Field Trials of Open and Disaggregated Transponder in Optical and IP Networking

Seiki Kuwabara, Yasuhiro Mochida, Takahiro Yamaguchi, and Hideki Nishizawa

Abstract

An open and disaggregated optical transmission system is a candidate enabler for future high-capacity, low-latency, and flexible optical networks. The open software architecture is key to developing an open transponder for this transmission system. In this article, we propose the new optical transponder architecture. We conducted field trials of low-latency optical transmission using an open and disaggregated transponder with the open software architecture in a datacenter interconnect network to confirm the feasibility and usefulness of this transponder.

Keywords: whitebox, datacenter interconnect, TIP

1. Introduction

NTT proposed and is working on the Innovative Optical and Wireless Network (IOWN), which is composed of the All-Photonics Network, Cognitive Foundation®, and Digital Twin Computing [1], resulting in an innovative network with excellent capacity, low latency, flexibility, and energy efficiency to create a smart world. Focusing on the physical layer, in addition to time-of-flight of light in an optical fiber and signal processing time at transmission ends, one of the bottlenecks for achieving ultimate low latency might be a hierarchical tree-type network topology with vertically integrated optical transmission equipment. There have recently been serious discussions on an open and disaggregated optical transmission system, which can add more flexibility to the network topology. This activity is expected to drive the development of a wide range of services by providing openness and multi-vendor implementation at the component level and enabling the addition of user's own applications and autonomous operation. It will also enable us to tailor network topology for each application, such as high-speed storage backup via a wide area network or transmission of multi-channel uncompressed ultra-high-definition images captured at a sporting event via a network to a broadcast station. It is therefore important to create a platform for accelerating flexibility and technical innovation in this optical transport network.

2. Activities towards open and disaggregated optical transmission systems

In the traditional optical transport network, optical transmission equipment is locked into specific vendors in a vertical integration model and fixed from the transceiver to the operating system. This approach results in high implementation and maintenance costs, makes decentralization of supply sources difficult, and usually forces network interoperability on the user. It also makes it difficult to tailor network topology for applications. NTT laboratories have been developing flexible control technology for optical transport networks that facilitates the virtualization of ICT (information and communication technology) resources and started collaboration with its

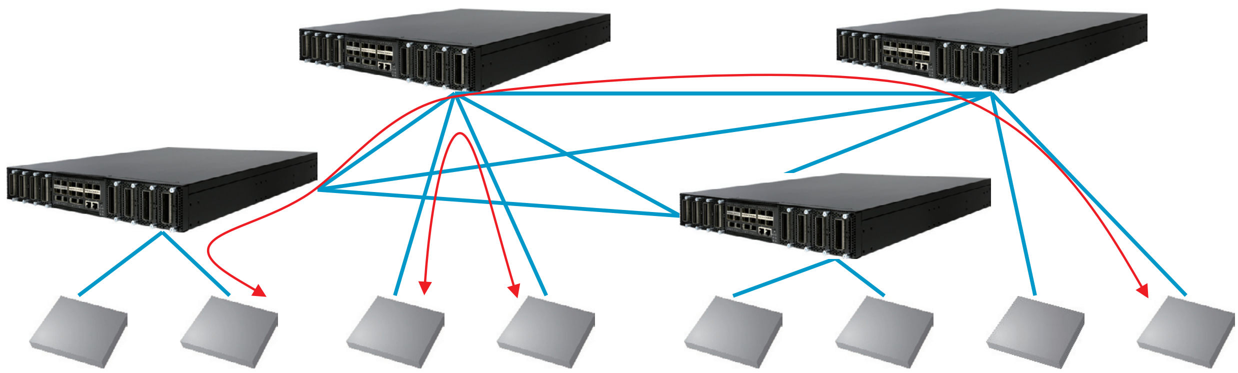

Fig. 1. Full mesh network topology with whitebox packet transponder.

global partners including network operating system (NOS) vendors, original design manufacturing vendors, optical component vendors, and other partners to define the open interface of an optical transponder through activities in the Telecom Infra Project (TIP). In December 2017, the first interface specification and architecture of the Transponder Abstraction Interface (TAI) [2], which facilitates disaggregation between software and hardware of an optical transponder, was proposed to TIP. Its working model was then exhibited at TIP Summit 2018 and the Optical Networking and Communication Conference & Exhibition (OFC) 2019 with open hardware [3]. This section describes an optical network adaptable to cloud-native systems that we have been studying and software architecture for an open optical transponder.

2.1 Optical network with open and disaggregated optical transmission systems

Conventional networks feature a hierarchical tree-type topology based on the telephone network and Internet access. One key advantage of this topology is user-manageability; it allows operators to handle and maintain a huge number of calls or services to each of their users simply with a hierarchical structure. On the other hand, an optical transport network that handles cloud services, Internet of Things, and edge computing used to be required to support ultra-low-latency communication machine to machine (M2M). An issue with tree-type topology is the high latency for M2M because communications between edges when they are under different branches need to pass up and down the tree through many optical fiber paths and equipment units. The full-mesh network with a whitebox packet transponder shown in **Fig. 1** enables lower latency at low cost because of capital expenditure reduction with multi-vendor coherent module capability, transponder-switch converged architecture, open hardware, and rich network function implementation capability at the carrier edge with cloud-native and micro-service architecture.

2.2 Transponder architecture for open optical transponder

Achieving an optical network adaptable to cloud-native systems, as described above, will require a reduction in the cost of implementing and operating an optical transport network as well as flexible network control. In datacenters, the evolution of open source software (OSS) accelerates automation of operations such as zero-touch provisioning and streaming telemetry. When the disaggregation of hardware and software technology developed for datacenter servers and switches spreads to the optical transport network field, operators can also use automatic operation technologies with OSS for optical transport networks. We propose the optical transponder architecture shown in **Fig. 2** that adopts a Linux-based NOS and enables the disaggregating of optical transmission equipment into hardware and software in a whitebox format. This architecture provides Ethernet-based optical and Internet Protocol (IP) networking capable of simple operation while adopting packet switching integrated architecture.

It also hides the proprietary specifications for the coherent components loaded on the optical transmission equipment and adopts the TAI [4], which is an application programming interface for vendor/generation-independent coherent module control. The use of the TAI reduces NOS development and maintenance costs and enables NOS and optical transmission equipment to be combined in diverse ways. In

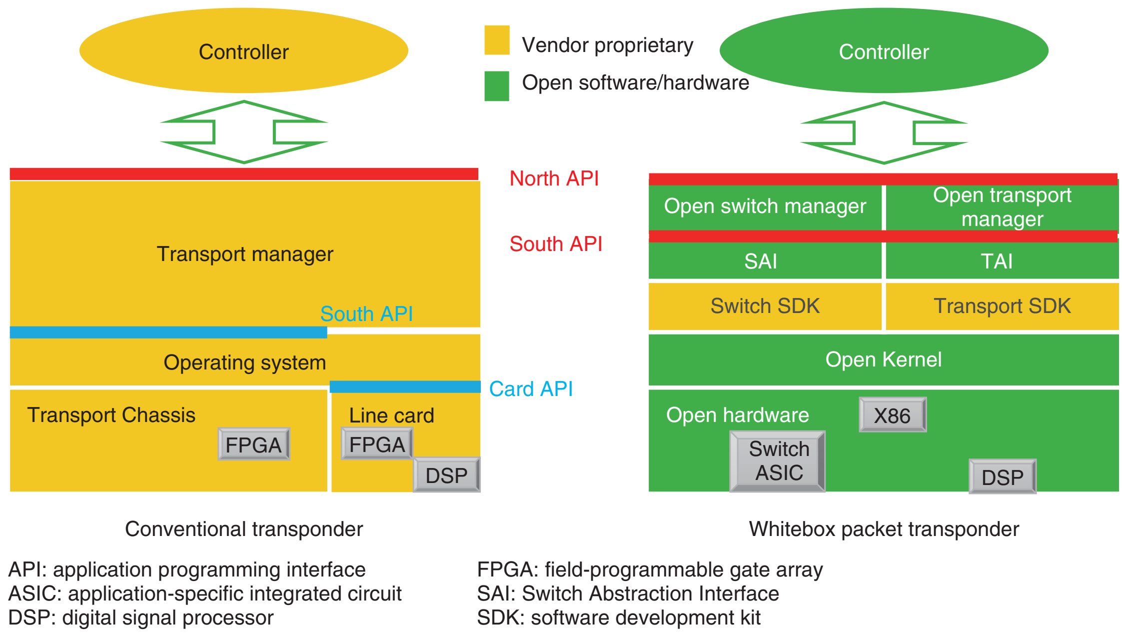

Fig. 2. Conventional and proposed transponder architectures.

Fig. 3. Whitebox packet transponders.

addition, hardware in this architecture takes on a modular configuration, which means that it can be used for small starts and easily exchanged as needed. The whitebox packet transponders Cassini and Galileo shown in **Fig. 3** are being proposed at TIP for an open optical transport network [5].

3. Field trials of uncompressed video transmission in commercial datacenter interconnect

There is currently a major move toward the use of IP for transmitting video and audio in broadcast facilities. This transition is expected to enable uncompressed video/audio transmission, making full use of the large-capacity, low-latency, and bidirectional communication characteristics. Interest is also growing in developing a remote production system that interconnects a relay site and broadcast station over an IP network and sends the video and audio acquired in the field to a broadcast station without prior editing (**Fig. 4**). Since the editing process takes place at the broadcast station, fully equipped production vans are no longer required and editing crews are allowed to stay at the broadcast station. However, multiple Ethernet switches are required for long-distance transmission, which can affect the Precision Time Protocol used for synchronization among video devices. Long-distance and large-capacity capabilities in the transmission of such video and audio are therefore important. Taking this into account, we conducted field trials of 4K/60P video using commercial dark fiber between datacenters to assess the effectiveness of our proposed optical transponder architecture (**Fig. 5**). In these field trials, we used Cassini whitebox packet transponders to directly connect two

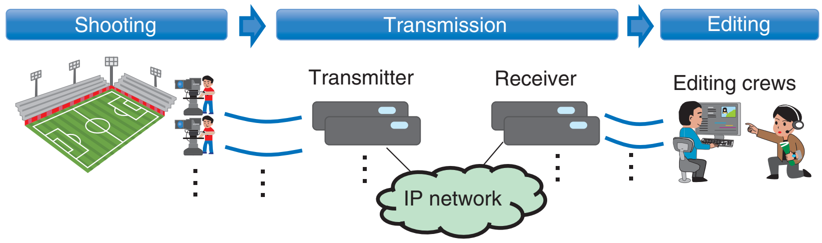

Fig. 4. Remote production workflow.

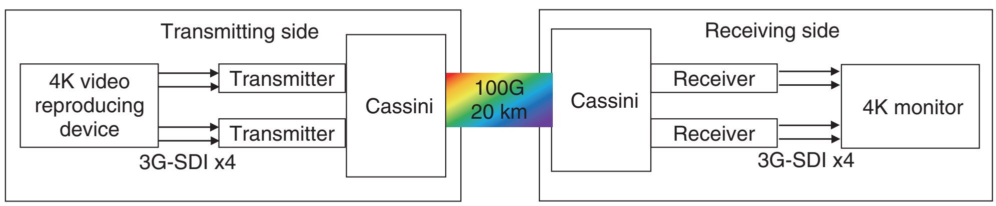

Fig. 5. Experimental setup of large-capacity transmission of uncompressed 4K video.

points over approximately 20 km of dark fiber. For optical transmission, we used an analog coherent optics transceiver for carrying out digital coherent processing on the digital signal processor mounted on a Cassini plug-in unit. This pair of Cassini transponders is equipped with different NOSs, uses quadrature phase-shift keying as the modulation system, and interconnects by 100-Gbit/s Ethernet.

The 4K/60P video to be transmitted is output from a 4K video-reproducing device using four 3 Gbps Serial Digital Interface (3G-SDIs). These video streams are then input to two transmitters—two 3G-SDIs per transmitter—and the outputs from these transmitters are finally output as separate SMPTE ST 2110* flows. These transmitters connect directly to a Cassini transponder. The receivers used in this trial likewise connect to a Cassini transponder and the received IP flows are output by the four 3G-SDIs. Using this system, we conducted the field trials from July to September 2019 (**Fig. 6**). These trials confirmed that the video could be correctly reproduced on the receiver side and that 4K/60P uncompressed video could be transmitted using Cassini transponders.

Fig. 6. Transmission of 4K video to receiver side.

4. Conclusion

The optical transponder architecture we proposed is adaptable to cloud-native systems and enables flexible control of the optical network and easy addition of services. Going forward, we plan to develop technology for autonomously controlling and stabilizing the optical network in response to changes in the environment, application operations, etc.

* SMPTE ST 2110: A standard developed by the society of motion picture and television engineers (SMPTE) for transmitting video over IP networks for the professional media industries.

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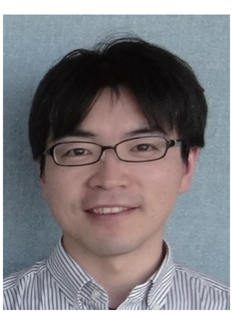

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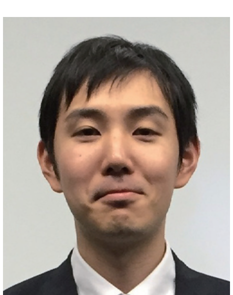

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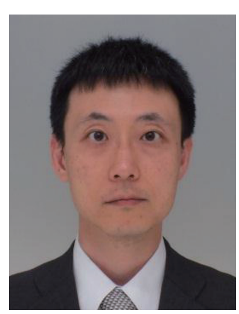

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