Open APN Controller PoC Reference

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1 Introduction

1.1 Purpose: Why this PoC project makes carriers' enterprise networking business sustainable

Today, the carrier's WAN terminates optical signals from customer sites at local points of presence (POPs). This results in very high CAPEX and, eventually, a higher price for connections, as this approach forces carriers to continually upgrade WAN equipment, such as transceivers, switches, and transponders, whenever the market's mainstream transceivers speed increases.

Despite its high cost structure, the above architecture made sense because site-to-site direct optical communication with long-distance transceivers would require more network management skills from customers, and the price of long-distance transceivers was not high enough to motivate customers to acquire such skills.

However, the emergence of IP over DWDM (IPoDWDM) will eventually change this situation. Starting with bandwidth-hungry customers, such as over-the-top (OTT) players and large enterprises, more and more customers would gradually choose self-networking with IPoDWDM and dark fibers without a counter-proposal from carriers.

Given the above, the purpose of this PoC project is to develop a new **carrier's enterprise networking business that is sustainable for the age of IPoDWDM**.

IOWN Global Forum's Open All-Photonic Network (APN) will enable site-to-site direct optical communication using on-demand wavelength/fiber paths created on a shared fiber infrastructure. With this architecture, carriers no longer need to upgrade their WAN equipment every time the market's mainstream transceivers increase in speed. As a result, the cost structure will be significantly improved.

However, simply providing APN wavelength paths as lower-priced substitutes for dark fibers will not be an attractive business for carriers in the enterprise networking space, as it would be another form of service cannibalization, similar to that of dark fibers. On the other hand, an Open APN makes optical transport software-defined, enabling carriers to develop SDN applications for premium features that were previously impossible with today's static optical transport or dark fibers. Examples of such premium features are the following:

1. Dense area coverage (inclusion of small/medium-size sites as DWDM endpoints) with automated path computation/configuration and transceiver configuration
2. Enhanced connection/bandwidth agility and the ability to optimize for cost with nimble set-up/tear-down of wavelength/fiber paths
3. Enhanced availability/resiliency with automated fault detection and recovery of wavelength/fiber paths
4. Flexible interworking with existing optical transport

With the aforementioned features, the Open APN will serve as a hub for service providers and consumers in cloud computing, generating new revenue streams for carriers. Therefore, the key for the carrier's new sustainable business is to make the APN controller (APN-C) a platform for premium SDN applications.

That said, the objective of this PoC project is to **demonstrate the viability of the APN controller as a platform for SDN applications that deliver the premium features outlined above.**

1.2 Objectives: Proving the viability of the Open APN

To prove the viability of the Open APN controller as a platform for SDN applications that realize the premium features described above, the following items should be clearly shown for each premium feature described above.

Dense area coverage (inclusion of small/medium-size sites as DWDM endpoints) with automated path computation/configuration and transceiver configuration:

To provide the Open APN-based services widely as a conventional leased line and/or IP-based network, the system should be configured automatically. In conventional optical transmission networks, only fixed paths are provided, which requires a long time for optical path design and for the configuration of equipment by highly skilled personnel. These conventional operation methods are a barrier to providing large-scale network services. In the Open APN, automated path computation and equipment configuration are realized.

This PoC aims to demonstrate the feasibility of automated path computation and configuration of equipment with APN-C.

Second, as a novel configuration of APN, remote-side APN-T and APN-S are included, and the configuration/monitoring/operation of remote-side equipment are to be demonstrated in this PoC.

Above two will demonstrate realistic operation capability in the Open APN.

Enhanced connection/bandwidth agility and the ability to optimize for cost with nimble set-up/tear-down of wavelength/fiber paths:

With Automated path computation and configuration of equipment, which are previously described, the Open APN will be enabled to provide dynamic path service. In IOWN Global Forum, use cases are discussed such as "Remote Media Production for Broadcasting Industry" and "Service Infrastructure for Financial Industry", and these are the candidates for dynamic path service, with short term use. These kinds of short term use path, require quick path configuration. And it can be achieved higher performance with optimal transmission margin design differs to conventional long-term fixed path.

In this PoC, automated quick path creation/deletion with APN-C is demonstrated. Also demonstrated is multi-QoS service with appropriate margin design per use case.

Enhanced availability/resiliency with automated fault detection and recovery of wavelength/fiber paths:

In the event of large-scale disasters, the automatic and remote control feature of APN-C also helps identify network failures very quickly, as well as reconfigure the optical networks to bypass these failures. Advanced remote maintenance/root cause analysis of APN-C without on-site dispatch are also critical elements for this PoC.

In addition, the Open APN should support the live replacement of network equipment, meaning that equipment in the Open APN can be switched over without any impact to existing services.

Flexible interworking with existing optical transport:

For carriers who own conventional networks, interconnection between conventional networks with an Open APN and smooth migration to the Open APN from conventional networks are of great interest.

In this PoC, insights into scenarios with interwork capability, a provable dynamic path, and migration scenarios will be provided.

Additionally, a demonstration with multi-generation control/management, which is related to the feasibility of continuous evolution of the Open APN, will result in the faster evolution of APN-T compared with conventional Line System (LS), leading to the elimination of the need to "keep upgrading WAN equipment," as described in the "Purpose" section.

1.3 Scope: Subjects covered within the PoC

In this PoC, we plan to evaluate dynamic (automatic) optical path design methods, as well as their open interfaces, multi-vendor environment support, and automatic provisioning functions, as described above. If necessary, the work may also include abstraction, analysis, and evaluation of monitoring data, and provide additional feedback for network optimization, and the integration of open, disaggregated networks with proprietary networks.

However, the items listed below may be out of the scope of this PoC work.

- Development of open and disaggregated equipment. (This PoC will apply currently available technology.)
- Development of an open interface and data model. (This PoC will apply currently available interfaces and data models.)
- Wavelength/fiber path services with the advanced features mentioned above by multiple infrastructure operators (This PoC assumes that an Open APN is owned and operated by a single infrastructure operator).

2 Reference Cases

The following scenario in this PoC Reference document is evaluated to address the issues described in Purpose and Objective.

2.1 Basic Architecture

In this section, the basic architecture for verification of basic functions and interfaces of the APN-C is described.

There are three types of architecture: 1) configuration that APN-C directly controls APN-G/I, 2) configuration that APN-C controls APN-G/I through the Management System of APN-G/I, and 3) a mixture configuration of the two, 1) and 2). Figure 2.1-1 shows the case of a mixture configuration. The Management System of APN-G/I is equivalent to “proprietary controller” which is described in Option (3) of “5.3. A Recommendation Set of Southbound Interfaces” of the Open APN Architecture document version 3 [APN FA R3].

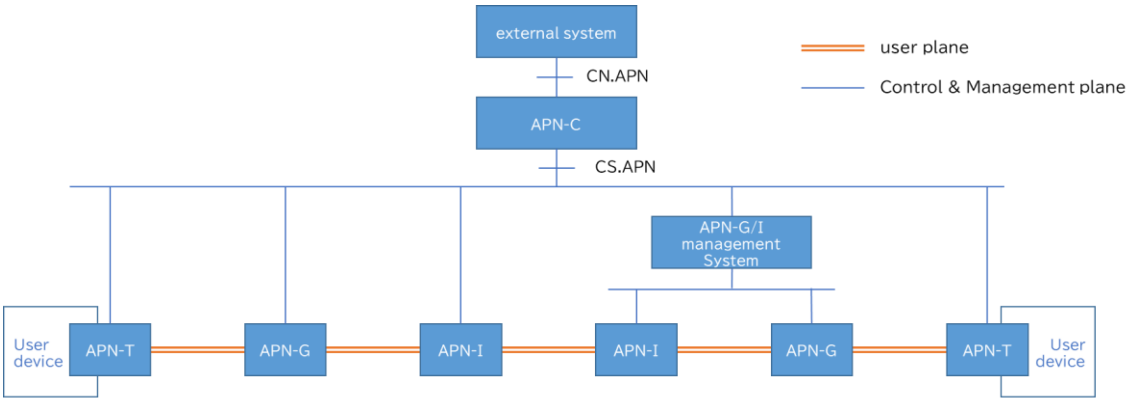

Figure 2.1-1 Basic Architecture for verification of basic functions and interfaces

The example of an external system may be a workflow controller, controllers for mobile networks and computing systems, including FDN (functional dedicated network), and an orchestrator. A workflow controller is a system that supports a more complex workflow than the standard controlling and management function of APN-C. For example, it is designed to execute a business flow unique to an operator. In this PoC, an external system, such as a workflow controller, is not mandatory; however, it is requested to demonstrate and report that APN-C can execute some kind of flow through CN.APN.

2.1.1 Minimum architecture

- Architecture that APN-C directly controls APN-G/I:
  - APN-T: 2
  - APN-G: 2
  - APN-I: 1
- Architecture that APN-C controls APN-G/I through the Management System of APN-G/I：
  - APN-G/I management system: 1

- APN-I that APN-G/I management system manages: 1
- APN-G that APN-G/I management system manages: 1
- APN-I that APN-C directly controls and manages: 1
- APN-G that APN-C directly controls and manages: 1

In case of evaluations with multiple paths, more APN-Ts are required. In cases where evaluation involves multiple routes of paths, additional APN-Is and/or APN-Gs are required.

Note that if the PoC implementer focuses on APN-T control, it is not necessary to use APN-G and APN-I, even with the minimum configuration above. And if it focuses on APN-G/I control, APN-T is not necessary.

Note that this PoC does not care about the range of distance or the number of hops between a pair of APN-Ts, because this PoC focuses on controlling features and does not require a specific interface specification for APN-T. The interface specifications are described in "2.2. User Plane Services" of the Open APN Functional Architecture document version 3 [APN FA R3].

2.2 Remote APN-T architecture

In this section, the remote APN-T architecture for verification is described.

In this architecture, remotely located APN-T should be controlled and managed without additional fibers for the control channel. Therefore, it should have an in-channel control channel that goes through the same access fiber as the main signal. In this PoC, it is requested to verify that APN-C controls and manages a remote APN-T through the in-channel control channel between APN-G and APN-T. The evaluation of the transmission distance between the APN-T and the APN-G is outside the scope of this PoC, as this PoC focuses on controlling features and does not require a specific interface specification for the APN-T. The interface specifications are described in "2.2. User Plane Services" of the Open APN Functional Architecture document version 3 [APN FA R3]. The in-channel control channel should comply to the OSCrt specification [OSCrt] specified as a part of the OpenROADM optical specification version 8.0.1.

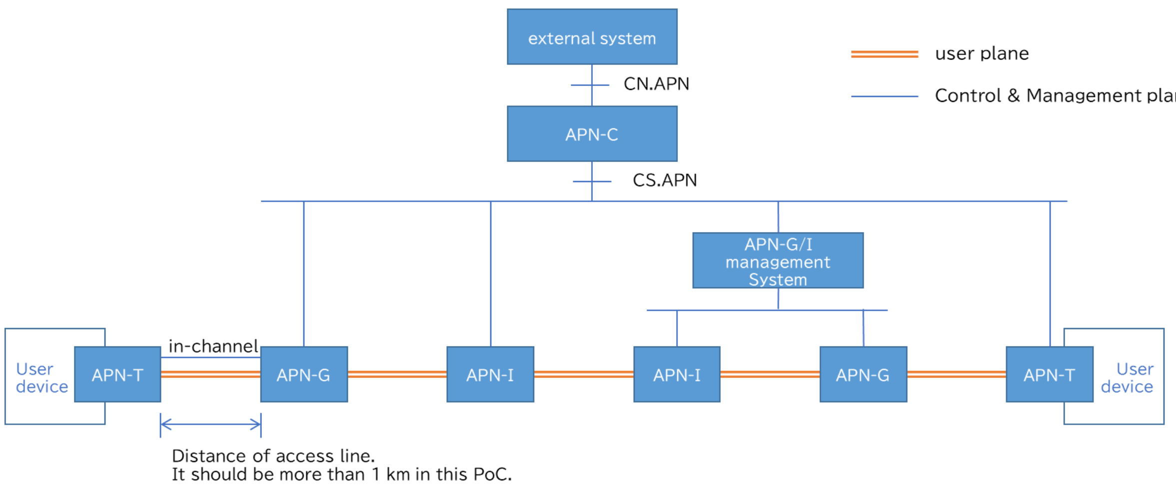

Figure 2.2-1 The Remote APN-T Architecture

2.2.1 Minimum architecture

With one of the following architectures, as described in Section 2.1, which should include at least one remotely located APN-T.

- Architecture that APN-C directly control APN-G/I
- Architecture that APN-C controls APN-G/I through Management System of APN-G/I

As for remote location, the followings are required.

- APN-T: 2, including at least one remotely located APN-T
- Fiber length between a remotely located APN-T and the connected APN-G is more than 1 km.

2.3 Remote APN-S architecture

In this section, the remote APN-S architecture for verification is described.

The Open APN Functional Architecture document version 3 [APN FA R3] shows a new function of APN-S that realizes multiple-wavelength access. In this PoC, it is requested to verify that remotely installed APN-S is controlled and managed through the in-channel control channel between APN-T, APN-S, and APN-G, ensuring that APN-T and APN-S are controlled and managed by the APN-C in this configuration. When the APN-S is a passive device, such as an optical power splitter or a WDM filter, APN-C does not control the APN-S. The evaluation of transmission distance between the APN-T, APN-S, and the APN-G is out of scope of this PoC, because this PoC focuses on controlling features and does not require a specific interface specification for APN-T. The interface specifications are described in “2.2. User Plane Services” of the Open APN Functional Architecture document version 3 [APN FA R3]. And the Open ROADM MSA OSCrt specification [OSCrt] may be referred to for the remote APN-T optical specification.

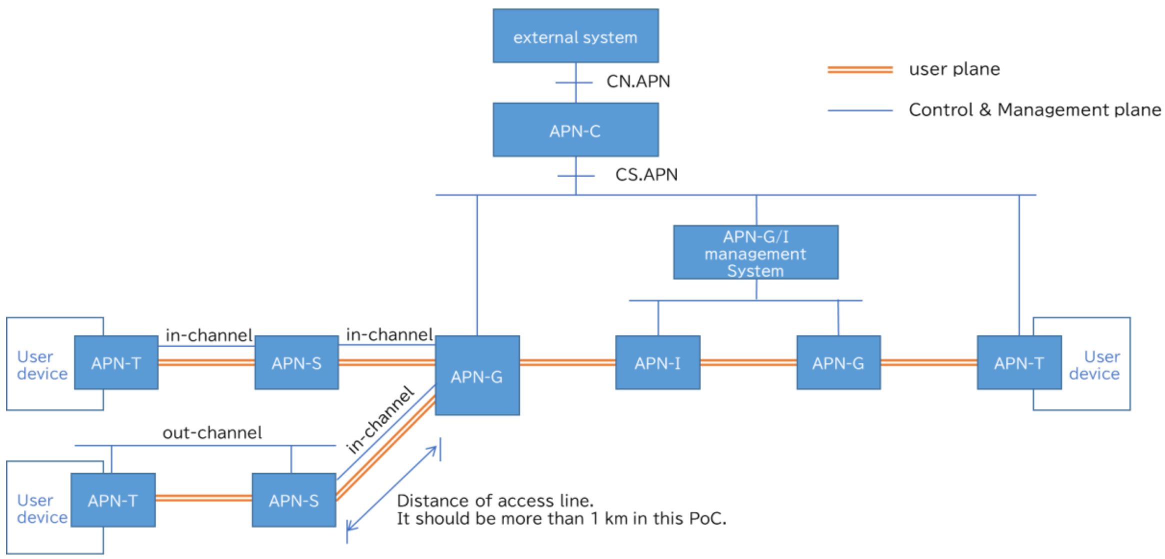

Figure 2.3-1 The Remote APN-S Architecture

2.3.1 Minimum architecture

With one of the following architectures, as described in Section 2.1, which should include at least one remotely located APN-S and APN-T.

- Architecture that APN-C directly controls APN-G/I
- Architecture that APN-C controls APN-G/I through the Management System of APN-G/I

As for a remote location, the following are required.

- APN-T: 2, including at least one remotely located APN-T and APN-S
- APN-S: 1 that is remotely located and connected to at least one APN-T.
- The control channel between APN-S and APN-T may be in-channel or out-channel.
- Fiber length between a remotely located APN-S and the connected APN-G is more than 1 km.

2.4 Interwork architecture with the existing network

In this section, interwork architecture with an existing network for verification is described.

To control and manage the existing network, APN-C utilizes an existing network controller to manage the network. Figure 2.4-1 and 2.4-2 show examples of this architecture. Any other architecture may be applied, as the configuration and required functions differ depending on the step of the migration at issue.

Figure 2.4-1 shows an architecture example of an existing network connected via the Client interface of a transponder/muxponder. It is similar to the Inter-GOIP connection of Figure 6.1.5-2 (c) in the Open APN Functional Architecture document version 3 [APN FA R3].

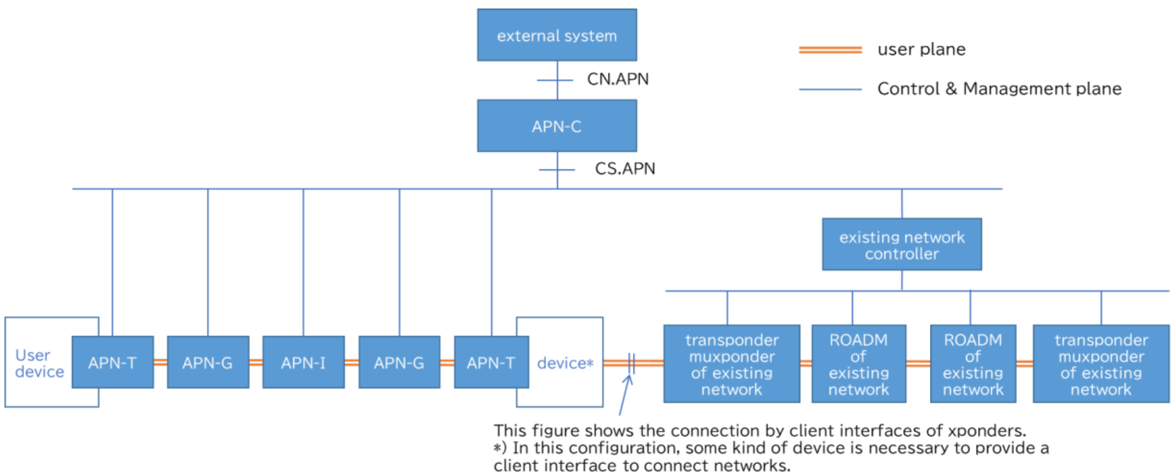

Figure 2.4-1 An example of interwork architecture with existing network (Connection with client interface)

Figure 2.4-2 shows an architecture example that an existing network is connected directly with an optical interface using a “hybrid APN-G”. This configuration is similar to the Inter-GOIP connection with the adaptation function of APN-I, shown in Figure 6.1.5-3 of the Open APN Functional Architecture document version 3 [APN FA R3].

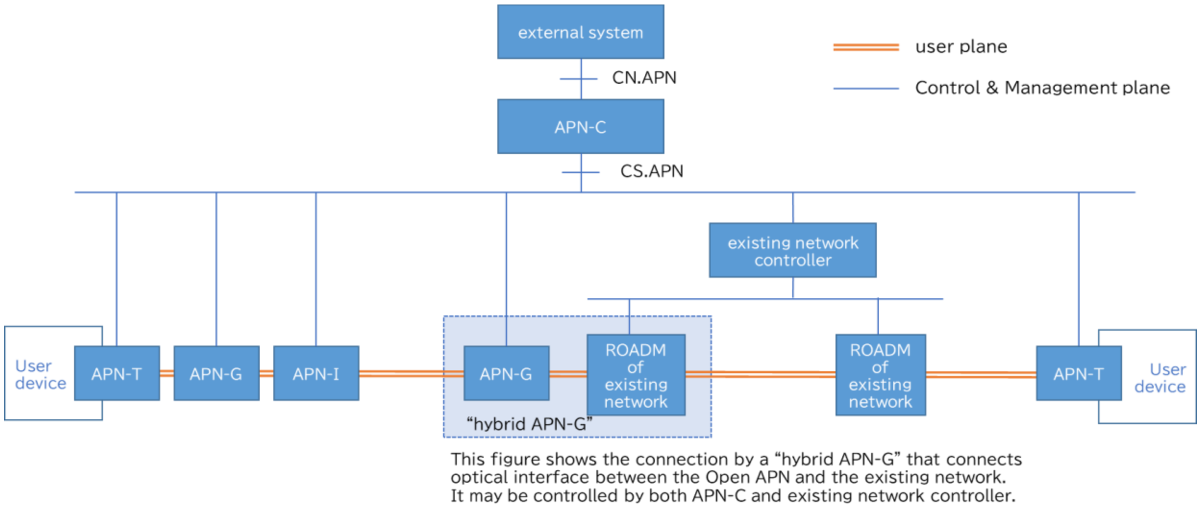

Figure 2.4-2 An example of interwork architecture with existing network (Connection with optical interface)

Check the details of the architecture, which are described in migration scenarios in the Annex A.

Note that, in the PoC demonstration and reporting, another set of APN equipment and APN-C can be used to emulate the existing network equipment and controller, instead.

3 Desired Features

3.1 Feature 1: Network-based configuration and monitoring of remote APN-T and APN-S for enhanced service coverage and agility

3.1.1 Interface of APN-C

Automatic operation methods are the key to the massive deployment of services. While deploying massive amounts of services on a traditional optical network requires a great deal of work by skilled engineers, the Open APN achieves automatic operation through the control and management interfaces. These include topology management, device control and management, device provisioning, end-to-end path creation, deletion, and update. In this PoC work, it should be evaluated that APN-C has the appropriate interfaces.

Feature 1-1-1: The APN-C should have a generic open and/or standardized southbound interface (SBI) which controls APN-T/G/I (CS.APN.WX). [APN FA R3]

Feature 1-1-2: The APN-C should have a generic open and/or standardized southbound interface (SBI) which controls APN-FX (Mandatory when the APN supports APN.FX). [APN FA R3]

Feature 1-1-3: The APN-C should have an interface that adapts to three cases: 1) control APN-G/I directly, 2) control APN-G/I through its Management System, and 3) a mixture of 1) and 2).

Feature 1-1-4: Open APN-related devices and their Management System should have generic open and/or standardized interfaces as described in Section 5.3, “A Recommendation Set of Southbound Interfaces” of the Open APN Functional Architecture document version 3 [APN FA R3].

- The interface between the Management System and APN-C should follow Option (3) in Section 5.3 of the Open APN Functional Architecture document version 3 [APN FA R3].
- It should be reported if any extension on the interfaces of Feature 1-1-1, 1-1-2, 1-1-4 is needed.

Feature 1-1-5: APN-C should provide an appropriate interface (CN.APN) to external systems.

The example of an external system may be a workflow controller, controllers for mobile networks and computing systems, including FDN (functional dedicated network) and orchestrator, as mentioned in Annex E of the Open APN Functional Architecture document version 3 [APN FA R3]. Through the interface, the APN-C provides network topology information and control/management functions for service paths based on the demands of these external systems. With this feature, the operator can realize automatic operation, optical and mobile converged networks, and network slices across the networks.

3.1.2 Functions of APN-C

Through the interfaces described above, the APN-C should control the Open APN automatically. In this PoC work, the following functions of APN-C should be evaluated for automatic operation.

Feature 1-2-1: The APN-C should have a service monitoring and management function that allows it to provide a status of the services (optical paths) implemented on the network.

- Quality monitoring API: APN-C requests APN-T, APN-G, and APN-I to send QoT information in a defined data model format.
- Quality assurance API: APN-C notifies APN-T, APN-G, and APN-I of the network configuration procedure in a defined data model format.

Feature 1-2-2: The APN-C should support disaggregated type equipment. For example, APN-C can manage multi-degree APN-I with disaggregated MUX/DEMUX function, and APN-G, as one node. These types of APN-I and APN-G are mentioned in Annex C of the Open APN Functional Architecture document version 3 [APN FA R3].

Feature 1-2-3: The APN-C should support multi-generation devices and the integration of traditional and new-generation equipment, including data model generation, such as multiple-generation transceivers.

3.1.3 Support of new configuration with remote APN-T and APN-S

The Open APN supports remotely located APN-T and APN-S, which achieves a cost-effective network with minimal configuration. Adapting these kinds of devices requires new management method. In this PoC work, the new management method for these devices should be evaluated.

Feature 1-3-1: The remote APN-T should have a control channel that goes through the same access fiber as the main signal (in-channel). It is desirable to use Gigabit Ethernet for the in-channel so that it should comply with the Optical Line Port of OSCrt specification in the OpenROADM optical specification version 8.0.1.

Feature 1-3-2: The APN-C should control and manage the remote APN-T through the in-channel, including firmware upgrades.

Feature 1-3-3: The remote APN-S should have a control channel that goes through the same access fiber as the main signal (in-channel.)

Feature 1-3-4: The APN-C should control and manage the remote APN-S through the in-channel, including upgrading the firmware.

Feature 1-3-5: The in-channel should be a generic open and/or standardized interface.

Feature 1-3-6: Control and management should be the same for both in-channel and out-channel. Out-channel means direct access to the management port of APN-T and APN-G.

Feature 1-3-7: For security reasons, the in-channel interfaces should be protected from user access.

Feature 1-3-8: Remote APN-T should be controlled and managed separately from user devices.

Feature 1-3-9: Replacement of the remote APN-T and APN-S should not request special work. Automatic configuration of the remote APN-T and APN-S should be realized through the in-channel.

Feature 1-3-10: Registration of a new APN-T/APN-T(FX) into the APN-C should be automatically performed through the in-channel when the APN-T is connected to the Open APN. See Figure E.3-3 (Detailed Sequences for Registration of User Network Device based on Plug-and-Play Concept) of the Open APN Functional Architecture document version 3 [APN FA R3] for an example sequence.

Feature 1-3-11: Path setup and update requests from APN-T/APN-T(FX) via the in-channel should be supported. See Figure E.3-4 (Detailed Sequences for Optical Wavelength Path Setup based on Plug-and-Play Concept) of the Open APN Functional Architecture document version 3 [APN FA R3] for an example sequence.

3.2 Feature 2: On-demand path provisioning for emerging applications requiring temporary optical transport, e.g., GPUaaS

With the automatic operational function of the Open APN, it can also provide dynamic path services. In the traditional optical network, a network path is often established permanently in order to serve as infrastructure of a nationwide IP network. This new feature of Open APN provides services that support short-term, frequently changing network paths, which are available on demand and can be easily altered according to the carrier's needs. The automatic on-demand path provisioning enables provisioning without human intervention, setting APN-T parameters (such as bit-rate, modulation format, and FEC) to maximize link performance while taking into account the receiver's sensitivity, which may be owned by the user. In this PoC, the new control feature for dynamic path service should be carefully evaluated.

Feature 2-1: The APN-C should support automatic path provisioning without human intervention, setting APN-T parameters, such as bit-rate, modulation-format, FEC, to maximize link performance while considering the sensitivity of the receiver.

Feature 2-2: The APN-C should support path designing with appropriate margins that meet the various service grades.

For example, a short-time path may request a small margin. With the appropriate margins, it can provide the highest performance for each service. The use cases for dynamic path are shown in the following documents of IOWN Global Forum: "Services Infrastructure for Financial Industry

Use Case", "Remote Media Production for Broadcast Industry Use Case", "Green Computing with Remote GPU Service for Generative AI / LLM Use Case".

Feature 2-3: The APN-C must support a reoptimization function capable of reorganizing resources by allowing optical paths to be created and deleted more dynamically (by user demand, for example) than existing optical transport networks.

For long-term operation of the network, some kind of reoptimization may be required to eliminate inefficiencies due to the sequential creation of paths and/or performance degradation due to aging.

3.3 Feature 3: Automated fault detection and path recovery of wavelength paths for enhanced availability and resiliency

The automatic operational function of the Open APN also enables enhanced availability and resiliency of the network. With the following features, closed-loop operation with monitoring and feedback can be realized. In this PoC work, the new control feature should be evaluated to achieve this.

Feature 3-1: The APN-C should monitor the Open APN and quickly identify the failure and/or degradation point when it occurs.

Feature 3-2: When failure occurs in the Open APN, the APN-C should recognize the affected service paths and automatically redesign and reconfigure them. The redesigned paths should be configured with an appropriate wavelength on the Open APN, including APN-T.

Feature 3-3: In the event of a failure, the APN-C should recognize the affected equipment, recover it, and restore the service.

Feature 3-4: To facilitate equipment restoration, the APN-C should have a function that allows the sharing of work progress between remote and center-side operators. Alternatively, it should have an interface with software that has a management function for work progress.

Feature3-5: The APN-C should have a backup function for the latest configurations to restore the pre-failure state. Alternatively, it should have an interface with backup systems.

Feature 3-6: The control and management network should have reliability and resiliency.

In this PoC work, the following details are considered for reporting.

1. Automatic or manual switchover (Primary APN-C switch to Standby APN-C) within 60 minutes for metro-area networks within 200 km.
2. Database synchronization between primary and standby APN-C.(Primary APN-C and Standby APN-C must regularly synchronize the database of configuration, alarm, and performance data).

3.4 Feature 4: Unified management and control of existing and Open APN-based line systems

From the viewpoint of telecom operators, who already have a large-scale network, the smooth migration is the key to deploying a new network and technology. The following features will help their migration scenarios. In this PoC work, the migration scenarios should be evaluated with the following features.

3.4.1 Interface of APN-C for existing network

Feature 4-1-1: APN-C should control and manage the existing transport network through its controller.

Feature 4-1-2: APN-C should have a southbound interface of CS.APN to connect the management system of the existing transport network and should control and manage the network through it. The interface should be a generic, open, and/or standardized one that supports the recommended Interface of (3) described in Section 5.3 of the Open APN Functional Architecture document version 3 [APN FA R3].

- It should be reported if any extension on interfaces is needed.

Feature 4-1-3: APN-C should also support the mixed environment with Feature 1-1-3 and 4-1-2.

Feature 4-1-4: Through the interface CN.APN, as described in Feature 1-1-5, APN-C should provide the control and management functions of the existing network for external systems.

3.4.2 Function of APN-C for existing network

Feature 4-2-1: APN-C should have a function to create, delete, and update the following types of paths.

1. Path across an Open APN
2. Path across an existing optical network
3. Path spanning an Open APN and an existing optical network

As for the path of type-3, it is recommended to refer to one of the connections shown in Figure 6.1.5-2 or Figure 6.1.5-3 of Section 6.1.5 (Inter GOIP) in the Open APN Functional Architecture document version 3 [APN FA R3].

Feature 4-2-2: The APN-C should have a service monitoring and management function that allows for providing a status of the services (optical paths of type-1, 2, 3 described in Feature 4-2-1).

4 Benchmark

This section describes benchmarking methods that we expect implementors to follow.

The Open APN Functional Architecture document [APN FA R3] does not show any detailed sequence so we expect PoC implementors to report sequences and procedures to be realized.

4.1 Benchmark 1: for feature 1

This benchmark requires PoC implementers to show interfaces for control and management.

4.1.1 Interfaces to be verified

Support of the following interfaces should be verified and reported.

- Interface CS.APN of APN-C, between APN-C and APN-T, APN-I, APN-G:
  - YANG-based open data model on the open transport protocol.
  - OpenConfig[OpenConfig], Open ROADM[OpenROADM] and/or its expansion are expected in this PoC.
- Interface CS.APN of APN-C, between APN-C and APN-FX:
  - YANG-based data model on the open transport protocol.
  - The YANG model should be an expansion of the conventional ROADM model.
  - To realize integrated control and management of APN.FX and APN.WX, the transport protocol should be the same as for APN-G and APN-I.
- Interface CS.APN of APN-C, between the APN-C and other Management Systems, including EMS/NMS of the existing network:
  - Open IFs to enable coordinated control and management between controllers.
  - TAPI[TAPI] is expected in this PoC, but other open interfaces can be used.

4.1.2 Control and management features to be verified

Through the above interfaces, PoC implementers should show that the following items can be controlled and managed and also should be reported.

- Management parameters for network topology and devices
- Service path creation, deletion, and update

See Figure E.3-2 and E.3-4 of Open APN Functional Architecture document version 3[APN FA R3] for an example sequence that comprises several processes.

4.1.3 Control and management features with remote APN-T/S to be verified

The following benchmark pertains to the control and management of remotely located devices, specifically APN-T and APN-S. Support of the following control and management should be verified.

4.1.3.1 Control and management features with remote APN-T to be verified

For remote APN-T, the remote control channel should be verified for the following items.

- PoC implementers should report how to realize the control channel (in-channel) for remote APN-T using the same fiber as the main signal (without additional fibers.) It should also be reported if the implementation of the control channel complies with the OSCrt specification in the OpenROADM optical specification version 8.0.1.
- This control channel (in-channel) should not be accessed from the user side, and administrative privilege separation from user facilities should be realized, and how access privilege separation is achieved should be reported.
- As for the control channel (in-channel), this remote control channel has Open interface, and WDM channel is expected as shown in Annex C.3 of the Open APN Functional Architecture document version 3 [APN FA R3] like an OSC between ROADMs, and should be reported about the control channel.
- Another method of in-band, such as GCC of OTN, can also be applied for PoC and should be reported.

4.1.3.2 Control and management features with remote APN-S to be verified

For remote APN-S, the remote control channel should be verified for the following items.

- PoC implementers should report how to realize the control channel (in-channel) for remote APN-S using the same fiber as the main signal (without additional fibers).
- This control channel (in-channel) should not be accessed from the user side, and administrative privilege separation from user facilities should be realized, and how access privilege separation is achieved should be reported.
- This remote control channel has an Open IF. As described above, CS.APN, the Open IF is expected to be a YANG-based open model on an open transport protocol. OpenConfig[OpenConfig], Open ROADM[OpenROADM], and/or its expansion are expected in this PoC, and should be reported on the remote control channel.

4.1.4 Connection features with remote APN-T/S to be verified

The following benchmark is related to the control and management of remotely located devices, APN-T and APN-S. Support of the following connection features should be verified.

4.1.4.1 Connection features with remote APN-T to be verified

Through the remote control channel (in-channel), the following functions for remote APN-T connection should be verified.

- APN-C should control the remote APN-T connection/disconnection/keepalive.
- APN-C should support the automatic registration of a newly connected APN-T. Processes for the automatic registration should be described (e.g., authentication, address/ID assignment, confirmation/identification of APN-G port, registration to database); see Figure E.3-3 of the Open APN Functional Architecture document version 3 [APN FA R3] for an example sequence that comprises several processes.
- The sequence of APN-T initial connection (including registration) and disconnection should be reported.
- The connection sequence of remote APN-T should include the automatic configuration of APN-T from APN-C, and the addition of a new APN-T to the APN should not affect the APN-C's existing services.
- It may also include APN-T authentication and the remote control channel encryption, and how authentication is achieved should be reported.
- The time to connect and configure the new APN-T should be reported. The time breakdown for each process should also be reported. (units: second.)

4.1.4.2 Remote control channel-related features with remote APN-C to be verified

Through the remote control channel (in-channel), the following functions of APN-C should be verified.

- APN-C should support the path setup and update requests from APN-T via the in-channel. Processes for the path setup and update triggered by APN-T should be described (e.g. endpoint mediation, path computation, selection of transmission mode, ID assignment, registration to database); see Figure E.3-4 of the Open APN Functional Architecture document version 3 [APN FA R3] for an example sequence that comprises several processes.
- APN-C gathers information on remote APN devices (APN-T and/or APN-G) with deep streaming telemetry through the channel.
- Controlled parameters should be enough for APN-T/APN-G configuration, and status monitoring should be reported.
- The report also highlights the differences between the conventional out-channel method, which utilizes a dedicated management port, and the in-channel method.
- APN-C should support firmware updates of remote APN-T/APN-S using generalized methods such as a standard file transfer protocol and/or software activation method, which should be reported.
- The firmware upgrade is expected to be within 10 minutes.
    - The time required for a firmware update per terminal should be reported (units: seconds).
    - PoC implementers should report how to realize administrative privilege separation, such as container-based technologies, on the remote device.

4.2 Benchmark 2: for Feature 2

This benchmark is related to dynamic path service provisioning. The support for the following control and management capabilities should be verified.

- APN-C should support path calculation and QoT estimation for the path with the requested margin that varies for each service, and should be demonstrated and reported.
- Depending on the WDM path QoT, select the optimum coherent mode (excluding IMDD) within 10 minutes and implement the required wavelength assignments. The implementation and selection time should be reported. (unit: seconds)
- The time for optimum coherent mode selection should be reported (unit: seconds).
- The impact of a newly added wavelength path over previously provided wavelength paths should be estimated within a few minutes. The estimation time should be reported. (time in, unit: seconds)
- The time for the estimation should be reported with the target scale of the network. (unit: seconds)

4.3 Benchmark 3: for Feature 3

This benchmark is for the closed-loop operation with network monitoring and feedback. Support of the following control and management functionality should be verified.

4.3.1 Switchover-related features to be verified

- Switchover from one optical line system, such as APN-G or APN-I, to another without on-site dispatch.
    - Switching and optimizing devices in the Open APN is expected within a 2-hour maintenance window.

Time for switching and optimizing should be reported with the target scale of the network. (unit: minute.)

4.3.2 Monitor device-related features to be verified

- Monitor devices in the Open APN.
    - When any damage occurs, APN-C redesigns WDM links.
    - According to the redesign WDM links' wavelength has changed, and APN-T has to change its wavelength accordingly.

The redesign is expected to be completed within one hour. The time should be reported in relation to the target scale of the network. (unit: minutes)

4.4 Benchmark 4: for Feature 4

This benchmark is for interworking with the Open APN and the existing optical transmission network, as well as network migration. The interwork and migration scenario shown in Annex A should be verified.

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Annexes

A. Migration Scenarios

In this section, migration scenarios for verification is described.

This scenario is for the installation of an Open APN in the real world. As a result, this scenario must be covered and proven in the PoC. This Annex shows the examples of migration scenarios from the existing transport network to an Open APN.

For all migration steps, existing network controllers may also be vendor EMS/NMS, depending on their implementations, and they are required to support Open IF as NBI so that APN-C can control existing devices through these controllers during migration.

A.1 Migration Step 1: Add APN-Ts into a single GOIP

In this step, the intent is to connect multi-vendor APN-Ts to the network with the existing vendor Optical Line System(OLS) and terminals.
Figure A.1-1 shows the network architecture of this step. The existing network controller controls the existing OLS and terminals; APN-Ts are controlled by APN-C with Open IF and may also be controlled by the existing network controller from the same vendor. APN-C can indirectly control existing OLS and terminals through the existing network controller.
Note that APN-C has NBI(Open IF) and SBI(Open IF) as described in the Open APN Functional Architecture document version 3 [APN FA R3].

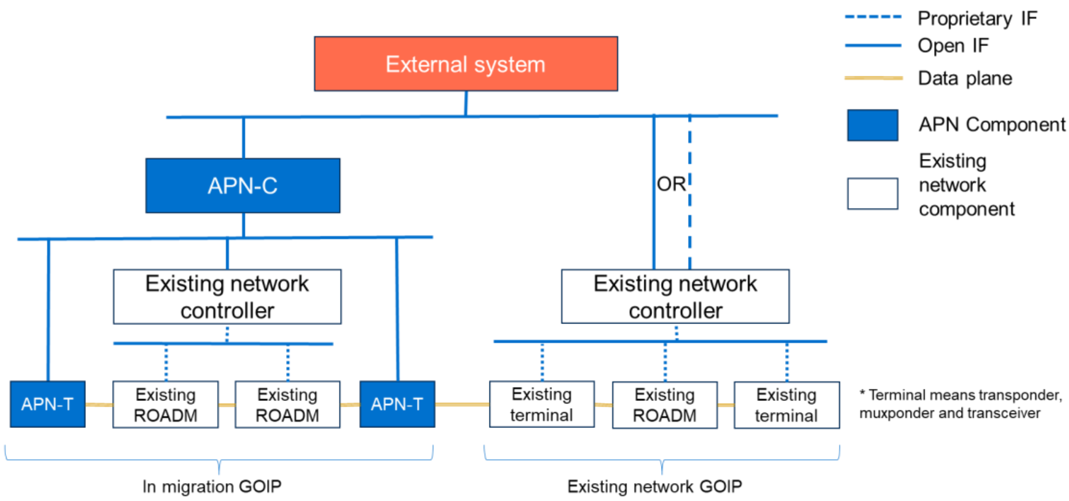

Figure A.1-1 Migration Step 1: Add APN-Ts into single GOIP

A.2 Migration Step 2: Migrate to full Open APN in single GOIP

In this step, the goal is to create a single Open APN GOIP to enable full Open APN functionality within GOIP.
Figure A.2-1 shows the network architecture of this step. APN-Ts, APN-Gs, and APN-Is are controlled by APN-C directly or through the APN-G/I management system with Open IF. APN-Ts, APN-Gs, and APN-Is may be from the same vendor or different vendors.
Note that APN-C has NBI(Open IF) and SBI(Open IF) as described in the Open APN Functional Architecture document version 3 [APN FA R3].

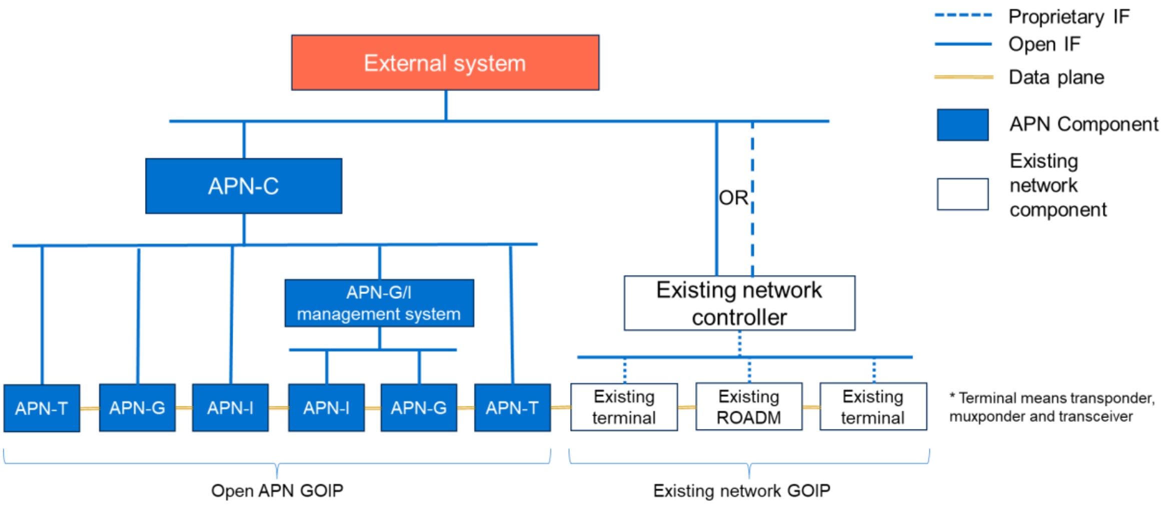

Figure A.2-1 Migration Step 2: Migrate to full Open APN in single GOIP

A.3 Migration Step 3: Connect Open APN GOIP with in-migration GOIP

In this step, the intent is to establish end-to-end paths connecting Open APN GOIP and in-migration GOIP for inter-GOIP migration.
There are some types of inter-GOIP connections. Figure A.3-1 and A.3-2 are examples of in-migration architecture with client-interface connection and optical-interface connection, respectively.

In the in-migration GOIP, similar to Migration Step 1, the existing devices and APN-Ts are controlled by the existing network controller and APN-C separately, and APN-C can indirectly control the existing devices through the existing network controller.
In Open APN GOIP, similar to Migration Step 2, APN-T/G/Is are controlled by the same APN-C above.
End-to-end paths across these two types of GOIP should be created and controlled by same APN-C above
Note that APN-C has NBI(Open IF) and SBI(Open IF) as described in the Open APN Functional Architecture document version 3 [APN FA R3].

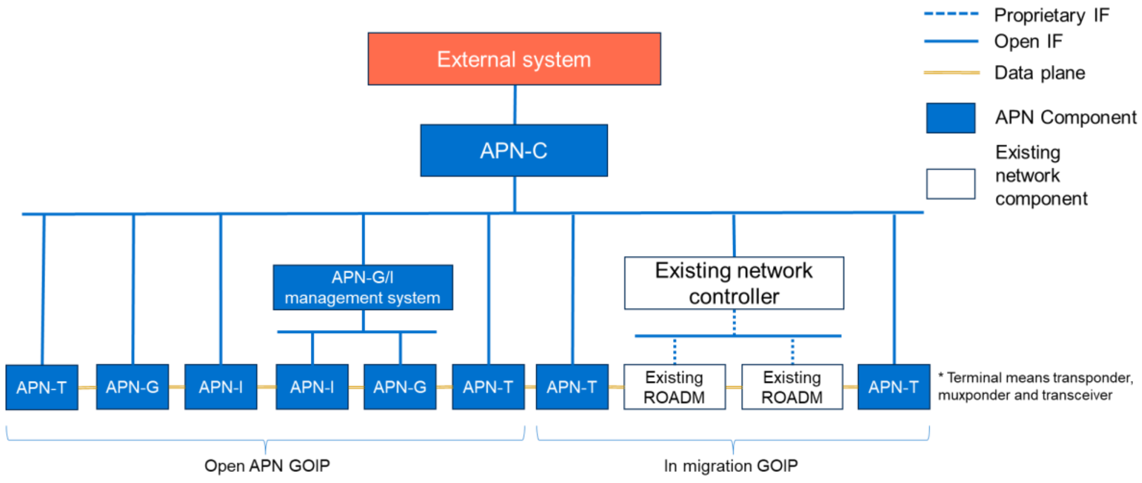

Figure A.3-1 Migration Step 3: Connect Open APN GOIP with in-migration GOIP (Connection with client interface)

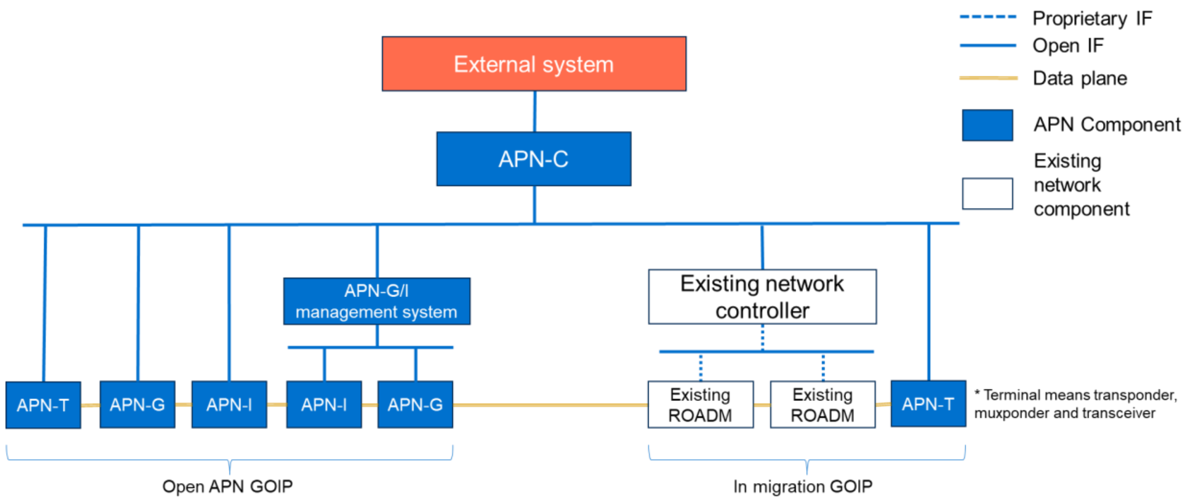

Figure A.3-2 Migration Step 3: Connect Open APN GOIP with in-migration GOIP (Connection with optical interface)

A.4 Migration Step 4: Fully migrate to Open APN

In this step, the intention is to migrate multiple GOIPs to Open APN and establish an end-to-end path connecting these GOIPs, ultimately leading to a full migration to Open APN.
Figure A.4-1 shows the network architecture of this step. Any existing devices within multiple GOIPs should be treated as APN-T/G/Is from the point of view of APN-C and be controlled by a single APN-C directly or through APN-G/I management system with Open IF. End-to-end paths across these two types of GOIP should be created and controlled by the same APN-C above. Note that APN-C has NBI(Open IF) and SBI(Open IF) as described in the Open APN Functional Architecture document version 3 [APN FA R3].

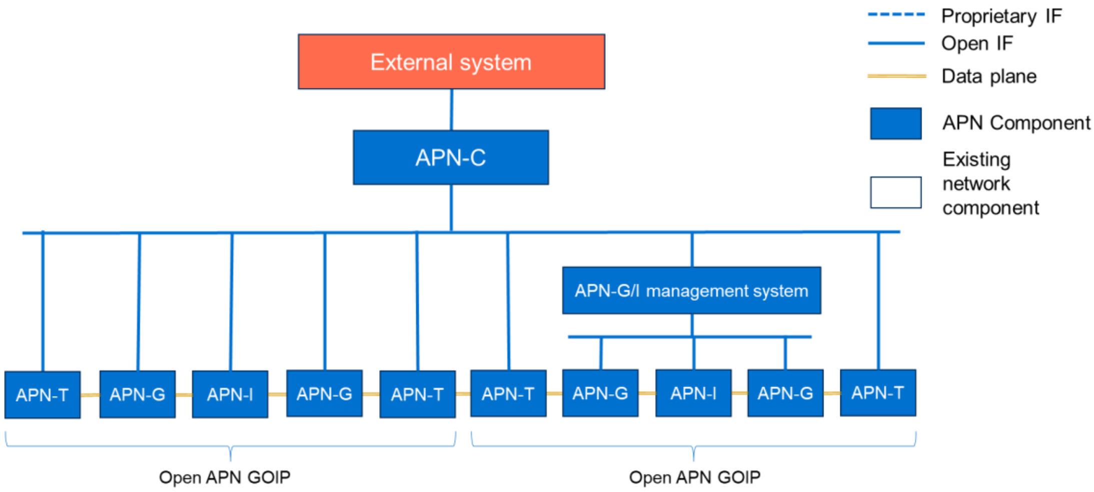

Figure A.4-1 Migration Step 4: Fully migrate to Open APN

A.5 Line System replacement and upgrade

When transitioning from the current Line System to a newly installed one, minimize the additional monitoring hardware required for automation and optimization, ideally to around one unit per line system. For current data-center interconnection deployments, the typical maintenance window is two hours; the goal is to reduce this to one hour or less. (This assumes that adequate bandwidth is allocated for the control channels of each device, ensuring real-time operability.)

History

Revision	Release Date	Summary of Changes
1.0	November 04, 2025	Initial Release