3-4 Research on GMPLS over JGNⅡ Test bed

OKAMOTO Shuichi, OKANO Yukifusa, OTANI Tomohiro, SAMESHIMA Yasunori, OHARA Takuya, and FUJIHARA Kazuhiro

We have been investigating basic technology to establish a Peta-bit/s class photonic netGMPLS is a set of network control protocols, which can meet the demands for on-demand high speed circuits or on-demand lamda paths. GMPLS/OXC network test bed was introduced in JGNⅡ, that provides the opportunity of operational experience on GMPLS in actual network environments. This paper overviews the researches and experiences made on GMPLS network technologies, network control and network administration. Studies on NNI/UNI and application based experiments are also briefly discussed.

Keywords
GMPLS router, Optical cross-connect, Network control, Network administration

1 Introduction

In the future we can expect to see an increasing number of applications that require service offering high-speed large-capacity circuits tailored to user needs; with uses ranging from high-resolution image transmission to GRID applications. Since existing networks cannot accommodate these sorts of applications, the use of GMPLS* technology—the basis of the next-generation information network infrastructure—will prove essential.

GMPLS and photonic network technologies are positioned as critical elemental technologies in Japan's IT strategy. Establishment of service interfaces and administration technology to support applications requiring on-demand large-capacity circuits is thus essential, and urgently so. The development of GMPLS network administration technology using the JGNⅡ will respond to this urgency in the implementation of Japan's IT policies.

This paper describes our research activities in the development of technologies related to GMPLS network administration; these technologies are critical if we are to establish service networks that can respond flexibly to the advanced demands of applications such as those mentioned above. This research and development employed GMPLS networks constructed on the JGNⅡ, in our study of GMPLS network administration technologies. This work was designed not only to promote R&D relating to the conventional broadband service network environment but also to make a comprehensive contribution to the establishment of network administration technologies, through R&D and verification in actual network environments.

* GMPLS (Generalized Multi-Protocol Label Switching): A set of protocols in which the concept of MPLS currently used for IP networks is expanded and applied to multiple layers of different types. GMPLS is attracting significant attention as a new protocol technology for control of next-generation photonic networks.

2 GMPLS network configuration and research themes

Figure 1 shows the JGNⅡ and GMPLS network configuration. The GMPLS network consists of a northbound route and a south-

bound route (hence, a multi-domain network). In our research, we used GMPLS networks established on JGNⅡ for studies aimed at establishing network administration technologies. Specifically, we focused on the following research themes:

(1) R&D on multilayer network administration technology
(2) R&D to improve the functionality and reliability of GMPLS networks
(3) R&D on multi-domain (E-NNI) integrated management technology
(4) R&D related to application connectivity (UNI)

3 R&D on multilayer network administration technology

We conducted research on a number of GMPLS network administration techniques. The following describes our research on the GMPLS and IPv6/MPLS multilayer administration methods and outlines our investigation of a method of connecting user applications to a GMPLS network.

In this fiscal year our R&D on the multilayer administration method focused on a technology to serve as the basis for connection of a GMPLS network to its upper-layer IPv6/MPLS network. Specifically, our work involved R&D on the enhancement of the GMPLS function of the JGNⅡ core router as well as study of the IPv6/MPLS network connection function.

In our research on the enhancement of the GMPLS function of the JGNⅡ core router, we added the GMPLS function to an IP-base JGN Ⅱ core router and conducted experiments to study the GMPLS route advertising function (OSPF-TE), the optical path setting function (RSVP-TE), and the interconnectivity of OXCs and core routers within a single domain. In these experiments, we confirmed satisfactory performance of each of the above functions. In terms of OXC connection, we demonstrated the feasibility of services allowing direct connection of user equipment to an OXC as well as optical path services for the connection of user equipment to a JGNⅡ core router. (See diagram below.)

As part of our research on the IPv6/MPLS network connection function, we conducted verification experiments on IPv6 data transport operations based on a configuration in which an IPv4-based GMPLS network is used as the core network and an IPv6/MPLS network is connected to the edge. Our experimental system involved a JGNⅡ GMPLS net-

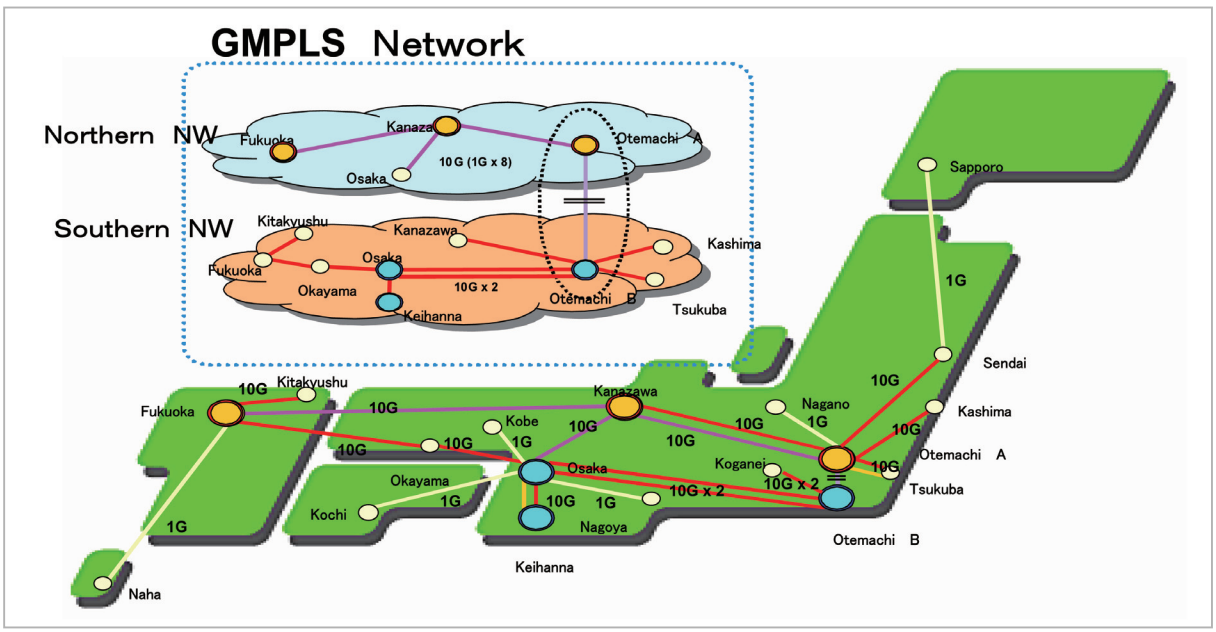


Fig.1 JGNⅡ and GMPLS network

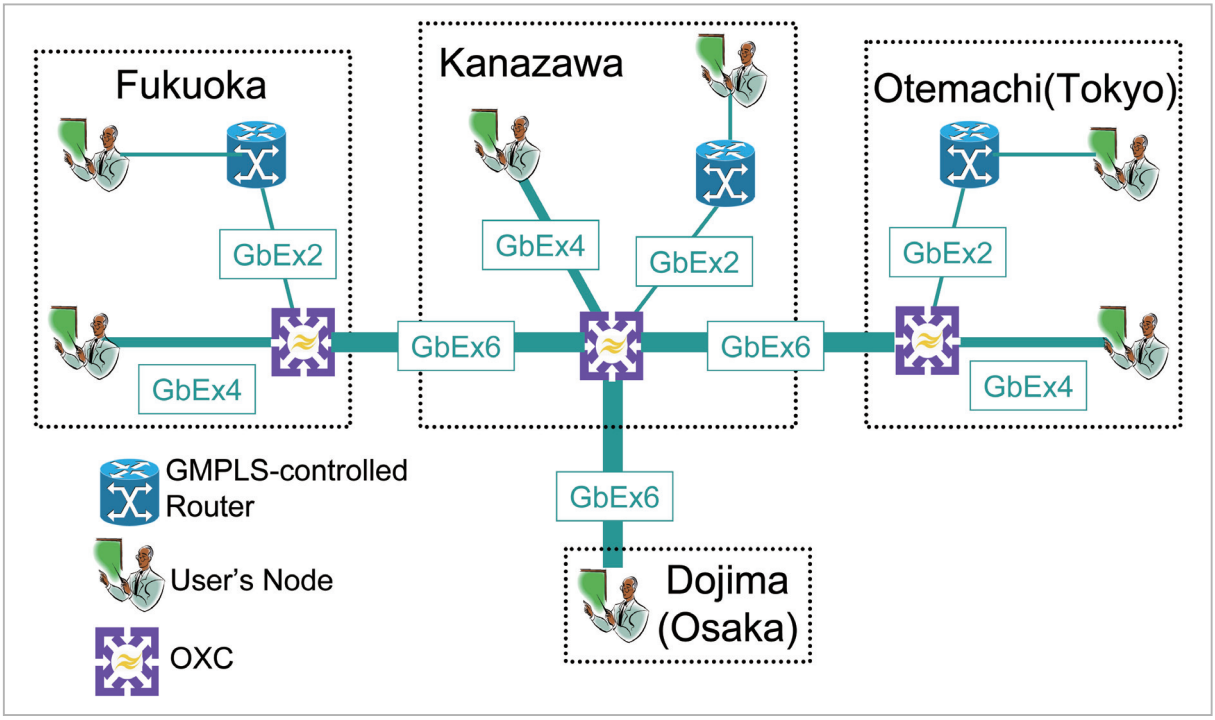


Fig.2 *GMPLS technology for OXC connection service over JGNII*

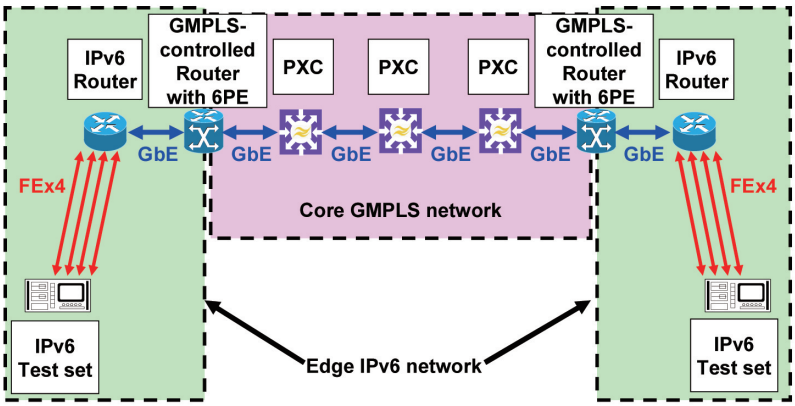


Fig.3 *System used in experiments on IPv6 transport over GMPLS*

work as the core network, and employed an edge IPv6 network configured by connecting an IPv6 router and an IPv6 measuring instrument. The IPv6 data transport experiments consisted of two technical themes: experimentation to set IPv6 route advertising via a GMPLS network and experimentation on IPv6 data transport using a GMPLS optical path. The success of these experiments enabled us to confirm the connectivity of an IPv6 data stream over the JGNII GMPLS network. We conducted experiments on MPLS network connectivity by setting an MPLS path on a GMPLS optical path using a JGNII core router. The results of these experiments confirmed connectivity of the MPLS path via a GMPLS network.

In our R&D on a method of connecting user applications to a GMPLS network, we conducted a basic examination of user-oriented optical path provisioning technology, identifying and narrowing down the parameters that user applications would require from the network. We also studied a method and proce-

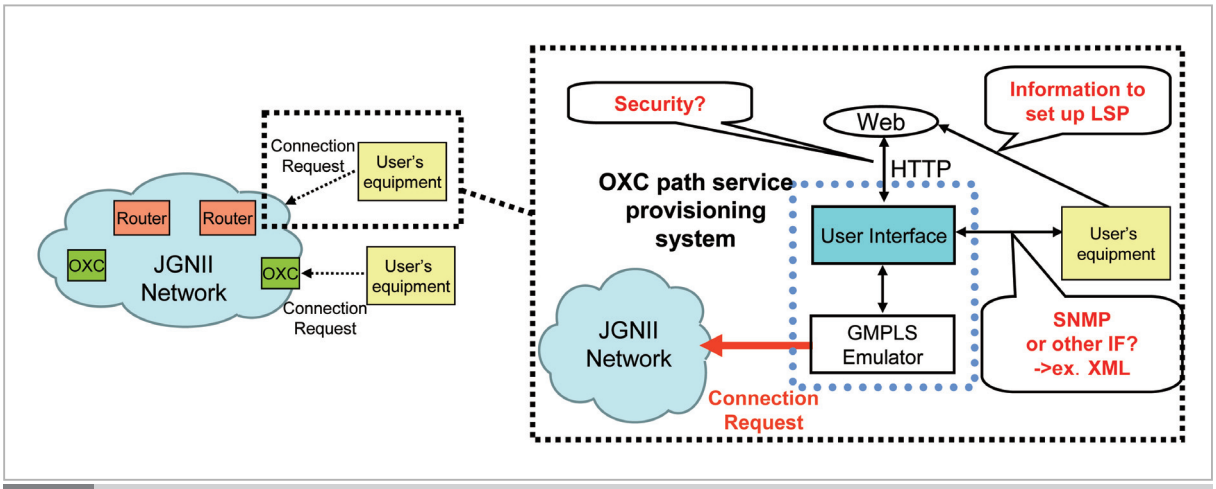


Fig.4 *Technology for connection of user applications to GMPLS network*

dure for connecting the user side to the network side.

JGNII was Japan's first testbed network to incorporate GMPLS technology in a core network. Therefore, daily operation and management of this network can make a significant contribution to research and development of GMPLS network administration technologies. Accordingly, researchers involved in routine administration of the GMPLS network are making improvements and refinements within the address system and in other network areas, rendering this testbed network more suitable for R&D of multilayer network administration and the connection of user applications.

4 R&D to improve the functionality and reliability of GMPLS networks

A GMPLS network is comprised of a wavelength-division multiplexing (WDM) optical transmission system, which sends multiple wavelengths of light through a single pair of optical fibers; an optical cross-connect system (OXC), which switches the path of light at nodes and converts wavelengths; a GMPLS router, which provides multi-layered control for IPs and light wavelengths; and a network management system (NMS) for network administration.

A GMPLS network also uses an interface (NNI) for inter-network connection to different GMPLS networks and an interface (UNI) for connection between the GMPLS network and user networks. We studied the functions and performance of these component elements and conducted verification experiments using an actual network (JGNII). The following is an outline of our research activities in these areas.

(1) For GMPLS routers, we conducted the following research and verification experiments with a GMPLS network over JGNII in order to clarify the requirements for service interfaces.
  (i) Assessment of the functionality and performance of the protocols, including stability and scalability
  (ii) Identification of essential service interface characteristics, problems, and bottleneck factors, as well as examination of their effects on network administration
  (iii) Evaluation of network performance for wide-area application transmission

(2) Our research on an optical cross-connect system (OXC) focused on high-speed control of optical paths. The OXC system cross-connects received wavelengths and also converts them to a specified wavelength. The currently installed wavelength-variable laser is of the temperature-controlled type and a few dozen seconds is required for the wavelength to stabilize. More time is required for the general con-

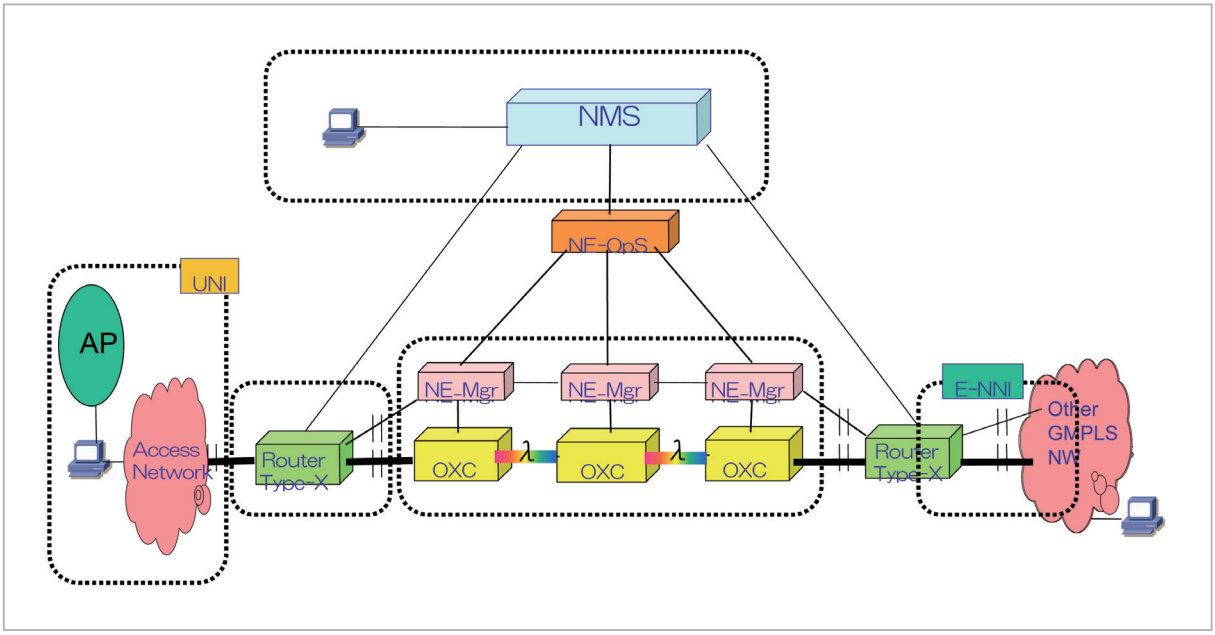


Fig.5 *Component elements of the GMPLS network*

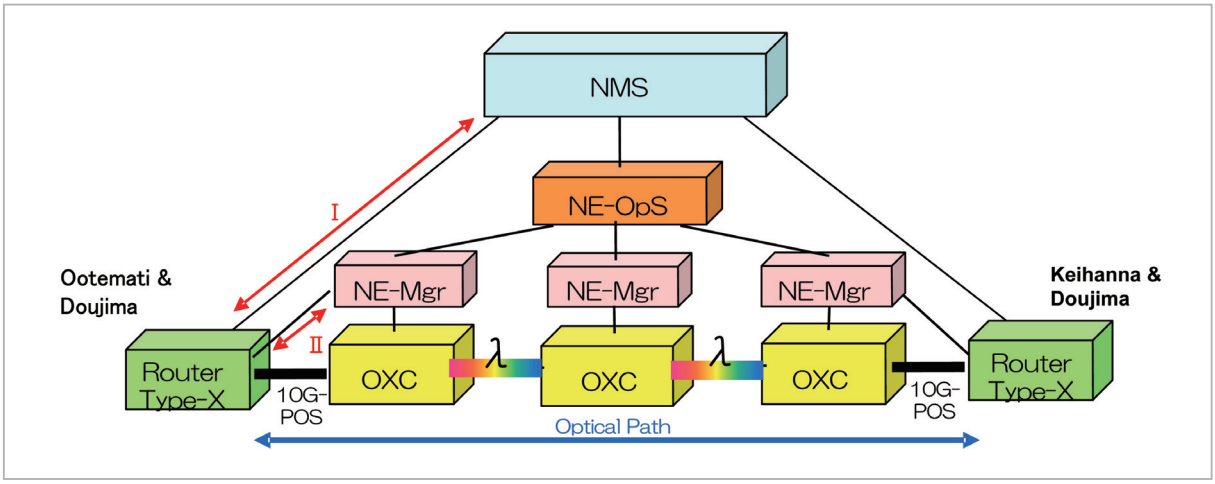


Fig.6 *GMPLS router verification test system*

trol system to stabilize. To improve laser stability, we used a high-speed wavelength-variable laser of the current-controlled type. This verification experiment showed improved speed and stability in the wavelength and control system. The test results showed a reduction in the time required for stabilization, from about 90 seconds to slightly more than ten seconds, in the general control process.

(3) We also engaged in research into customer control in a GMPLS network administration system. A GMPLS network provides high-speed on-demand circuits to users. Using this network, these users (customers) can obtain network information via external networks such as the Internet and also enables customer control of the networks.

We examined customer control functions such as a path opening function over multiple layers (based on the GMPLS function) and a function for displaying both path structure information and error information.

We set multiple privilege types for users exercising customer control and examined ways to achieve flexible authorization and administrative control functions. The follow-

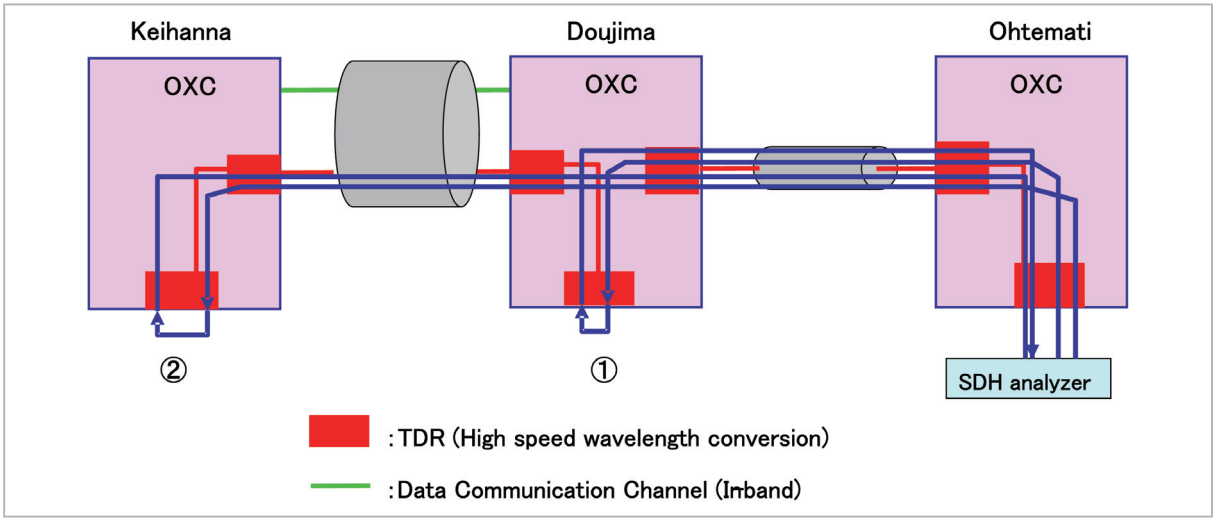


Fig.7 *Test system using high-speed wavelength-variable laser*

ing are the specific research topics in these areas.

- Confirmation and assessment of functions and stability relating to customer control
- Confirmation and assessment of functions relating to network control information
- Confirmation and assessment of functions and stability relating to an e-mail notification function for users; verification of customer control server/external network connection for confirmation of real-field operations; verification of basic functions such as functions for searches of network control information and displaying of results and an e-mail notification function

5 R&D on multi-domain (E-NNI) integrated management technology

The inter-network interface (NNI) establishes two types of connection. In one, the interface (I-NNI) makes connections within a single controlled domain, while the other (Exterior Network to Network Interface, or E-NNI) establishes connections to a different controlled domain, such as for an inter-carrier connection. We are currently working on the following R&D activities to realize interconnection (E-NNI) between different GMPLS domains—via the northbound and southbound routes—operated and managed separately in JGNII.

(1) Interconnectivity of GMPLS control plane networks in multiple GMPLS domains

(i) Examination of network architectures

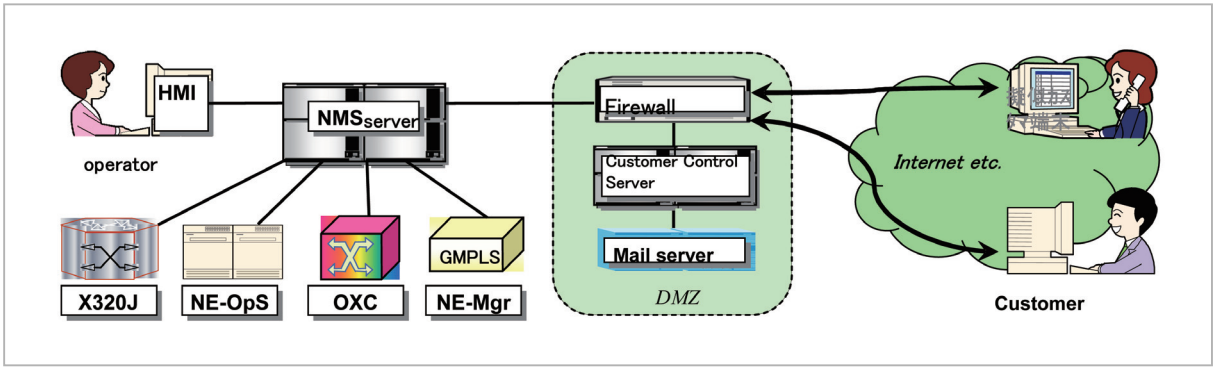


Fig.8 *Customer control in GMPLS*

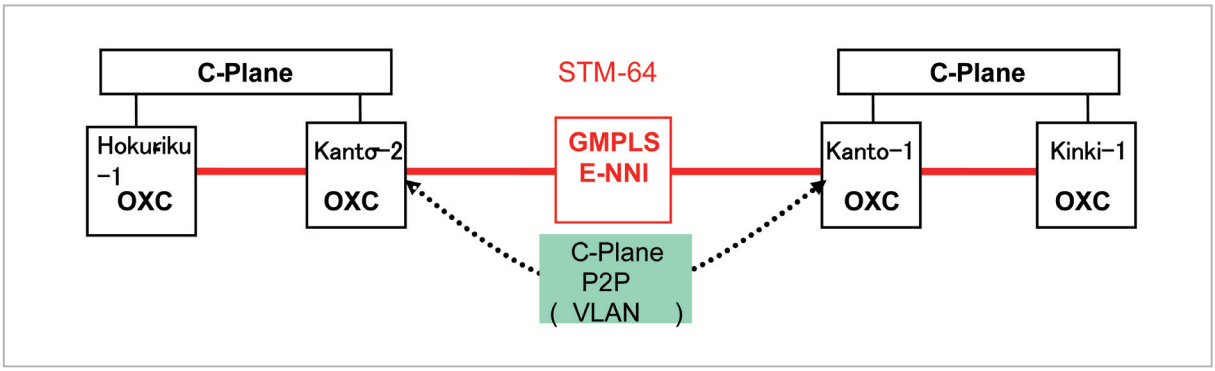


Fig.9 *E-NNI test system*

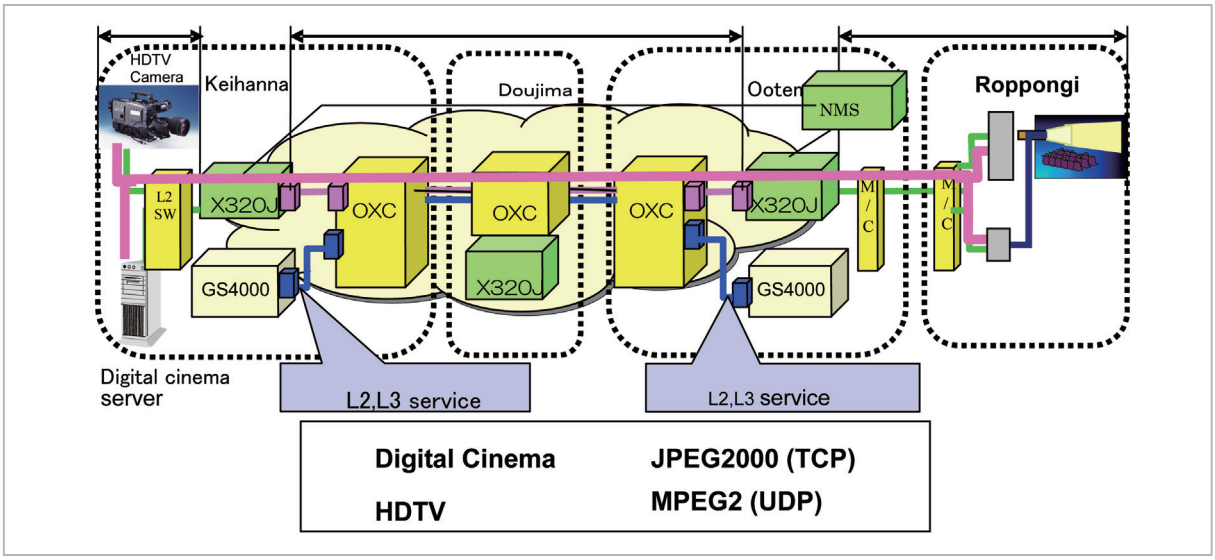


Fig.10 *4K transmission system used at the Tokyo International Film Festival*

(ii) Examination of address systems

(2) GMPLS E-NNI interconnectivity in multiple GMPLS domains

(i) Examination (e.g., of BGP/OSPF) and verification of path information exchange methods

(ii) LSP setting for RSVP signaling

Specifically, in the research we have conducted thus far, OXC points were connected on the data plane using experimental STM-64 wavelengths between Kanto-1 and Kanto-2. For the control plane, we achieved connection using the L2 service and subsequently identified problems and further topics relating to connectivity.

6 Application connectivity

In addition to research directly related to networks (such as our study of component network elements, control, administration, and interconnection), we also examined the connection of specific applications.

We conducted verification experiments for 4K digital cinema transmission at the Tokyo International Film Festival and at the JGNII Symposium 2005 in Osaka using a GMPLS network, verifying practical implementation of the technology.

We also promoted studies on GRID connectivity, such as GRID resource allocation and GMPLS network control linkage, and conducted a demonstration using JGNII in iGRID2005.

7 Conclusions

Using two GMPLS networks constructed on the JGNⅡ, we conducted research in a wide range of technical fields, including network construction technologies, control technologies, and administration technologies. We also conducted research and verification experiments for integrated management and application connectivity on a multi-domain platform using an actual network. Through these activities, we confirmed the usability and practicality of GMPLS.

We would like to take this opportunity to express our appreciation to Dr. Tatsuzo Koga, Director of the Tsukuba JGNⅡ Research Center, for his kind advice. We would also like to thank everyone who provided assistance in our experiments.

OKAMOTO Syuich

Expert Researcher, Tsukuba JGNⅡ Research Center, Collaborative Research Management Department

Optical Network Technology

OKANO Yukifusa

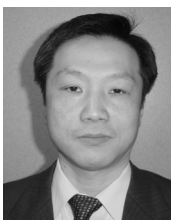
Expert Researcher, Tsukuba JGNⅡ Research Center, Collaborative Research Management Department

Network Technologie

***OTANI Tomohiro**, Dr. Eng.*

Guest Researcher, Tsukuba JGNⅡ Research Center, Collaborative Research Management Department

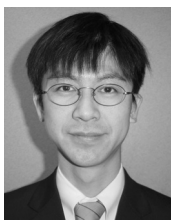
Optical Network Technology



SAMESHIMA Yasunori

Guest Researcher, Tsukuba JGNⅡ Research Center, Collaborative Research Management Department

Optical Network Control Technology



OHARA Takuya

Guest Researcher, Tsukuba JGNⅡ Research Center, Collaborative Research Management Department

Optical Transmission Technology

FUJIHARA Kazuhiro

Expert Researcher, Tsukuba JGNⅡ Research Center, Collaborative Research Management Department

Network Administration Technology