Recognized PoC Report – Significant Step Forward

Point-to-Multipoint Mobile Fronthaul over APN

OCTOBER 2025

1 PoC Project Completion Status

Overall PoC Project Completion Status: **Completed**

PoC Project Name: PtMP MFH over APN (Point-to-Multipoint Mobile Fronthaul over APN)

2 PoC Project Participants

Company	Name
KDDI	Hirotaka Ochi
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	Kenji Mizobuchi
	Masato Kushida

Table 1 – List of PoC participants

3 Confirmation of PoC Demonstration

PoC Demonstration Event Details:

- The PoC was demonstrated at KDDI, Tokyo, Japan.
- The date of PoC was Conducted during the period from September 2nd to 13th ,2024
- PoC report submission date: September 10th, 2025

4 PoC Goals Status Report

The PoC Project Goal #1: Achieved the original PoC objectives.

(1) Feasibility of mobile fronthaul over APN based on Point-to-Multipoint technology (Step1) has been successfully demonstrated, according to the “PoC Reference of Mobile Fronthaul over APN ver 2.0”.

(2) Feasibility of the Elastic Load Balancing (Step2.1) has been successfully conducted with the manual-based trigger for switching the relation between vDU and RUs.

(3) Energy Efficiency by Elastic Load Balancing (Step2.2) was estimated by assuming the server for the switched DU was turned off (power-off mode). Due to the restriction in the measurement equipment, we cannot completely follow the traffic model as described in the Appendix V of the PoC Reference.

5 PoC Feedback Received from non-member (Optional)

There was no feedback received from the non-members of the PoC.

6 PoC Technical Report

This PoC was conducted in two major steps for verification based on references [1][2] and involved KDDI, SEI, and APRESIA Systems.

- Step1: Feasibility Test
- Step2: Elastic Load Balancing Scenario (Limited)

6.1 Implemented System

6.1.1 Test Setup

Figure 1 shows the test setup for evaluating mobile fronthaul (MFH) over APN based on Point-to-Multipoint (PtMP) technology utilizing subcarrier-multiplexing scheme. O-RAN-compliant and 5G-SA-based RAN system together with the PtMP-based MFH were configured in the anechoic room of KDDI’s lab environment. APN-based MFH consisted of XR Optics modules as APN-Ts, an 1x2 optical splitter/combiner and APN-G/I ROADM-based ring network. The test setup follows the PtMP model of the PoC Reference [1] and the Point-to-Multipoint topology was realized by the use of optical splitter/combiner. We assumed two RUs were connected to two DUs via APN. Both DUs were implemented as a virtualized function in the COTS servers for each. Two physical RUs were connected to the Flexible Bridge with an SFP Bi-Directional transceiver module of 25GBASE-BX20. As the RUs used for the PoC cannot insert XR Optics module directly (module package and link speed are not supported), the Flexible Bridge was used to convert the module type. In PtMP network, 100G XR Optics modules were used as APN-Ts at two Flexible Bridge of the RU side, and 400G XR Optics module was used as an APN-T at one Flexible Bridge of the DU side. In APN-G/I ROADM ring network, two ROADM WSS were used with fiber spools of different lengths between two APN-G/Is to evaluate the maximum

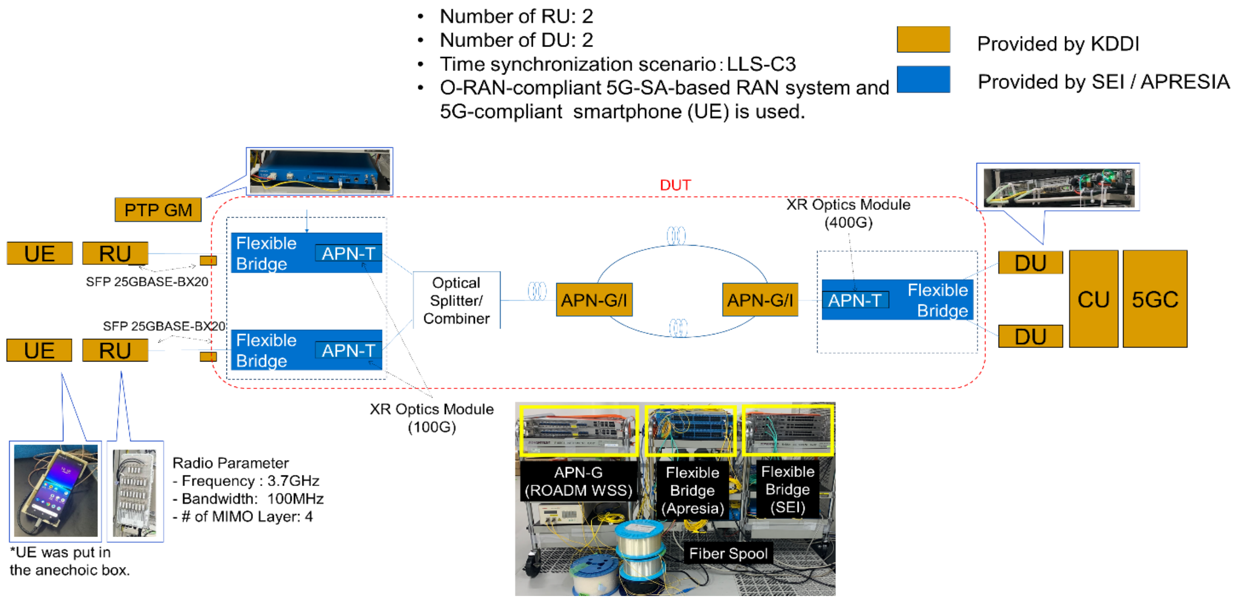

Figure 1: Test Setup

transmission length. The PTP Grandmaster (GM) was connected to one of the Flexible Bridge at RU side for providing the precise reference timing to the DU, RU and Flexible Bridges based on LLS-C3 time synchronization scenario. The user equipment (UE=5G Smartphone) was put in the anechoic box and the output signals of the RU were radiated inside the anechoic box so that the UE can be attached to the network. The pictures of the equipment used in the experiment were also shown in Figure 1.

For the feasibility test of step1, different combinations of the flexible bridge venders were tested and compared. Patterns for the combinations were summarized in Table 1.

Table 1: Combinations of flexible bridge vender

Pattern	DU side	RU side #1	RU side #2
(1) SEI only	SEI	SEI	SEI
(2) APRESIA only	APRESIA	APRESIA	APRESIA
(3) APRESIA + SEI	APRESIA	APRESIA	SEI

The other test parameters of the PoC were also summarized in Table 2. Power consumption and temperature of the PtMP modules during the experiment were 22W and 55 °C for 400G hub module, and 18W and 52 °C for 100G leaf modules. Further detailed specifications of PtMP module such as spectral width and received sensitivity are described in ref [3].

Table 2: Test Parameters

Parameters		Values	Note
PtMP Link	Link Speed	100 [Gbit/s] per link (16QAM-4Subcarriers were assigned for both UL and DL)	The aggregated link speed was 200 [Gbit/s] in this experiment.
	Wavelength	1545.32 [nm]	
	Optical Power	(Hub) Tx: 0.0 [dBm] / Rx: -13.5 [dBm] (Leaf) Tx: -16.0 [dBm] / Rx: -16.5 [dBm]	
	Fiber Type	Dual Fiber	
PTP Profile		ITU-T G.8275.1 telecom profile	

Core Network		5G SA	
Radio Parameter of RU	Radio Frequency	3.7 [GHz]	
	Bandwidth	100 [MHz]	
	MIMO layer	4	
	Duplexing	TDD	

6.1.2 Bill of Materials

Table 3 is the list of equipment that was used during the PoC tests.

Table 3: Bill of Materials

Equipment	Detail [F/W version]	Supplier
UE	5G-compliant smartphone	KDDI
RU	Lab equipment of O-RAN-compliant 5G-SA-based RAN system equivalent to that commercially used in KDDI	KDDI
DU/CU		
5G Core	Lab equipment equivalent to that commercially used in KDDI	KDDI
APN-T	Infinera XR Optics Module (400G and 100G) [1.2.3]	KDDI
APN-G/I	ROADM WSS commercially used in KDDI	KDDI
Flexible Bridge	FTU9100 [v0.0.1.1.1578]	SEI
	CA220 [10.03.01]	APRESIA Systems
PTP Tester	VIAVI MTS-5800	KDDI
Network Tester	VIAVI ONT-804D	KDDI
PTP GM	The commercially used equipment by KDDI	KDDI
Fiber spool	SSMF with the length of 20, 10, 2, 1km	KDDI
Optical Splitter/Combiner	1x4 optical splitter/combiner	KDDI
25GBASE-BX20	SFP28 transceiver module with Bi-Directional compatibility	KDDI

6.2 Measurement Method

6.2.1 Throughput and Latency

For the measurement of the latency and the packet delay of PtMP-based fronthaul, we used the network tester and layer 2 traffic was transmitted bi-directionally via the Flexible Bridges as shown in Figure 2.

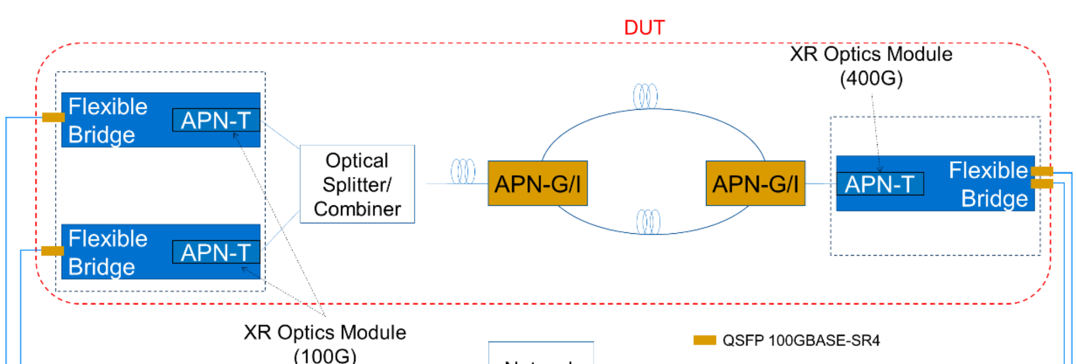

Figure 2: Test setup for traffic measurement

6.2.2 Applicability for Fronthaul Link

For the evaluation of the applicability of the PtMP-based fronthaul, test setup as depicted in the figure 1 was used. The status of the DU and the RU were checked with NMS, i.e., the alarm status of M(Management)-plane, S(Synchronization)-plane, C(Control)-plane, and U(User)-plane were checked whether each plane was properly established with no alarm. Table 4 shows the evaluated data items for the PoC. We set the items for each M/S/C/U Plane based on the reference [1][2] to confirm each plane is established. As this is not the test of DU and RU, detailed M-plane messages were not checked. All prerequisites for O-DU, O-RU and Flexible Bridging were properly preconfigured, i.e., IP address setting, VLAN setting, preparation of O-RU configurations, and so on.

Table 4: Evaluated Items

Object	Evaluation Items (and criteria)		Remarks
M-plane	The "Operational state" of RU	"Enabled"	
	Alarms for the DU and RU are cleared.	All cleared	
S-plane	The PTP synchronization state of the L2SW	"Locked"	PTP redundancy was not implemented for this PoC.
	The "lock state" of the DU and RU	"Locked"	
	Max |TE| between the RUs	<100ns	For Category B, regular O-RU
C/U-plane	Antenna bars displayed on the UE	Full bars	To check the registration of UE.
	UE Throughput (DL/UL)	>1Gbps (DL) >200Mbps(UL)	Iperf was used
	Retrieving UE logs	No Critical errors	

Regarding the S-plane evaluation, LLS-C3 configuration is utilized for fronthaul synchronization as explained in Section 6.1.1. For the measurement of PTP synchronization, PTP tester was connected to the network as depicted in Figure.3. PTP tester has both Grandmaster and TimeReceiver function and connected to the two flexible bridges at the RU side. PTP packet flow was also depicted in Figure.3. PTP tester and Flexible Bridges are operated as Telecom Boundary Clock and synchronized sequentially from Grandmaster port of PTP tester to the TimeReceiver port of PTP tester via multiple flexible bridges. SyncE was activated only for the ports to which the RU was connected.

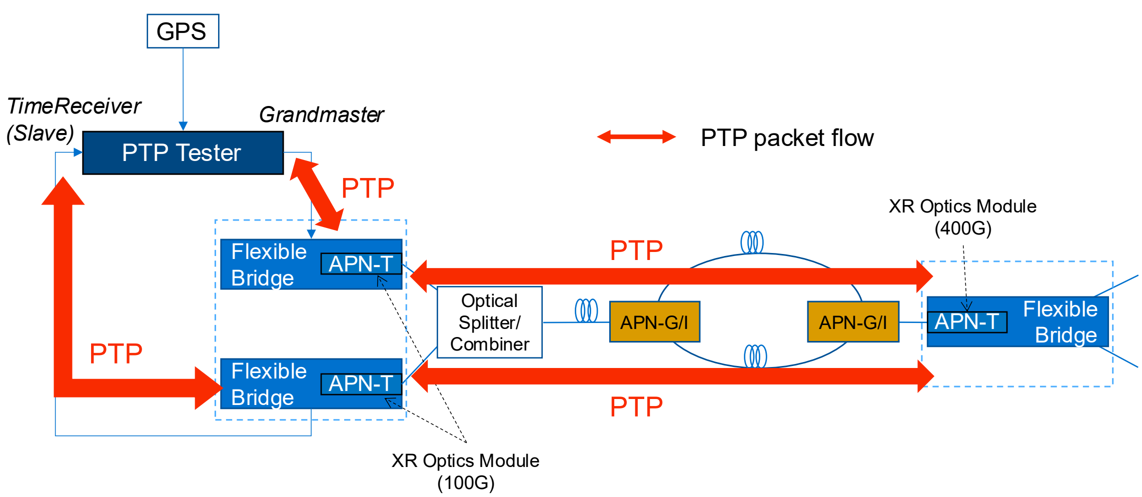

Figure 3: Test setup for PTP measurement

6.2.3 Maximum Length of MFH

Maximum length of MFH was evaluated by changing the transmission fiber length from 10 km to 35 km with checking abovementioned items (M/S/C/U-plane status) were properly operated. For this experiment, the flexible bridges from Apresia Systems were only used for evaluation.

6.2.4 Elastic Load Balancing

Regarding the ELB evaluation, only step 2-1 of PoC Reference document (feasibility test of ELB) was conducted. Step 2-2 was not conducted due to the restriction of the test equipment for measuring traffic patterns as defined in the PoC Reference document. Figure 4 depicts the procedure of how we “switchover” the vDU for the ELB scenario. In this experiment, the network configuration of Figure 4 follows the key features of “Packet switching method” for PtMP topology which was described in the Figure 16 of the PoC Reference [1]. In the initial state (lefthand of Figure 4), each RU was registered to the designated vDU. Different M-plane VLAN ID (VID) of A and B were assigned to identify M-plane connections between vDU and RU. Each RU sends and receives the M-plane message without VLAN tag, and flexible bridges at the RU side add or remove VLAN tag. Prior to the switchover of the vDU, serial number information of the RU02 was added to the list of registered RUs of the vDU1 so that the vDU1 can communicate with RU02 after the switchover. The switchover process was initiated by changing VLAN setting for M-plane of the flexible bridge connected to the RU02 from VID=B to VID=A (righthand of Figure 4). By doing this, the connection between vDU2 and RU02 was lost and RU02 restarts registration process with vDU1. We have checked the period from the start of switchover to the time of RU02 and UE re-registration by checking the NMS status and the UE’s antenna bar. We also measured the period of re-establishment of IP connectivity by pinging the UE.

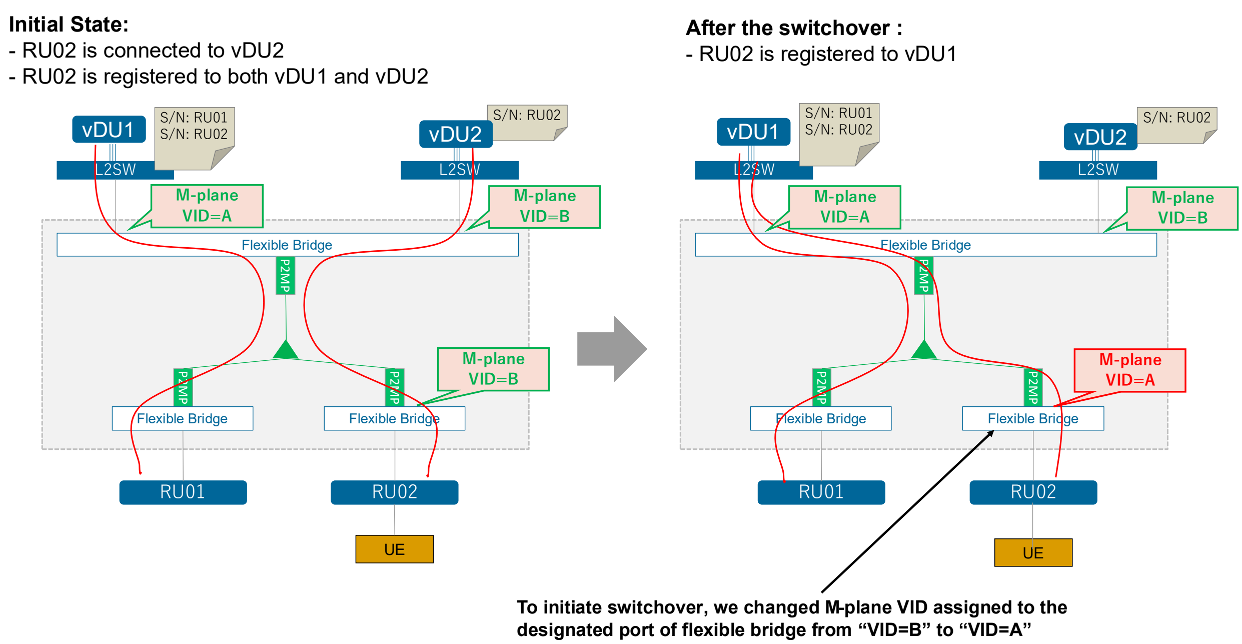

Figure 4: Test procedure for ELB evaluation

6.3 PoC Results

6.3.1 Interface Requirements

As per the interface requirements defined in the PoC reference, each item was checked.

Table 5: Interface requirements and results

Requirement in the PoC Reference		PoC conditions and Results
(1) Optical interface between APN-T and APN-G :	1. In the case of Flexible Bridging Service is used: ・W 100-200G 31.6 Gbaud ・W 200-400G 63.1 Gbaud	**N/A** *In this PoC, a new type of optical interface (XR Optics) was used. This is not defined in the current PoC Reference (v2.0)
	2. In the case RUs connect to APN directly: − NRZ 10G (N, W) of ITU-T G.698.2 − NRZ 2.5G (N, W) of ITU-T G.698.2 However, this is not limited depending on the optical interfaces supported by the RU side.	**N/A**
(2) O-RAN interface between RU and DU :	・ Ethernet (for transporting eCPRI and PTP/SyncE) ・ CPRI IEEE- 1914.3 (for transporting CPRI over a packet-based infrastructure)	**Compliant** (Ethernet was supported)

6.3.2 Throughput of PtMP link

Table 6 summarizes the throughput of the 1x2 PtMP-based MFH links. "Hub" is a PtMP APN-T at the DU side, and "Leaf1" or "Leaf2" is a PtMP APN-T at the RU sides. Each link between Hub and Leaf was configured to 100 Gbit/s as shown in Table 2. It should be noted that as we obtained the same results for all patterns of flexible bridge venders in Table 1, only a single table was shown as the result. The throughput exceeded the peak data rate requirements of 25-75 Gbit/s for MFH.

Table 6: Throughput of 1x2 PtMP Link

		Throughput [Gbit/s]			
		Hub-Leaf1		Hub-Leaf2	
Fiber Length [km]	Frame Size [Byte]	DL	UL	DL	UL
10	64	99.90	99.90	99.90	99.90
	512	99.98	99.98	99.98	99.98
	1518	99.98	99.98	99.98	99.98

Note: The same throughput was obtained for all combinations of the flexible bridge venders (SEI only, Apresia only, and SEI + Apresia).

6.3.3 Latency

Latency of the 1x2 PtMP MFH link was shown in the Table 7. Due to the signal processing inside the PtMP optical module (XR Optics), there is an intrinsic amount of delay around 40 microseconds even for the back-to-back case.

Table 7: Latency of 1x2 PtMP Link

		Latency [μs]			
		Hub-Leaf1		Hub-Leaf2	
Fiber Length [km]	Frame Size [Byte]	DL	UL	DL	UL
0 (Back-to-back)	64	39.6	39.6	39.4	39.2
	512	40.1	40.2	39.7	40.5
	1518	42.8	43.4	39.6	40.4
20	64	138.2	138.9	138.2	138.9
	512	137.9	139.5	136.1	139.2
	1518	137.4	139.1	138.5	140.0

Note: No significant difference was observed for all combinations of the flexible bridge venders. Only the result for the case where the SEI's flexible bridge were used for both Hub and Leaf sides was shown.

6.3.4 Time Synchronization

PTP accuracy was measured for different flexible-bridge vender's combinations of Table.1. Results of maximum absolute time error (Max|TE|) and Two-way constant time error (cTE) were summarized in the Table 8. It should be noted that the FW version of APN-T for this experiment was ver 2.0 (PTP performance is improved). Regardless of the flexible bridge vender combinations, it was confirmed that max|TE| between two O-RU UNI ports (= between Grandmaster port and TimeReceiver port of PTP tester) was smaller than 60 ns, which is O-RAN fronthaul network contribution limit for Category A O-RU for topology configuration LLS-C3.

Table 8: Results for PTP measurement (Max|TE| and Two way cTE)

Pattern	Max|TE| [ns]	Two Way cTE [ns]		
		Avg.	Min.	Max.
(1) **SEI only**	27	2	-3	3
(2) **APRESIA only**	30	-5	-5	-5
(3) **APRESIA + SEI**	39	15	13	15

6.3.5 O-RAN interoperability test

According to the criteria listed in Table.4, the status of the DU and RU was checked with NMS. For all patterns of flexible bridge vender combination, it was confirmed that all criteria were satisfied, and RUs were successfully registered to each DU. After confirming the stable operation of RU, UE (5G Smartphone) was connected to the network through the air interface radiated in the anechoic box. Figure 5 is an example of the screen capture of the UE. "Full bars" was confirmed as shown in the red frame, and the UE was successfully registered to the network. Table. 10 summarizes the results of UL/DL throughput measured using Iperf for all combinations of flexible bridge vender. Obtained throughput showed almost reasonable value considering the radio bandwidth (100MHz), number of layers (4), modulation order (6 = 64QAM), and TDD operation.

Table 9:M/S/C/U-plane Test Results

Object	Evaluation Items (and criteria)		Results
M-plane	The “Operational state” of RU	“Enabled”	**Confirmed.**
	Alarms for the DU and RU are cleared.	All cleared	**Confirmed.**
S-plane	The PTP synchronization state of the L2SW	“Locked”	**Confirmed.**
	The “lock state” of the DU and RU	“Locked”	**Confirmed.**
	Max |TE| between the RUs	<100ns	**Confirmed. (See Table 8 in Sec 6.3.4)**
C/U-plane	Antenna bars displayed on the UE	Full bars	**Confirmed. (See Figure 5)**
	UE Throughput (DL/UL)	>1Gbps (DL) >200Mbps(UL)	**Confirmed. (See Table 10)**
	Retrieving UE logs	No Critical errors	**Confirmed.**

Figure 5: Screen Capture of UE

Table 10: Results of UE Throughput

Pattern	UE Throughput	
	Downlink	Uplink
(1) SEI only	1.42 Gbps	224 Mbps
(2) APRESIA only	1.21 Gbps	221 Mbps
(3) APRESIA + SEI	1.41 Gbps	216 Mbps

6.3.6 Maximum Length of MFH over APN

Based on the feasibility of Mobile Fronthaul over APN scenario in PoC reference [1], the maximum transmission length between APN-G/I were measured. Up to 32 km, we confirmed the normal operation, and the UE throughput was almost unchanged as shown in Table 10. The UE throughput gradually degraded from the MFH length of 33 km, and finally the UE could not be attached to the network at the MFH length of 35 km. Note that the maximum length of MFH depends on both MFH transport latency and processing delay in the DU and RU. We also conducted the same evaluation using the other vender’s RU, and the maximum MFH length was 17 km for this case. Detailed implementation difference of both RUs is not the topic of this report. It should also be noted that the PtMP module based on XR Optics has an intrinsic excess delay in comparison with gray SFP module due to its coherent signal processing. The excess delay was approximately 30 microseconds at its maximum, depending on frame length, which results in a reduction of up to 6 km in maximum MFH length. Nevertheless, the PtMP-based APN showed the maximum MFH length of over 30 km and it could be said that the PtMP-based APN have a potential to be adapted to MFH with more than 30 km transmission length using selected combinations of DU and RU.

6.3.7 Elastic Load Balancing

We have measured the duration between events from the initiation of switchover (Event 1) to the recovery of IP connectivity of the UE (Event 5) as explained below. The results were shown in Table 11.

[Event 1] Command input to change M-plane VLAN setting of flexible bridge

[Event 2] Clearance of all NMS Alarms

[Event 3] Confirmation of the RU02's operational state: "Enabled" in the NMS

[Event 4] Confirmation of the antenna bar on the UE's screen

[Event 5] Establishment of the IP connectivity (Successful pinging)

Table 11: Result of ELB evaluation

	Duration between events [mm:ss]		
	1st time	2nd time	3rd time
Event 1 -> Event 2	01:59	01:37	02:28
Event 2 -> Event 3	00:04	00:13	00:17
Event 3 -> Event 4	00:22	01:16	01:01
Event 4 -> Event 5	00:09	00:09	00:08
Total Duration	**02:34**	**03:15**	**03:54**

The same measurement was conducted three times to see the variations in the processing time for each event. It took around 3 to 4 minutes from the start of switching to the re-establishment of IP connectivity to the UE. It should be noted that only the M-plane VLAN setting of the flexible bridge was changed, and there was no configuration change in PtMP-based APN in this evaluation. This assumes the aggregation of DU resources inside a single location. The other ELB use case where the DUs are switched across the location has not been evaluated for this evaluation due to the limitation of the number of flexible bridges. For that case, PtMP-based APN also needs to be reconfigured, and it will take extra time for the re-connection of PtMP link. This will be evaluated in further study.

The energy-saving effect of the ELB at the DU site was estimated by assuming the unused vDU server transitioned to power-off state (because the actual shutdown of the server or the transition to hibernation mode could not be carried out in the PoC). As depicted in Figure 4, two vDU servers and three switches (one of them is expressed as "flexible bridge") were used at the DU site. The power consumption of the server and the switch were 452W and 142W, respectively. Table 12 summarized the estimated power reduction effect by the ELB. 33 % of the power could be saved at DU site for this PoC configuration by assuming the shutdown of the unused vDU server. The vDU server used in the PoC was capable to accommodate up to three RUs. As we couldn't measure the variation in power consumption when the number of RU accommodated to the vDU was changed, the power consumption of vDU server was assumed to be unchanged before and after the switchover. In this PoC, we could assume the complete shutdown of one of the vDU servers because only a single RU was accommodated to each vDU server before switchover, however, the energy-saving effect could be more limited if there remains the other RUs after the switchover. Further investigation will be needed for clarifying the relation between power consumption and vDU workload as well as the implementation of hibernation mode. It should be noted that the configuration of PtMP-APN link was not changed before and after the switchover, so there is no effect for power reduction by the APN-related devices in this PoC.

Table 12: Power reduction effect by Elastic Load Balancing

Power Consumption	vDU server	Switch (incl. flex-bridge)	PtMP Module	Total.	Power reduction ratio at DU site
Pre-switchover	904 [W]	426 [W]	22 [W]	1352 [W]	
Post-switchover	452 [W]	426 [W]	22 [W]	900 [W]	-33%

6.4 Technical Discoveries from the PoC

Technical feasibility and the applicability of PtMP-based APN to mobile fronthaul was demonstrated according to the PoC Reference Step1. We confirmed that the O-RAN compliant DUs and RUs were successfully connected using 1x2 PtMP-based mobile fronthaul link with time synchronization scenario of LLS-C3, and the UE was successfully attached to the network with expected throughput. Maximum MFH transmission length was 32 km with the DU and RUs used for this PoC, during which UE throughput remained unchanged. We also evaluated the feasibility of ELB according to Step 2-1 of the PoC Reference and confirmed the vDU switchover with a communication recovery time of around 3-4 minutes. It should be noted that the obtained values such as maximum MFH length and ELB switchover time are not only dependent on PtMP technology itself but also related to the implementation of vDU and RU.

This PoC has been conducted using commercially available PtMP technology with limited amounts of equipment which was not optimized to show the concept of this PoC. Although the technical feasibility has been confirmed through the PoC, there are several items to be addressed in the future development.

- ELB switchover was initiated by changing the M-plane VLAN setting of the L2 switch at the RU side because this is the only scheme to change the relation between vDU and RU with available test equipment in this PoC. There was no interaction between RAN and APN operation. The RU parameters to be registered to a new vDU were also pre-configured in this PoC. To shorten the network downtime during ELB switchover, further study for cooperative management of RAN and APN resources will be needed.

- In this PoC, two vDU servers were in the same location, due to the limitation in the numbers of flexible bridge and PtMP optical module. To see the feasibility of ELB to the different site's vDU, we need to conduct another evaluation including the configuration change in the APN, i.e., switchover of the PtMP Hub module (PtMP leaf modules at RU side are accommodated to the other PtMP hub module). This operation requires the re-registration of PtMP leaf modules to the new PtMP hub module, and this may take extra down time for ELB switchover.

Objective Id:	#1: Feasibility of MFH over APN using PtMP technology (Step1) #2: Feasibility of Elastic Load Balancing (Step2-1)	
Description:	**Description of the PoC Demo Objective**: · The first objective of the PoC Step1 (Objective Id #1) was to evaluate the feasibility of the PtMP technology to Mobile Fronthaul network which is compliant to the O-RAN specification. · The second objective of the PoC Step2-1 (Objective Id #2) was to evaluate the technical feasibility of the Elastic Load Balancing for the PtMP-based MFH over APN configuration.	
Pre-conditions	N/A	
Procedure:	**1**	(Setup) PtMP-based MFH over APN is configured using a PtMP hub module and two leaf modules. These modules are connected via 1x2 optical splitter, ROADM-based APN-G/I and optical fibers. Flexible bridges are used for converting the different types of optical module form factors at both hub and leaf sides. Two DUs are connected to the flexible bridge at the hub side, and two RUs are connected to the flexible bridges at the leaf side for each. A PTP grandmaster is connected to one of the flexible bridges for configuring LLS-C3 time synchronization scenario. Iperf server needs to be located at the CN above a UPF function. All prerequisites for connecting DUs and RUs such as IP address and VLAN ID should be set properly for each equipment. In this PoC, different VLAN-ID are assigned for each DU's M-plane connectivity (to distinguish the designated DU). CU and CN functions should also be prepared for UE communication test.
	2	(Pre-test) Throughput and Latency of the PtMP MFH optical links should be measured before connecting the DUs and RUs. Connect the traffic tester and send traffic load for both upstream/downstream directions. After checking the throughput and latency, PTP connectivity and PTP accuracy should be measured. Connect the PTP tester to both flexible bridges at the RU side (one port is used as a Grandmaster, and the other is used as a TimeReceiver). Max |TE| between the two flexible bridges is measured and evaluated.
	3	(Measurement) [#1(Step1)] (1) Connect the RUs to the flexible bridges at the leaf side to initiate registration process to the designated DUs. (2) Check the status of the DU and RU on the NMS to see the M/S/C/U-plane sequence is properly processed and the RU is registered to the DU. (3) After the RU registration, connect the UE to the mobile network and check the UE is successfully registered to the network by checking antenna bars on the screen. (4) UE throughput is measured using Iperf. (5) Repeat (1)-(4) with changing the MFH fiber length until the UE throughput degradation and/or RU registration failure are confirmed. [#2 (Step2-1)] (1) Connect the RUs to the flexible bridges and confirm the successful registration of the RUs to the designated DU. (2) Connect the UE to one of the RUs (RU02) and continuously send/receive traffics using Iperf. (3) Trigger the switchover of the DU by changing the VLAN setting of the flexible bridge connected to the RU02, i.e., M-plane connectivity is reset and restarted to another DU. (4) Confirm that the RU02 is re-registered to the new DU and UE traffic is recovered. (5) Measure the time taken from (3) to (4).

Finding Details:	In this PoC, the applicability of PtMP technology based-on Open XR Optics to MFH network has been evaluated. The following basic characteristics were confirmed. - For 1x2 configuration, throughput was 99.9Gbps per link. - An intrinsic delay of around 40 us for a back-to-back case (which includes the delay of the flexible bridge) was obtained. - Max|TE| between two O-RU UNI ports (= between Grandmaster port and TimeReceiver port of PTP tester) was smaller than 60 ns, which is O-RAN fronthaul network contribution limit for Category A O-RU for topology configuration LLS-C3. Through measurement 1 (Step1), successful connection of the O-RAN-compliant DU and the RU was confirmed, i.e., all the M-plane, S-plane, C-plane, and U-plane messages were successfully transferred over the PtMP-based MFH link. Furthermore, the UE (5G Smartphone) was connected to the PoC mobile network through the air interface and expected radio throughput of 1.4 Gbps (for downlink) and 224 Mbps (for uplink) were obtained. We also evaluated the maximum length of MFH link, and the normal operation was confirmed up to 32 km without changing UE throughput. It should be noted that the maximum MFH length depends on the internal processing delay of the DU and the RU, and the obtained maximum length of 32 km is not the universal value for every cases. [#2 (Step2-1)] The switchover time of ELB was measured three times and the time taken from switchover to the recovery of IP connectivity (pinging) were 02:34, 03:15, and 03:54, respectively. With that, it could be said that the PtMP MFH link and the DU and the RU employed in the PoC have the capability of ELB switchover although there was a large communication failure period. This is because the current DU was not optimized for ELB, i.e., it is not considered to shorten the re-registration period of the RU.
Lessons Learnt & Recommendations	Technical feasibility of PtMP technology and its applicability to MFH network have been shown. Although this PoC has been conducted with primitive configuration, PtMP-based MFH over APN satisfied the requirements as specified in the O-RAN fronthaul interoperability specification. Regarding the maximum transmission length, the length for PtMP-based APN was shortened compared with that for gray SFP modules due to the processing delay as described in section 6.3.6. However, there is a possibility for PtMP modules to be inserted directly to DU and RU hardware without using flexible bridges. In this case, the buffering delay in the flexible bridge can be ignored and the maximum MFH length could be further extended. Based on the results, it is recommended to add the PtMP specification defined in the Open XR Optics Forum to one of the optical interfaces between APN-T and APN-G which is specified in the MFH over APN PoC Reference. DU switchover of ELB was also conducted and technical feasibility was proved. As we used 1x2 PtMP configuration as a fronthaul link in this PoC, there was a limitation in the location of the vDU where two vDUs were connected to the same flexible switch which accommodates PtMP hub module and we assumed the computing resources were located in a single location. To evaluate the vDU switchover to the different site, we need an additional PtMP hub module at the different vDU site and re-allocation of hub-leaf relation needs to be considered. This was not possible at this PoC due to the limitation in the available equipment and will be conducted in future study. Furthermore, the switching procedure in this PoC was not fully optimized. It took around 3-4 minutes for the reestablishment of IP connectivity after the vDU switchover. Although the requirement for the downtime is not specified at this moment, this service downtime of several minutes will not be accepted in the actual system. To shorten the service downtime during switchover, the registration process of DU-RU and UE should be improved as well as the link-up time of PtMP modules. Additionally, interaction between RAN controller and PtMP-based APN controller will also be needed from the coordinated process point of view.

7 PoC's Contribution to IOWN GF

Contribution	WG/TF	Study Item (SI) / Work Item (WI)	Comments
A	IMN	WI	The PoC showed the technical applicability of PtMP-based APN to O-RAN-compliant MFH network. In addition to that, the possibility of ELB use case was also validated over PtMP-based MFH over APN, although the switching procedure was limited only to this PoC.

8 PoC Suggested Action Items

(1) Gaps identified in relevant standardization

O-RAN alliance has started the discussion about "transport inclusion" where the "Transport Network" is included in the overall O-RAN architecture and cooperatively controlled from "service management orchestrator (SMO)" via "Transport Network Management Interface (TNMI)". Transport network includes whole types of networks related to RAN, i.e., mobile backhaul (MBH), mobile midhaul (MMH), and MFH. When we consider applying APN to MFH, APN and APN-C should follow the O-RAN specification for cooperative operation between RAN and APN. There is no description about APN in the O-RAN discussion so far, and if there is a specific requirement for controlling APN including ELB, the IOWN-GF needs to discuss it with O-RAN alliance.

(2) PoC Suggested Action Items

- As described in (1), the discussion between IOWN-GF and O-RAN alliance will be needed.
- In the current MFH over APN PoC Reference document, Open ROADM MSA-compliant optical interfaces are the only solution as the MFH over APN optical interface when flexible bridge is used. Through this PoC, PtMP technology based on Open XR Optics is found to be one of the alternative solutions. It is recommended that to add the PtMP specification defined in the Open XR Optics Forum to the PoC Reference given the TF and WG members' approval [3].

(3) Any Additional comments the PoC Team wishes to make?

Nothing special.

(4) Next Step?

There are no specific plans for conducting further PoC, including a detailed evaluation based on the procedure described in Step 2-2 of the PoC Reference (energy efficiency evaluation), as long as the existing DU and RU are utilized. Based on the results of the technical feasibility of ELB for this PoC and the other related PoC of MFH over APN, detailed procedures to control RAN and APN interactively should be discussed in both IOWN-GF and O-RAN. With those functions implemented in the controller, the next step of evaluation could be started as well as the discussion of standardization.

9 Acronym List

Acronym	Definition
APN-G	All Photonic Network- Gateway
APN-I	All Photonic Network - Interchange
APN-T	All Photonic Network – Transceiver
DU	Distributed Unit
GM	Grandmaster
IMN	IOWN for Mobile Networking
MBH	Mobile Backhaul
MFH	Mobile FrontHaul
MMH	Mobile Midhaul
NMS	Network Management System
PtMP	Point-to-Multipoint
POC	Proof of Concept
PTP	Precision Time Protocol
RAN	Radio Access Network
RU	Radio Unit
SFP	small form factor pluggable optical transceiver
TDD	Time Division Duplexing
TE	Time Error
UE	User Equipment
UL/DL	Uplink/Downlink
UNI	User Network Interface
VLAN	Virtual Local Area Network

10 Reference

[1] PoC Reference of Mobile Fronthaul over APN Version 2.0, August 23rd, 2024

[2] O-RAN.WG4.IOT.0-R003-v11.00, O-RAN Fronthaul Working Group Fronthaul Interoperability Test Specification (IOT), March 18th, 2024

[3] OXR.TCVROPTCLI.01.0, Open XR Optics Transceiver Optical and Client Interface Specification, Jan, 2024

11 Document History

Version	Date	By	Description of Change
1.0	Apr.15th ,2025	Ryo Inohara - KDDI Chenxiao Zhang – KDDI Junichi Michimata – SEI	Initial draft for TF review.
1.1	May.12, 2025	Ryo Inohara -KDDI	Minor Revision from v1.0 based on the comments received at Stockholm AMM. This is for TF-internal review. (6.4 Technical Discoveries from the PoC was updated)
1.2	Jul.4, 2025	Ryo Inohara -KDDI	Comments from TF members to v1.1 were reflected.
1.3	Jul.25. 2025	Ryo Inohara -KDDI	Additional Comments from TF members to v1.2 were reflected.
1.4	Aug.26, 2025	Ryo Inohara -KDDI	Additional comments from TF members to v1.3 were reflected. (Table 2 was modified)
2.0	Sep 18, 2025	Ryo Inohara -KDDI	PoC Report Submission Date was updated & prepared for publication.