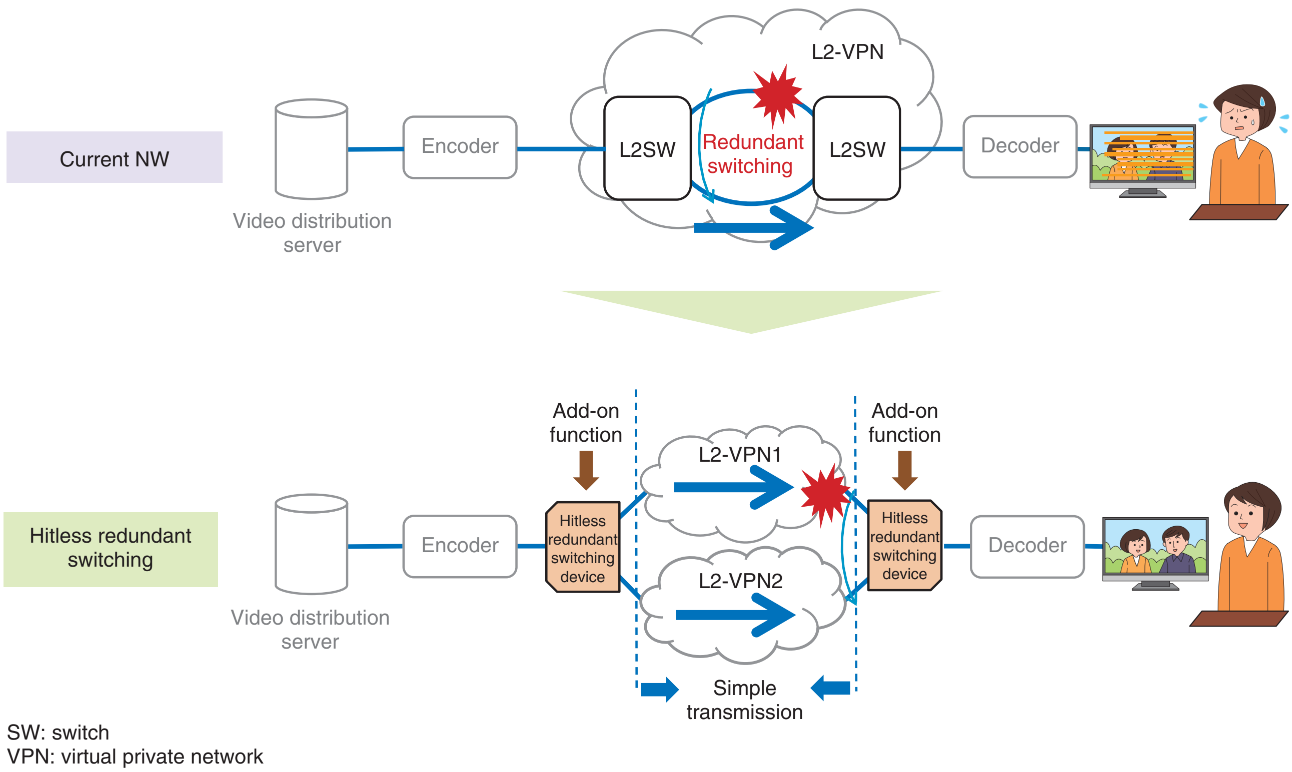

Fig. 6. Hitless redundant switching.

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He received a B.E., M.E., and Ph.D. in communication engineering from Osaka University in 1996, 1998, and 2007. In 1998, he joined NTT Multimedia Systems Development Center. In 1999, he moved to NTT Access Network Service Systems Laboratories, and has been engaged in research on next-generation optical access networks and systems. From 2013 to 2015, he was involved in the research of wavelength division multiplexing/time division multiplexing-PON and worked on the standardization of optical access systems such as NG-PON2. Dr. Yoshida is a member of the Institute of Electrical and Electronics Engineers (IEEE) and Institute of Electronics, Information and Communication Engineers (IEICE).