iPOP2024 Interoperability Experiments for Verification of Advanced Optical Network Orchestration

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1. Introduction

Increase in traffic is driving not only an increase in network communication capacity but also new communication demands such as Ultra Reliable Low Latency Communications (uRLLC) toward the Beyond 5G/6G era. From the viewpoint of large capacity and low power consumption, there are high hopes for a mechanism that can give programmability to a network such as the All-Photonics Network (APN) in IOWN (Innovative Optical and Wireless Network) and optimize and control the entire network consisting of virtualized network slices, optical equipment on the physical layer, etc. by an orchestrator. At the same time, network services used by users generally consist of multiple interconnected networks and data centers. It is therefore important to conduct not only functional tests in a single network configured with equipment from a single vendor but also tests in an interconnected communication environment configured with various types of equipment.

This article provides a brief introduction to International Conference on IP/IoT & Processing + Optical Network (iPOP) 2024[1], a key event providing an interoperability verification environment. It also introduces the purpose and details of Showcase interoperability experiments, a major feature of this conference. These interoperability experiments are conducted through the collaboration of the Research Promotion Council of Keihanna Info-Communication Open Laboratory, Interoperability Working Group, and various other institutions. For iPOP 2024, these experiments were conducted by the iPOP showcase members in an environment that connected a variety of devices and equipment installed mainly at the National Institute of Information and Communications Technology (NICT) in Koganei City and the Yagami Campus of Keio University in Japan via the JGN*, which is a network testbed for research and development provided by NICT[2].

2. What is iPOP?

The iPOP conference is an international gathering on next-generation networks integrating optical and IP technologies. The iPOP2024[1] conference was held from June 27th to 28th, 2024 in Harmony Goryokaku, Hakodate-shi, Hokkaido, Japan. It consisted of technical presentations and exhibitions as well as Showcase interoperability experiments that are a major feature of iPOP conferences. The iPOP international conference began in 2005 as "IP + Optical Network" but became "IP/IoT & Processing + Optical Network," the current name, after adding the fields of IoT and computing in 2021. Recently, moreover, given the rapid progress in AI technology, iPOP has also come to mean "Intelligent and Processing over Optical networks." In this sense, it has also become a place for discussing all-optical/photonic networks and AI platforms targeted by IOWN and 6G.

Although iPOP is usually held in the Tokyo area, it has sometimes been held in other areas such as Okinawa Prefecture in 2015 owing to deepening collaboration with Okinawa Open Laboratory (OOL). This time, on the occasion of the 20th anniversary of the iPOP conference, it was held in Harmony Goryokaku, Hakodate-shi, Hokkaido, Japan. Sponsored and managed by Photonic Internet Lab. (PIL) and ISOCORE, there was no participation fee for iPOP2024. This conference featured 3 keynote speeches, 9 technical lectures, 17 exhibitions, 2 sponsor sessions, a special panel discussion session on multicore fiber transmission and other topics under the theme of "Innovation in Optical Technology," and a Showcase exhibition and presentation.

3. Showcase interoperability experiments at iPOP2024

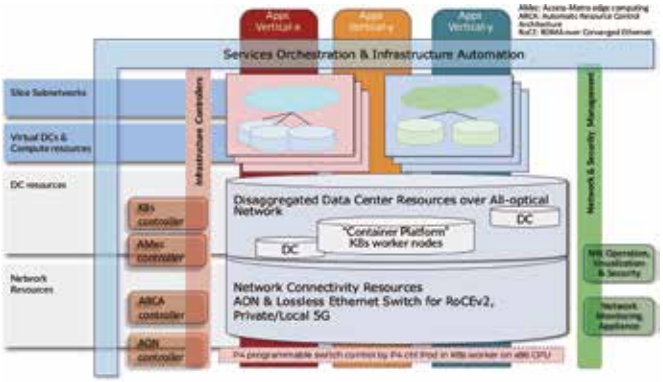
The Showcase was conducted in collaboration with Showcase committee members as valuable opportunities for experiments/demonstrations that would be difficult for a single organization (in particular, a single research and development group) to perform could be held. Here, a variety of companies bring technologies they would like to promote and content they would like to demonstrate in an interoperability environment while providing each other with facilities and technologies.

At this year's iPOP2024, Showcase committee members and others studied technology themes and other matters and recruited institutions for participation under the Showcase title of "Integration of the Heterogeneous All Optical Network and End-to-End Automation in Hybrid Cloud Era." Figure 1 shows a conceptual diagram of all optical/photonic networks of the hybrid cloud era and end-to-end autonomous control and service provisioning that have been taken up since 2021. Main technology themes are listed below. Items 9 and 10 represent newly added technology trends for iPOP2024 Showcase.

* Supported by JGN (TB-A24002)

1. Open/disaggregated packet and optical network systems
2. All-optical/photonic networks
3. Remote control/orchestration
4. Machine learning-based networking
5. Lifecycle management in cloud and edge computing
6. In-network computing for network service application
7. Enhanced technology of network security
8. Monitoring/streaming telemetry
9. Technologies for robust networks
10. Technologies for network digital twin

Figure 1: iPOP Showcase target



3.1 Showcase Configuration

This Showcase was conducted over a one-month period in June 2024 by nine institutions (NICT, ALAXALA Networks, OA Laboratory, OKI Electric Industry, Keio University, TOYO Corporation, Furukawa Electric, Mitsubishi Electric, and UBiqube) in cooperation with three companies (Fujitsu, Spirent, and Calnex) providing equipment.

Figure 2 shows detailed configuration diagrams of equipment connections for the above institutions. The equipment corresponding to APN-T, APN-G, and FXC was configured as the core optical network and networks, applications, and the control plane were constructed on the edge side.

In addition, this configuration installed 1Finity transponders, 16 x 16 optical switches, traffic testers, servers for machine learning, etc. (provided by NICT), Open ROADM-compliant Degree/SRG (Mitsubishi Electric), OLTs and ONUs (OKI Electric Industry and Furukawa Electric), XR-Optics (Furukawa Electric), and Open ROADM-compliant transponders (Fujitsu) at NICT (Koganei City) (Figure 3) and connected the above equipment via JGN to the experimental equipment installed at Keio University (Figure 4). It also connected a computer server group (Keio University) for applications using the constructed network. This system also installed a Spirent Network Emulator (SNE) (Spirent and Calnex) and an AX-Sensor (ALAXALA) at the Yagami Campus of Keio University and connected this equipment to a computer server group at the Shin-Kawasaki Campus of Keio University via an inter-campus network. An MSActivator orchestrator (UBiqube) running on a server in Grenoble, France controlled part of the above. During iPOP2024,

Figure 3: Experimental setup at NICT (Koganei City)

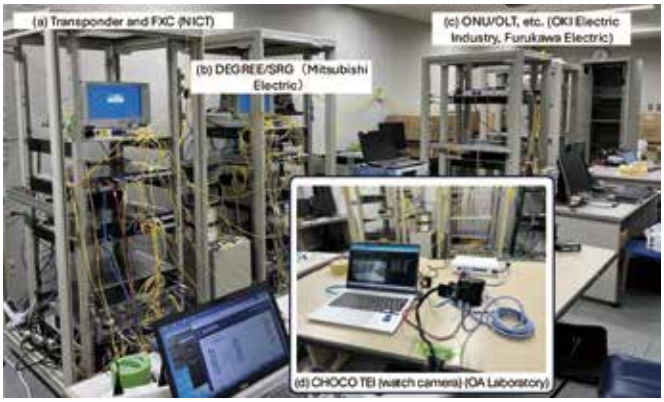


Figure 2: Showcase experimental system

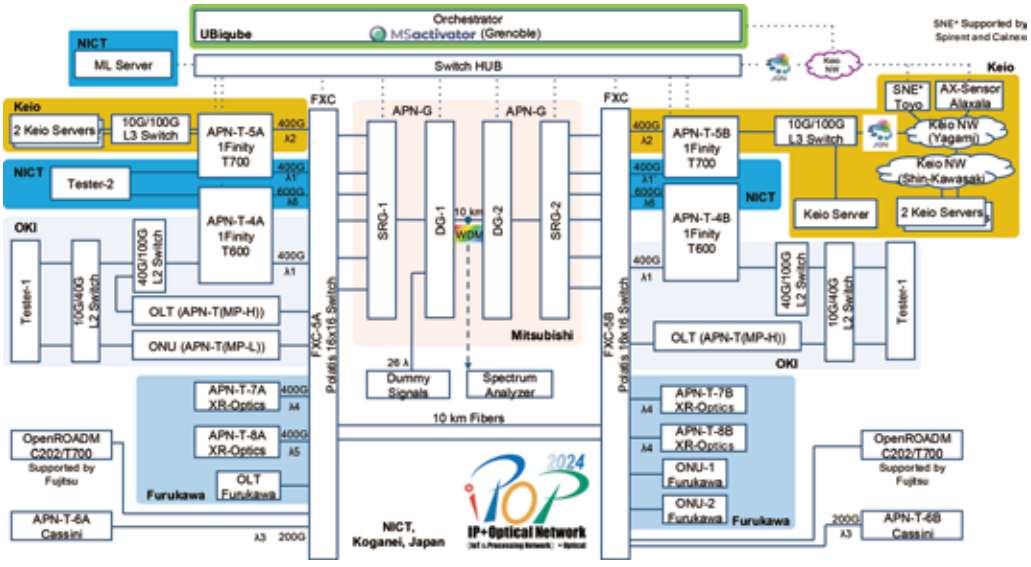
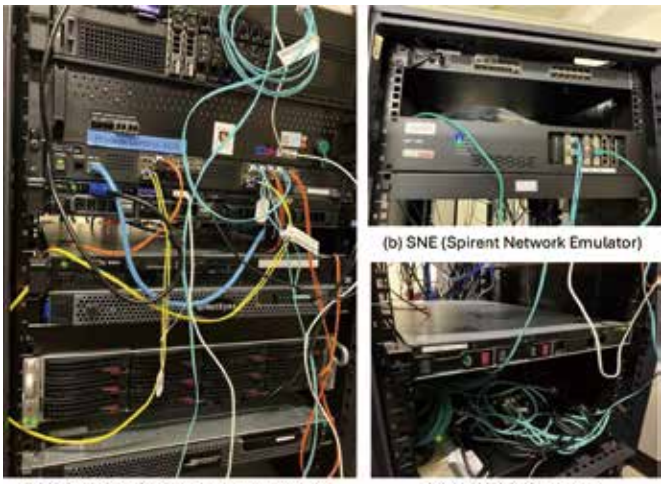


Figure 4: Experimental equipment installed at Keio University



a connection was made between the iPOP hall and NICT (Koganei City) to provide a real-time dynamic exhibition of "CHOCO TEI (watch camera)" (OA Laboratory), a live demonstration of APN equipment control by the orchestrator and security sensor, etc.

3.2 Interoperability Experiment 1

Interoperability experiment 1, titled "APN control and performance experiments with OpenROADM and PON system Plus Applications on the APN," provided an example of cloud-native orchestration control. It featured a demonstration of lightpath setting/release conforming to OpenROADM, demonstration of P2P (point to point) and P2MP (point to multi-point) transmission functions and latency characteristics in a PON domain, etc.

For this experiment, we first used Scenario A, titled "Multi vendor APN control including ROADM (APN-G) using NETCONF/OpenROADM interface." Here, assuming an environment in which APN-G configured with a disaggregated-type Degree/SRG conforming to Open ROADM MSA accommodates multiple lightpaths for different transponders, an experimental system was constructed connecting a total of 32 lightpaths including 6 transponders. This experimental system was used to verify equipment management functions (lightpath setting/release) by NETCONF protocol from the orchestrator.

Next, in Scenario B titled "APN-T (MP-H/L (XGS-PON)) with low latency DBA and APN," P2P and P2MP connections were verified using ONUs and OLTs configured with XGS-PON as APN-T (Figure 5). In addition, transmission delay, jitter, etc. were measured when connecting two FXC units by a lightpath and a fiber path.

In Scenario C titled "XR Optics, EPON and APN," P2P and P2MP connections were verified using XR-Optics as APN-T and EPON transmission quality was measured on a fiber path. Additionally, we verified a simulation of automatic operation and control using two disaggregated edge servers connected via APN. This evaluation also included DDoS attack detection and damage mitigation using in-network computing, as well as real-time operation of the "CHOCO TEI (watch camera)", a compact factory IoT device.

In this interoperability experiment, the P2P/P2MP configurations with a view to applying APN to the access system revealed the feasibility of a core/metro system via APN equipment and opened up the prospect of an APN that merges the access and metro systems.

3.3 Interoperability Experiment 2

Interoperability experiment 2, titled "Closed loop control based on ML analysis of network information," incorporated an NICT-developed machine learning system in an experimental system and conducted a closed-loop control experiment of switch control according to optical network quality. An overview of this experiment is shown in Figure 6. Here, MSActivator, the orchestrator, periodically monitored network status at APN-related equipment and filtered essential information for input into a machine-learning server. Then, using this input time-series data

Figure 5: Three types of transmission paths in interoperability experiment 1

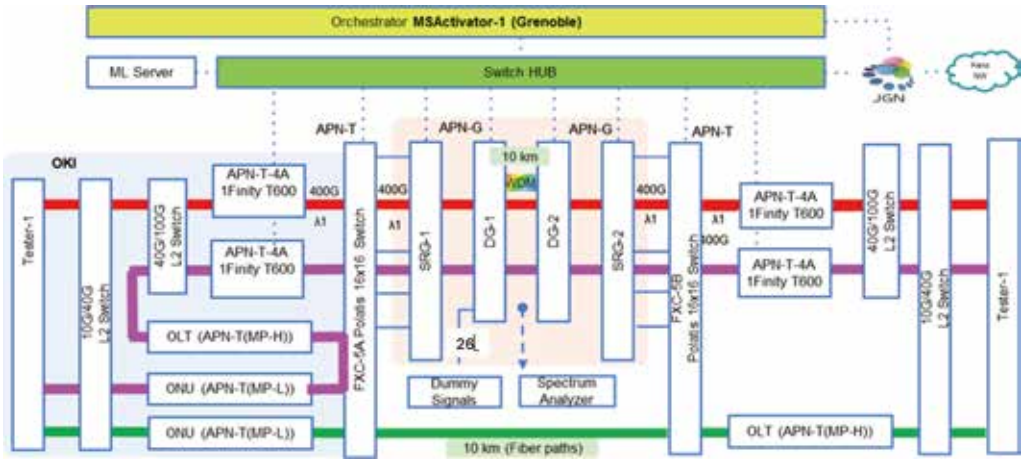
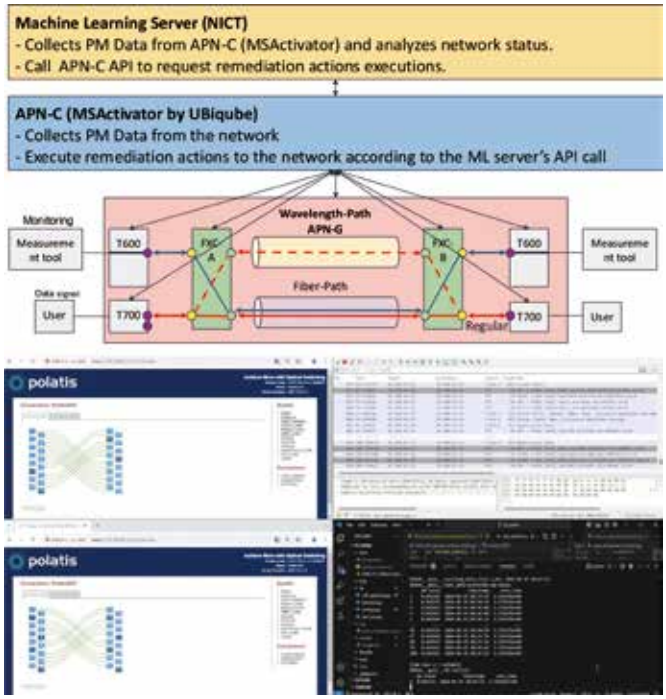


Figure 6: Closed-loop control by machine learning



on network status, the machine-learning server determined that path switching was necessary, switched fiber paths in collaboration with the orchestrator, and succeeded in verifying a sequence of control functions for controlling various types of equipment via the API of the MSActivator. In the future, the plan is to enhance telemetry information collection technology and machine learning servers toward efficient autonomous control of optical networks with no human intervention.

3.4 Interoperability Experiment 3

Interoperability Experiment 3, titled "Network failure simulation and visualization with closed loop control," involved the construction of a data plane at the Yagami Campus and K2 Campus of Keio University (see Figure 7). It performed a closed-loop control experiment by inserting a pseudo failure simulator for testing purposes in the network to generate failures such as pseudo packet loss, detecting those failures by a security sensor, and having the orchestrator instruct operations to be performed. This experiment artificially lost partial packets as pseudo failures that could be caused by silent failures that are difficult to detect by communications equipment itself and detected such packet losses by a security sensor. In this way, the experiment opened up a path toward the prevention of large-scale failures by automatically identifying silent failures.

4. Conclusion

This article provided an overview of iPOP2024 celebrating its 20th anniversary and introduced Showcase interoperability experiments that are one of its main features. This is an extremely unique conference that has been held in an ongoing manner in Japan that, while targeting optical networks, has also contributed to industry and the formulation of new standards. The iPOP Showcase, in particular, has been providing valuable opportunities for organizations to hold interoperability experiments. In addition, some of the results of these experiments are being presented at other international conferences, used by individual companies for studies toward standardization, etc.

Next time, the plan is to hold iPOP2025 at NICT (Koganei City in Tokyo) on July 17th and 18th, 2025. The period for submitting applications for holding exhibits, presenting technical lectures, etc. will run from March to April as usual. Exhibitors on the silver level or higher may participate in Showcase—it is hoped that many new companies will participate in the 2025 and future interoperability experiments.

References

[1] iPOP2024, https://www.pilab.jp/ipop2024/
[2] JGN, https://testbed.nict.go.jp/jgn/

Figure 7: Automatic control experiment by packet-loss simulation and detection system