RIM and PoC Reference for Open APN with APN-G port sharing

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[Open APN APN-G PS RIM PoC Ref]
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1. Purpose, Objectives, and Scope

1.1. Purpose: Why we encourage this PoC

In today's networks, optical paths are disjointed and operated on a segment-by-segment basis, i.e., LANs, access networks, and inter-data-center networks. The Open All-Photonic Network (APN) is a network that connects endpoints directly with optical paths. It provides high-speed, ultra-reliable, low-latency connections. However, the per-port cost of Open APN Gateway (APN-G) remains relatively high in the APN architecture defined in Open APN Functional Architecture version 2. This is because the architecture is such that each port of the APN-G placed at operator's site is exclusively used by an Open APN Transceiver (APN-T) placed at user's site. This poses a significant barrier to the widespread deployment of APN services across diverse user segments. To address this challenge, the Open APN Functional Architecture has been expanded to allow multiple APN-Ts to share each APN-G port in version 3. For this purpose, Open APN Splitter (APN-S) has been defined. APN-S enables the sharing of APN-G port costs.

For example, in mobile fronthaul (MFH) networks, it is essential to efficiently accommodate signals from numerous geographically distributed Radio Units (RUs). Likewise, as data centers (DC) transition from traditional centralized architectures to geographically distributed configurations to address land and power shortages, it becomes increasingly important to efficiently aggregate signals at distributed sites.

However, applying a large-scale APN-G to gather traffic from the distributed RUs presents challenges in terms of cost. APN-S, a small-scale node that can be deployed either as an alternative to APN-G or in combination with it, offers an effective solution to this problem.

In addition, by applying Wavelength Division Multiplexing (WDM) transmission between APN-G and APN-S, it becomes possible to maximize the transmission capacity per optical fiber. This enables efficient aggregation and transport of signals not only from multiple RUs to the Distributed Unit (DU) in MFH networks, but also among distributed data centers and across the cloud-edge computing continuum. By improving fiber utilization, this approach can reduce the required amount of optical fiber, thereby lowering capital expenditure and operational costs.

Given that APN-S is a kind of small-scale ROADM node as mentioned above, it enables the construction of ring-type networks as well. This contributes to enhancing the overall network's availability and fault tolerance. In the event of a failure, alternative routes can be secured for communication, thereby improving service continuity. Based on these advantages, APN-S is an effective solution for MFH and DC networks.

As another approach, the Point-to-Multipoint (PtMP) technology allows multiple APN-T(MP-L)s to share APN-G port costs since it supports multi-lambda or fiber resource sharing.

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As yet another approach to achieve APN-G port sharing, time-sharing of APN-G ports via APN-FX can also be considered. Although this approach is limited to APN Fiber Path Services, it enables APN-G port sharing by connecting the APN-G port to APN-FX and then to multiple APN-Ts. This configuration can be implemented in combination with the second approach, i.e. PtMP. In this case, an optical splitter is placed between APN-FX and a set of APN-Ts to create a point-to-multipoint topology in the physical layer. A single wavelength can be shared among the set of APN-Ts, thus allowing efficient use of APN-G resources further.

The purpose of this PoC reference is to encourage comparative consideration of these approaches and promote the clarification and adoption of the optimal solutions for various applications.

1.2. Objectives: What we shall accomplish

This PoC reference mainly deals with the following approaches of (a) to (d).

(a) Optical Infrastructure with APN-S

(b) Applying PtMP architecture

(c) Time Sharing of an APN-G Port via APN-FX

(d) Combinations of three approaches

(a) Optical Infrastructure with APN-S

Applications in the access networks such as MFH and DC require severe cost reduction. APN-S is defined to support multi-λ under each APN-G port, i.e. in access networks. APN-S can be passive or active.

In each approach, it is expected to:

・show that by simplifying the configuration, equipment costs can be reduced, and by multiplexing signals, the number of fibers used can be decreased, thereby lowering the total cost per port. The simplifying the configuration means that reducing the number of ports and replacing the multiplexing and demultiplexing devices with simpler ones, such as AWGs or couplers(splitters).

・(optionally) demonstrate improved fault tolerance by showing that traffic can be switched to an alternative path in the event of a failure. In the later sections, features and benchmarks are defined to show how each approach can work with low cost with using comparable scalers.

(b) Applying PtMP architecture

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A PtMP architecture enables the accommodation of multiple APN users through a single ROADM port. Unlike the conventional one-to-one connection between APN-G and APN-T, this architecture allows for one-to-many connectivity, which can significantly reduce the number of ROADM ports required. This reduction translates into lower cost associated with transceivers and optical fibers, contributing to a more cost-efficient APN infrastructure. This architectural approach is particularly beneficial in scenarios where resource sharing is essential, such as MFH and remote media production (RMP). By leveraging PtMP, network operators can optimize infrastructure investment while maintaining service quality and scalability.

This PoC reference outlines many desirable features and benchmarks; however, it is not necessary to achieve all of them simultaneously. For example, if a PoC is conducted using PtMP and proves effective, it already holds value. Furthermore, if any of the technologies—such as WDM, SCM, TDM, BiDi, or other indicated methods—contribute to reducing per-port cost of ROADM, regardless of which one is selected, the PoC would be considered sufficiently valuable.

(c) Time Sharing of an APN-G Port via APN-FX

By effectively introducing APN-FX, there is potential to reduce APN costs through a different approach compared to APN-S and PtMP. APN-FX enables wavelength sharing among multiple users. It is important to note that this method is only applicable to the combination of Wavelength Path Service and Fiber Path Service.

(d) Combinations of three approaches

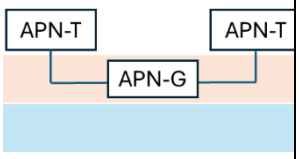
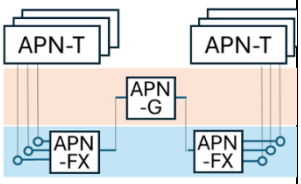
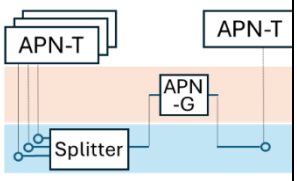
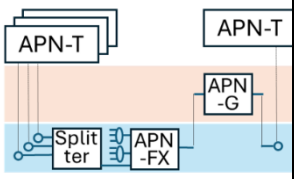
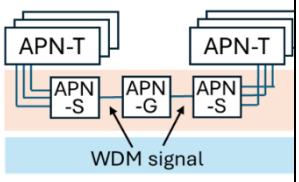
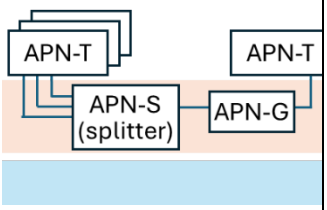
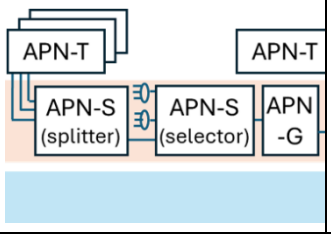
Combining the approaches described in (a) through (c) has the potential to reduce the APN-G port cost more effectively. For example, combining (a) APN-S with (b) PtMP is expected to allow a single APN-G port to accommodate a larger number of users under specific conditions. Similarly, combining (b) PtMP with (c) APN-FX is expected to enable a single APN-G port to provide wavelength-sharing services to a greater number of users.

However, careful attention must be paid to QoS performance particularly the low-latency characteristics of the APN and overall system performance must be thoroughly evaluated to ensure that APN services are not degraded.

Table1-1 shows the PoC applicable architecture based on this PoC reference. PoC owners are expected to indicate which architecture they used for their PoC. Case #1 represents a typical APN architecture. Comparisons Case #1 with Cases #2 through #5 enable an evaluation of the potential for reducing APN-G port cost. However, the recommended bandwidth, latency, and transmission distance differ significantly among the approaches. Therefore, comparisons should be conducted under specific use cases and communication conditions.

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Table 1-1 PoC applicable architecture

	Wavelength Path Service		Combination of Wavelength Path Service and Fiber Path Service	
	PtP	PtMP	PtP	PtMP
Without APN−S	#1 	–	#4 (c) APN−FX  Only 1 APN-T is connected by APN-FX at a time	#5 (d) PtMP  (e) PtMP & APN−FX 
With APN−S	#2 (a)APN−S 	#3 (a) APN−S  (b) APN−S & PtMP 	–	–

#1: PtP Wavelength Path Service Architecture

This represents the standard architecture for APN Wavelength Path Service. It serves as a baseline for comparison with other cases and can also be evaluated against technologies that aim to reduce per-port cost while maintaining this architecture.

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2: PtP Wavelength Path Service with APN-S Implementation

This architecture introduces APN-S into a PtP Wavelength Path Service architecture to evaluate APN-S capabilities. Comparisons with Case #1 provide insights into per-port cost implications.

3: PtMP Wavelength Path Service combined with APN-S

This architecture will be designed to evaluate the functionality and scalability of two architectures. The first architecture is the APN-S with optical splitter function. The second architecture assess the combined characteristics of APN-S and PtMP Wavelength Path Service architecture. It is typically used two APN-Ss as a Selector and optical splitter to devidce an optical power into multiple outputs and compared with Cases #1, or #2 to evaluate per-port cost.

4 PtP Architecture on the Combination of Wavelength Path Service and Fiber Path Service

In this architecture, the APN-G is connected to the APN-T via an APN-FX, enabling APN-G port sharing through wavelength-based time-sharing mechanism. This configuration enables performance and cost analysis in comparison with #1, and also it serves as a baseline for comparison with Cases # 5 and can also be evaluated against technologies that aim to reduce per-port cost while maintaining this architecture.

5 PtMP Architecture on the Combination of Wavelength Path Service and Fiber Path Service

This architecture will be designed to evaluate the functionality and scalability of two architectures. The first architecture is PtMP architecture, in which an APN-G is connected to multiple APN-Ts via an optical splitter. The second architecture combines time-sharing using APN-FX with PtMP architecture, in which APN-G and APN-Ts are connected through APN-FX. Comparisons with Case#1 or Case # 4 provide insights into per-port cost implications.

1.3. Scope: What we do and what we don’t do.

In this PoC work, we analyze the cost and performance differences between conventional model cases and the four approaches described in Section 1.2, leveraging the unique characteristics of each.

For example, in the PtMP approach, it is possible to compare the per-port cost of ROADM between the referenced typical APN architecture and one that adopts the PtMP architecture.

Furthermore, the following evaluations are planned for each approach:

(a) Optical Infrastructure with APN-S

- Passive/active APN-S configurations that support moderate DWDM of main signals (about 4 to 16) and APN-T remote control for MFH applications. In some configurations, the route

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can be switched by remotely controlling APN-S or APN-Ts for elastic load balancing or fault tolerance.

(b) Applying PtMP architecture

- Demonstration of APN-G Port sharing way
- Evaluation of APN-G Port Sharing Impact on QoS

(c) Time Sharing of an APN-G Port via APN-FX

- Time sharing mechanisms to share single wavelength to multi APN-Ts

What we don't do

- This document does not define conditions or benchmark items related to APN-C. For PoC activities concerning APN-C, please refer to the Open APN Controller PoC Reference.

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2. Reference Cases

This section describes reference cases implementation models for each of the four approaches defined herein. It focuses on promising architectures that can reduce APN-G port costs and, as stated in Sections 1–3, does not cover APN-C. Furthermore, the quantitative implementation requirements for each architecture depend on the specific use case, as the required bandwidth and latency differ between applications such as MFH and DC connections. These values should be referenced from other sources. For the overall architecture, please refer to Figure A-1-1, Figure A-2-1, Figure B-1, and Figure C-1.

2.1. APN Reference Model

Figure 2.1 illustrates the basic APN configuration used as the baseline reference model for this PoC. In the conventional APN architecture, multiple APN-Ts are directly connected to an APN-G without utilizing APN-G port sharing. The purpose of this model is to provide a baseline for comparison when evaluating the effectiveness and operational benefits of APN-G port sharing described in the subsequent sections.

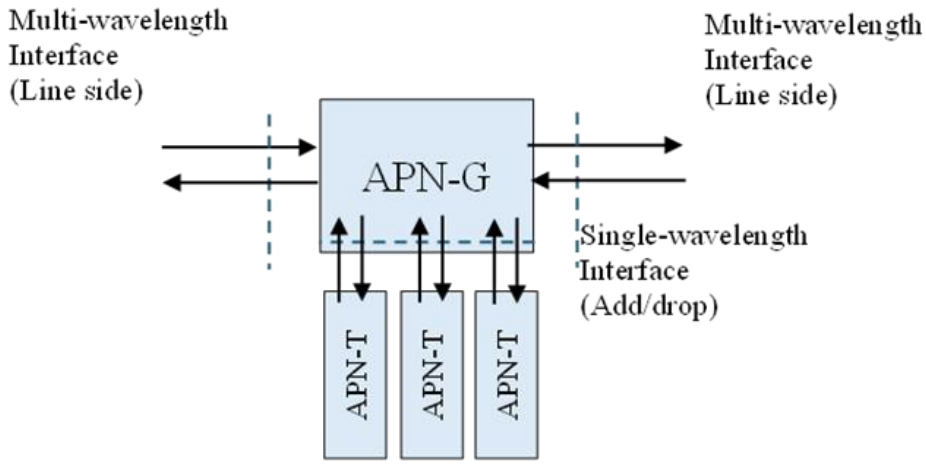


Figure 2-1 APN-G to APN-T Connection

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2.2. Multi λ connection with APN-S

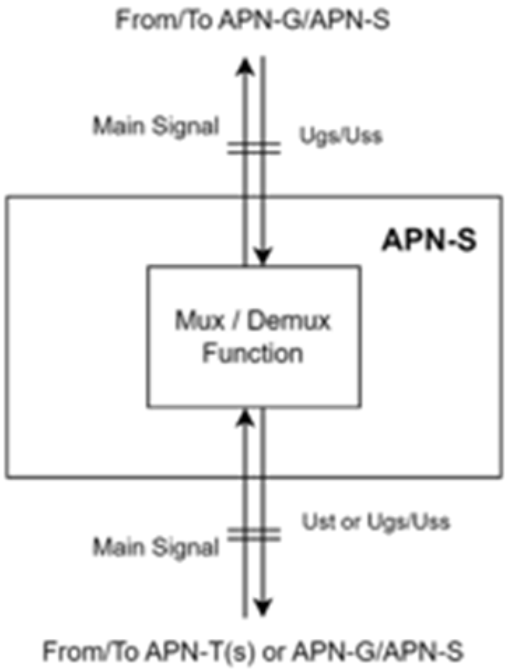


Figure 2-2 depicts the basic model of APN-S.

A) Interface
APN-S is typically installed between APN-G and APN-T, featuring Ugs (APN-G/APN-S) and Ust (APN-S/APN-T) interfaces for the main signal.
In cases such as ring topologies or cascade connections, APN-S may be connected to each other. In this case, APN-S may have an Uss interface (APN-S/APN-S). Furthermore, when configuring a redundant system, it may be connected to multiple APN-G.
*Uss has not been defined in Open APN Functional Architecture version 3 yet. Need to discuss in OAA-TF.

B) Functions
APN-S possesses a Mux/Demux function to multiplex and demultiplex multiple wavelength paths. It may also include wavelength selection switch function. Active/passive configurations can be selected according to the requirements of each use case. If we are concerned about privacy, we can also choose to send only one signal from APN-S to APN-T using filters or similar methods.

C) Parameters

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The parameters of APN-S are described as follows.

- Number of Ugs, or number of connection to APN-G
- Number of Uss, or number of connection to APN-S
- Number of Ust, or number of connection to APN-T
- Fiber type of Ugs, Uss and Ust, which is Bidirectional single-fiber or Dual-fiber.
- Device type of Mux/Demux for main signals, which is WSS, AWG, DWDM thin filters and so on.
- Aggregation ratio of APN-T.
- With/Without Amplifier

The deployed system should support the following.

1.APN-S can connect to the add/drop side of APN-G.

2.APN-S can connect to the line side of APN-G. In this case, an APN-S can connect to another APN-S.

(Option) If network is ring, the route can switch in case of a failure.

Figure 2.3 describes the architecture when APN-S is connected to the Add/Drop side of APN-G. By aggregating APN-T with APN-S and connecting it to APN-G, we can increase the number of APN-Ts connected to a single port of APN-G.

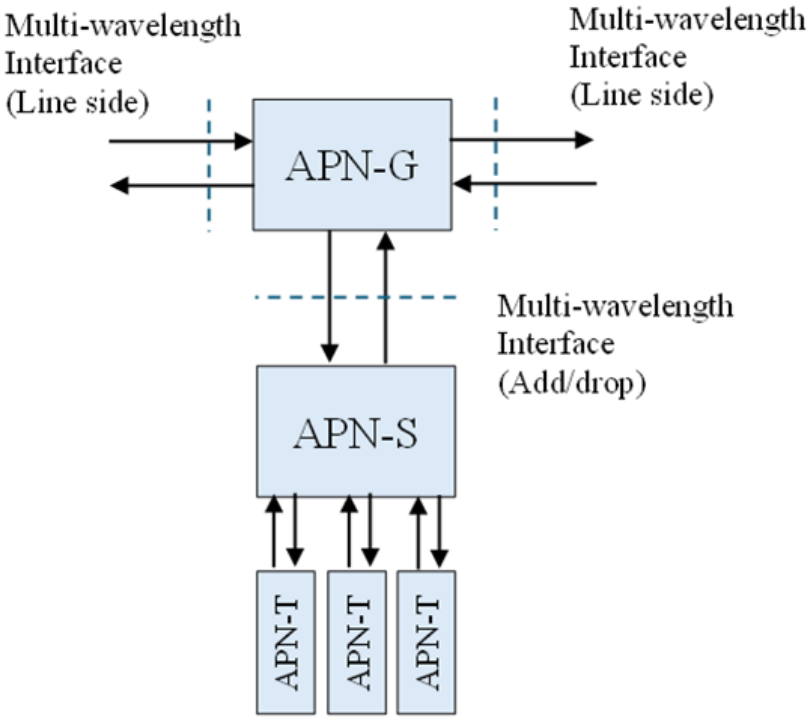


Figure 2-3 APN-G to APN-T Connection with APN-S (Add/Drop side)

Figure 2.4 describes the architecture when APN-S is connected to the Line side of APN-G. By aggregating APN-T with APN-S and connecting it to APN-G, we can increase the number of APN-

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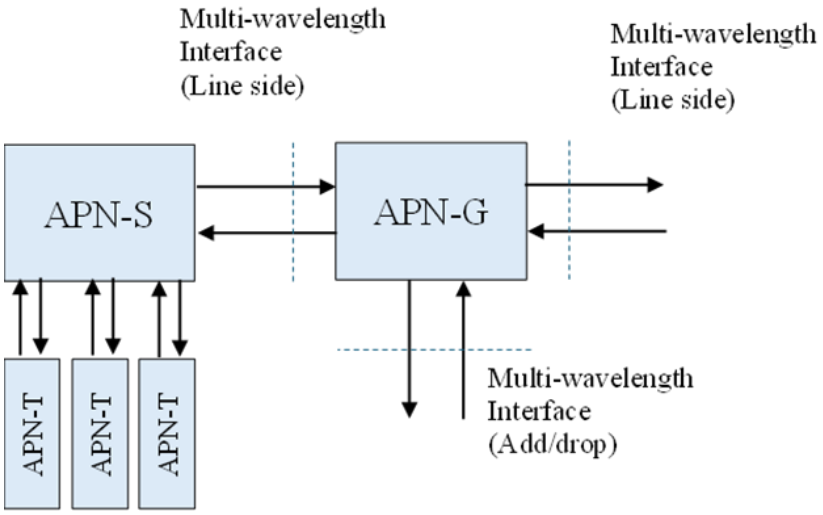


Figure 2-4 APN-G to APN-T Connection with APN-S (Line side)

Ts connected to a single port of APN-G. Additionally; by connecting a simplified APN-S to APN-G, we can reduce the cost of node.

APN-S is designed to multiplex traffic from multiple APN-T units. While it is desirable to maximize the number of APN-Ts that can be aggregated by APN-S, the optimal number must ultimately be determined by considering economic rationality.

The APN-S architecture offers various deployment options like Figure 2.5(a) - (c), including multi-tier branching, amplifier options, Ring topologies, and Bus topologies. The selection of the most suitable topology APN Reference Model

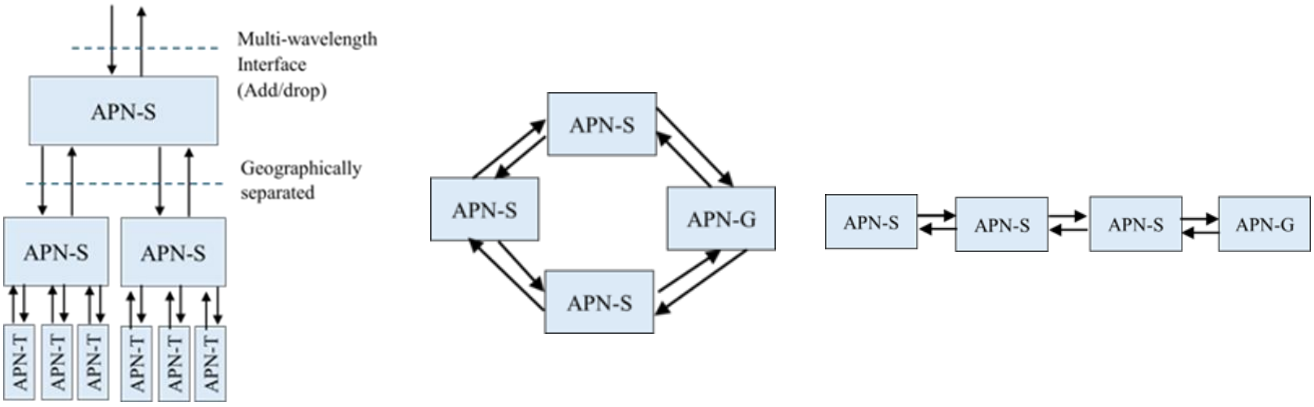


Figure 2-5 (a) Multi-tier branching topology, (b) Ring topology, (c) Bus topology

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2.3. PtMP Reference Model

Figure 2.6 describes a representative example of the PtMP architecture, based on Annex F of the Open APN Functional Architecture version 3. PtMP enables multiple APN-T (MP-L) nodes to share a single APN-G port via APN-S or optical splitters, supporting both wavelength-path and fiber-path services. Applicable technologies are TDM, WDM, TWDM, and SCM, offering flexible multiplexing and scalability. The architecture supports dynamic resource allocation and energy-efficient transmission, making it suitable for MFH, Data center Connection, remote media production, and enterprise connectivity. This document does not define the specific control mechanisms used in the PoC. Various control approaches, such as centralized or in-band mechanisms, may be meaningful if they contribute to cost reduction, depending on deployment requirements and latency constraints.

(a) Functions

To enable scalable and flexible sharing of APN-G port resources, the system should ideally support the following capabilities:

1. Support for multiple APN-T (MP-L) instances to realize PtMP configurations.

· Optional control mechanisms may be required to manage multiple APN-T (MP-L) instances; however, the control method is not constrained.

· In-band configuration toward peer APN-T (MP-L) may be supported, depending on the deployment scenario.

2. Scalability should be ensured by allowing the number of APN-T (MP-L) instances to be configurable.

For a more precise estimation of the per-port cost, it is recommended to clarify whether the following architectural features are supported:

3. Path redundancy mechanisms.
4. Capability to switch from PtMP to PtP modes via configuration.
5. Dynamic resource allocation or sleep mechanism

(1) both cases of XR optics, TDM/TWDM/WDM PON and PtP/PtMP selection;
(2) sleep and Automatic provisioning

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6. If required, mechanisms for channel selection or data collision avoidance should be implemented to ensure QoS, and upper-layer encryption should be used to protect privacy.

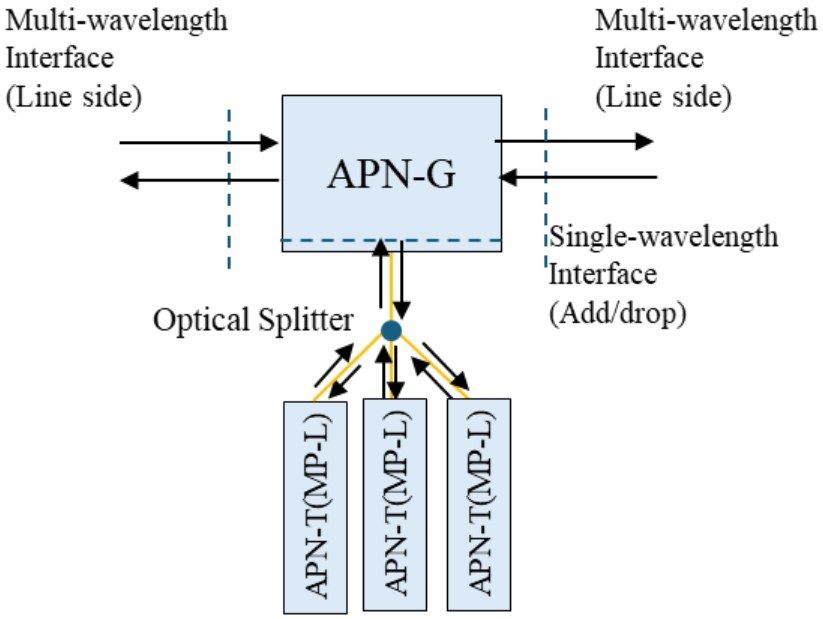


Figure 2-6 APN-G to APN-T Connection with PtMP

2.4. Time Sharing of an APN-G Port via APN-FX

Figure 2.4 illustrates the system example for sharing an APN-G port using APN-FX or splitter. A single wavelength of APN-G may be freely allocated to any APN-Ts selected at will, enabling APN-G port sharing. There are no constraints on the methods by which a wavelength may be assigned to any APN-T, nor on the frequency with which the assignment of the APN-T may be changed. For example, techniques such as time division multiplexing and sub carrier frequency division multiplexing may be employed.

(a) Functions

An APN-G port using APN-FX enables a single wavelength of the APN-G to be flexibly allocated to any selected APN-T. As described in Section 2.4, there are no constraints on the method by which a wavelength is assigned to an APN-T.

However, when port sharing is implemented using APN-FX, the available time resources per user are limited, resulting in a trade-off with the number of users. For proper evaluation in the PoC

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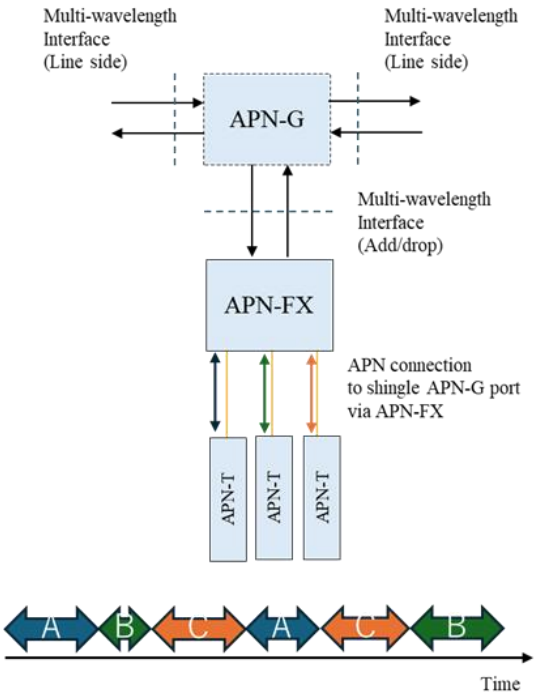


Figure 2-7 APN-G to APN-T Connection with TDM approach

document, the assumed number of users and the wavelength-path switching frequency should be specified.

2.5. Combination of APN-S and PtMP

The architecture combines APN-S with Point-to-Multipoint (PtMP) to increase APN-G port utilization and reduce per-port cost, as shown in Figure 2.8. APN-S is typically connected on the add/drop side of the APN-G and performs wavelength aggregation and selection functions. PtMP enables the shared use of wavelength and fiber resources among multiple APN-T nodes. This combination supports dynamic resource allocation and may enable energy-efficient transmission, depending on deployment constraints. As a result, a single APN-G port can serve a larger number of APN-T nodes under specified conditions. The per-port cost may be reduced compared with non-aggregated architectures.

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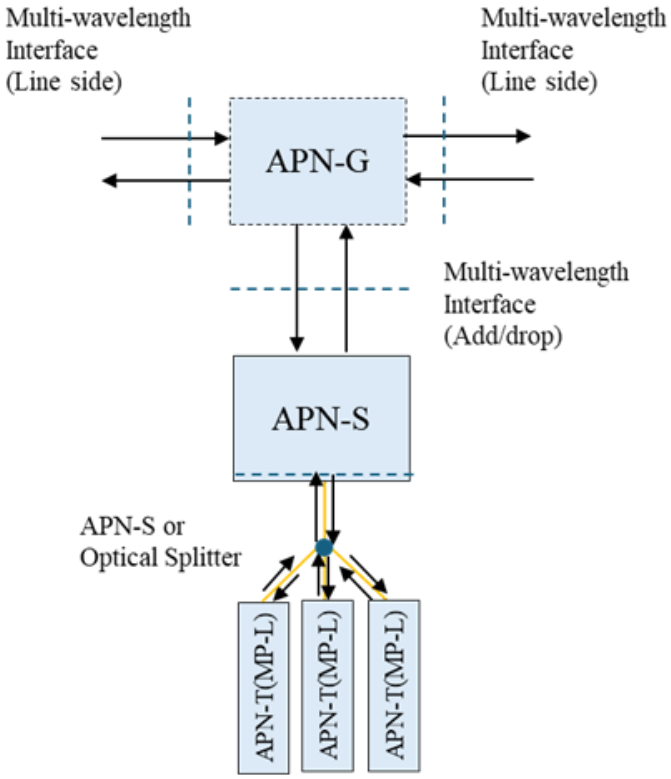


Figure 2-8 APN-G to APN-T Connection with the combination of APN-S and PtMP

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2.6. Combination of PtMP and APN-FX

As shown in Figure 2.9, the PtMP architecture can be introduced into the time-sharing mechanism using APN-FX, enabling the accommodation of a larger number of users. As described in Section 2.4, various technologies, such as time-division multiplexing and sub-carrier frequency-division multiplexing, can be applied.

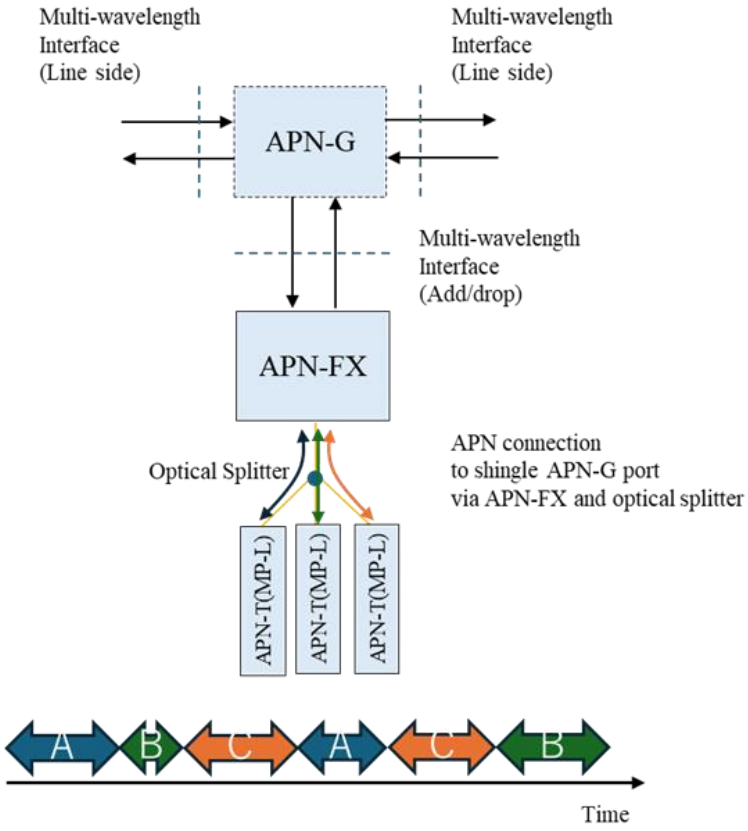


Figure 2-9 APN-G to APN-T Connection with the combination of PtMP and APN-FX

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3. Example Reference cases

For MFH scenarios, the latency requirement between the Radio Unit (RU) and Distributed Unit (DU) is ideally less than 160 μs. If this condition is met, there will be no problem connecting to APN-G after passing through multiple APN-Ss. The signal bitrates are typically around 25-100 Gbps(The value may be even larger in the future).

For DC scenarios, the baseline transport capacity is evaluated based on 400 Gbps-class high-speed interfaces at the APN-T termination, while future expansion toward higher transmission rates is also taken into consideration. The allowable loss between APN-S and APN-G, as well as between APN-S and APN-S, is assumed to be within the range of 0 to 20 dB. In addition, the acceptable one-way latency requirement is defined as less than 100 μs, considering only equipment-induced latency and excluding fiber propagation delay.

The power of each signal may vary due to variations in the output power of APN-T and changes in path loss. In such cases, power adjustment is performed using APN-G's power adjustment mechanism, APN-S's power amplification, or an attenuator, to ensure the power matches the required input power of APN-T.

The same assumptions may also be applied to the PtMP and APN-FX reference cases. The signal bitrate is typically assumed to be 25–100 Gbps, and the allowable one-way latency is assumed to be less than 100 μs. The achievable per-user data rate and upstream latency, however, depend on the selected multiplexing method. Accordingly, the transmission distance and branching factor should be appropriately adjusted based on the target deployment scenario and service requirements.

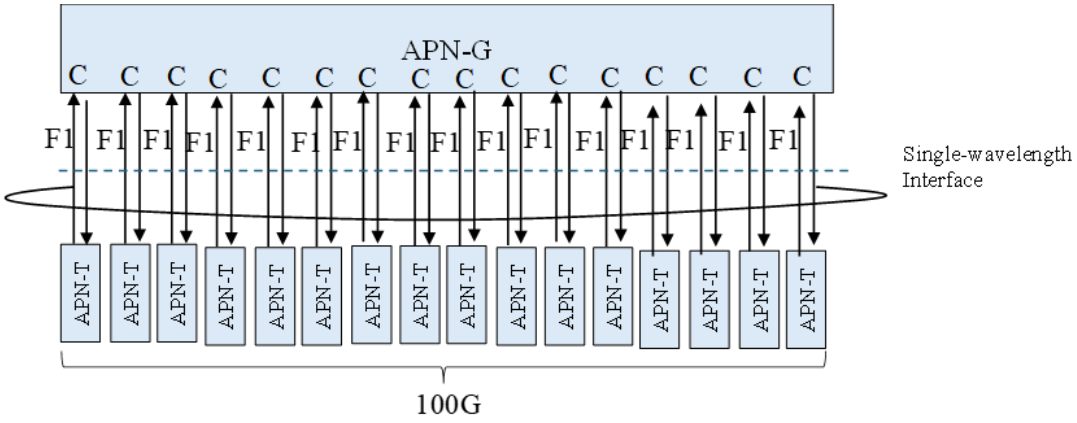
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4. Techno-Economic Analysis

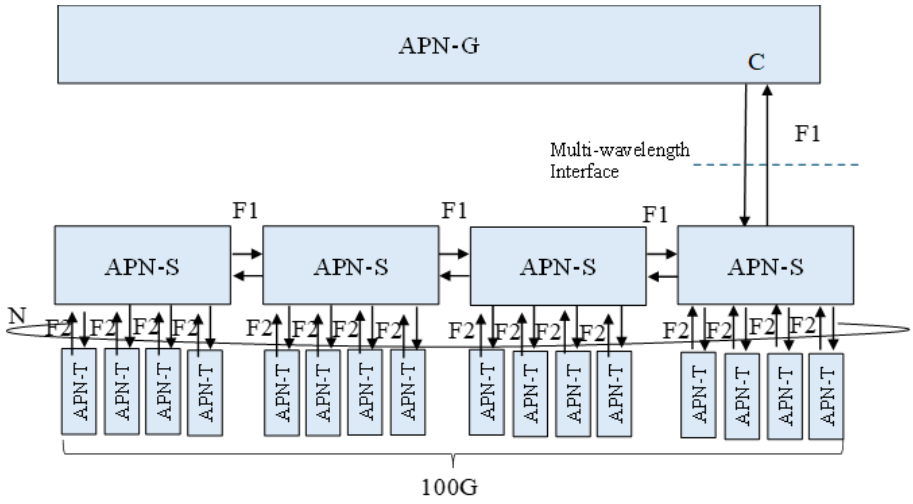
4.1. Example for APN-S Architecture

To enable a meaningful Proof of Concept (PoC), the capabilities of APN-S will be clearly articulated.

The following Figure 4-1 is the simplified example comparative consideration for cost between a conventional configuration and a configuration with APN-S.



(a) A conventional configuration



(b) A configuration with APN-Ss

Figure 4-1 A simplified comparative consideration for cost

In the configuration, if parameters are assumed as follows, the costs are calculated as shown in table 4-1

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F1～F2	Relative Fiber Cost
C	Relative APN-G Port Cost
T1	Relative APN-T Cost
N	The number of the APN-Ts under An APN-G
S	Relative Cost of APN-S
K	Generally, it becomes N/S. In the example in the figure 4-1, K = 16/4 = 4.

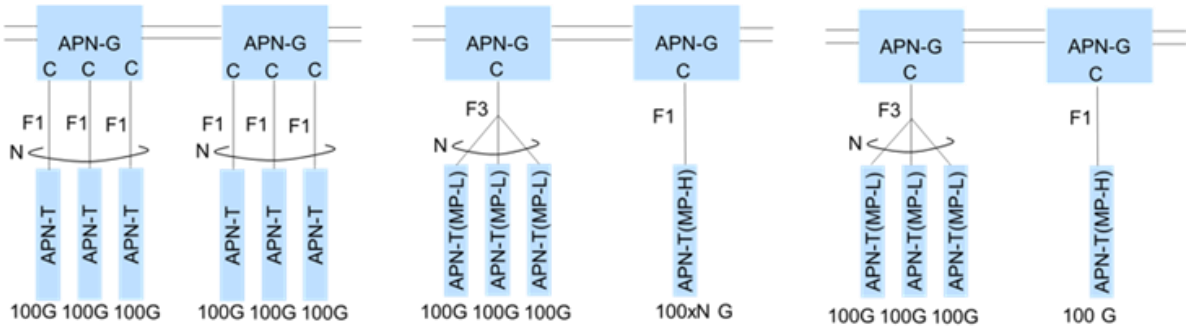
Table 4-1Estimated cost for conventional and with APN-S configurations

Configuration	Cost	Throughput between both side APN−Ss (one way)
Conventional configura−tion	N(T1+C+F1)	100xN Gb/s
Configuration with APN−S	N(T1+F2)+C+K(S+F1))	100xN Gb/s

By applying the comparison results to the formula in Table 4-1, it is possible to evaluate benefits of APN-S at the system level.

4.2. Examples for PtMP Architecture

It also enables PtMP architecture to analyze APN-G port cost. The following Figure 3-6 is the figure indicating parameters for PtP and PtMP configurations which also enables the simplified comparative consideration for cost of PtP and PtMPs



(a) A PtP configuration (b) PtMP configuration 1 (c) PtMP configuration 2

Figure 4-2 A simplified comparative consideration for cost (PtMP)

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In the configuration, if parameters are assumed as follows, the costs are calculated as shown in table 4-2

F1 ,F3 Relative Fiber Cost used for PtP and PtMP with a N branch splitter

C Relative APN-G Port Cost

T1 Relative Cost for APN-T used for PtP

T2 Relative Cost for APN-T (MP-L) used for PtMP when line rate of APN-T(MP-H) is the same with the rate of the APN-T(MP-L) x the number of ANP-T(MP-L)

T3 Relative Cost for APN-T (MP-H) used for PtMP when line rate of APN-T(MP-H) is the same with the rate of the APN-T(MP-L) x the number of ANP-T(MP-L)

T4 Relative Cost for APN-T (MP-L) used for PtMP when line rate of APN-T(MP-H) and APN-T(MP-L) are the same

T5 Relative Cost for APN-T (MP-H) used for PtMP when line rate of APN-T(MP-H) and APN-T(MP-L) are the same

N The number of the APN-Ts under An APN-G

Table 4-2 Estimated cost for conventional(PtP) and with PtMP architercture

Configuration	Total Cost	Cost for access side	Cost for server side	Throughput between both side APN-Ss (one way)
Conventional (PtP)	2N(T1+C+F1)	N(T1+C+F1)	N(T1+C+F1)	100xN Gb/s
PtMP1	NxT2+T3+2C+F3+F1	NxT2+F3+C	T3+F1+C	100xN Gb/s
PtMP2	NxT4+T5+2C+F3+F1	NxT4+F3+C	T5+F1+C	100 Gb/s

By applying the comparison results to the formula in Table 4-2, it is possible to evaluate conditions under which APN-S provides system level benefits.

Also, the evaluation should identify either:

① The relative cost reduction result with a selected branching number N, or

② The break even point between PtP and PtMP configurations,

i.e., the minimum value of N at which PtMP becomes advantageous.

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The equations above represent the minimum required parameters. Additional parameters may be introduced depending on the PoC. For example, it may be valuable that the cost impact of the Flexible Bridge inserted on the APN–T side, passive components such as optical splitters or the deployment method for new optical fiber.

4.3. Examples for APN-FX

The following Figure 4-3 is indicating parameters to use APN-FX configurations which also enable

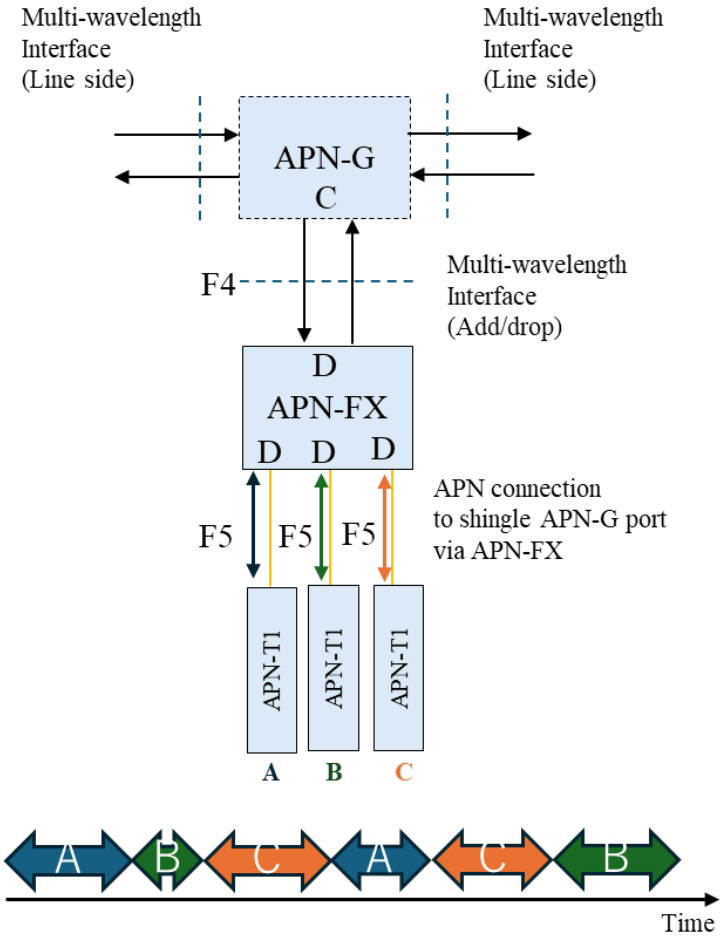


Figure 4-3 A simplified comparative consideration for cost (APN-FX)

In the configuration, if parameters are assumed as follows, the costs are calculated as shown in table 4-3

F4	Relative Fiber Cost between APN-G and APN-FX
F5	Relative Fiber Cost between APN-FX and APN-Ts
C	Relative APN-G Port Cost

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D	Relative APN-FX Port Cost
T1	Relative Cost for APN-T used for PtP
N	The number of the APN-Ts under An APN-G

Table 4-3 Estimated cost for conventional and with APN-FX configurations

Configuration	Total Cost	Throughput between both side APN-Ss (one way)
Conventional configura-tion	2N(T1+C+F1)	100xN Gb/s
Configuration with APN-FX	N(T1+F5)+(N+1)D+C+F4	100 Gb/s

The equations above represent the minimum required parameters. Additional parameters may be introduced depending on the PoC. For example, it may be valuable that the cost impact of the Flexible Bridge inserted on the APN-T side or the deployment method for new optical fiber.

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5. Key Benchmarks and Commercial Operability Validation

This section defines the benchmark metrics (what to measure) which include environmental conditions, parameter designs, test procedures, and benchmark metrics. Benchmarks are designed to verify the features described in Section 3 and to reflect the representative WDM transmission conditions described in Section 2.

5.1. Common Benchmarks

1. Calculation of the efficiency of user accommodation or cost relative to conventional system w/o APN-G port sharing. (unit: the number of users / 1U rack, Calculation example)Uss x Ust) *1, 2
2. Signal can communicate.
3. The latency and jitter measurement. (unit: usec)
4. Average throughput (unit: user)
5. Optical loss measurement (unit: dB) *3
6. The time for change/add of the number of accommodating users
7. (optional) Route redundancy

*1 If your PoC focuses on Energy Efficiency, it could potentially be positioned under the theme of “Driving Energy Efficiency and Sustainability.” Please refer to Section ~~5~~6.
*2 If it is difficult to estimate the APN-G port cost, assume the port cost as a variable and clarify the following when implementing any of the selected approaches (a) through (d):
(1) Components or costs that remain unchanged
(2) Additional components or costs required
(3) Components or costs that can be reduced or eliminated
Then, clearly indicate the total cost for (i) the conventional configuration and (ii) the configuration with Port Sharing.

*3 e.g.:

・APN-S case: Acceptable loss between APN-G and APN-S, and between APN-S and APN-T.

・PtMP case: Acceptable loss between APN-G and APN-T.

Please include the input/output optical power (dBm) of APN-G/S/T as reference information for the acceptable loss.

5.2. Benchmarks for APN-S

1. The ability to switch routes by remotely controlling APN-S or APN-Ts
2. The ability to switch routes on failure

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5.3. Benchmarks for PtMP Architecture Support

Measurement of switchover time when the number of leaf-side connections is modified.

5.4. Benchmarks for APN-FX n

Measurement of switchover time when switching a specific wavelength to a different AP

5.5. Benchmarks for Combination of APN-S and PtMP

To assess the feasibility, performance, and cost efficiency of the combination of APN–S and PtMP, the following benchmarks are proposed in addition to those defined in Sections 4.1 through 4.3:

1. Evaluation of latency and jitter resulting from the combined use of APN–S and PtMP.
2. Verification of the maximum acceptable transmission distance for this combined architecture.

5.6. Commercial Operability Validation

In addition to benchmark testing, the following items are recommended for verification from a commercial deployment perspective:

1. Tolerance of optical power variance
   The ability to support transceivers located at different distances is a critical requirement for practical network deployment. For example, Transceiver 1 : 3m from the splitter, Transceiver2 : 500m from the splitter, Transceiver 8: 2km from the splitter. etc.
2. The APN's WX Functionality
   Verify that the APN's WX capability can route traffic received on an APN–G port to different destination ports as intended.

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6. Cross-Reference with the PoC on Driving Energy Efficiency and Sustainability

The PoC conducted based on the architecture described in this document may have a secondary effect of reducing power consumption, in addition to lowering the per-port cost of ROADM. If this is the case, it could potentially be positioned as a PoC under the theme of Driving Energy Efficiency and Sustainability, and PoC owner could make an additional PoC report focusing on power consumption and environmental sustainability aspects.
Cross-Reference : Toward a Unified Metric for Energy Efficiency and Sustainability in Next-Generation Networks: An IOWN Global Forum's Perspective

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Appendix

A. Application of APN-S to MFH

A-1. APN-S connects to add/drop side of APN-G

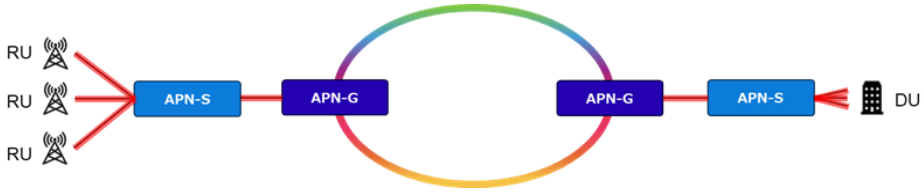


Figure A-1-1 APN-S use case example of MFH

Figure A-1-1 shows an example of applying this APN-S to MFH. Using the APN-S enables multiple RU and DU to be connected to the port of APN-G, and the cost per port of the APN-G can be reduced.

Figure A-1-2 shows a configuration example for connecting an APN-S to the add/drop port of APN-G to aggregate 8 APN-T. In the simplest implementation, a passive multiplexer and a demultiplexer can be used for the aggregation of main signals from/to 8 APN-T. Furthermore, by utilizing PON (Passive Optical Network) for transmitting control signals to 8 APN-T, it becomes possible to configure APN-S as a passive node.

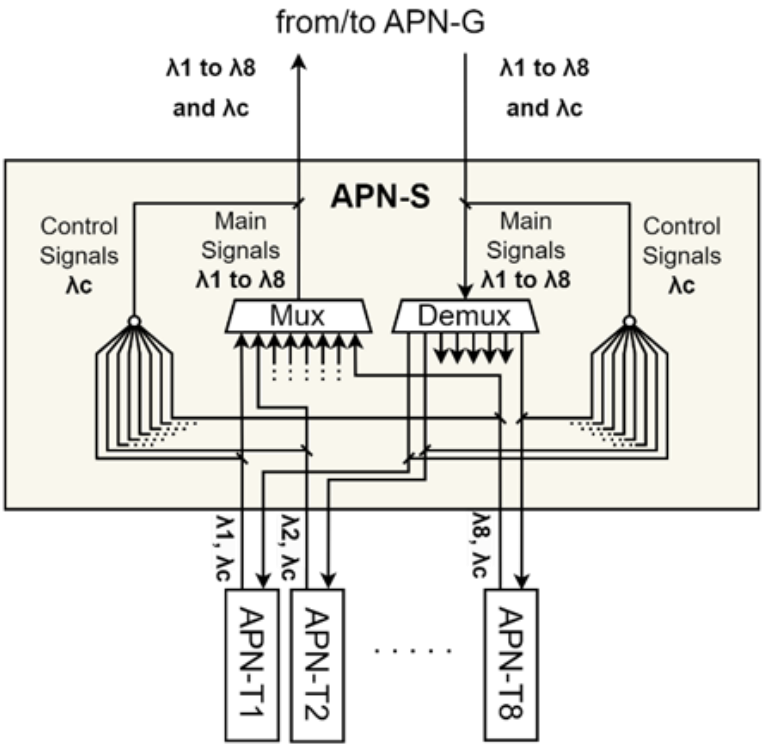
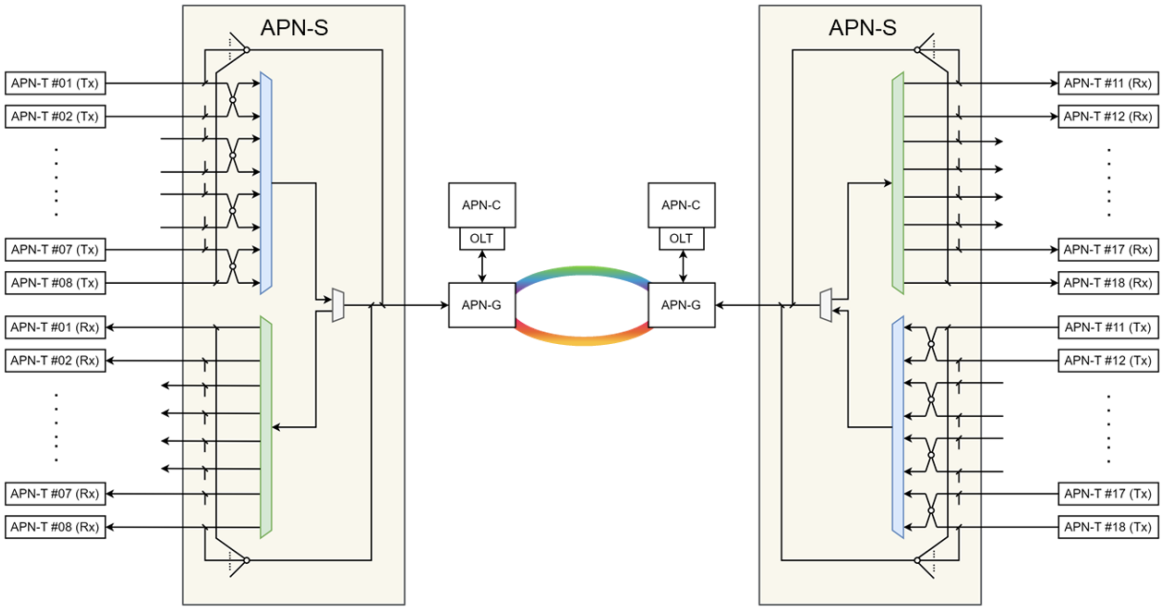


Figure A-1-2 APN-S configuration example to connect add/drop side of APN-G

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- Number of Ugs = 1
- Number of Uss = 0
- Number of Ust = 8
- Fiber type of Ugs and Ust is Bidirectional single-fiber or Dual-fiber. Figure A-1-1 shows a Dual-Fiber implementation.
- Device type of Mux/Demux for main signals is AWG or DWDM thin filters.
- Aggregation ratio of APN-T = 8
- Without Amplifier
- Without APN-S control
- Type of control distribution to multiple APN-T is PON.
- Latency that satisfies the connection requirements between DU and RU



Transmitter (Tx) and Receiver (Rx) parts of APN-T are depicted separately.

Figure A-1-3 Enhanced APN-S configuration example for MFH use case

Figure A-1-3 shows an example combining a power splitter (PS) with the Mux block of the APN-S, and the fiber type is single-fiber between APN-G and APN-S. In this example, the APN-T transmitter is connected to two APN-S ports. By controlling the APN-T transmitter wavelength, the wavelength assigned to either of the two APN-S ports can be selected. This allows the destination to be changed. IMN Task Force PoC reference documents Elastic Load Balancing (ELB) as an MFH use case, making this configuration applicable. This configuration enables limited path switching without changing APN-S and APN-G settings. For use cases where limited path switching is sufficient, it suggests that APN-FX can be used instead of APN-G. APN-FX would be also suitable to connect the bidirectional single-fiber. In this passive configuration, PON is utilized for the control path. It is assumed that there are OLTs at APN-C side and the APN-Ts have the ONU function.

A-2. APN-S connects to line side of APN-G

As also stated in the main text, in mobile fronthaul (MFH) networks, it is essential to efficiently accommodate signals from numerous geographically distributed RUs to the DU. However, applying a

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large-scale APN-G to gather traffic from the distributed RUs presents challenges in terms of cost. By utilizing APN-S to connect the aggregated traffic to the APN-G, the cost per port of the APN-G can be reduced.

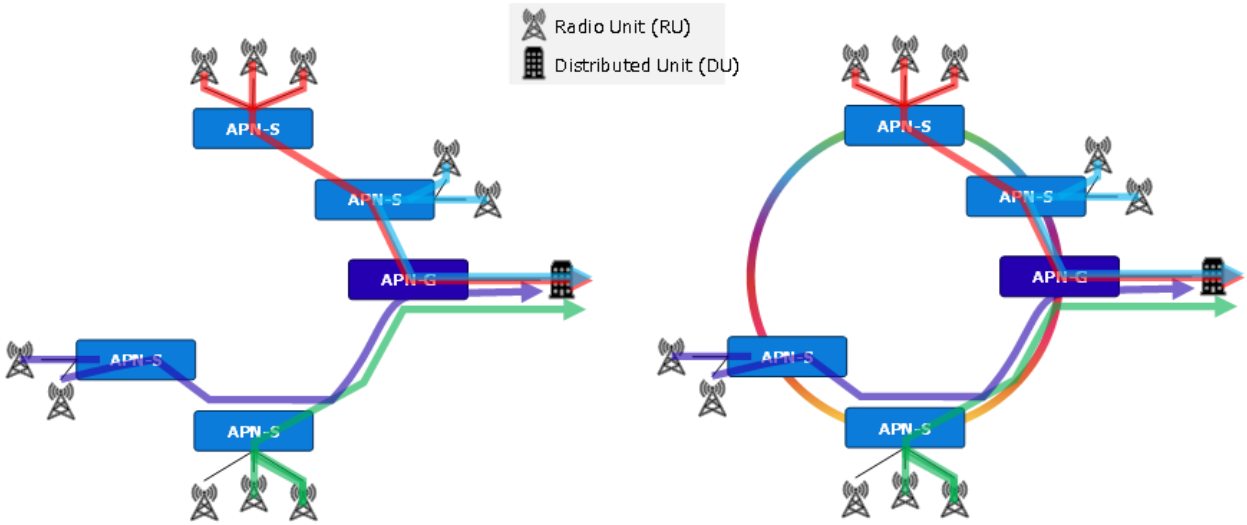


Figure A-2-1 APN-S use case example of MHF (Ring Connection)

For example, by using APN-S, even if communication between RU and DU is changed from bidirectional to unidirectional, the number of fiber optic cables can be reduced, leading to cost savings.



Figure A-2-2 Reduction of the number of fibers used by APN-S

Specifically, the configuration would be as shown below. The left side represents a Hub configuration, and the right side represents a Ring configuration.

For example,

- Number of Ugs, Number of Uss There are patterns in the figure above.

・Number of Ugs = 0, Number of Uss = 2

・Number of Ugs = 1, Number of Uss = 1

・Number of Ugs = 0, Number of Uss = 1

・Number of Ugs = 2, Number of Uss = 0

・Number of Ugs = 1, Number of Uss = 0

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- Number of Ust = 4
- Fiber type of Ugs and Ust is Dual-fiber.
- Device type of Mux/Demux for main signals is WSS(APN-G) and DWDM thin filters or Tunable filters(APN-S).
- Aggregation ratio of APN-T = 4 or more
- Without/with Amplifier(APN-S), With Amplifier(APN-G),
- Without APN-S control(without Amplifier case or without tunable filter), with APN-S control(with Amplifier case or with tunable filter)
- Type of control distribution to multiple APN-T is external control.
- latency that satisfies the connection requirements between DU and RU

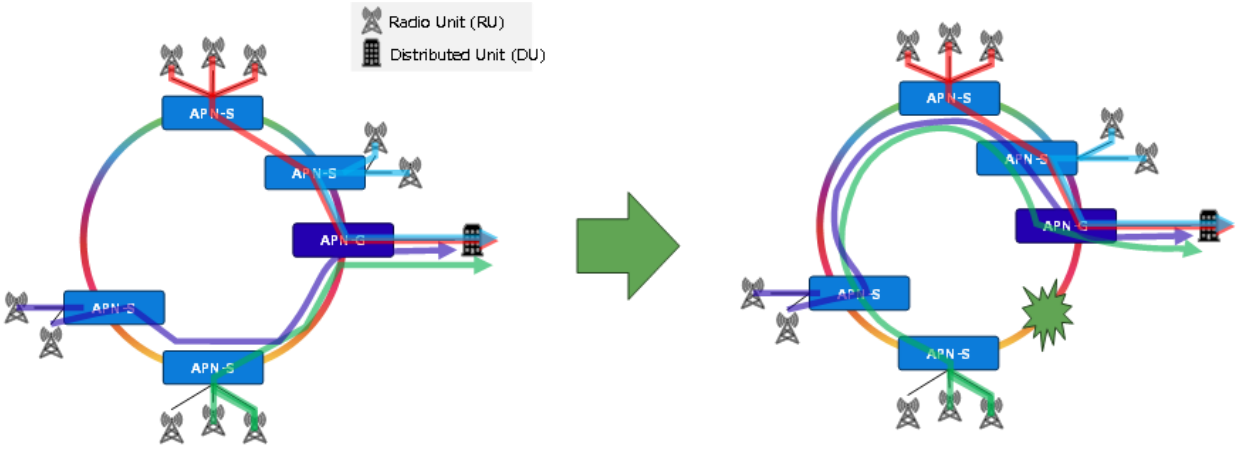


Figure A-2-3 APN-S application for fault tolerance

As an option, in the case of a Ring configuration, if a section is interrupted, fault tolerance is improved by switching traffic to an alternative path.

B. Application of APN-S to Data Center (DC)

B-1. APN-S connects to line side of APN-G

In distributed data centers, deploying APN-G for traffic aggregation from each user sites and regional data centers could lead cost challenges.
To reduce the cost and simplify the network among distributed data centers, APN-S can aggregate traffic efficiently, and reduce cost per port instead of APN-G.
For example, APN-S enables physical resource savings by reducing the number of WDM-multiplexed backbone fibers, decreasing rack occupancy space, minimizing cabling counts, and lowering power consumption. Additionally, it reduces Capex by Simplified component architecture. While the total cost of ROADM equipment varies depending on deployment scale, the simplification of the system architecture remains effective regardless of scale.

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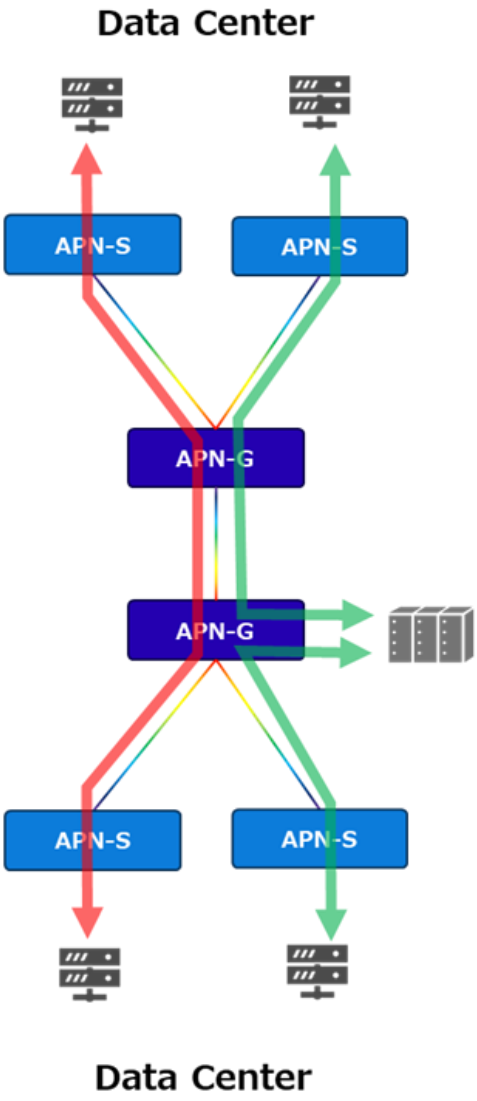


Figure B-1 Example of network configuration using APN-S for DC

The APN-S parameters and requirements in this configuration sample are shown below.
・Number of Ugs = 1
・Number of Uss = 0
・Number of Ust = 8
・Fiber type of Ugs, Uss and Ust is Dual-fiber.
・Device type of Mux/Demux for main signals is AWG
・Aggregation ratio of APN-T = 8 or more
・With Amplifier
・With APN-S control
・Type of control distribution to multiple APN-T is external control via APN-S
・Low latency: Target value 100 usec (excluding distance-related delay)

C. Port Sharing Deployment and Configuration

This section presents an example configuration for validating port sharing on APN-G using PtMP and APN-FX along with a method for assessing cost reduction effects. Figure C.1 illustrates the

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overall architecture to clarify the overall system. APN–T for PtP and APN–T (MP–L) for PtMP are connected to APN–T and APN–T (MP–H) via APN–G or via APN–FX + APN–G in the combination of wavelength path service and fiber path service. By conducting measurements in both conventional (PtP) and proposed (PtMP, APN–FX, or their combination) architecture, the impact of the proposed architecture on communication performance can be evaluated. For example. these architectures enable to valuate performances such as latency or jitter and analyze the crossing point between PtP and PtMP performance as a function of PtMP leaf count (see Figure C.2). Please refer to C–1 and C–3 to understand typical configuration. The evaluation methodology is described in Section 3.

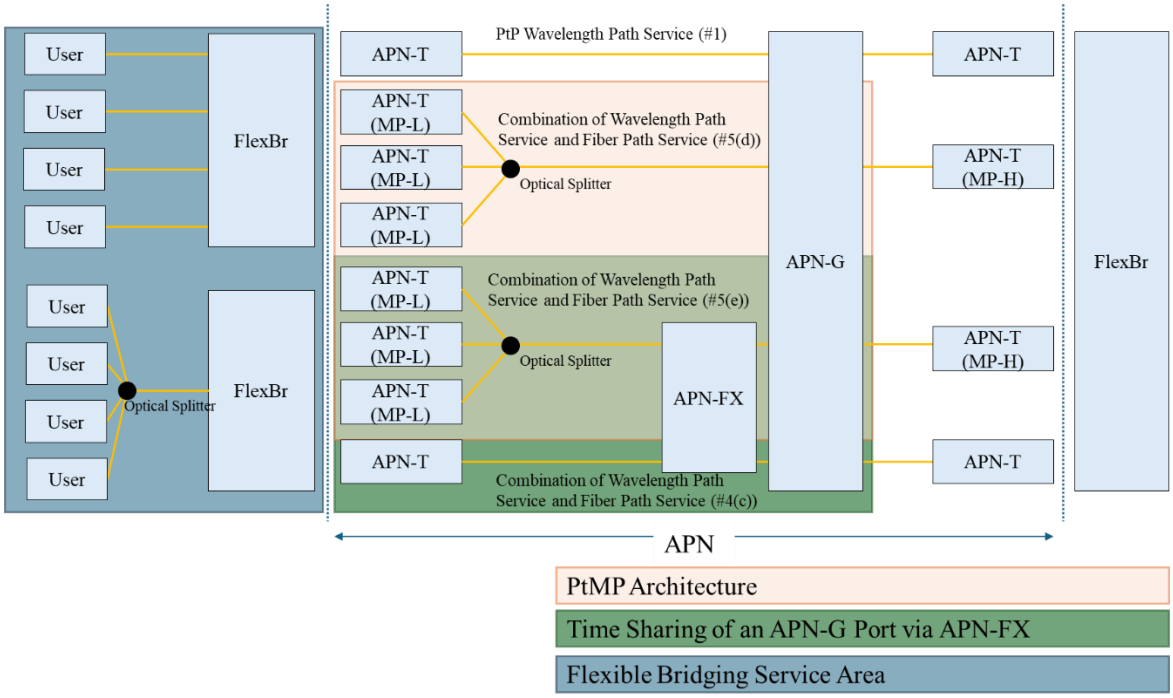


Figure C–1 Overall Architecture when implementing three approaches

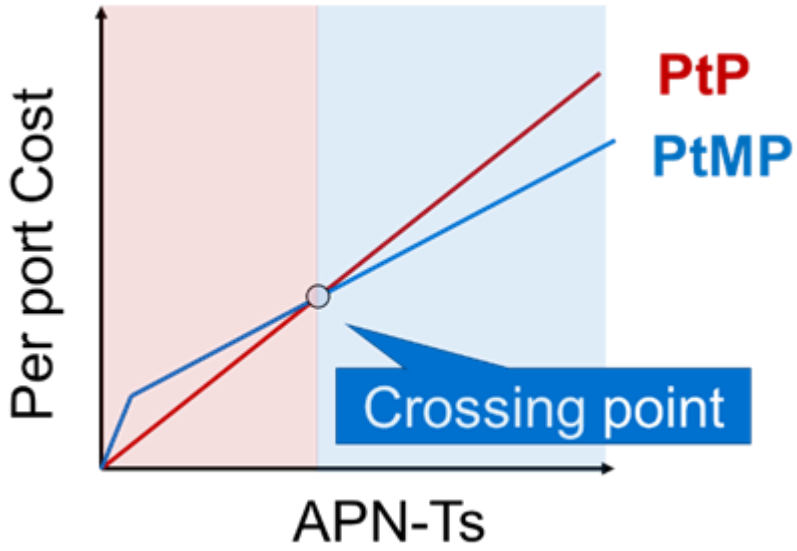


Figure C–2 The image of crossing point

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C-1 A configuration of the PtP Services over a APN-FX service

The configuration illustrated in Fig.C-3 can reduce not only the number of the ports of APN-G but also the total fiber length between the APN-G and APN-Ts.

Its performance and benefits can be benchmarked, as described in “4.1 Common Benchmarks and 4.4 Benchmarks for APN-FX” for the system using APN-FX services.

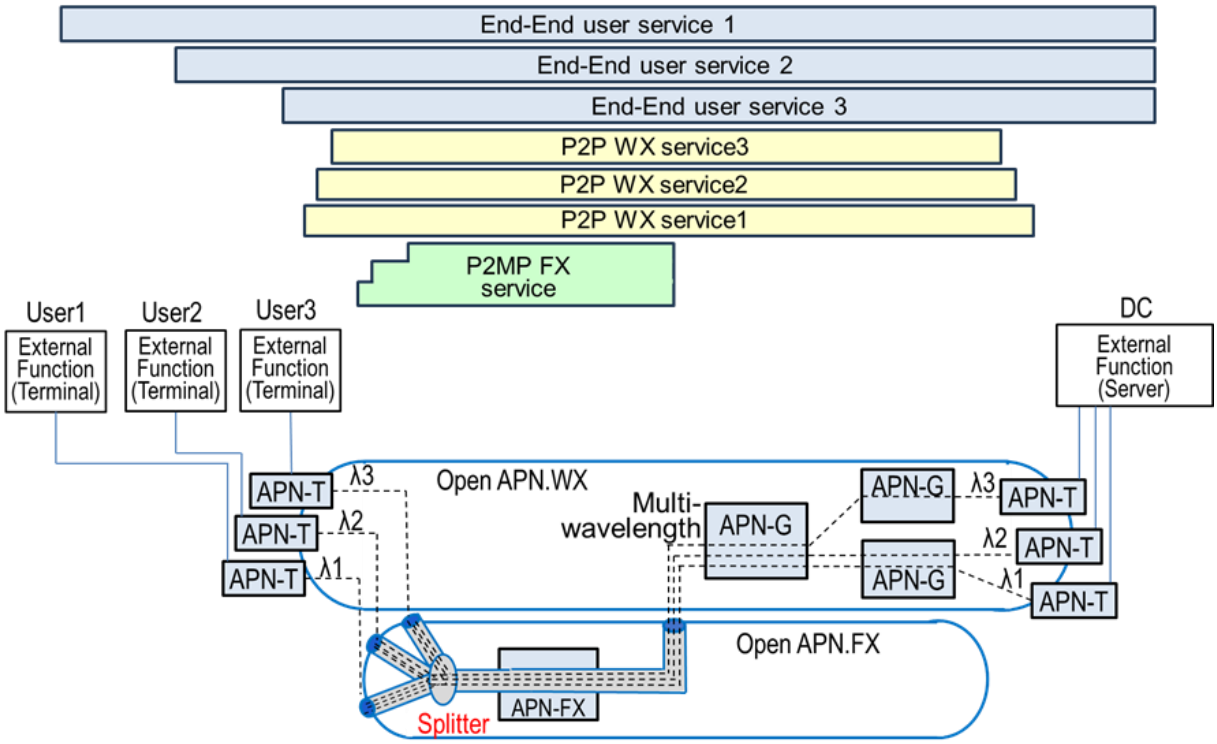


Figure C-3 A configuration of the PtP services over a PtMP fiber path service

C-2 A configuration of a PtMP WX service over a PtMP FX service

This configuration illustrated in Fig.C-4 can reduce not only the number of the APN-G ports but also the total fiber length between the APN-G and APN-T. In addition, it enables a reduction in the number of the APN-Ts.

One of the technologies available in this configuration is XR Optics utilizing subcarrier multiplexing ((b) Applying PtMP Architecture). Details of this technology are provided in Annex F of the Open APN Functional Architecture Version 3. It typically enables the distribution of subcarriers at a granularity of 16 branches × 25 Gbps. Another technology in this configuration is the sharing of a single wavelength among multiple APN-Ts using a TDM approach ((c) Time Sharing of an APN-G Port via APN-FX). A more detailed explanation is provided in Section 2.4: Time Sharing of an APN-G Port via APN-FX. The performance and benefits of this configuration can be benchmarked, as described in “5.3 Benchmarks for PtMP Architecture Support for the system providing APN-WX services.

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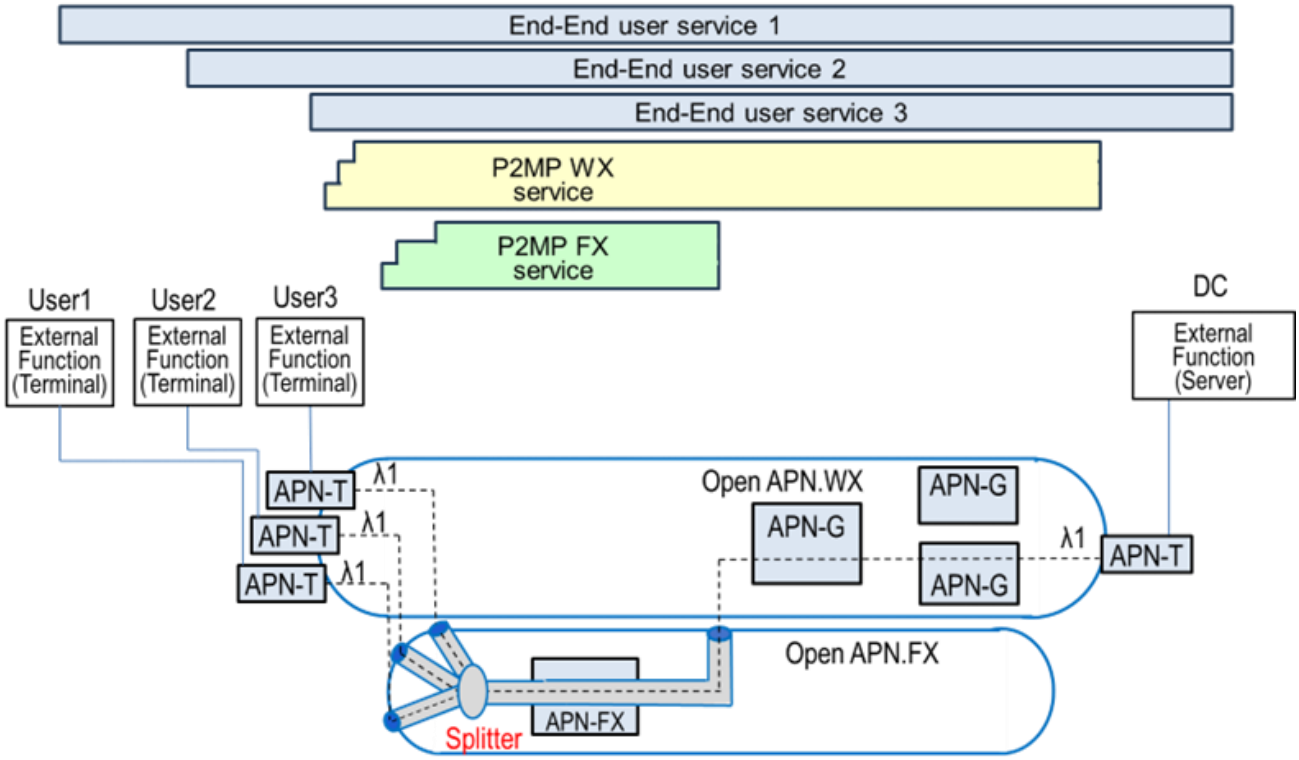


Figure C–4 A configuration of a PtMP WX service over a PtMP FX service (with XR optics)

C–3 Additional configurations for port sharing

As additional related configurations, the following options can be considered.

(a) FlexBr connected to the user–side interface of APN–T

This configuration can increase the number of users per APN–G port. The average available bandwidth per user port of FlexBr is limited; however, it may be sufficient for some applications. In such cases, this configuration is useful for reducing the number of APN–G ports.

(b) PtP WDM shared access over the existing splitter network

The configuration shown in C–1 (WDM shared access on a splitter network) is effective in reducing the number of APN–G ports. In the deployment stage, it is expected to be built over the existing splitter network (PON). In such a case, we should consider how to coexist with current systems. One suitable approach is to use WDM filters. Since most current systems do not use C–band signals, the system shown in C–1 can be implemented on existing systems with low–cost optical WDM filters to separate the existing signals from the IOWN WX path signals. This configuration is useful for deploying C–1.

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References

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History

Revision	Release Date	Summary of Changes
1	November 2026	Initial Release

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