Real-time Assessment of PtP/PtMP Fixed Access Serving RAN with MEC Capabilities

Anas El Ankouri[1,2,*], **Santiago Ruano Rincón**[2], **Gaël Simon**[1], **Luiz Anet Neto**[1], **Isabel Amigo**[2], **Annie Gravey**[2], **Philippe Chanclou**[1]

[1]*Orange Labs,2 Avenue Pierre Marzin,22300 Lannion, France*
[2]*IMT Atlantique,655 Avenue du Technopôle,29200 Plouzané France*
**anas.elankouri@orange.com*

Abstract: In this paper we propose the introduction of an intelligent access network equipment capable of hosting Mobile Edge Computing capabilities in a convergence scenario of PtP and PtMP topologies. © 2020 The Author(s)

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1. Context and Motivation

5G tests and deployments have started to see the light around the world, promising a wide range of different services beyond eMBB (enhanced Mobile Broad Band). Those include uRLLC (ultra Reliable Low Latency Communications) and mMTC (massive Machine Type Connectivity). To support these services, which present very different constraints, it is imperative to optimize the whole network, including the Fixed Access Network (FAN), i.e. the optical last-mile segment connecting the different Radio Access Network (RAN) equipment.

The RAN is mostly deployed today following a Distributed-RAN (D-RAN) approach, where the mobile processing functionalities are all located at the antenna site (see Fig. 1(a)). We can classify theses functionalities in three main blocks, namely CU (Central Unit), DU (Digital Unit) and RU (Radio Unit), with a backhaul bitrate similar to that one of the air interface and relaxed latency constraints between the CU and the mobile core. In order to partly centralize some RAN functions without stressing the underlying optical network in terms of bit-rate or latency [1], the mobile processing functions can be organized differently inside the CU, DU and RU blocks in what is known as "functional" splits of the RAN protocol layer [2]. Some of the higher layer functions of the RAN (CU block) can also be virtualized and placed inside generic servers at the central office (CO) site, giving birth to the new vRAN (Virtualized Radio Access Network) topology.

By adopting this new RAN topology, we can use generic servers to enable Mobile Edge Computing (MEC). MEC introduces new service scenarios such as connected vehicles or video stream analysis. Those are discussed in particular within the Industry Specification Group (ISG) of the European Telecommunications Standards Institute (ETSI) on MEC [3]. MEC services require that computing resources are located close to the user.

In addition to serving the RAN through layer 2/3 network devices, the FAN is used to serve fixed residential clients with PtMP (Point to MultiPoint) architectures or enterprises with PtP (Point to Point) links through FTTX (Fiber To The X). The FTTX users are connected to the network through PON (Passive Optical Network) technology in which their traffics are aggregated by the Optical Line Terminal (OLT) (See Fig. 1(b)).

In this paper we propose an architecture where a server simultaneously hosts MEC applications and an aggregation equipment for both fixed and mobile architectures, as shown in Fig. 1(c). We propose to use intelligent 10Gb/s SFP (small-form factor plug and play) devices to support all the functions of an OLT (SFP+/OLTs). Then, generic

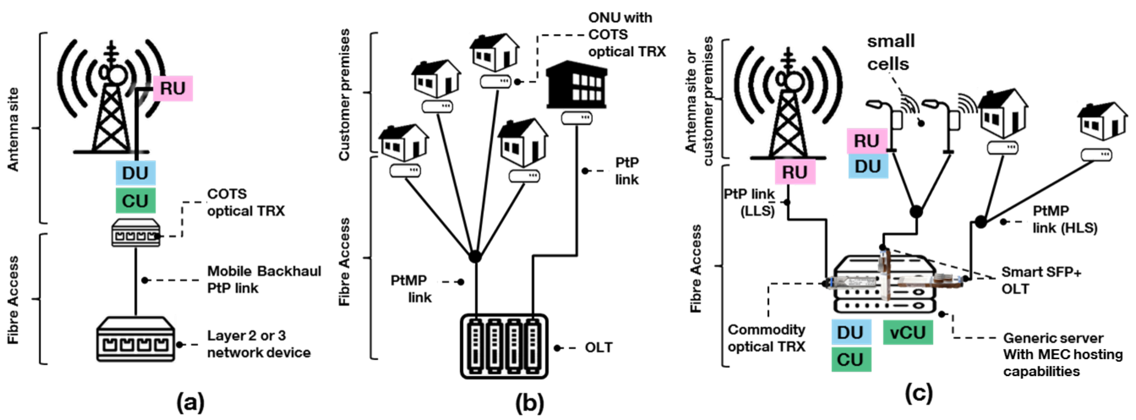

Fig. 1: (a) D-RAN topology, (b) PON topology, (c) D-RAN/PON convergent topology

server ports can be adapted to support PtMP usages. This is done thanks to an abstraction of the PON control layer and proper forwarding of ONU Management and Control Interface (OMCI) in what is currently referred to as part of the virtual OLT (vOLT) trend. This solution is particularly interesting in the sense that scalability can be obtained in a pay-as-you-grow fashion by simply adding new OLT PON ports, i.e. new SFP+/OLTs, to a generic switch (or server) port. Enabling easier coexistence scenarios between RAN and PON, PtP and PtMP topologies

In our proposed solution, the server and IT infrastructure are shared to host MEC and vCU, while the server interfaces support SFP vOLT. Each port of the server supports a specific topology. For example one port connects the PtP link dedicated to the mobile antenna macro site, another one connects a PON PtMP linking multiple small cell antennas, while a third one connects a PON for fixed clients.

In addition, multiplexing the PON link used by small cell antennas with the macro cell antenna link in the same equipment potentially allows offloading some traffic from one link to the other depending on current link occupation and service requirements. For instance when the load supported by a small cell is low, we can offload its traffic through the macro cell antenna link and put the small cell in sleep mode in order to save energy. Or inversely, when the macro site antenna link is overloaded, we can offload part of it onto the set of small cells. As offloading may increase latency, only services that present non-stringent latency requirements are suitable for a PtMP offloading. These are for example identified by the Metro Ethernet Forum (MEF) that defines Class of Services (CoS) for Ethernet applications, for example the ”medium” CoS relating to streaming media is a good candidate to be offloaded [4].

2. Experimental Setup

In order to assess how offloading can be performed on our proposed solution, an experimental setup has been designed. It is illustrated in Fig. 2. Our experiments rely on four main parts described in the rest of the present section: traffic emulation, vRAN implementation, multiplexing scheme, optical transmission links

2.1. Traffic Emulation and vRAN implementation

We have experimented with two different kinds of traffic related to the green and purple components from Fig 2. The first traffic (purple) emulates PtMP traffic coming from multiple small cells. The second one (green) represents traffic from a macro-cell antenna. Both traffics are produced by an ethernet generator. For the vRAN implementation, we are using an implementation with a real time transmission of a high layer PDCP-RLC functional split [2]. The vRAN system has some limitations : the maximum bitrate at which we can transmit without having any packet losses is 100 Mbit/s, also it is difficult to maintain Transmission Control Protocol (TCP) connections so we chose to use User Datagram Protocol (UDP).

2.2. Aggregation DPDK Server and Optical Transmission Links

The central block in Fig. 2 represents the server we used. It is a general purpose workstation that runs Linux and whose 10GbE SFP+ network interfaces have been bound to Data Plane Development Kit (DPDK) [5]. DPDK enables fast packet processing and forwarding between the four ports of the machine, by circumventing the Linux kernel to avoid overhead of interrupt management. Then, to link the ports together and being able to specify switching rules we created a virtual bridge using Open vSwitch (OVS) [6]. It has allowed us to switch the traffic as well as to control the maximum outgoing bitrate from each port of our server.

The PtMP is implemented using a smart XGS-PON SFP+ with the OMCI control plane deported and located in a machine connected to our DPDK server. The optical PtMP link serves two Optical Network Units (ONUs). The PtP link is an optical link served by a COTS (Commercial Off the shelf) 10G SPF+.

Both the PtP link and the branch serving the vRAN server in the PtMP link are aggregated through a 10G switch that enabled us to emulate the handover from a macro site to a small cell and offload the vRAN traffic from one link to the other. The offload of the traffic is done using VLAN tags, so each type of traffic is tagged differently making it possible to differentiate them in the switch as well as the DPDK server. To assess this offloading, we put a probe measuring the bitrate in both of the links in the (A) and (B) positions.

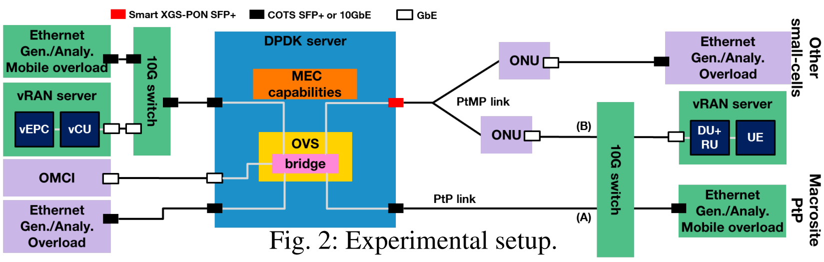

Fig. 2: Experimental setup.

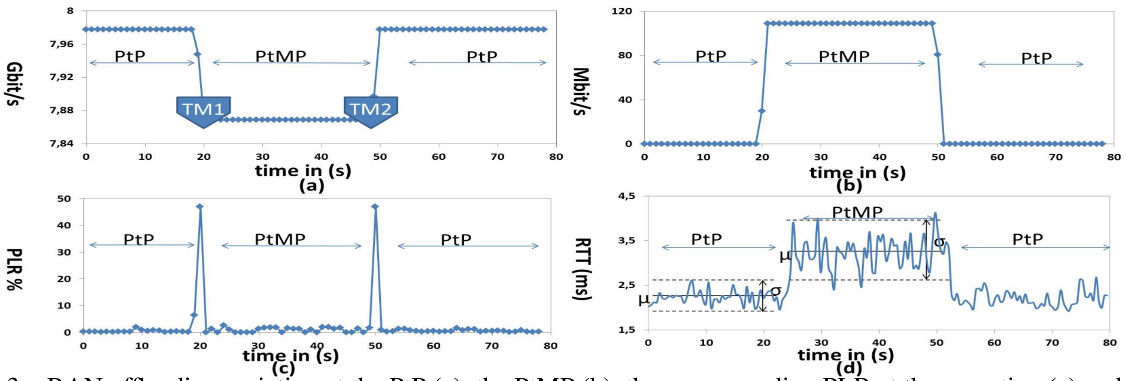

Fig. 3: vRAN offloading variation at the PtP (a), the PtMP (b), the corresponding PLR at the reception (c) and the variation of latency and jitter (d).

3. Results and Discussions

For the experiment we have created an uplink transmission by generating a UDP traffic at 100 Mbit/s going from the User Equipment (UE) to our mobile core node: the virtual Evolved Packet Core (vEPC). This traffic is the one representing the user's data that initially will be served by the PtP link then being switched to the PtMP link and inversely. The Traffic emulation for the macrosite as well as the other small cells is set at 7,88 Gbit/s each. First, we are going to take a look at the backhaul offloading that occurs when the vRAN uplink traffic is initially transported on the PtP link with a bitrate of a 100 Mbit/s along with the traffic coming from the macrosite totalling up to 7,98 Gbit/s. At a certain time mark TM1, we shift the small cell load from the PtP link to the PtMP PON by instructing the OVS bridge to allow the VLAN tagged small cell traffic to go through the server port serving the PtMP link. Now, the PtP link is having a traffic of 7,88 Gbit/s and the PtMP link a traffic of 100 Mbit/s. At a second time mark TM2 we offload the traffic going through the PtMP link back to the PtP link. Fig. 3 (a), shows the variation of bitrate inside the PtP link, Fig. 3 (b) the variation inside the PtMP link, and Fig. 3 (c) the Packet Loss Rate (PLR) at the reception of our EPC. We should note here that the PLR is stable in both PtP and PtMP at less than 2,5%. At the moment of switching the traffic from one link to the other, a big surge in PLR occurs at around 50%, this could be due to the limitation in our 10G switch that plays the role of a handover emulator or a limitation in the DPDK server which blocks the traffic at the moment of the offloading. Moreover, the nature of the UDP traffic doesn't allow for re- transmissions, so momentarily when we go from one link to the other, the packets are lost. In a real life scenario where the offloading will occur using handover, there are mechanisms in place to ensure the reliability of the communication such as HARQ (Hybrid Automatic repeat request).

Then we did a latency assessment for both the PtP and the PtMP link, Fig. 3 (d) show the jitter and latency differences between the two links. The fiber length of the transmission is less than 1km for both PtP and PtMP. The results are valid without loss of generality for up to 10km, since our COTS SFPs are capable of transmitting over this distance. In average, the round trip time (RTT) of the PtP is μ = 2,22 ms and has a packet jitter value of σ = 0,11 ms. For the PtMP the values were respectively μ = 3,21 ms for RTT and σ = 0,29 ms for packet jitter. We should also mention that we only had two ONUs in our PtMP link, the packet jitter value could increase if we add more ONUs to our link. With these results, the majority of mobile services can be offloaded to the PtMP link apart from latency and packet jitter strict applications.

4. Conclusion

In this paper we propose a scenario at the level of the Fixed Access Network, where we use a convergence equipment associating a PtP with a PtMP PON based on vOLT implementation. We chose a server running a fast packet processing software framework to show the potential to host MEC (Mobile Edge Computing) applications which requires hardware resources closer to the end user. We demonstrated the transmission and the offloading of a real time PDCP-RLC functional split traffic from the PtP to the PtMP and inversely, giving performance results indicating the feasibility of this transmission for the mobile services with relaxed latency constraints.

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