Perspective on Optical Access Networks

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Abstract

Future optical access networks will require two important functions: high flexibility for mobile networks and Internet of Things networks, and low maintenance to reduce maintenance operations. This article presents the future direction of optical access networks and introduces FASA® (Flexible Access System Architecture), which is an important elemental technology. Optical-mobile cooperative control technology, a concrete example of applying FASA, is also introduced. Finally, FASA applications and standardization activities relevant to the architecture are explained. This article is based on a lecture given during workshops at the Tsukuba Forum 2018 held in October 2018.

Keywords: FASA, mobile network, low maintenance

1. Optical access networks

Recent decades have seen rapid growth in fiber-to-the-home (FTTH) services in Japan, with NTT EAST and NTT WEST having more than 20 million subscribers in total. The NTT Group now faces the challenge of determining how best to respond to changes such as the transition to the B2B2X (business-to-business-to-X) model, the increase in mobile traffic due to the momentous expansion of mobile phone base stations, the emergence of new uses such as the Internet of Things (IoT), and the difficulty in securing maintenance personnel. With today's expanding and diversifying networks, many terminals are connected at the same time, and maintenance personnel will be needed to support them. However, the working population in Japan is expected to decrease year by year and by 2060 to be only 60% of what it is today. Thus, a major issue will be whether there will be sufficient maintenance personnel to continuously and easily maintain the enormous amount of access network facilities. Because access network equipment will be distributed and installed in a great many homes, it will be very important for maintenance personnel to get to the homes quickly when maintenance operations need to be performed.

2. Vision of future optical access networks

Under these circumstances, we believe that *high flexibility* and *low maintenance* will be important key terms for future optical access networks. High flexibility means we must be flexible enough to handle mobile networks, IoT networks, and other networks that are expected to grow in the future. Specifically, we will need to meet new access network requirements such as low latency and massive device connectivity. Low maintenance refers to developing ways to reduce the amount of maintenance that access systems need. The key to putting these two objectives into action is the modularization and virtualization of access functions.

The technical points involved are the separation of transfer functions and service functions and the sharing of optical access networks by overlapping services. The basic idea is to disaggregate the service functions for providing various services onto the upper level, and to use simple general-purpose

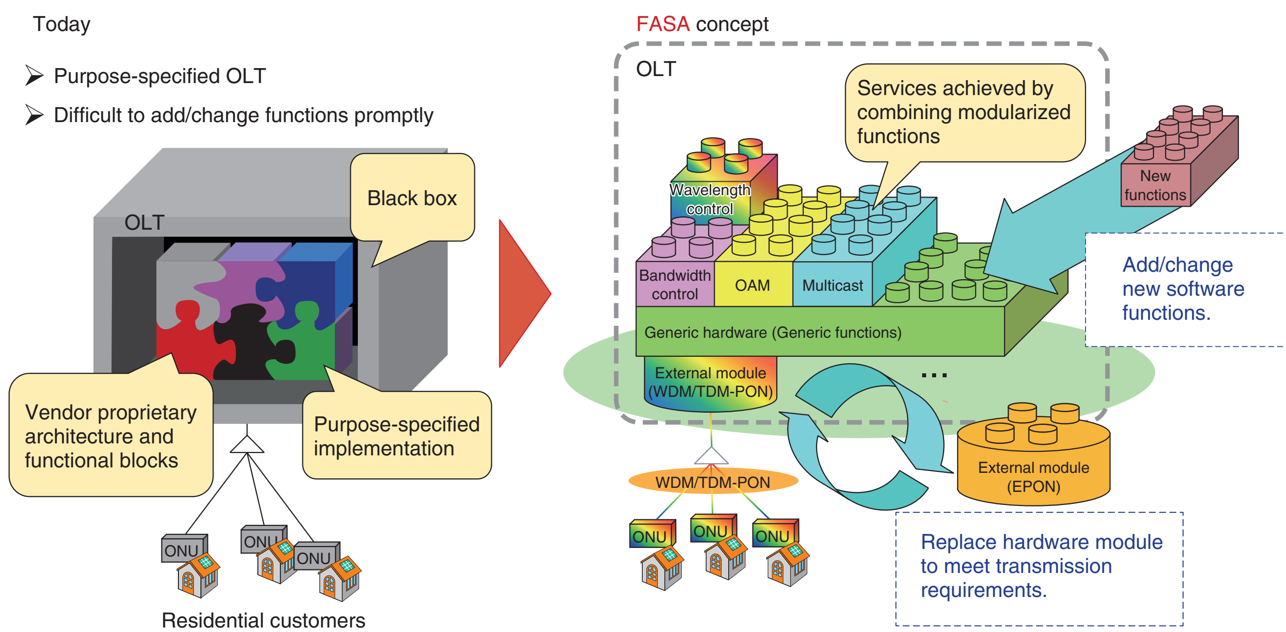


Fig. 1. FASA® concept overview.

hardware as much as possible. Functions can easily be added or removed by concentrating the service functions on the upper level. It is very difficult to change the entire system in order to add new functions in an access network, so it is desirable to disaggregate the service functions as much as possible. New network requirements can be met by adding functions only to the upper level of the systems.

3. FASA® initiatives

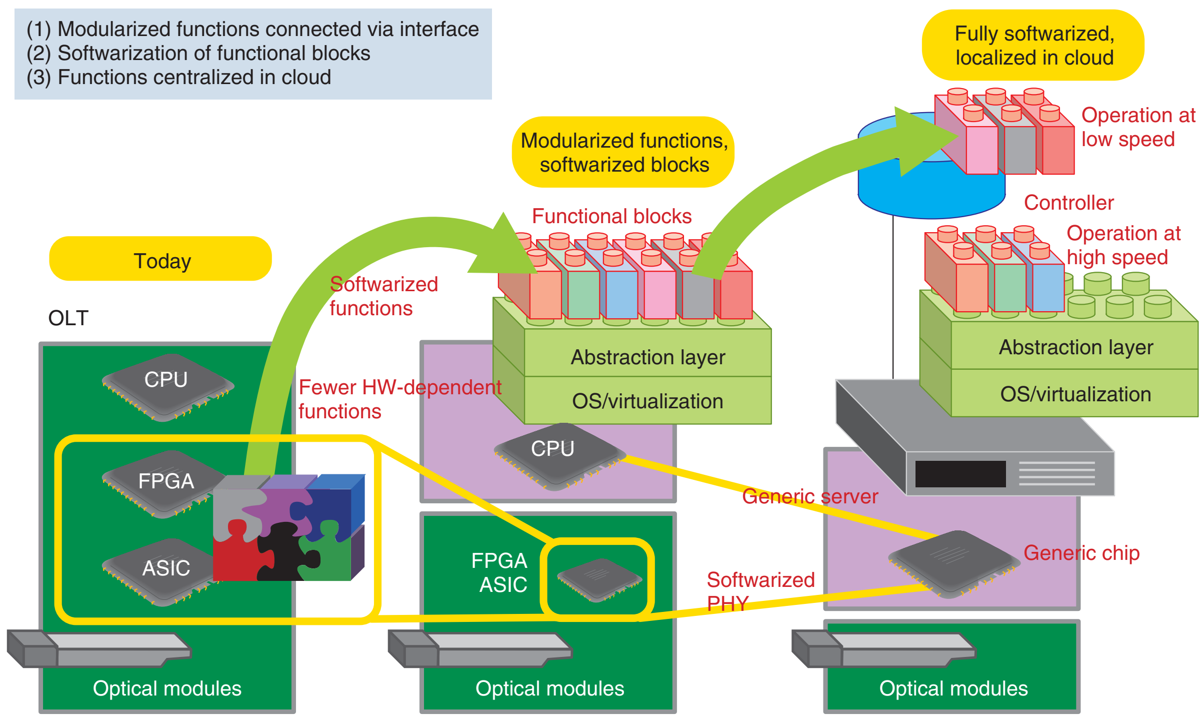
NTT Access Network Service Systems Laboratories announced the FASA®*1 (Flexible Access System Architecture) concept [1] in February 2016. This concept is designed to provide a variety of services quickly and economically and to enable continuous development over a long period of time. Current access networks have introduced different access systems for each service, making it difficult to add or change functions. For example, in the case of FTTH, equipment exclusive to both FTTH and NTT are installed and optimized for each.

In contrast, in the FASA concept, services can be achieved by using a combination of functional blocks (software) that are modularized and implemented on general-purpose hardware (**Fig. 1**). This makes it easy to add or change software functionality. Functions that can only be achieved with hardware, such as hardware modules that are compatible with transmission technology, can be handled by switching hardware.

The FASA concept is designed to achieve four goals:

(1) Faster service delivery: Supports operator specific modularized functions and simplifies installation of such functions
(2) Reduction of operating expenses (OPEX): Contributes to the reduction of OPEX by standardizing spare parts and maintenance work
(3) CAPEX (capital expenditure) reduction: Common, affordable hardware for a variety of services
(4) Service continuity: Enables hardware upgrades and replacements without impacting existing functionality

*1 FASA is a registered trademark of Nippon Telegraph and Telephone Corporation in Japan.



ASIC: application-specific integrated circuit
CPU: central processing unit
FPGA: field-programmable gate array

HW: hardware
OS: operating system
PHY: physical layer

Fig. 2. Key features of FASA technologies.

4. FASA technical features

FASA has three main technical features (**Fig. 2**) as listed below. They are expected to be developed in a step-by-step process in order to achieve FASA utility.

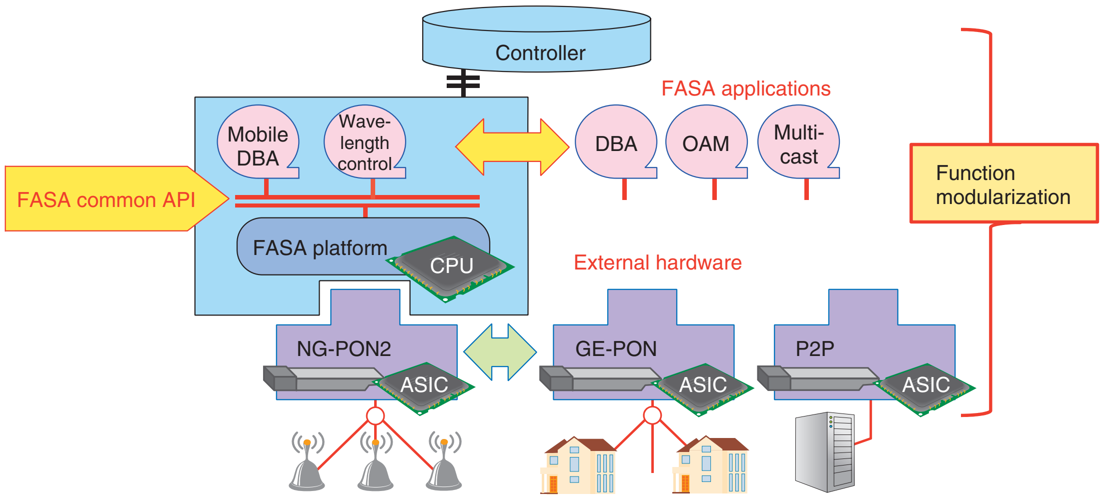
(1) Modularized functions that are connected via interfaces
(2) Softwarization of functional blocks
(3) Functions centralized in cloud

Complex configurations in present systems cause bottlenecks, and functions cannot be easily exchanged. With FASA, however, functions can be modularized (softwarized) from complex configurations and flexibly replaced via interfaces that are defined. Ultimately, we aim to centralize these functions in the cloud. NTT is promoting research and development (R&D) of the FASA common application programming interface (API) to enable various FASA applications to be operated on optical line terminals (OLTs), and R&D of the modularization of functions to enable add/change and dynamic combinations of functions in appropriate blocks, in order to flexibly add/change software functions.

The FASA White Paper was announced in May 2016 (June 2016 for English version) and updated in February 2017 (March 2017 for English version), and a standardization project was proposed to the Broadband Forum (BBF). For example, the dynamic bandwidth allocation (DBA) function can be implemented for mobile bandwidth control as an application that runs on the FASA platform and can be replaced with the DBA application for FTTH. This can be done through the FASA common API (**Fig. 3**).

5. Development direction

The underlying FASA platform and standardized communication protocols must be made available and maintained in an open environment, although features that achieve uniqueness can be developed quickly and flexibly by people who need them. Thus, an environment that can be used in the future is required. Furthermore, in order to reduce maintenance operations as much as possible, it is necessary to be able to concentrate the functions in the upper level as much as possible. To achieve these goals, the



GE-PON: Gigabit Ethernet PON
NG-PON2: Next-Generation PON Stage 2
P2P: point to point

Fig. 3. FASA common API.

platform and API must be open and standardized. We will work with operators not only in Japan but also globally to develop this system as a common architecture.

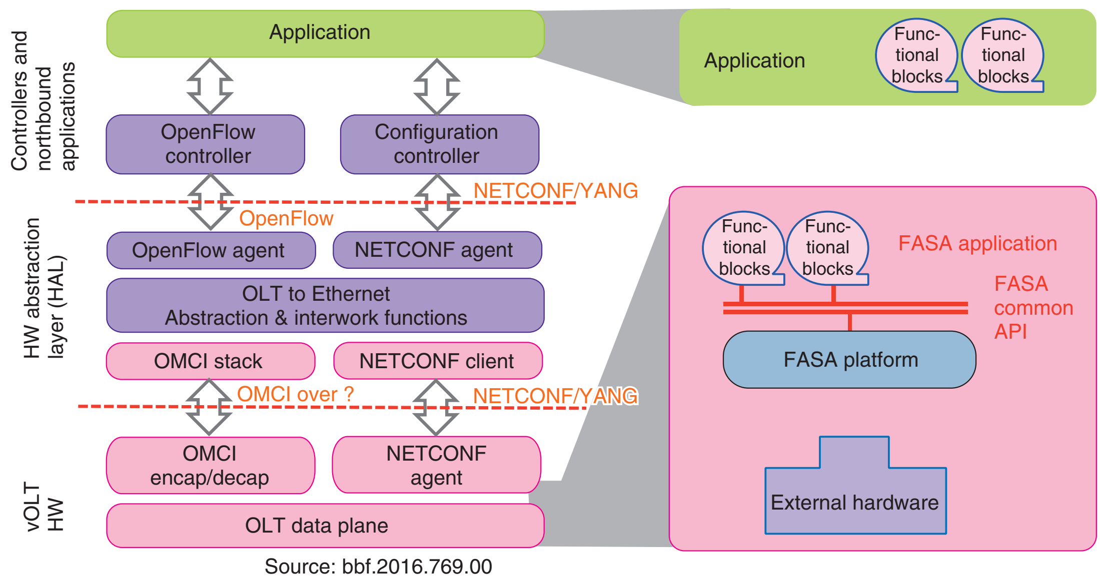
As an example, FASA and the SEBA*2 platform released by the open source software organization Open Networking Foundation (ONF) are complementary, and we are aiming for virtualization that combines FASA and SEBA (**Fig. 4**). The goal is not only to provide flexible control and settings through virtualization but also to create architectures that can be flexibly changed, for example, by adding functions that require high-speed operation.

6. Optical-mobile cooperative control

When combined with FASA, the application area of optical access systems can be expanded to enable optical-mobile cooperative control. With the increasing number of base stations in future mobile networks, it has become a challenge to efficiently accommodate mobile base stations connected by optical fiber. Coordinated operation of optical access and mobile signal control enables optical access networks to achieve low latency and to be used in mobile networks, and to efficiently accommodate a large number of base stations. This was announced in a press release issued on February 14, 2018 [2], and it means that technology for efficiently accommodating mobile base stations using optical access has already been established.

The key point is the Cooperative DBA. A mobile base station functioning as a central unit (CU) notifies an OLT of user terminal scheduling information such as the amount of transmission data and accelerates the transmission permission of a passive optical network (PON) system to achieve low delay (**Fig. 5**). To enable PON systems to transmit upstream, the optical network unit (ONU) sends a transmission request to the OLT after the data arrive at the ONU, and the DBA controls the transmission timing of each ONU by shifting the timing with other ONUs. This increases the delay between the arrival of data and the actual transmission. Since the CU shares the radio frequency with multiple terminals, it performs upstream transmission scheduling in a manner similar to that of PON systems. This radio scheduling information is received by the OLT, and the PON upstream transmission permission is issued in advance in accordance with the radio upstream transmission timing to reduce the delay time. As a result, the uplink delay time, which used to be about 1 ms, has been reduced to less than 50 μs. This was demonstrated at the BBF meeting.

*2 SEBA: SDN (software-defined networking) Enabled Broadband Access platform on a variant of R-CORD (Residential Central Office Re-architected as a Datacenter).



Encap/decap: encapsulation and decapsulation
NETCONF: Network Configuration Protocol
OMCI: optical network terminal management and control interface
YANG: A data modeling language for NETCONF. YANG is an acronym for Yet Another Next Generation.

Fig. 4. FASA and SEBA.

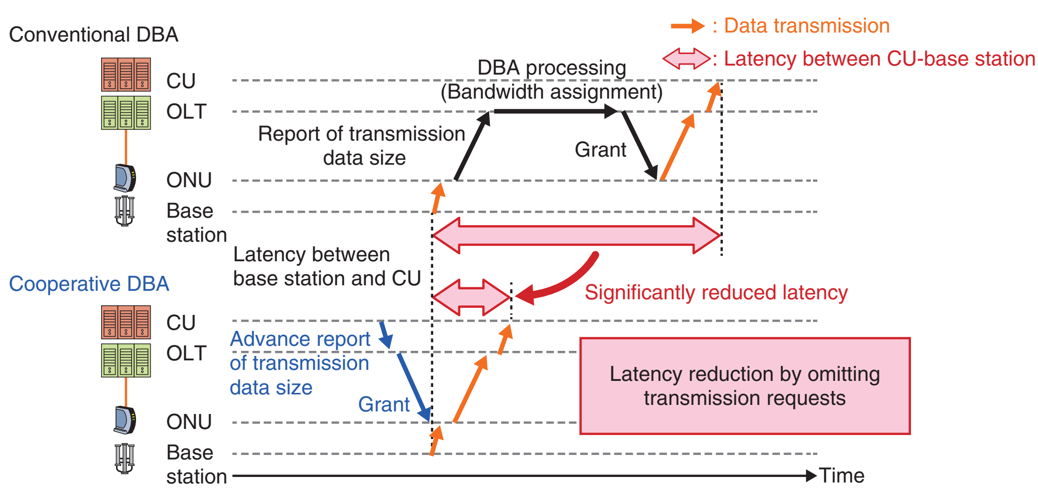
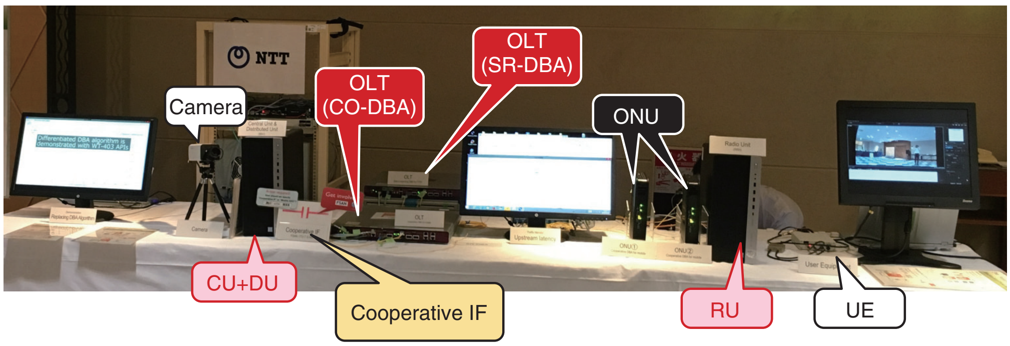


Fig. 5. Cooperative DBA.

In the demo, we compared the delay time between the conventional DBA for FTTH (SR-DBA: Status-Report-DBA) and the DBA for mobile (CO-DBA: Cooperative DBA) in the end-to-end configuration of a mobile system using an LTE (Long-Term Evolution) dongle. This demo was well received by BBF members (**Fig. 6**).

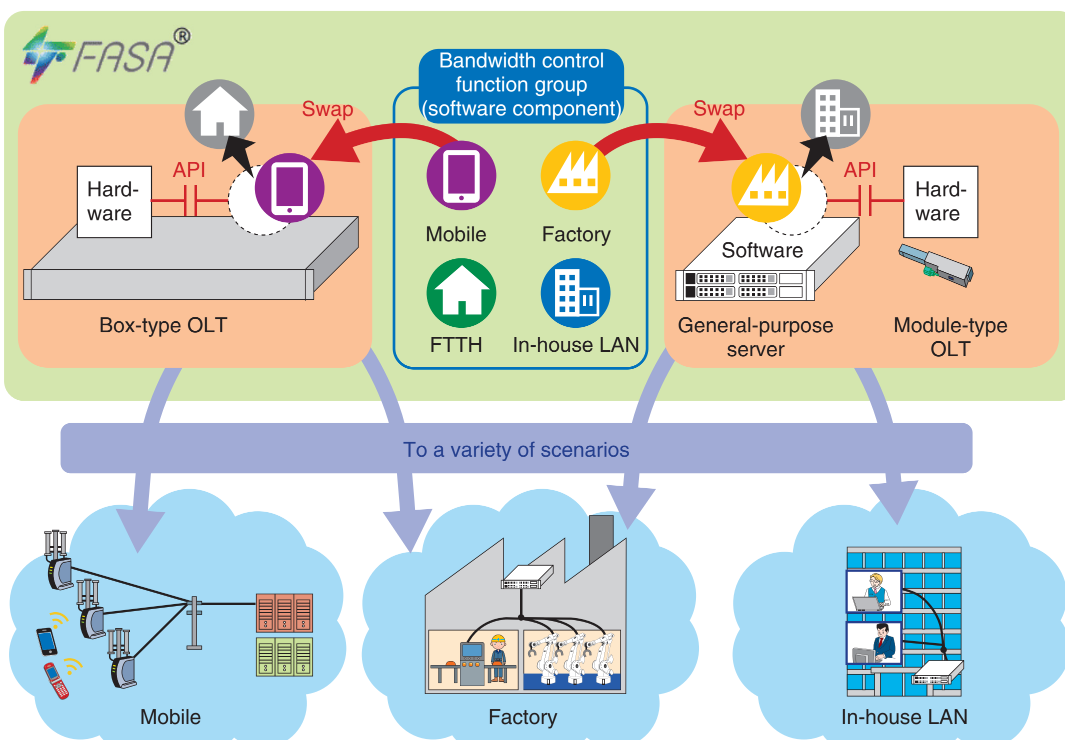
7. Demonstration of DBA function software modules

Among the various functions required for the access system, the DBA function provides high processing performance in real time, so it was considered difficult to replace it by software modularization. A



CU: central unit
DU: distributed unit
IF: interface
RU: radio unit
UE: user equipment

Fig. 6. Demonstration at BBF meeting.



LAN: local area network

Fig. 7. Experimental demonstration on replacing DBA function.

demonstration was conducted in which the DBA function was replaced with software modules in accordance with the usage scenario of the optical access system by two different OLT prototype models with defined APIs (**Fig. 7**). The box-type OLT shown in the figure is expected to be used in environments such as the central office of telecommunications carriers. It is expected to be used to provide conventional FTTH services and in 5G (fifth-generation) mobile systems, which require low latency, in combination with the aforementioned optical-mobile cooperative control.

The module-type OLT shown in the figure is a small module that does not contain all the conventional OLT functions—only those that the hardware is required to achieve. It is used in combination with a general-purpose server with functions that can be achieved with software. It is possible to start on a small scale, so it is expected to be applied to local area networks in factories, universities, and office buildings.

8. Promotion of standardization

It is important for the Cooperative DBA to be able to cooperate without depending on the CU vendor and that it can be installed in commercially available OLTs. We are promoting two standardization projects to achieve this. One involves standardizing the cooperative handling of scheduling information between the CU and OLTs, which the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) and the Full Service Access Network (FSAN) Group are promoting. The other is a BBF project that involves standardizing the DBA algorithm and the IF (interface) between the common processors. Both standardization issues are being discussed with major international operators and vendors. We are working to expand this globally.

9. Future development

For future optical access networks, we plan to promote R&D to put the key terms high flexibility and low maintenance into action. R&D of optical access networks for 5G mobile systems will be carried out as FASA development continues in order to flexibly construct access network systems. We will participate in standardization activities at FSAN/ITU-T and BBF and start development activities at ONF to continuously develop software functions that can be changed flexibly. We will also promote R&D of optical access through discussions with various stakeholders.

References

[1] Website of FASA, http://www.ansl.ntt.co.jp/e/global/FASA/index.html

[2] Press release issued by NTT, “Development and Trial of Low-latency Optical Access Technology that Operates in Coordination with a 5G Mobile System,” Feb. 14, 2018.
http://www.ntt.co.jp/news2018/1802e/180214a.html

■ Author profile

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He received a B.E. in science and engineering and an M.E. in computer science from Keio University, Kanagawa, in 1993 and 1995. He joined NTT LSI Laboratories in 1995, where he engaged in R&D of low-voltage analog circuits, especially analog-to-digital and digital-to-analog converters. He has also been involved in developing small and low-power wireless systems for sensor networks and high-speed front-end circuits for optical transceivers. He is currently responsible for R&D management of optical access networks including fixed-wireless convergence and virtualization technology. He is a senior member of the Institute of Electronics, Information and Communication Engineers (IEICE). He also serves as a technical committee member of the Asian Solid-State Circuits Conference (A-SSCC) and as the vice chair of the IEICE technical committee on Communication Systems (CS).