6 Interoperability

6-1 A Study for Technology of Controlling Next-Generation Backbone Network

OTSUKI Hideki, ARAI Nahoko, and MORIOKA Toshio

It is strongly required from both viewpoints of reducing operation cost and advanced network functionality, to achieve a technology to control kinds of network equipments by single protocol set. For development of wavelength division multiplex network, as next generation optical network, it is expected to be in practical use the GMPLS technology to control optical paths.

NiCT is investigating to realize a global inter-operability of GMPLS in Kei-Han-Na Info-Communication Open Laboratory, collaborating with industry, academia and government and aiming to lead international standardization, furthermore, to achieve a wide area field test bed for GMPLS network utilizing JGN Ⅱ.

Keywords
Photonic network, GMPLS (Generalized Multi-protocol Label Switching), Standardization

1 Introduction

In optical communications handling high-speed transmission of information, a variety of multiplexing technologies allowing for capacity expansion have come into use for circuit switching, including time division multiplexing (TDM) and wavelength division multiplexing (WDM). On the other hand, another protocol, referred to as MPλS (Multi-Protocol Label Switching), is also available from among the various technologies ensuring effective circuit switching on the Internet. Further, MPLS has been extended to applications in wavelength-multiplexed transmission; this process is known as MPlS (Multi-Protocol Lambda Switching). These technologies simplify switching by assigning a destination label or wavelength with a specified destination to a range of communications protocols of different types in order to achieve the desired transmission. At the same time, different connection technologies have been employed for physical control of optical-fiber connections in photonic networks and for traditional TDM. GMPLS (Generalized Multi Protocol Label Switching)[1] is now available to ensure unified control over these optical and TDM switching applications. GMPLS applies the same method of control method throughout the whole network, namely, the fiber connection, wavelength, TDM, and packet layers. Further, GMPLS allows all layers to work in a coordinated fashion to create a given communication path. In GMPLS, these layers are collectively referred to as “multi-layers”.

While today’s GMPLS has been standardized to support operability within a single carrier, in a so-called “domain” configuration (I-NNI), many challenges remain in terms of inter-domain operability (E-NNI), due, for example, to scalability problems and differences in management policies. Further, products developed based on current standards are often problematic in terms of interoperability because of differences in the interpretation of standardization documents and in implementation. Thus while devices from a single vendor can be interconnected, it is difficult to build a multi-vendor environment.

This presentation provides an overview of research relating to the above GPMLS issues conducted at the Kei-han-na Info-Communication Open Laboratory and in a wide-area experimental environment using the JGNⅡ network.

2 Interoperability working group

The Interoperability Working Group of the Kei-han-na Info-Communication Open Laboratory's High Performance Networking Subcommittee (referred to below as the "IWG") is working to verify GMPLS interoperability, achieve inter-domain operation, and provide a multi-vendor environment. The present working group, comprised of participants from 14 different organizations* in industry, academia, and the government, focuses on the following four subjects, each of which is treated as a project (abbreviated as "PJ" below).

* NICT, Keio University, NTT, NTT Communications, KDDI, KDDI R&D Laboratories, Fujitsu, Fujitsu Laboratories, NEC, Mitsubishi Electric, Hitachi, Hitachi Communication Technologies, Furukawa Electric and Anritsu (in random order, abbreviated names)

(1) PJ1: Standard GMPLS interoperability verification (C-Plane/D-Plane) project
(2) PJ2: Development and verification project for physical interface for inter-carrier operation
(3) PJ3: Development and verification project for logical interface for inter-carrier operation
(4) PJ4: Nationwide GMPLS network building project

The PJ1 is an experiment-oriented project designed to verify the interoperability of GMPLS equipment. This verification of interoperability is underway using equipment brought to the Kei-han-na Info-Communication Open Laboratory from the participating organizations. The objectives of the project include (1) verification of interoperability, including parameter-tuning of control messages for such as OSPF-TE (a routing protocol for GMPLS) and REVP-TE (a signaling protocol for GMPLS); (2) verification of establishing optical-fiber communication paths, and implementation of lambda, TDM, and MPLS layers in a transport network; and (3) verification of successful end-to-end transmission. It is hoped that all of these endeavors will together lead to the establishment of an Implementation Agreement, or IA.

The PJ2 is charged with development and verification of an inter-carrier physical interface. Currently the project is focusing in particular on transmission of 10 GbE-LANPHY (a 10 G/s Ethernet physical interface that has come into use in recent years in the Internet) over a photonic network known as OTN (Optical Transport Network). ITU-T, the international standardization organization for telecommunications, has provided a definition, in G.8080, of network architecture using GMPLS referred to by the acronym ASON, for Automatic Switched Optical Network[2]. ASON uses GMPLS as a control protocol and OTN, defined under G.709[3], as a transmission line. We believe that it will prove critical to transmit 10 GbE signals directly using OTN, as this signal is likely to be used for mainstream traffic in the future; accordingly we have been submitting a number of relevant proposals to the ITU-T international standardization organization. While no international standard exists for the transmission of 10 GbE-LANPHY over OTN, vendors have made an early start by interconnecting devices under development for testing purposes. With IWG-led interoperability verifications and experiments already conducted with overseas vendors, we will aim in the future to achieve not only standardization but also de-facto standard status.

PJ3 is engaged in developing a GMPLS control layer interface between carriers. Theoretical studies are underway focusing on requirements and functions in relation to RSVP-TE, a signaling protocol, in addition to investigation of a routing protocol, which will be necessary for E-NNI. With respect to the requirements identified in the course of these studies, participating organizations have been submitting standardization proposals to the IETF (an international standardization organization). Meanwhile, tests were conducted on a prototype E-NNI control node for GMPLS.

PJ4 works mainly on an independent basis to perform field tests in response to results generated by PJ1 and PJ3. This project is scheduled to expand the scale of testing in PJ1, building a wide-area GMPLS network using JGNⅡ and conducting a verification experiment to assess interoperability. In the experimental network, verification will be carried out by fitting the inter-carrier interface with a number of connection points.

Figure 1 shows the objectives of each project.

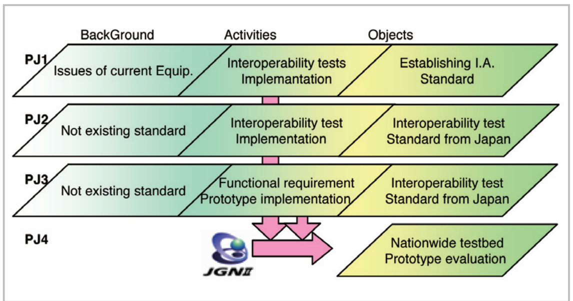

Fig.1 Objectives of each project

3 Activities and field tests

3.1 Verification of standard GMPLS interoperability

The PJ1 experiments have centered on verifying interoperability of existing equipment. This verification was carried out by installing and using GMPLS equipment, configured for use as a reference system, in the Kei-han-na Info-Communication Open Laboratory. Moreover, a conversion node was developed that can convert parameters and object-related data from the GMPLS protocol between the devices under verification, and analyses were performed on devices between which interoperability was faulty. The analysis results were then incorporated in the equipment, leading to successful direct connection of devices. This problem-solving experience is exploited in the experiments of the PJ3 and PJ4, which will be described later. The eventual objective of the project is to feed back analysis results to the reference system as well as to develop standard implementation specifications, as shown in Fig.2.

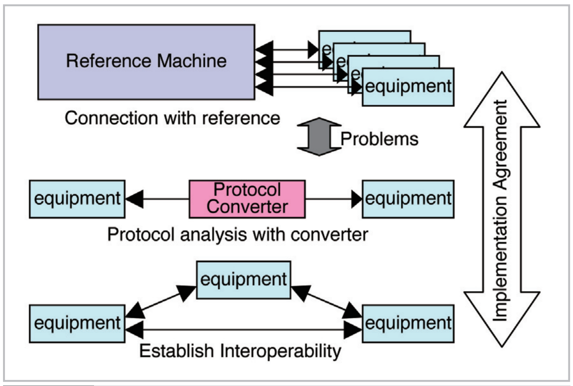

Fig.2 Verification of Standard GMPLS Interoperability

3.2 10 GbE lanphy over OTN

Covering the physical layer, the PJ2 has been engaged in activities centering on active theoretical studies. In light of the lack of standards for direct transmission of 10 GbE Lanphy signals over OTN, the PJ2 has submitted proposals[4] and [6] to the ITU-T. In this case, transparent transmission of 10 GbE Lanphy data over OTN without modification to the data will exceed the specified OTN bit rate. Therefore, a technique referred to as “overclocking” has been proposed to enable transmission in this manner. To push ahead with the international standardization of Japan’s original technology, verification of the interface proposed herein and a basic performance evaluation are underway, in cooperation with carriers and vendors, domestic and foreign alike. The relevant points of evaluation are shown in Fig. 3. As a result of these efforts, interoperation between devices using the pre-

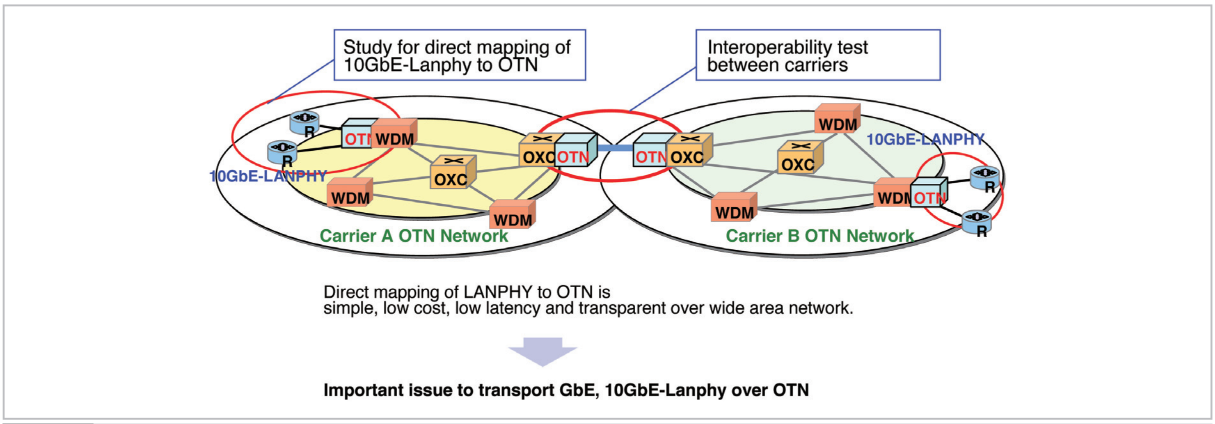

Fig.3 *10 GbE-Lanphy-over-OTN interoperability verification*

sent interface was successfully demonstrated, representing a worldwide first. Thanks to the ease of processing when transmitting 10 GbE Lanphy signals over OTN, we confirmed quantitatively that information can be transferred with minimal delay time. Moreover, interoperability was confirmed as a result of basic verification of the alarm transfer function, one designed to detect faults and identify faulty areas when networks of different carriers are interconnected. The project aims to achieve standardization and de-facto standard status by continuing in its demonstrations of the efficacy already evidenced by the results of the present test.

3.3 Research and development of GMPLS inter-carrier interoperability

Covering the control layer, the PJ3 is engaged in reviewing inter-carrier operation with GMPLS protocols. An E-NNI node was prototyped following a theoretical study of the requirements for inter-carrier operation. While ambitious wide-area experiments using inter-carrier JGNII are scheduled by the PJ4, PJ1 and PJ3 jointly carried out, as a preparatory step toward the launch of the PJ4, interoperability verification in a multi-vendor environment, testing on multi-layer control, features of the GMPLS network, and interoperability verification with an MPLS network.

The configuration of the JGNII and the experimental network is shown in Fig. 4. JGNII's L2 service used for the GMPLS control layer (C-Plane) made it possible to achieve interoperation among Keihanna Center, Otemachi, and Koganei. The C-Plane is used to enable GMPLS nodes to exchange control protocols. For the transport layer (D-Plane), on the other hand, JGNII's STM-64 (standard for 10-Gbps synchronous transmission) service was used. STM-64 was employed under constant connection, with the GMPLS nodes at both ends controlled as a lambda path (LSC-LSP). A multi-layer control experiment was conducted by controlling the STM16 (standard for 2.5-Gbps synchronous transmission) path, with GMPLS as a TDM path (TDM-LSP) and connecting to the MPLS network (MPLS-LSP). In the meantime, settings for a virtually wider control network (total extension distance for signaling: 1,320 km) were attempted by dividing the control layer in two and causing signals to

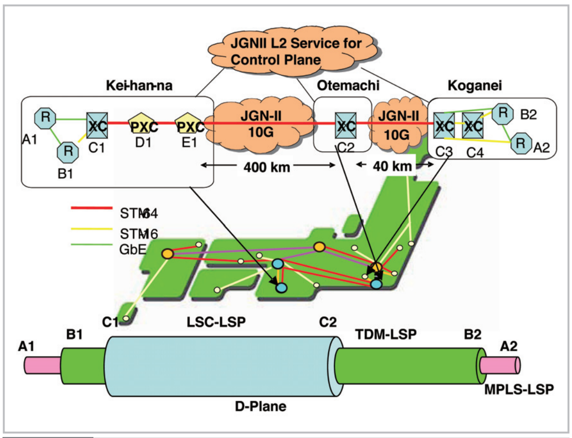

Fig.4 *Experimental configuration of the wide area network*

perform a round trip between Koganei and Keihanna. As for the multi-vendor environment, verification was carried out by combining different items of equipment from nine different vendors and generating several types of paths.

3.4 Inter-carrier operation experiment

Using the E-NNI prototype fabricated in the PJ3, a wide-area experiment was carried out in the PJ4 with JGNⅡ. In inter-carrier operation, the endpoint's address information, band information, and connection capacity—information required for interoperation—must be notified to other carriers. For this reason, an extension of the BGP used in Ethernet applications was implemented in the prototype for use as E-NNI routing protocol. In the meantime, two GMPLS network architecture models are available: IETF the ITU-T/OIF. With the IETF model, a single-session approach is used, which provides end-to-end connection with a single path. For the ITU-T/OIF model, on the other hand, a multi-session approach is used, which splits the session across a domain boundary to establish an end-to-end transmission line. In this case, paths are joined as many times as the number of sessions to establish a transmission line. Thus, conversion was functionally implemented irrespective of the architecture used by each of the carriers.

To verify the relevant functions, a field experiment was conducted by creating a wide-area experimental environment using JGNⅡ and interconnecting the research networks of the participating organizations, thereby establishing a multi-carrier environment. Fig. 5 shows the experimental configuration. Interoperation experiments were conducted between IETF models, between ITU-T/OIF models, and between IETF and ITU-T/OIF models, as a result of which inter-carrier operation using the routing and model conversion functionalities was successfully completed. As shown in the figure, even a single path has a different appearance in each network model.

In the meantime, inter-carrier operation failed with some combinations, making it evident that interoperability presents a challenge in terms of route calculation.

5 Conclusions

This paper presented the IWG of the Keihan-na Info-Communication Open Laboratory, its activities geared toward standardization, and wide-area GMPLS field tests using JGNⅡ. This research demonstrated the feasibility of a multi-vendor environment and multi-layer control in GMPLS. We believe that feasibility was also demonstrated in interoperation between the GMPLS network (as a backbone) and existing MPLS networks. We also believe that the importance and efficacy of E-NNI were also shown by the successful completion of an inter-carrier operation field test using JGNⅡ and the E-NNI prototype incorporating

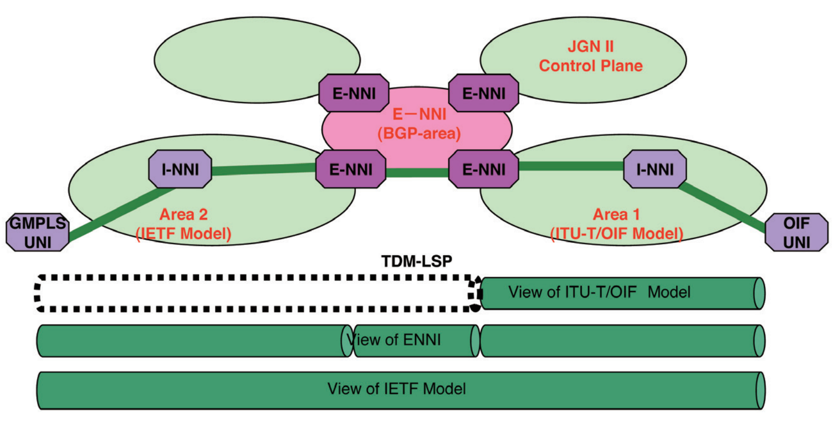

Fig.5 *Experimental configuration in multi-carrier environment*

results of research to date. Although IWG activities end in March 2006, we hope to continue our efforts to achieve standardization and to pursue the feasibility of interoperability through further testing.

This research is a result of the efforts of the participating organizations and the participants of the Kei-han-na Info-Communication Open Laboratory's Interoperability Working Group. We would like to extend our sincere gratitude to Professor Yamanaka of Keio University, the chief, as well as to all of the participants, and express our wishes to continue working with even greater cooperation. We would also like to express our deep thanks to all parties working with the JGNⅡ for their extraordinary contributions in establishing the experimental network.

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***OTSUKI Hideki**, Dr. Eng.*

Senior Researcher, Network Architecture Group, New Generation Network Research Center (former: Senior Researcher, Ultrafast Photonic Network Group, Information and Network Systems Department)

Network Architecture

***MORIOKA Toshio**, Ph.D.*

Reseaerch Manager, Network Architecture Group, New Generation Network Research Center (former: Senior Researcher, Ultrafast Photonic Network Group, Information and Network Systems Department)

Photonic Network

***ARAI Nahoko**, Ph.D.*

former: Expert Reseaercher, Ultrafast Photonic Network Group, Information and Network Systems Department

Photonic Network