

April 25, 2017
Nippon Telegraph and Telephone Corporation
Hitachi, Ltd.
Oki Electric Industry Co., Ltd.
Keio University
KDDI Research, Inc.
Furukawa Electric Co., Ltd.

Report on the successful demonstration of innovative basic technologies for future optical access network “Elastic Lambda Aggregation Network”

~ Elastic access-metro integrated network that flexibly changes the transmission speed and optical frequency bandwidth towards future multiple services accommodation beyond 2030 ~

Nippon Telegraph and Telephone Corporation (NTT, Chiyoda-ku, Tokyo, CEO: Hiroo Unoura), Hitachi, Ltd. (Hitachi, Chiyoda-ku, Tokyo, President & CEO: Toshiaki Higashihara), Oki Electric Industry Co., Ltd. (OKI, Minato-ku, Tokyo, President Shinya Kamagami), Keio University (Keio, Minato-ku, Tokyo, President Professor Atsushi Seike), KDDI Research, Inc. (KDDI Research, Fujimino-shi, Saitama, president, CEO: Yasuyuki Nakajima) and Furukawa Electric Co., Ltd. (Furukawa Electric, Chiyoda-ku, Tokyo, President: Keiichi Kobayashi) have jointly challenged the advanced future network for 2030 and beyond by conducting innovative studies on “Elastic Lambda Aggregation Network (E λ AN^{*1})”.

E λ AN sets an adaptive modulation^{*2} OFDM^{*3} transmission system, which leads to the significant improvement of optical frequency utilization efficiency, into the access (subscriber’s home-central office)-metro (central office-central office) network that directly connects the subscriber’s home and the metro central offices via fibers and WSSs^{*4}. Therefore, E λ AN provides flexible assignment of the transmission speed and optical frequency bandwidth to support diversified services with different types of traffic, such as internet, enterprise line, and mobile services.

We demonstrated the reliability of E λ AN through a prototype testbed network which utilizes optical path provisioning and switching technologies. The demonstration successfully showed, for the first time, that the service accommodated in the failed office was automatically re-connected within 10 sec to another office some 10km away with the same transmission speed as before the failure. The project accomplishments will be presented at an international conference on optical communications, iPOP2017 (The 13th International Conference on IP + Optical Network 2017: Kawasaki-city, Kanagawa, Japan: June 1-2, 2017).

This research and development project was contracted with the National Institute of Information and Communications Technology (NICT) of Japan under a research contract titled “Research and development of elastic lambda aggregation network.”

【Background】

Along with the wider penetration of FTTH (Fiber to the Home) services, efficient operation of a large number of network sets is essential in recent optical access networks. Moreover, the future access network must support, in addition to conventional FTTH service, multiple access services, such as mobile, high-definition video and IoT (Internet of Things) services.

Until now, multiple access services have been provided using distinctly different network infrastructures to

meet the disparate service requirements. However, to provide them more efficiently, all services should coexist on the same service-adaptive network that can flexibly meet individual service requirements. If multiple access services share an optical fiber network, high reliability is essential so that the network can keep providing services by autonomous reconfiguration of the network resources*⁵ remaining after a disaster. Furthermore, high optical frequency utilization efficiency (transmission rate per unit of optical frequency) should also be provided to accommodate a large number of services and subscribers.

From this background, as advanced research studies targeting beyond 2030, the six institutions (NTT, Hitachi, OKI, Keio, KDDI Research, and Furukawa Electric) have been researching E λ AN, a service adaptive access-metro network that provides multiple services with high reliability and high optical frequency utilization efficiency.

【Elastic lambda Aggregation Network (E λ AN)】

In conventional access networks, the central office equipment (OLT) is located at access central offices close to subscribers' homes. E λ AN, on the other hand, transfers the OLT to a metro central office that aggregates the traffic of metro networks, as shown in Fig.1. Moreover, E λ AN improves the reliability of access-metro networking, which will need to accommodate a huge number of subscribers, by using WSSs to switch optical paths flexibly. This innovative architecture offers lower end-to-end latency and power consumption, since Optical-Electrical-Optical (O-E-O) conversion in the access central office is not needed.

E λ AN employs a digital coherent*⁶ OFDM system with adaptive modulation, a technique that can realize dramatically high optical frequency utilization efficiency and large-scale flexible service allocation by using the elastic control of transmission speed and optical frequency bandwidth. In addition, E λ AN applies the world's first dynamic bandwidth allocation algorithm in OLTs. This makes it possible for the users to share the additional bits in a fair manner regardless of optical distribution network (ODN) conditions.

【Project Details and Accomplishments】

The jointly developed E λ AN consists of six basic technologies as follows.

- (1) Dynamic bandwidth allocation algorithm in OLT [NTT] (Fig. 2)
E λ AN accommodates multiple subscriber premise sets (ONUs) that have different ODN conditions, thanks to adaptive modulation; it assigns high bit rate optical signal parameters to near ONUs which yields additional bits. Our dynamic bandwidth allocation algorithm shares these additional bits among all users in a fair manner while also satisfying traffic requirements. Successful demonstrations using an OLT and 512-ONUs have been conducted.
- (2) Telecommunication control technology for adaptive modulation OFDM transmission system [Hitachi] (Fig. 3)
Hitachi developed a telecommunication control protocol that features automated search of ONU responding to adaptive modulation OFDM transmission system and automated set up various optical signal parameters in ONU. When optical transmission line is disconnected by any disasters, this developed technology is capable of recovering the transmission automatically by optimizing optical signal parameters for newly-built optical transmission line. Conventionally, this type of transmission recovery has been difficult to perform. Hitachi developed a prototype of OLT and ONU applying this technology on their logic circuits and realized the demonstration of recovery operation.
- (3) Programmable OFDM transceiver and adaptive control algorithm [OKI] (Fig. 4)
OKI developed a programmable digital coherent OFDM transceiver that offers high-speed digital signal processing. It can change the optical signal parameters dynamically. OKI has also developed an adaptive

control algorithm that decides the most suitable optical parameters for the current network configuration. These technologies maximize EλAN performance in the context of high optical spectrum efficiency.

(4) Dynamic traffic capacity allocation algorithm among multiple OLTs [Keio University: Prof. Naoaki Yamanaka, Faculty of Science and Technology] (Fig. 5)

A Logical OLT (L-OLT) is defined as a subscriber accommodation function configured in each OLT to provide the subscriber's required network service. Keio Univ. has developed an algorithm that calculates the optimal placement (i.e. migration destinations) of L-OLTs and assigns traffic capacity among multiple OLTs in about one millisecond based on policies such as fault recovery or energy saving. The developed algorithm has been implemented into the resource controller, which monitors and manages OLTs. Keio Univ. has established dynamic subscriber accommodation technology that ensures cooperation between the optical switch controller and OLTs.

(5) Elastic optical path provisioning system [KDDI Research] (Fig. 6)

KDDI Research, Inc., developed an elastic optical path provisioning system (Optical Switch Controller) that can provide optimum routes and available frequency grids considering multiple service requirements (bitrate, quality of transmission, and latency etc.) in EλAN. In the case of network equipment or optical link failure, this system calculates restoration paths and sets up WSSs.

(6) High Port Count Wavelength Selective Switch (WSS) [Furukawa Electric] (Fig. 7)

Flexible-grid WSS modules with 30 output ports or more have been developed. Furthermore, a massive port count wavelength selective switch with 93 output ports has been demonstrated experimentally. It employs an input/output array with planar lightwave circuit technology. The leading-edge technologies enable low insertion loss and massive port count switches.

To validate the reliability of EλAN with the above six basic technologies, we conducted protection experiments assuming a metro central office failure with total span length of up to 40 km, 10 Gbps/λ channel and 512 ONUs accommodated in an OLT (Fig. 8). The demonstration successfully showed, for the first time, that the service accommodated in the failed office was automatically switched to another office some 10km away in real time with the same transmission rate as before the failure; the switching time was short, less than 10 sec (Fig. 9 and 10).

【Future Outlook】

We will work to enhance the maturity and the reliability of basic technologies for EλAN, and will carry out further development activities.

<Glossary>

- *1 EλAN
Abbreviation for Elastic lambda Aggregation Network.
- *2 Adaptive modulation
Adaptive modulation is the technology that allows the system to adaptively change the optical signal parameters (the modulation level, the symbol rate, the number of subcarriers and the carrier frequency) according to the latest conditions of the optical distribution network (ODN).
- *3 OFDM
Abbreviation for Orthogonal Frequency Division Multiplexing.
A number of subcarriers are multiplexed while meeting orthogonality constraints, so even if they are transmitted with an overlap in the frequency domain at a transmitter, they can be separated at a receiver. This dramatically improves the frequency utilization efficiency.
- *4 Wavelength Selective Switch
Wavelength selective switches select output ports for individual WDM (Wavelength Division Multiplexing) channels without Optical-Electrical-Optical conversion.

- *5 Network resource
Network equipment, optical transmission network, optical frequency resources etc.
- *6 Digital coherent
Technique that remarkably improves optical transmission performance by employing high-speed digital signal processing in the optical transceivers

<Press Contact>

Nippon Telegraph and Telephone Corporation
Information Network Laboratory Group
Planning Department, Public Relations Section
TEL: +81-422-59-3663
Email: inlg-pr@lab.ntt.co.jp

Hitachi, Ltd.
Public Relations and Investor Relations Dept.
Corporate Brand & Communications Division
Kensuke Katagiri
TEL: +81 3-5208-9324

Oki Electric Industry Co., Ltd.
Public Relations Division
TEL: +81-3-3501-3835
Email: press@oki.com

Keio University
Office of Communications and Public Relations
TEL: +81-3-5427-1541
Email: m-koho@adst.keio.ac.jp

KDDI Research, Inc.
Sales and Public Relations Department
E-mail: inquiry@kddi-research.jp

Furukawa Electric Co., Ltd.
IR Department
Shin Katoh
TEL: +81-3-3286-3049
E-mail: fec.pub@furukawaelectric.com

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【Figures】

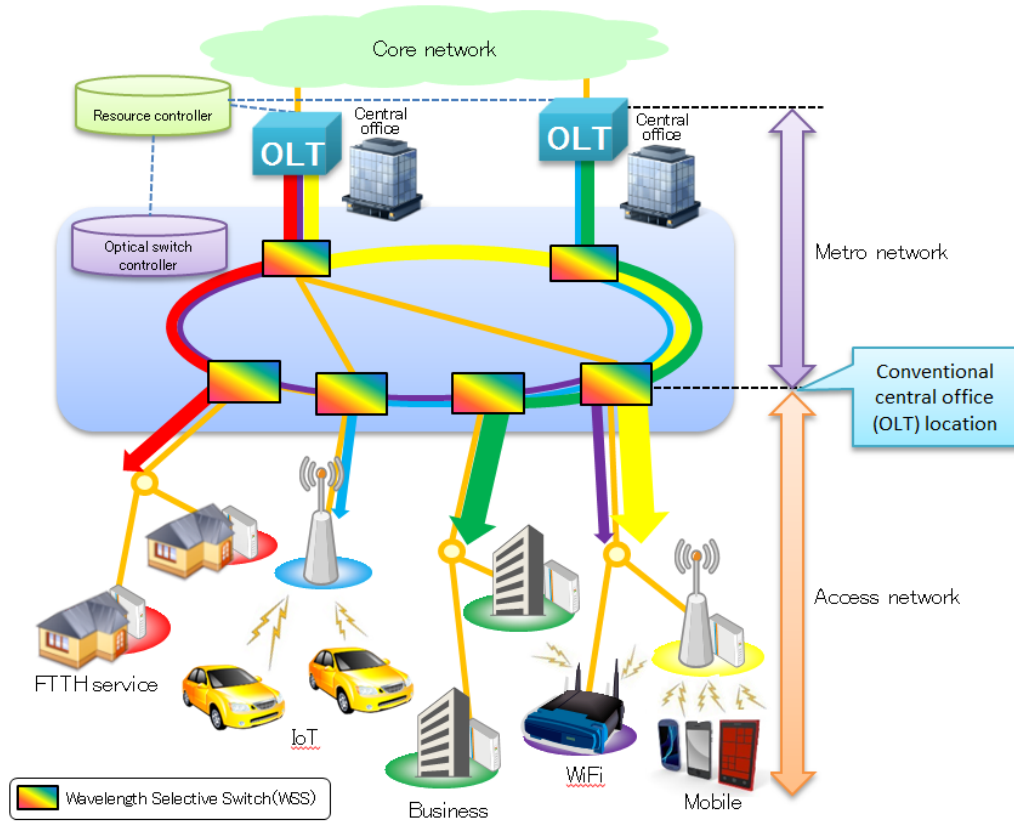


Fig.1 Concept of E-AN

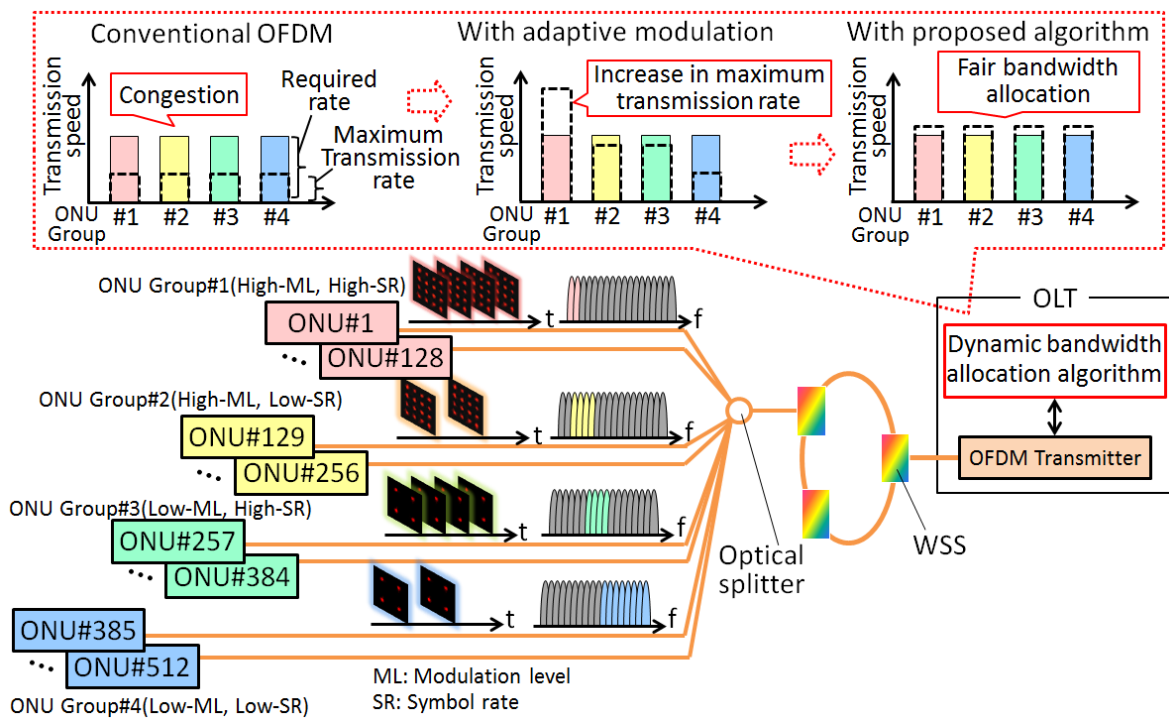


Fig.2 Dynamic bandwidth allocation algorithm in OLT [NTT]

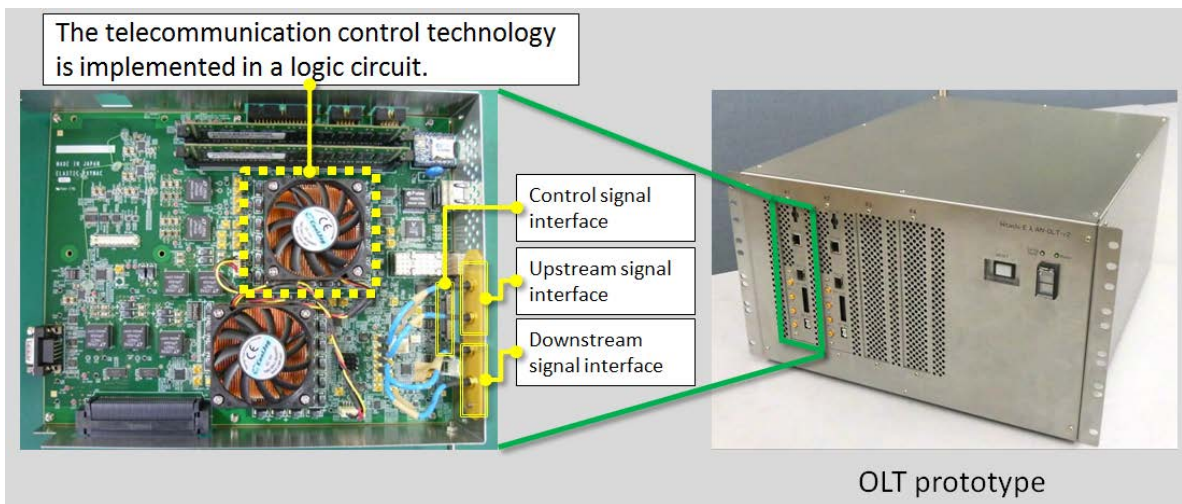


Fig.3 Central office equipment (OLT) with the developed telecommunication control technology [Hitachi]

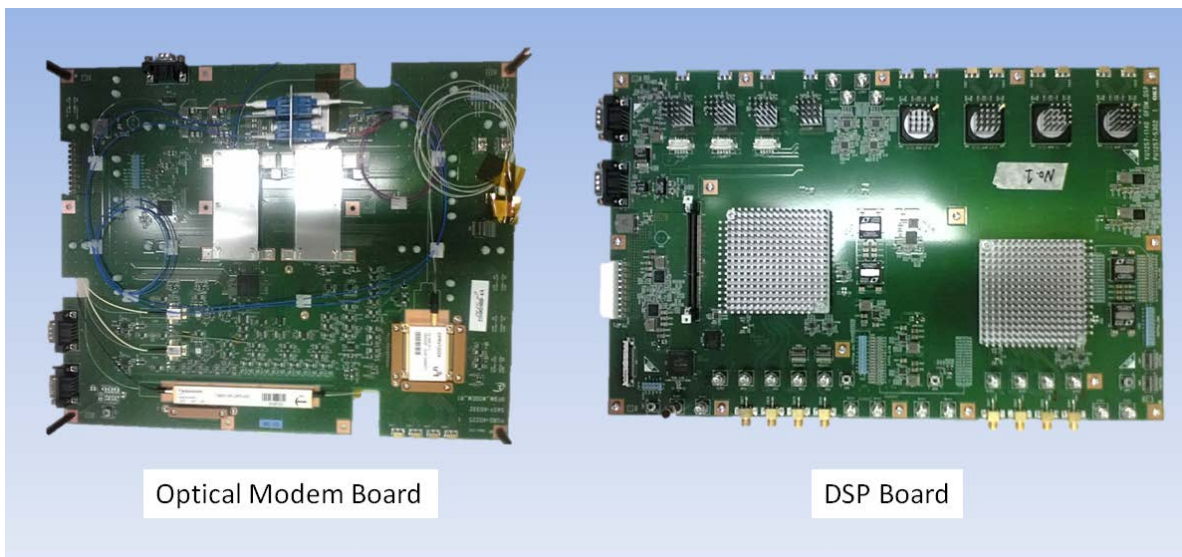


Fig. 4 Programmable OFDM transceiver [OKI]

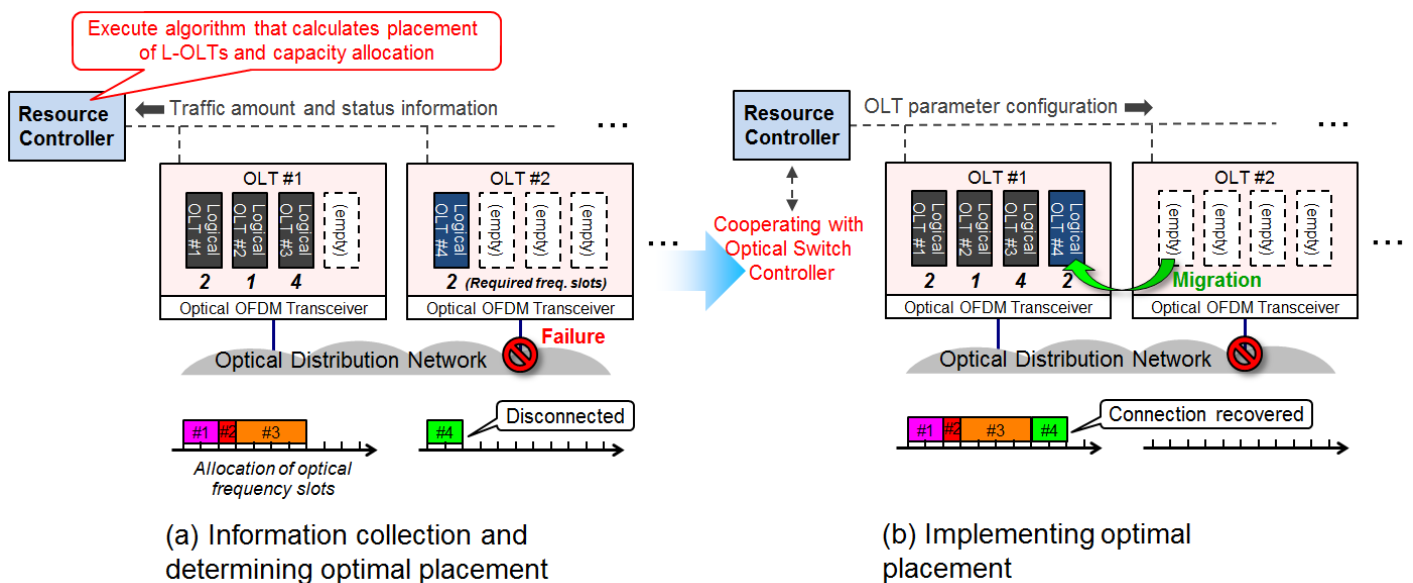


Fig.5 Dynamic traffic capacity allocation algorithm for multiple OLTs [Keio University]

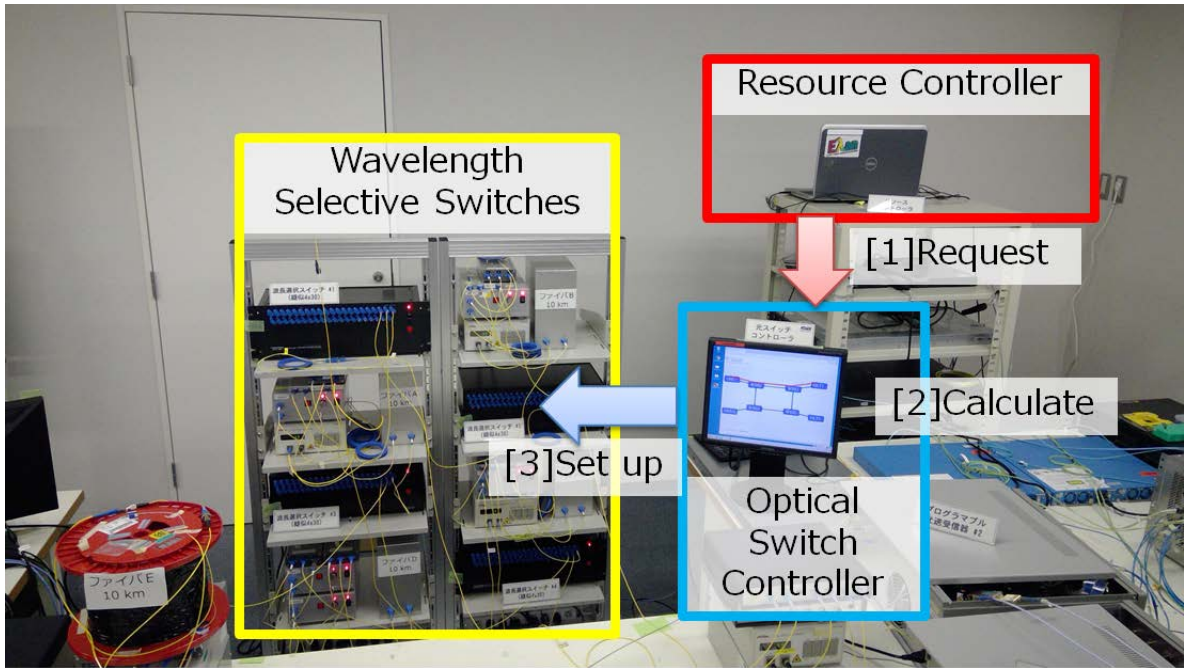


Fig. 6 Elastic optical path provisioning system [KDDI Research]

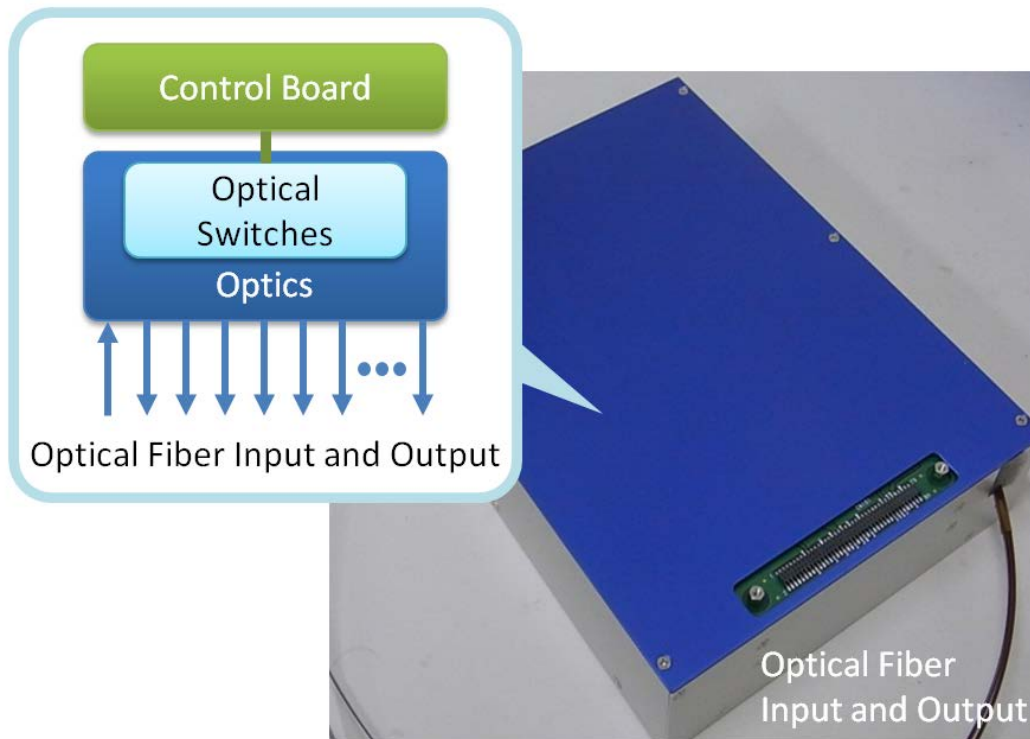


Fig.7 Developed High Port Count Wavelength Selective Switch Module [Furukawa Electric]

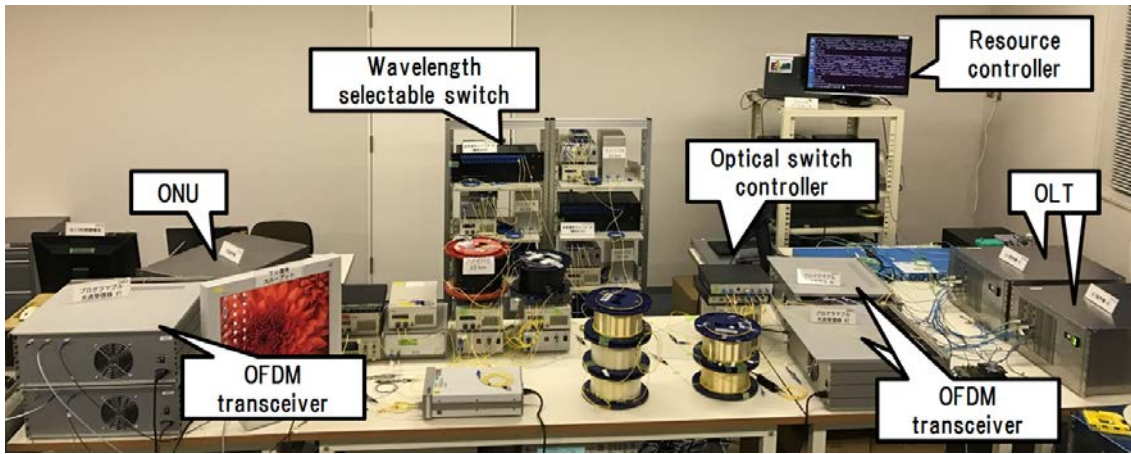


Fig.8 Picture of the experimental setup

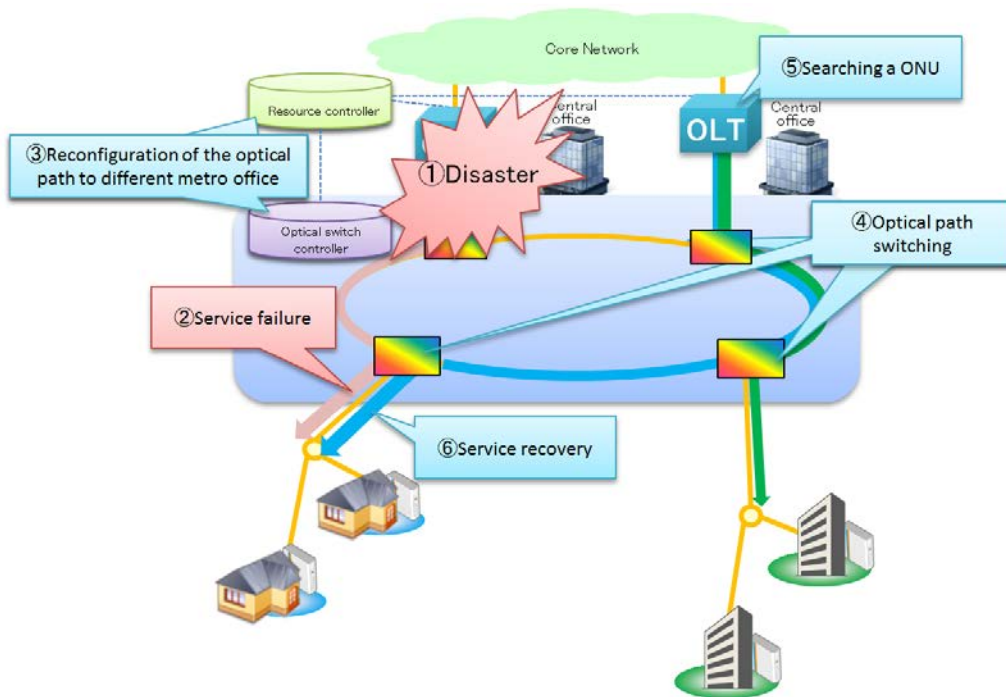


Fig.9 Use case of EλAN (Service recovery for the disaster)

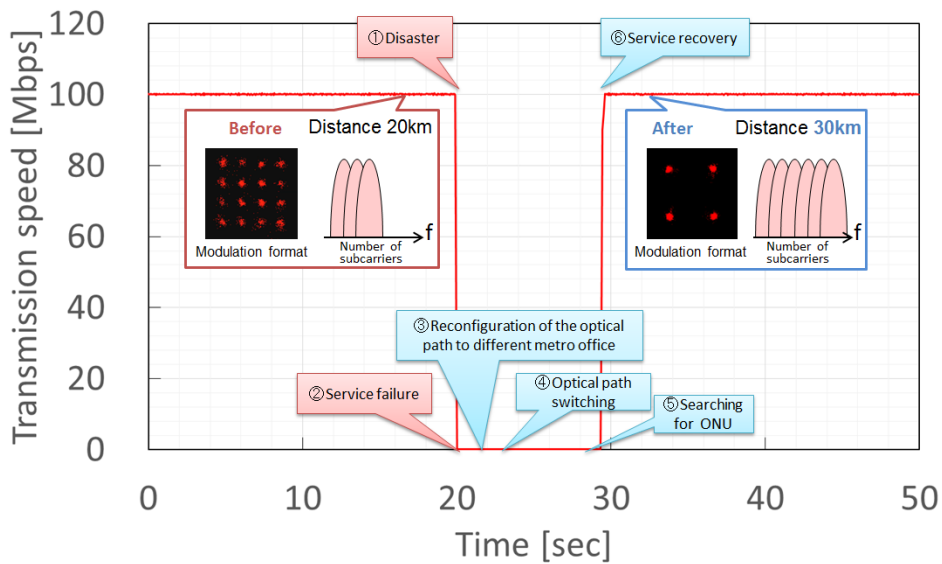


Fig.10 Results of the real-time experiment on service recovery