# A MEC and UPF Compatible OLT for Time-Critical Mobile Services

Minqi WANG*†, Gaël SIMON*, Luiz ANET NETO†, Isabel AMIGO†, Loutfi NUAYMI‡, Philippe CHANCLOU*
* *Orange Innovation, Fixed Access Networks, Lannion, France*
† *IMT Atlantique, Lab-STICC, UMR CNRS 6285, F-29238 Brest, France*
‡ *IMT Atlantique, Lab-STICC, UMR CNRS 6074, F-35700 Rennes, France*
Email: {minqi.wang, gael.simon, philippe.chanclou}@orange.com,
{luiz.anetneto, isabel.amigo, loutfi.nuaymi}@imt-atlantique.fr

***Abstract*—A proof-of-concept of an optical central office with Multi-Edge Computing (MEC), User Plane Function (UPF) and disaggregated Optical Line Terminal (OLT) sharing an X86-server is experimentally demonstrated. 200 µs ultra-low latency and 10 µs jitter performances are realized for 5G time-critical services.**

***Index Terms*—OLT, MEC, latency, jitter, 5G**

## I. Introduction and Proposition

With the great progress of Software Defined Network (SDN) and Network Function Virtualization (NFV), the applications of virtualization technologies are finally arriving at the access network. The concept of Cloud Central Office (Cloud-CO), defined by the Broadband Forum (BBF) in 2018 [1], recasts the CO that utilizes cloud technologies, SDN and NFV. In parallel, many research works have been published with different technical focuses.

Regarding the optical line terminal (OLT) functions hosted at the optical central office, the Flexible Access System Architecture (FASA) project aimed at the full virtualization of the OLT (vOLT). Since Dynamic Bandwidth Allocation (DBA) is a critical time-critical function in the OLT, virtualized DBA (vDBA) on general-purpose servers is the most challenging task and was demonstrated in [2]. Following the same idea of full vOLT, the transport of future mobile services is proposed via Time-Division Multiple Access PON (TDMA-PON) with the help of disaggregated DBA and cooperative DBA (Co-DBA) for upstream traffic in [3]. In [4], the authors introduce the vDBA mechanisms for multi-tenancy use cases in Passive Optical Networks (PON) and disaggregated Reconfigurable Add & Drop Multiplexer (ROADM) for dynamic optical switching in metro access networks.

Concerning the mobile network, the 5G core provides different new entities to improve QoS: 5G's slicing concept ensures the end-to-end QoS from the core network to the User Equipment (UE) with the help of an SDN controller. Another approach is to redeploy the User Plane Function (UPF) closer to the access segment for an optimal UEs' experience, the UPF being the data plane's gateway to "the outside world" that is called the Data Network (DN) in the mobile network terminology. The authors in [5] discuss Multi-Edge Computing (MEC) synergies in Fixed Access Network (FAN) for industrial needs with virtualization technologies and in [6], an optimal selection between two UPFs is proposed for each attached UE to access the DN or a local MEC.

The innovative idea of replacing an OLT chassis (see Fig.1a) by a generic server allows adding mobile core network functionalities such as UPF and MEC services on the same server (see Fig.1b), thus showcasing a deep fixed and mobile convergence. Our motivation is to experimentally demonstrate that an advanced and virtualized optical access architecture such as the one proposed in Fig.1b can be used to meet the latency and jitter constraints of time-critical mobile services, with the help of optical access technologies. This paper supposes the use case where a mobile network carries two types of service, with either very tight or relaxed constraints in terms of latency and packet jitter. The former is associated to an UPF closer to the UEs (UPF1) and is implemented with an MEC functionality in our OLT. On the other hand, the latter option can be associated with a distant UPF (UPF0 in Fig.1b), which is located in the core network. Since it is transmitted through the metro network segment (with distances typically of the order of 500 km in France [7]), it could be subject to severe and variable latency and jitter depending on the network load. In this paper, an enhanced convergence between the OLT, UPF, and MEC functions is proposed and experimentally evaluated by implementing all these functions on a generic server located in the access segment, as shown in Fig.1b.

## II. Experimental setup

The experimental setup in Fig. 2 includes five parts: the real 5G core and the simulated RAN / UE that communicates through a real-time backhaul interface, the latency and jitter generator emulates the metro network, the MEC / UPF enabled OLT on a generic server, and a traffic generator and analyzer. Our testbed provides different types of optical access connectivity with optical point-to-point (PtP) or point-to-multipoint (PtMP) topologies, allowing for more flexible optical transport in future fixed-mobile convergence architectures [8]. The UPF0/mobile core (Open5GS) implemented in virtual machine 1 (VM) and the RAN/UE emulator (UERANSIM) is implemented in another VM, VM2, thus the 5G backhaul interface is realized between these two VMs. The simulation of air propagation is disabled in our experiment, as it is not the main

978-3-903176-44-7 © 2022 IFIP

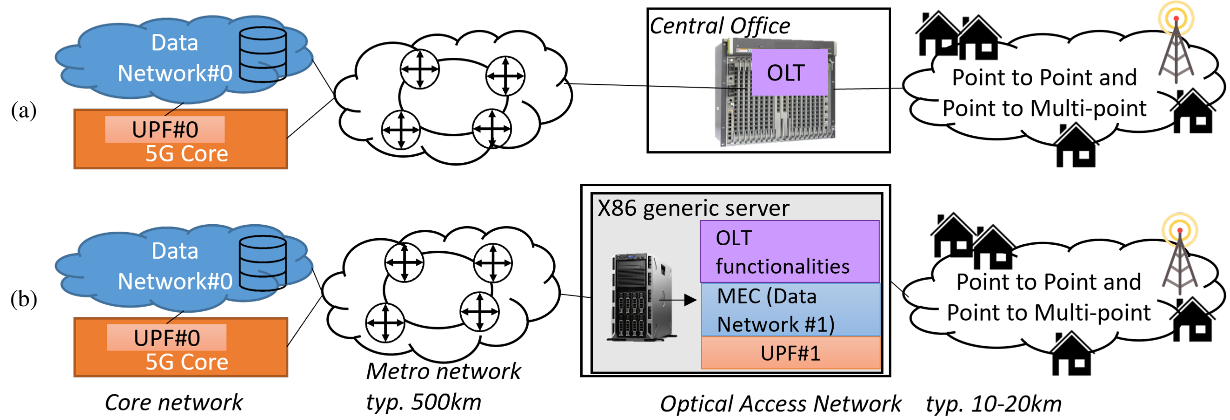


Fig. 1: a) Traditional architecture with UPF in the mobile core and legacy OLT. b) Proposed architecture with MEC and UPF compatible OLT.

focus of this work. The second UPF is in VM3 inside the OLT generic server. All three VMs are configured with 8 CPU cores and 10 GB memory; however, VM1 and VM2 use Intel(R) Xeon(R) CPU E5-2630v4@2.20 GHz and VM3 uses Intel(R) Xeon(R) Silver4110 CPU@2.10 GHz. The latency and jitter simulator can emulate two paths: 1) bypass/reference, with 0 latency and jitter, and 2) simulated metro path, configured with normally distributed latency with mean value 2.5 ms and standard deviation of 0.1 ms considering the distance of the metro network 500 km and 3-4 routers / switches interconnected. The x86 generic server in the CO includes Open vSwitch (OVS) for the OLT switching capabilities with SFP+/OLT for PtMP links and standard black & white SFPs for PtP links. The VM3 interconnects with an internal port of OVS. The traffic generator generates additional downlink and uplink traffic between the DN and the UE. The circles 0 and 1 marked in Fig. 2 represent the two data paths with UPF0 and UPF1, respectively. The analyzer measures both average latency and jitter values with different bitrates for mobile traffic. The CPU's performance is shown for the VM in order to give an idea of its occupation status according to the traffic throughput.

## III. Results and Discussion

Fig. 3 summarizes all possible combinations in terms of the location of the UPF (placed in the CO in the access network or

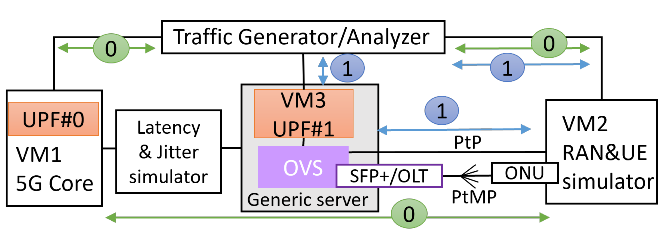


Fig. 2: Experimental setup and test traffic paths: UPF#0 in the 5G core (path 0 indicated in green) and UPF#1 in the OLT generic server (path 1 indicated in blue).

in the core network) and the optical access architecture (either PtP or PtMP). As introduced previously, for each chosen bit rate at the abscissa, the CPU performance of the VMs and the latency/jitter of uplink traffic are measured. The results in Fig. 3 allow us to conclude that:

(1) VM2 saturates earlier than other VMs (UPF0&UPF1), seeing in the Fig. 3 b that the CPU performance of the RAN / UE VM is always higher than that of the 5G core VM. For the two cases where the UPF is located with the other 5G core functions, the bit rate limitation to saturate the CPU is around 150 Mbps (CPU utilization reaches 100%). When the UPF is in the optical access CO, this limit reaches 1 Gbps. This is because VM3 is dedicated to UPF functionality, while VM1 also provides resources for other mobile core functions.

(2) Additional uplink latency and jitter are introduced in PtMP due to DBA processing. However, by optimizing the best type of PON Traffic Containers (T-CONT) type [9], the performance difference between PtMP and PtP could be reduced. Taking an example of 600 Mbps throughput when the UPF is in the optical access CO (Fig. 3 a)), more performing T-CONT parameters could allow for 704 μs and 80 μs latency and jitter, respectively. For the sake of completeness, an additional measurement was performed with a legacy chassis OLT in Fig.4 as a reference. The TCONT is configured as fixed 7 Gbps, assured and best effort 0 Gbps. The common latency is 55 μs and the common jitter is less than 5 μs. The best UL latency for SFP+/OLT is 350 μs and the jitter varies between 5 and 20 μs.

(3) Since the MEC and UPF entities are implemented on the same disaggregated OLT server, there is a trade-off between latency / jitter performance and resource allocation for each function hosted by the generic OLT server. Such a trade-off, considering a fixed-mobile scenario as discussed in this paper, could be found with the help of an SDN controller and a deeper fixed-mobile cooperation.

(4) A data-plane accelerator as Data Plane Development Kit (DPDK) could dramatically reduce the latency if applied on the generic server. Based on our experimental results, the OVS

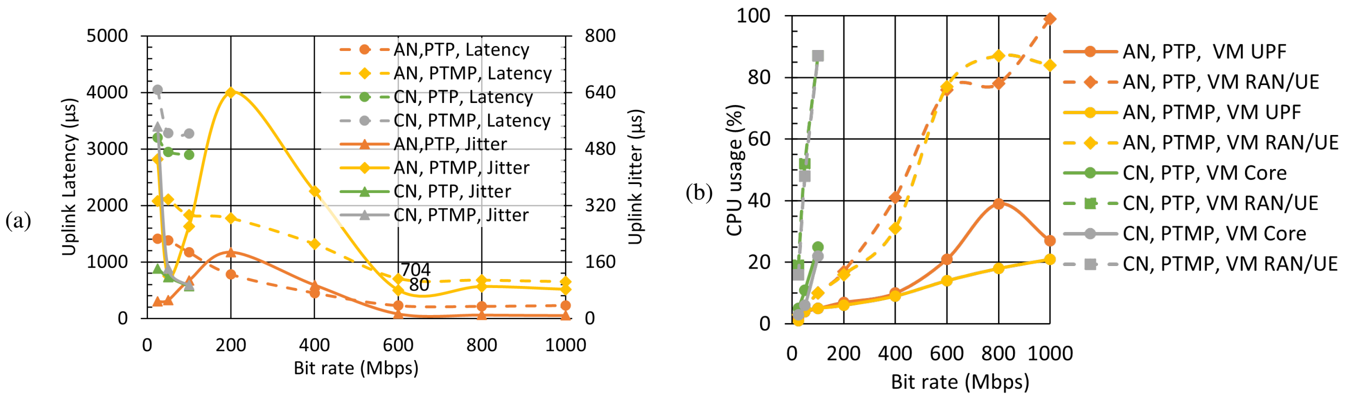


Fig. 3: Different experimental results with UPF in the core network (CN) or access network (AN) with PtP or PtMP optical topology. a) Experimental results of uplink latency, jitter. b) CPU performance of the VMs that holds UPF (VM UPF and VM Core), the VM of RAN/UE.

latency is somewhere around 100 µs but can be reduced to 10-12 µs with DPDK. In other words, each latency value in Fig. 3 could be reduced by 90 µs with DPDK. The latency for the 5G air interface is normally around 5 ms for non-time-critical services and could go down to 100 µs for time-critical services [10]. Thus, in our best case where the UPF is in the optical access CO and using the PtP topology, the uplink latency at 600 Mbps will be around 200 µs.

According to the use cases from vertical industries in [11], the most strict latency demand is real-time control for discrete automation with less than 1 ms, and non-time-critical automotive usage could tolerate up to 100 ms end-to-end latency. So, by implementing the MEC and the UPF function at the optical access CO with PtP topology, a 1 ms latency is achieved with optimized VM's resource allocation in the general-purpose OLT server. Moreover, the PtMP architecture could be considered for most use cases with more relaxed latency constraints such as media entertainment, IoT, health, wellness, etc. The authors in [12] specified that the jitter for deterministic data delivery should be less than 10 µs for beyond 5G networks. Our best case experimental allows for 8-9 µs jitter.

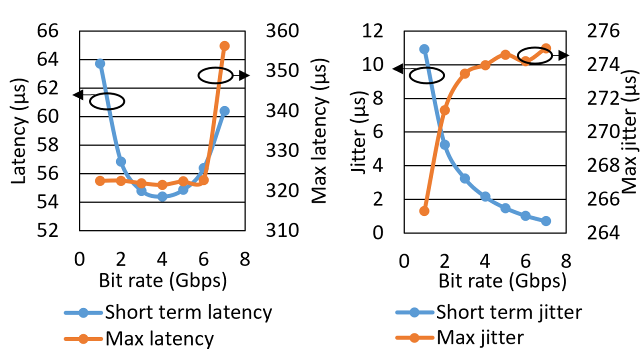


Fig. 4: Legacy OLT's short-term/max latency and jitter with the best performance's T-CONT (fixed 7 Gbps, assured 0 Gbps and best effort 0 Gbps)

## IV. Conclusion

We demonstrated a generic purpose server hosting disaggregated OLT functions for fixed access, but also mobile functions such as edge cloud and UPF. The convergence of those functionalities enables the mobile network to meet the strong latency and jitter constraints, benefiting from the central office location of the FTTH. By co-hosting the UPF from mobile network and edge cloud with the OLT, we showed an end-to-end latency decrease of 93% and 80% in our real-time test bed with PtP and PtMP topologies, respectively, and of 90% and 11% for packet jitter.

## Acknowledgment

This work was supported by the European H2020-ICT-2019 project 5G-COMPLETE and MARSAL.

## References

[1] K Georgios et al. Cloud Central Office Reference Architectural Framework. Technical report, Broadband Forum, 2018.
[2] T Suzuki et al. Software Implementation of 10G-EPON Upstream Physical-Layer Processing for Flexible Access Systems. JLT, 2019.
[3] K. Asaka et al. Disaggregation of time-critical applications in flexible access system architecture. JOCN, 2019.
[4] M Ruffini et al. Moving the Network to the Cloud: The Cloud Central Office Revolution and Its Implications for the Optical Layer. JLT, 2019.
[5] G. Simon et al. MEC and Fixed Access Networks Synergies. In OFC, 2021.
[6] Alevizaki V.M. et al. Dynamic User Plane Function Allocation in 5G Networks enabled by Optical Network Nodes. In ECOC, 2021.
[7] J.P Elbers et al. Optical metro networks 2.0. SPIE 7621, Optical Metro Networks and Short-Haul Systems II, 2021.
[8] M. Wang et al. SDN-oriented Disaggregated Optical Access Node for Converged 5G Mobile and Residential Services. In ECOC, 2021.
[9] G-PON: Transmission convergence layer specification Amendment 1 . Technical Report G.984.3, ITU, 2020.
[10] N.A. Mohammed et al. Mission-Critical Machine-Type Communication: An Overview and Perspectives Towards 5G. IEEE Access, 2019.
[11] 5G Service requirements for next generation new services and markets. Technical Report 22.261, 3GPP, 2018.
[12] E Inaty et al. Generalized multi-access dynamic bandwidth allocation scheme for future generation pons: A solution for beyond 5G delay/jitter sensitive systems. JLT, 2021.