Activities for Detailing the Architecture of the Open APN and Promoting Its Practical Application

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Abstract

The IOWN Global Forum has proposed the Open All-Photonic Network (Open APN) as a network infrastructure that achieves low latency and low power consumption and issued an architecture document entitled "Open All-Photonic Network Functional Architecture," in early 2022. This article introduces the activities carried out since the release of the above architecture document to detail the Open APN architecture and promote its practical application.

Keywords: IOWN, Open APN, PoC

1. Introduction

The Open All-Photonic Network (Open APN) is an open architecture for photonics networking proposed by the IOWN Global Forum (IOWN GF), which is studying ways that would enable service providers to integrate photonics networking capabilities with their overall computing and networking infrastructure at a finer level of granularity. Since the architecture document, Open All-Photonic Network Functional Architecture release 1 [1], was issued in early 2022, the forum conducted a proof of concept (PoC) based on this architecture document and issued the Open All-Photonic Network Functional Architecture release 2 in October 2023 [2], which expands and details the architecture. This article introduces the forum's activities since the publication of the architecture document release 1.

2. Open APN

Let us first briefly explain what the Open APN is. It is a network that enables different locations to be directly connected using optical wavelength paths and consists of Open APN Transceivers (APN-Ts), Open APN Gateways (APN-Gs), and Open APN Interchanges (APN-Is). An APN-T is an endpoint for an optical wavelength path and transmits and receives optical signals. An APN-G is a gateway for an optical wavelength path and sets up control channels to communicate with the connected APN-Ts, executes user plane admission control, multiplexes/demultiplexes, turns back, and adds/drops optical wavelength paths. An APN-I is an interchange for an optical wavelength path, executes wavelength cross-connect, and provides adaptation between interfaces (**Fig. 1**).

For more details on the architecture, please refer to the article, "Study on Open All-Photonic Network in IOWN Global Forum" in the May 2022 issue of this journal [3].

3. Open APN PoC

IOWN GF planned the Open APN PoC [4] activities to show the global market that the Open APN Functional Architecture is not a technology of the future but can be built and operated using technologies already available. These activities have prompted many organizations around the world to aim at building and introducing the Open APN, create use

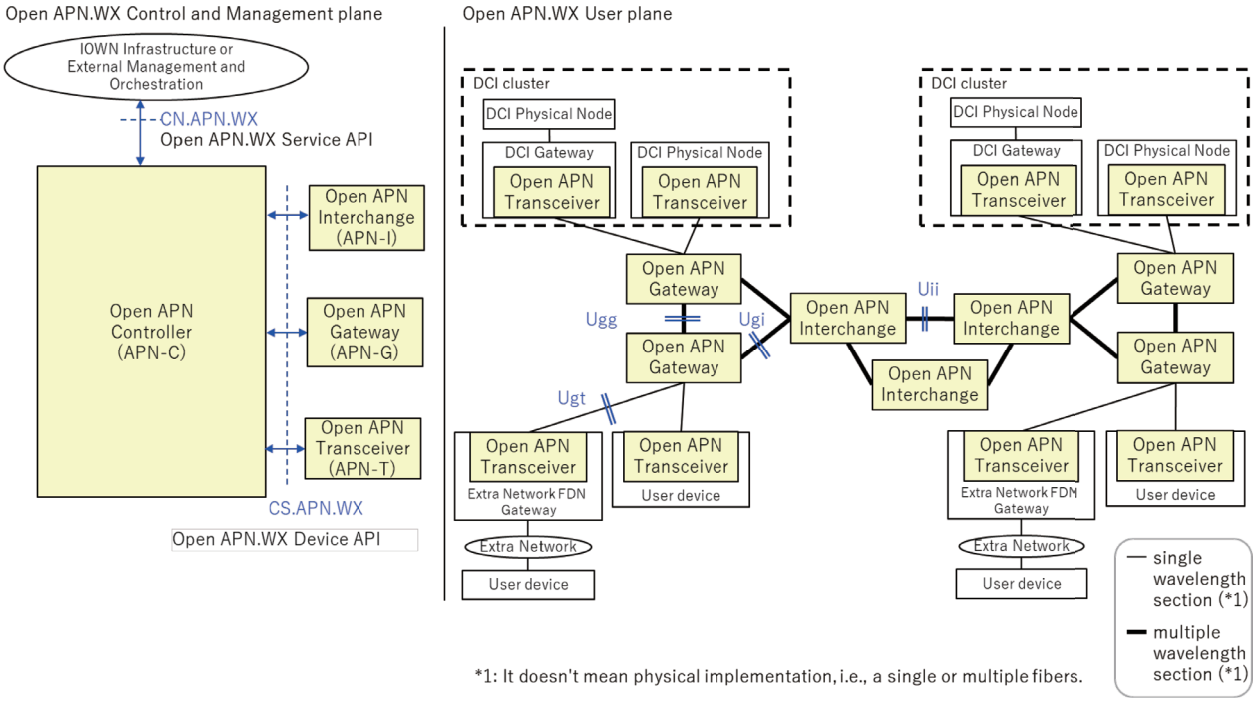

Fig. 1. Open APN reference architecture for optical wavelength path services.

cases, and deploy them in the global market. IOWN GF has published a PoC Reference document, which provides guidelines for conducting PoC, enabling anyone to undertake PoC under a common set of guidelines. The PoC Reference document for the Open APN provides guidelines for the following items to enable those interested to conduct a comprehensive demonstration of the architecture defined not only by the two task forces (TFs) studying the Open APN architecture, namely the Open APN Architecture TF and Open APN Wavelength Availability TF, but also by the Open APN Fiber Sensing TF, which is studying technology for sensing using optical fibers. The functions subject to evaluation as defined in the PoC Reference document are introduced below.

3.1 Basic functions of an APN-G

(1) Setting up a control channel for an APN-T
(2) Executing user plane admission control of optical signals
(3) Multiplexing/demultiplexing optical wavelength paths
(4) Turning back optical wavelength paths
(5) Adding/dropping optical wavelength paths
(a) Flexible Bridging Service: A service that aggregates multiple data flows with extremely stringent quality-of-service requirements and forwards them into a single optical wavelength path
(b) Open interface: An open interface used to connect devices from different vendors to the Open APN Controller (APN-C) or used for control by the APN-C
(c) Multi-vendor support: Interoperability between an APN-T and APN-G supplied by different vendors
(d) Automatic provisioning: Automatic provisioning of optical wavelength paths, including physical design, on the basis of link parameters such as fiber type and power profile
(e) Mechanism for transceiver connection at user sites: Automatic registration of transceivers at user sites that terminate optical wavelength paths
(f) Monitoring: Automatic and periodic collection of monitoring data from an APN-T and APN-G by the APN-C
(g) Fiber sensing: Confirmation of fiber sensing at an APN-G under the following conditions:
- The interrogator is an optical time-domain reflectometer for general loss measurements. It uses a wavelength of 1550 nm.

- The circulators and couplers are general commercial products.
- The optical switch is a commercial switch that supports 1550 nm.
- The sensing fiber is a commercial single-mode optical fiber with a length of more than 10 km.

Many IOWN GF member companies have conducted PoC on the basis of this PoC Reference document. IOWN GF will publish the results of PoC implementation with a view to promoting further study and expanding the number of participants.

4. Updating of architecture document

IOWN GF issued the Open APN Functional Architecture release 2 document in October 2023 [2]. This document is an update of the release 1 architecture document issued in early 2022 [1]. Its main focus is expanding and detailing the basic architecture, control plane architecture, and user plane architecture.

4.1 Basic architecture

The basic architecture of the Open APN has evolved into a two-layer structure with the definition of a new fiber layer in addition to the wavelength layer defined in the release 1 document. The wavelength-layer architecture is called Open APN Wavelength Exchange (Open APN.WX) while the fiber layer architecture is called Open APN Fiber Exchange (Open APN.FX). Open APN.FX newly defines Open APN Fiber Cross-connect (APN-FX), which is a gateway for setting up a fiber path using a physical fiber to connect endpoints in the Open APN, and various interfaces on the fiber path. It also clearly describes how these layers are combined to set up fiber paths and wavelength paths (**Fig. 2**).

While the architecture in the release 1 document had a point-to-point (PtP) configuration, the release 2 architecture additionally incorporates a point-to-multipoint (PtMP) configuration, in which a single signal is branched into multiple points. This new document describes both PtMP in Open APN.WX and PtMP in Open APN.FX.

4.2 Control and management plane architecture

The new document further details control and management plane architecture for optical wavelength paths in a PtP configuration. Assuming a reference model in which an APN-T is deployed at the user's location, the document systematically presents the functions required for the APN-C to set up an end-to-end optical wavelength path including user devices and describes the application programming interfaces (APIs) used for interfacing with the orchestrator and each APN node. It also clarifies how the APN-C cooperates with each entity to control and manage optical wavelength paths (**Fig. 3**).

The use of existing open interfaces, such as OpenConfig, OpenROADM (reconfigurable optical add-drop multiplexer), and Telephony Application Program Interface (TAPI), in implementing the southbound interface is also described (**Fig. 4**).

4.3 User plane architecture

The release 1 document defined the concept of Group of Optically Interoperable Ports (GOIP), which is a subnetwork within the Open APN that can connect to other GOIP subnetworks through optical paths. The release 2 document newly describes the interworking between GOIPs, which was treated as an item for future study in the release 1 document. The release 2 document defines a method for setting up an optical connection when a wavelength can be assigned and the required transmission characteristics are satisfied and a method for setting up a connection that involves electrical conversion using optical-electrical-optical (O/E/O) repeaters or Ethernet/Optical Transport Network (OTN) connections. These methods make it possible to construct the Open APN that scales beyond GOIPs (**Figs. 5(a)**, **(b)**).

In addition to these updates, annexes have been added to the release 2 document. The annexes describe methods for implementing each Open APN node, use cases, and PtMP implementation examples, thus providing more detailed guidelines for implementing and using the Open APN.

5. Activities at NTT

NTT's contribution to these IOWN GF activities has not been confined to the submission of documents but also includes other activities. Two of these are introduced below.

5.1 Demonstration test of Open APN function group

Prior to the publication of the release 2 document, NTT laboratories conducted, within a laboratory, a demonstration test of "a group of functions that enable high-capacity, low-latency communications between required locations when needed," which is a mandatory condition for further expanding use cases in the Open APN architecture [5]. This function group enables Open APN endpoints to be installed at

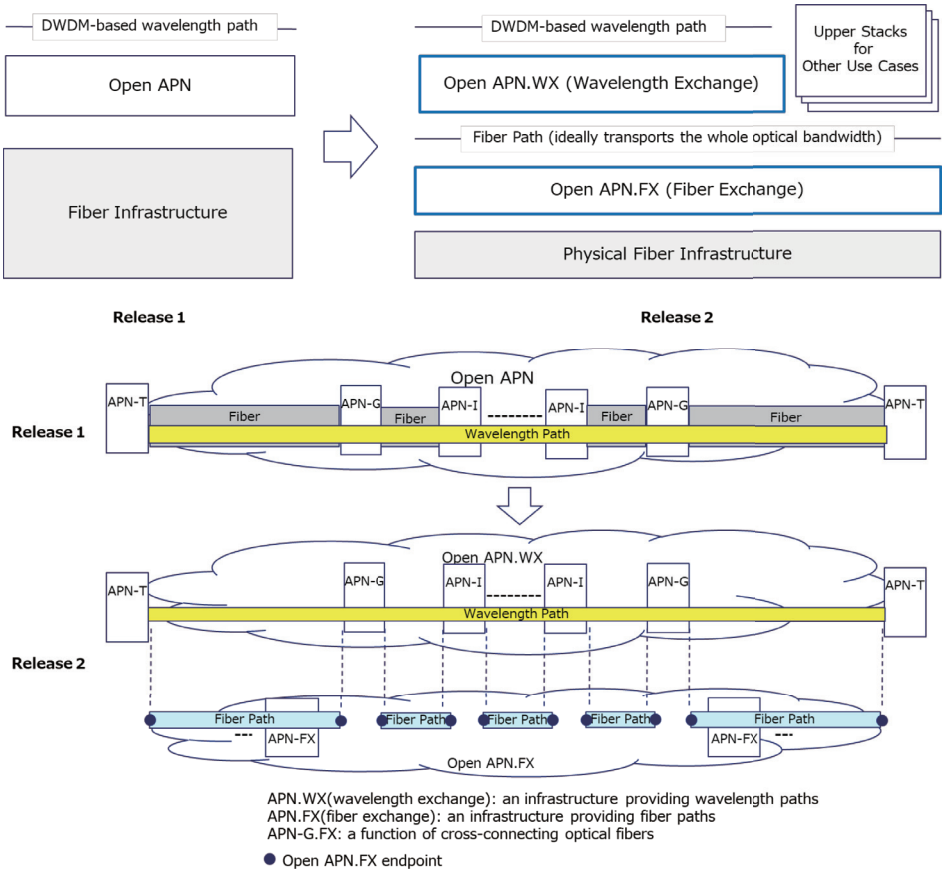

Fig. 2. Basic architecture of the Open APN.

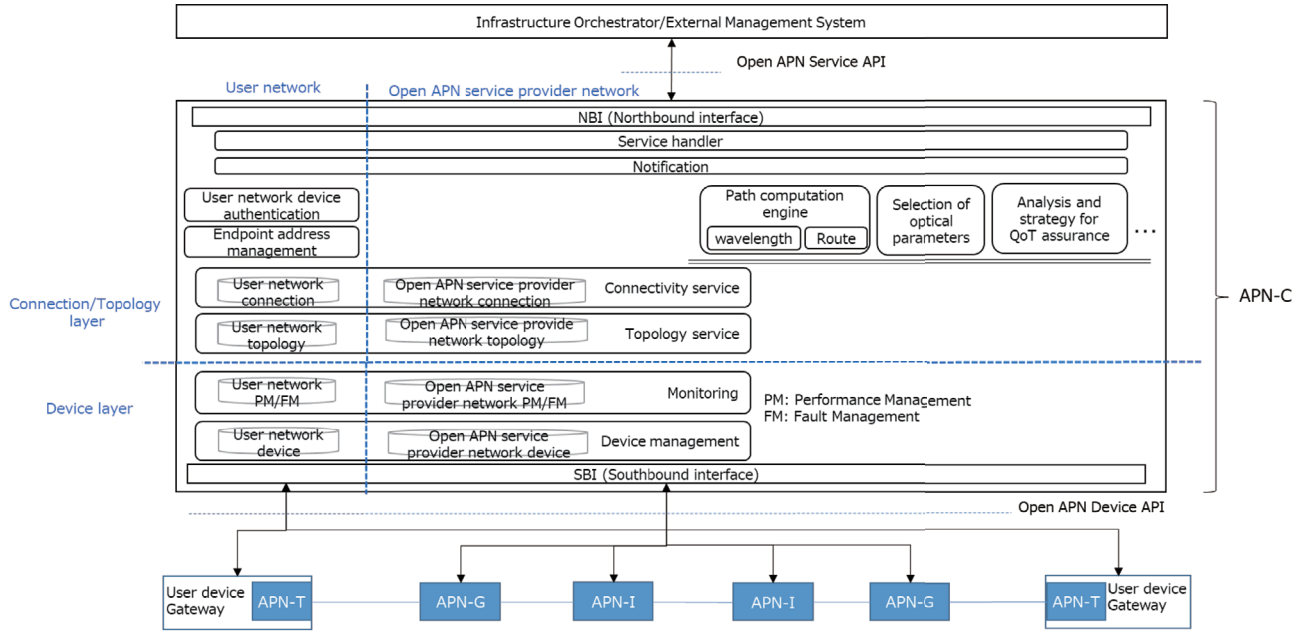

Fig. 3. Example reference of APN-C functional model.

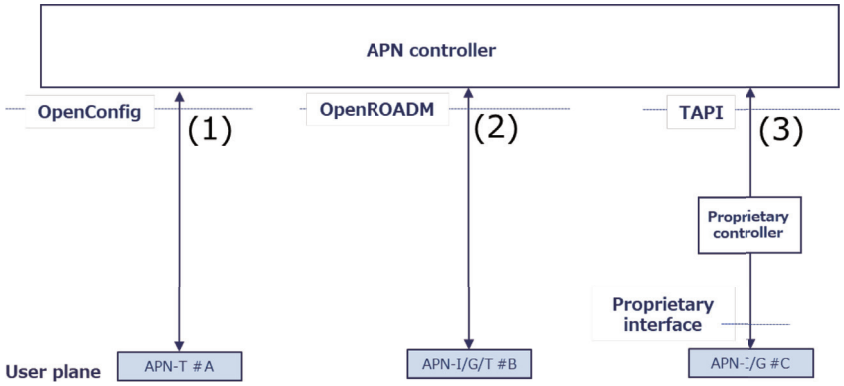

Fig. 4. Recommendation set of southbound interfaces for the APN-C.

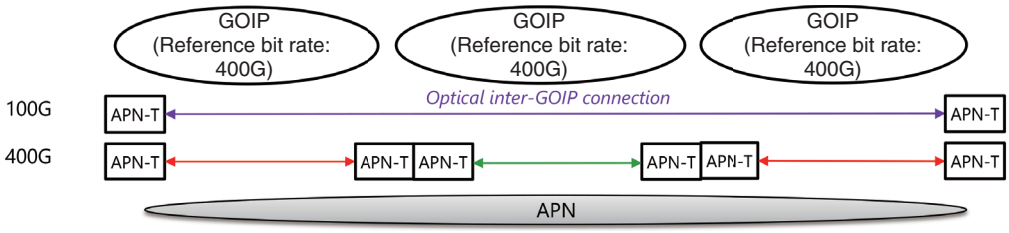

Fig. 5. Inter-GOIP connections.

different sites, including user sites. This function group consists of the following three functions (**Fig. 6**):

(1) A function for automatic design and provisioning of optical wavelength paths that satisfy service conditions, implemented through coordination and collaboration between user site terminals and telecommunications operators' devices, and function for adjustment, such as selection of an optimal mode

(2) A function for setting and managing optical wavelength endpoints at a user site terminal and function for passing/stopping optical signals at telecommunications operators' devices on the basis of the authentication status of the terminal

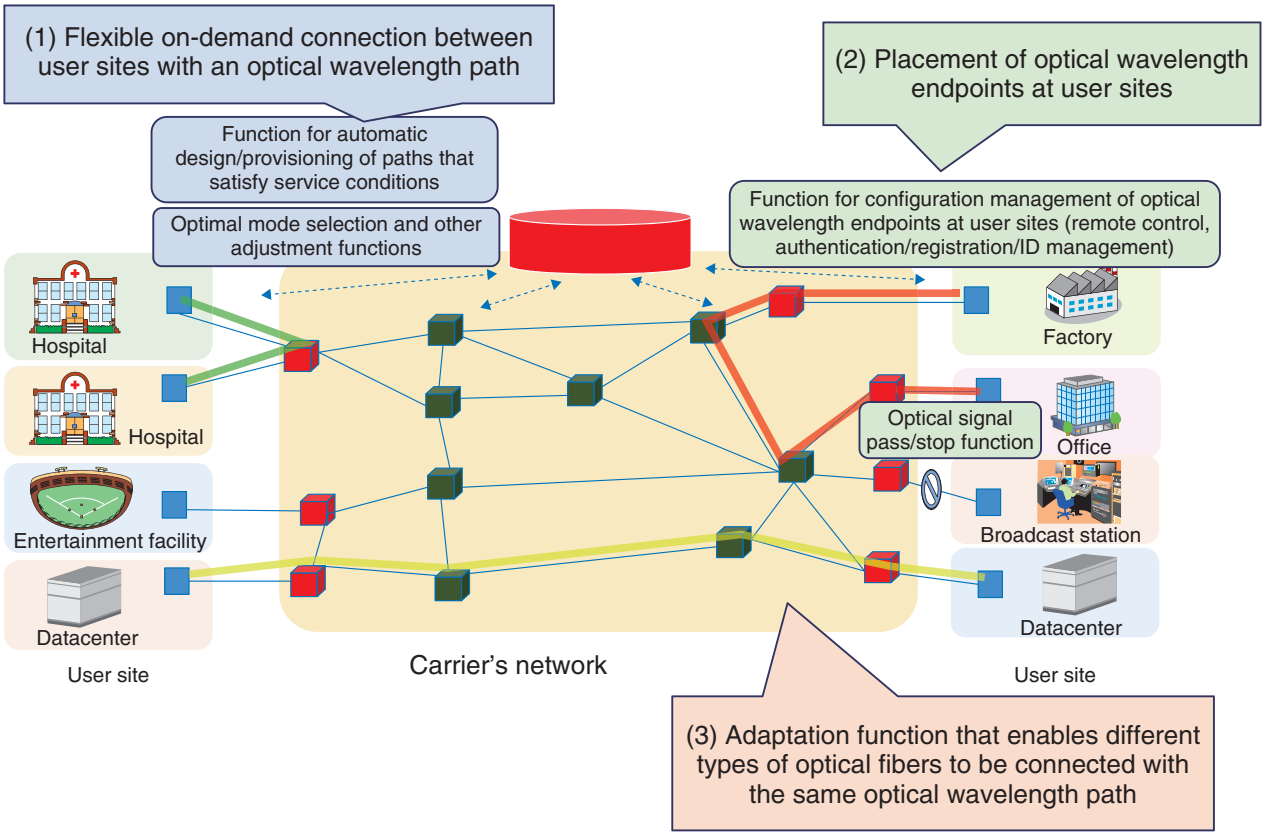

Fig. 6. Demonstration test of an Open APN function group for on-demand wavelength connections between user sites.

(3) An adaptation function that enables different types of optical fibers to be connected with each other while keeping the optical wavelength path unchanged

Using the results of the OpenROADM Multi-Source Agreement and Telecom Infra Project Open Optical & Packet Transport, which are organizations promoting flexible and highly interoperable open optical transmission systems, NTT is conducting a field test in the Tokyo metropolitan area to demonstrate that the system can operate under a variety of conditions, including fiber lengths and loss levels that occur in real-world environments. On the basis of the results of this field test, NTT submitted documents for the compilation of the release 2 document.

5.2 Use of the Open APN in a real environment through a dynamic exhibit at a trade show

At Interop Tokyo 2023 held in June 2023, a dynamic exhibit of the Open APN was staged [6]. This dynamic exhibit featured the following three points:

(1) A network connecting multiple remote locations was constructed.
(2) Various services, such as GPU (graphics processing unit) as a service, public cloud access, and internet access, were provided.
(3) Multi-vendor connections of APN-G/Is and connections of multi-vendor APN-Ts were presented.

Through this dynamic exhibit, we were able to show that the Open APN is a low-latency, low-jitter network that can be built using multi-vendor devices. By providing services that involve connections to sites outside the exhibition site at a large trade show, such as Interop, we were able to show that the Open APN is a cost-optimal solution in such cases because it does not require separate fibers for each service. Previously, the Open APN had been mainly constructed in restricted environments for demonstration purposes. The exhibit at the Interop was the first version of the Open APN that had been constructed as a network able to provide a variety of services in a situation that corresponded closely to a practical implementation. A report on the exhibit was presented at

the IOWN GF September 2023 Member Meeting held in Munich as the event demonstrated that a new step forward had been taken in the transition of the Open APN from the PoC stage to practical application.

6. Future development

This article introduced the Open APN-related activities undertaken after the publication of the release 1 architecture document. The Open APN is expected to be used for various use cases in combination with the data-centric infrastructure, which is also introduced in another article in this issue. As a network infrastructure for IOWN Data Hub and IOWN Mobile Network, which were also introduced in another article in this issue, the Open APN plays a significant role in meeting extremely stringent requirements. Together with many IOWN GF partners, NTT will continue to engage in a series of discussions and demonstrations to contribute to the further development of technologies and social implementation.

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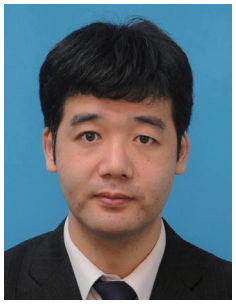

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