New approaches in optical access networks to increase network flexibility and achieve 5G targets: an operator's view

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Abstract *The telecom network ecosystem is currently facing unprecedented challenges driven by new consumer habits in digitalization and 5G mobile communications. In this paper, multi-PON technology and open access for higher speed PON evolution and virtualization are described and discussed from a network operator perspective.*

Introduction

The telecom network ecosystem is currently facing unprecedented challenges driven by digitalization and ubiquitous connectivity with everything and everyone. Recently, unexpected crises such as the COVID-19 pandemic has shown not only that high speed broadband access and network resilience is critical to keep people's lives connected, but also that network flexibility and digitalization are also key to keep society safe and more human in emergency situations.

By 2023, it is forecasted [1] that nearly two-thirds of the global population will have Internet access, the number of devices connected to IP networks will be more than three times the global population, and the number of connected 4K TV sets will grow at a 27% Compound Annual Growth Rate (CAGR) in the 2018–2023 period. The traffic increase figures may be widely surpassed due to the new scenarios caused by the COVID-19 crises, which as an example, only in a few days caused an IP traffic increase close to 40% in Spain, due to the massive and simultaneous use of the network for remote work, remote education, entertaining and instant messaging during business time.

At the same time, the fifth generation of mobile communications is opening up innovation opportunities for new industries and applications such as vertical markets and edge computing, and network users are demanding personalized and low-latency services that can be provisioned in real-time.

In this challenging environment, network operators require very flexible, high-performance real-time response network architectures that can be deployed quickly in a cost-effective and sustainable way.

The journey towards Open Broadband in the fixed networks

Optical Line Terminations (OLTs) are the access nodes for FTTH networks. In the case of Fiber to

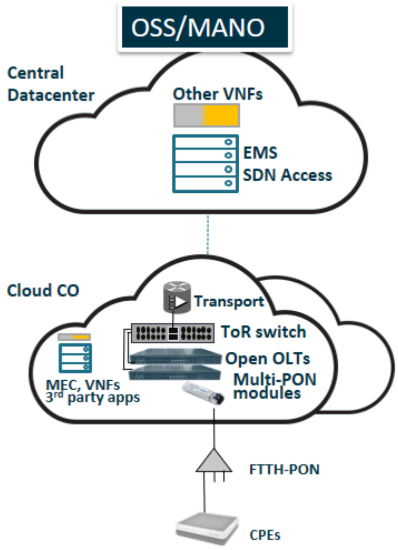

Fig. 1: Open Broadband Multi-PON CloudCO scenario for fixed networks evolution (OSS: Operation and Support Systems. MANO: Management and Orchestration)

the Home (FTTH) Passive Optical Networks (PONs), the OLTs connect with the customer premises equipment (CPE) using a branched optical distribution network with passive optical splitters.

Currently, access nodes in the legacy networks are monolithic equipment where the software (SW) is tightly coupled to the hardware (HW), reducing the flexibility of the network evolution and the development of customized services.

In the recent years, In order to overcome the restrictions of monolithic network equipment, several industrial groups such as the Open Networking Foundation (ONF), the Open Compute Project (OCP) and the Telecom Infra Project (TIP), as well as standardization organisms such as the Broadband Forum (BBF), have been offering solutions for legacy networks transformation and migration towards Software Defined Networks (SDN) and Network Functions Virtualization (NFV) using Cloud technologies

In Telefónica, the Open Broadband program is the evolution of our access network based on hardware (HW) and software (SW) disaggregation, Software Defined Networking and cloud computing technologies. As shown in Fig. 1, Open Broadband access nodes are formed by Open OLTs and Top of Rack (ToR) switch-routers for Open OLTs traffic management and aggregation, orchestrated in a Cloud-native Central Office (Cloud CO [2]) domain with Multi-access Edge Computing (MEC) services, Virtual Network Functions (VNFs) and third-party applications. As part of the Open Broadband program, a converged fixed and mobile network sharing the same virtualization infrastructure for the network control plane and MEC applications for FTTH customer service auto-provisioning and real time facial image processing was demonstrated by Telefonica at the Mobile World Congress 2019 [3].

The most important principles of our Open Broadband program are the following:

- Disaggregate the SW from HW of the access node. With this approach, the SW for switching and routing as well as the control plane for the OLT can be designed agnostic to the specific hardware platform.
- Commoditize the HW components and customize the design. The Physical Network Functions (PNFs) for access and aggregation equipment are built based on off-the-shelf equipment, also known as whiteboxes, with design flexibility and customization.
- Using a GPP (General Purpose Processor) architecture. The software can be deployed in virtualized environments, thus allowing convergence with 5G mobile networks, edge computing applications and future VNFs.

Software virtualization as enabler of hardware and software disaggregation

Virtualization technologies can bring benefits to some functions that can often change their resource usage in time and are frequently modified, because of network usage, standard evolution and network security threads.

The virtual ONU Management and Control interface (vOMCI) from the Broadband Forum in the Open Broadband – Broadband Access Abstraction (OB-BAA) project [4], and the virtual OLT Hardware abstraction (VOLTHA) from ONF [5] are examples of virtualized software stack for whitebox OLTs.

Other control plane functions, such as Internet Group Multicast Protocol (IGMP) and Dynamic Host Configuration Protocol (DHCP) snooping, subscriber access management such as IP Relay Agents (RA) and Point to Point Protocol (PPP) Intermediate Agent (IA), as well as the node management functions of the Element Management System (EMS), can also benefit from virtualization and cloud scale out technologies.

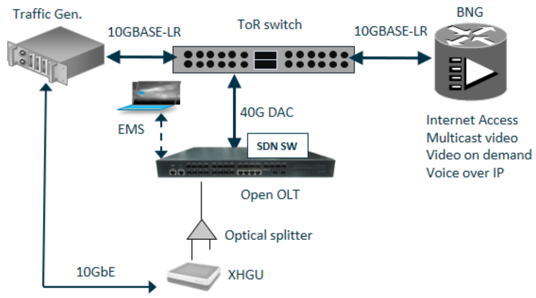

Fig. 2: Setup for the stand-alone Open Broadband trial

Customer-specific services such as FTTH customer self-provisioning [3], home and third-party apps, and specialized network applications such as the cooperation between the mobile network and OLTs Dynamic Bandwidth Allocation [6] can change or be updated very often and virtualization technologies can also bring flexibility and reduce the time to market for new services. Finally, virtualization is key to deploy innovative content and cloud services at the network edge, such as vehicle infotaining, gaming streaming and consumer blockchain, as well as to support the emerging 5G radio access network scenarios sensitive to latency, such as massive Internet of Things, tactile internet and low latency services for autonomous devices.

Stand-alone Open Broadband trial

In the short term, it is mandatory that the Open Broadband access is not only capable of providing innovation potential and long-term benefits, but also needs to fully support legacy services and be interoperable with the legacy network architecture and equipment.

In order to demonstrate the integration of the new Open Broadband architecture with our legacy network, we have performed a stand-alone Open Broadband trial, see Fig. 2.

For this trial, we used an XGS-PON OLT model ASXvOLT16 with 16 XGS-PON ports as Open OLT and an AS5812-54X as ToR switch for OLT traffic aggregation, both from Edgecore Networks Corporation. We used a 40GbE Direct Attached Cable (DAC) to connect the OLT uplink to the ToR switch, even though 100GbE connection is also possible. The ToR switch is directly connected to a Broadband Network Gateway (BNG) from Juniper using a 10GBASE-LR SFP+ optical transceiver. The BNG provides access to the IP network and service routers of the Telefónica production network.

In the customer premise side, Telefónica owndesigned XGS-PON Home Gateway Units (XHGU) were used as customer premises equipment. Two XHGUs were simultaneously connected to the OLT using a passive optical splitter emulating an FTTH-PON.

Point to Point Protocol over Ethernet (PPPoE) client was used for internet access and IP over Ethernet Interfaces are used for video and Voice over IP services. We configured an stacked VLAN bridge with queue in queue (QiQ) VLAN in the Open OLT and ToR switch in order to stablish the PPPoE session between the HGU and the BNG for internet service. TV and VoIP services were delivered using single VLAN tag and routing interfaces configured in the ToR switch.

We used a laptop running the Element Management System (EMS) software for out of band management of the Open OLT. The SDN software can be instantiated on a cloud native environment such as an edge cloud, but in the context of this trial it is fully running inside the whitebox OLT processor without the need for additional processing resources from a datacenter or a cloud.

We successfully achieved access to all the Telefónica residential triple play services over FTTH: high speed internet, voice over IP and IPTV with multicast TV and video on demand. Moreover, we achieved interoperability with Telefonica XHGUs as well as interoperability with third-party PON transceivers plugged into the OLT.

Maximum throughput between the OLT uplink and the XHGU Local Area Network interfaces was tested versus the Ethernet frame packet size using a traffic generator and analyzer. The traffic emulation uses bidirectional IP traffic transmission between the OLT and the XHGU gateway over PPPoE. The test results, see Fig. 3, show a maximum Ethernet bidirectional throughput around 8.5 Gbps for a frame size around 1024 bytes and above, reaching 8.6 Gbps for jumbo frames of 9000 bytes. The observed reduction of the 10 Gbps line rate of the XGS-PON interface is caused by the bidirectional Forward Error Correction (FEC) used in the transmission layer of the XGS-PON interface. Due to the different processing power between OLT and HGU and because the source traffic in the downstream direction has double VLAN tags while the upstream traffic is untagged, a slight difference in the maximum Ethernet throughput between the upstream and the downstream direction is also observed.

The trial setup is able to run without the need to use additional equipment such as servers, thus a fully stand-alone software defined Open BroadBand access network has been demonstrated, which will be useful for quick deployment in scenarios where datacenter resources are not available or cost-effective.

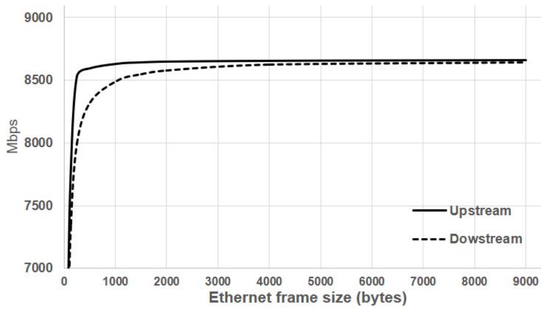

Fig. 3: Maximum Ethernet throughput between Open OLT and XHGU

FTTH network evolution with Multi-PON technology

Gigabit capable PON standards were published almost 20 years ago, 10G capable standards [7, 8] have been ratified in the recent years and 25G and 50G PON are currently under standardization [9, 10].

Typically, PON interfaces consist of Small Form-factor Pluggable (SFP) optical transceivers supporting a single optical access technology. In order to add 10G access technologies in the same PON optical distribution network, a traditional approach is to install additional OLTs in the central offices with 10G transceivers and to use wavelength multiplexers to combine legacy and 10G optical signals into the same PON. This traditional approach involves re-cabling inside central offices, more space for additional OLTs, fiber cables and wavelength multiplexers, and increased power consumption. As an alternative, Multi-PON Modules (MPM) have been recently considered in the standard architectures [11] and new MPM modules have appeared in the market. With this approach, OLT PON interfaces can be built with PON and 10G PON optical components integrated in the same SFP+. These transceivers, also known as COMBO modules, allow to save space and reduce complexity.

In the Open Broadband scenario, Open OLTs are designed considering Multi-PON technology using interoperable third-party PON transceivers. This way, GPON SFPs are used for GPON deployment, and XGS-PON can be smoothly added on customer's demand on a per PON port basis, just by replacing a GPON SFP module with a COMBO SFP+ module, thus supporting simultaneous access to GPON and XGS-PON technologies in the same PON interface.

Conclusions and future work

We have presented and demonstrated our Open Broadband program for the evolution of FTTH networks, based on hardware and software disaggregation, virtualization and Multi-PON technology. After our sucessful Open Broadband lab trial, we plan to test the new architecture with real customers in the field.

This architecture provides a graceful migration path towards XGS-PON technology and has the potential to provide unprecedented flexibility to access network design and deployment, offer new services based on multi-access edge computing and achieve the targets of the emerging 5G mobile network scenarios.

Acknowledgements

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