Dynamic Traffic Management of OLT Backhaul/Service Ports with SDN Controller

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Abstract *We propose and verify experimentally a dynamic traffic management of both backhaul and service ports of an OLT by using a switch, some smart SFP and SDN abstraction. In addition to efficient management, energy savings can be obtained.*

Introduction

The next generation Passive Optical Networks (PONs) will not only target higher bandwidths, but will also focus on a wider range of applications: optical local area networks (LAN) for campuses[1], home LANs for in house connectivity[2], and mobile applications for Radio Access Networks (RAN) support[3]. Moreover, since PON technologies are intended for diversified applications, operators are interested in more generic hardware and new ways to manage the equipment in PON to reduce Capital Expenditures (CapEx), Operational Expenditures (OpEx) and avoid vendor lock-in much as possible. Therefore, virtualization technology is introduced which mainly includes Software Defined Networks (SDN) and Network Functions Virtualization (NFV). SDN separates the control plane from the data plane[4] and allows network abstraction. One example is the VOLTHA project by Optical Network Foundation (ONF)[5]. In the same trend, NFV moves the dedicated function in an equipment to a generic server. A virtualized PON is proposed in [6], [7]. All those contributions and the current state of standardization and specification bodies highlight the benefits of SDN/NFV in optical access networks today.

The reference Fixed Access Networks (FAN) PON equipment is the Optical Line Termination (OLT). It is traditionally made of a chassis with shelfs embedding cards of different types: line cards for PtMP access applications (e.g. residential access), PtP access applications (enterprise or mobile site connectivity) and backhaul cards which connect the OLT to the Wide Area Network (WAN) as shown by Fig.1. The OLT plays a role in traffic management for the PON terminations, namely the Optical Network Units (ONUs). This is done by granting their upstream (US) traffic with different priorities of access to the feeder fiber thanks to the Dynamic Bandwidth Allocation (DBA) function.

When fixed optical access is to be employed for mobile applications, some considerations need to be taken into account. Today, RAN interfaces are mostly transported by Point-to-Point (PtP) topologies with layer 2 or 3 switching nodes and independently from PON architectures. Since next generation RAN will need a massive fiber deployment to connect high-data rate 5G antenna sites, a reuse of PON architecture could thus be interesting to the operators. The optical access system is supposed to deal with different constraints in terms of latency, bitrate and reliability associated to different mobile services[8].

The Cooperative Transport Interface (CTI) (see Fig.1), recently proposed by the O-RAN alliance[9], enables cooperation between the mobile and PON schedulers. The CTI work is completed by the Cooperative Dynamic Bandwidth Allocation (co-DBA)[10], which optimizes PON traffic allocation according to the mobile applications.

However, co-DBA is not the only key element that allows the use of PON for fixed and mobile applications. Today's residential networks typically aggregate several thousands of users

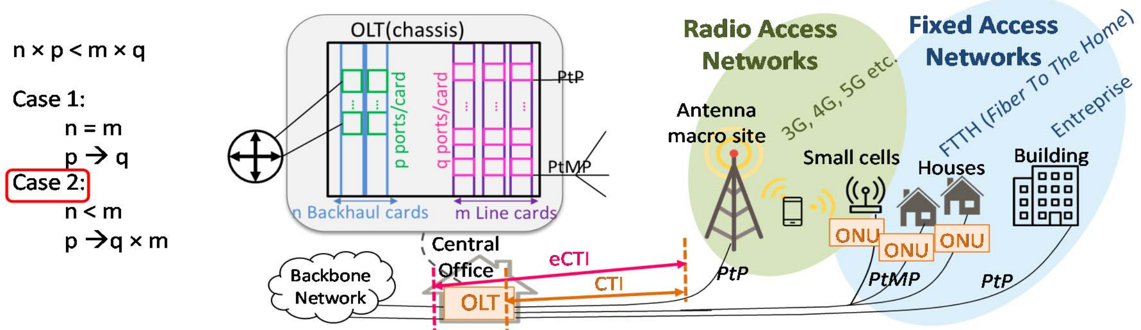

Fig. 1 : OLT architecture and PON for fixed and radio access networks

on a single OLT and several tens of PON trees. The PON deployment architecture and traffic engineering rules at the OLT depend on specific policies which vary from operator to operator. For some operators, each PON line card corresponds to a backhaul card[11] as indicated in Fig.1 "Case 1". The evident benefit of this overprovisioning deployment strategy is that there is very little traffic congestion at the OLT between the backhaul cards and the line cards. However, all backhaul ports need to be connected to a WAN node to aggregate the traffic before going to the rest of the network. The disadvantage of this approach is the higher CAPEX with respect to "Case 2" (Fig.1): in case 2, each backhaul card in the OLT chassis is connected to all line cards[12],[13]. Thus, the OLT combines and dispatches the traffic as an aggregation node between the access and backbone network.

We propose to extend the concept of CTI to the "extended-CTI" (eCTI), to also consider the backhaul OLT ports (see Fig.1). The fixed-mobile convergence required by the field deployments in the same access node requires the community to rethink the OLT not only in view of the potential US latency introduced in the PON segment, but also in taking into account the backhaul ports' segment, the management of the different interfaces and their type (PtP or PtMP), alarms and energy consumption.

Proposition

In order to realize the eCTI, we propose a whole management and adaptation of QoS from OLT backhaul ports all the way to the PON clients ONUs (OLT backplane switching + DBA) by our network controller to meet different tenants' strategies. In this paper, we focus on the joint dynamic management between the backhaul ports of an OLT and PtP / PtMP links between OLT and ONUs. As shown in Fig.2a, backhaul ports are dynamically enabled when the required downstream (DS) or US approach their maximum capacity thanks to an algorithm implemented on top of our SDN controller. When not used, those ports are disabled in order to reduce energy consumption of the access central-side equipment. This dynamic ports allocation system could potentially avoid a deployment based on overprovisioning of the OLT and also allow footprint savings in central offices allowing thus for CapEx and OpEx reductions.

We take advantage of the last advances in network technologies to disaggregate the OLT and replace it by a generic hardware, which will be more detailed in the next section. Basically, we propose to use a regular switch as the aggregation element with small-form factor pluggable OLT (SFP+/OLT) modules[14] as shown in Fig.2a. This is done to demonstrate that the mobile backhaul could intelligently reuse the PON architecture for some of its services and interfaces in the future. The proposed disaggregated OLT is controlled and managed through a REST client[16], which holds the backhaul/line-cards traffic management intelligence. The different equipment (switch and SFP+/OLT) with their different hardware specificities are equivalent to an OLT and are modeled by a unified YANG data model[15] in our controller. The generic OLT can then be managed through the network controller using the RESTConf protocol[16] (See SDN controller and application layer in Fig.2a).

Other management features are also enabled by the proposed approach, namely:

- Allow seamless selection of PtP or PtMP links according to different mobile services in a zone covered by both macro and small cells thanks to VLAN tag management[3].
- OLT link redundancy.

Experimental setup

The setup includes the following parts: infrastructure, controller mechanism and provisioning scenarios.

In the infrastructure (or physical) layer, a PtP link on the switch uses regular 10Gbps Ethernet Small Form-factor Pluggable (SFP+) modules (in purple in Fig.2b) for macro cell antenna connectivity and latency constrained mobile services. Three PtMP links, which are traditionally used for residential clients only, are supposed here to connect both fixed subscribers and small cells in one PON tree. Three miniaturized 10Gbps symmetrical single-port

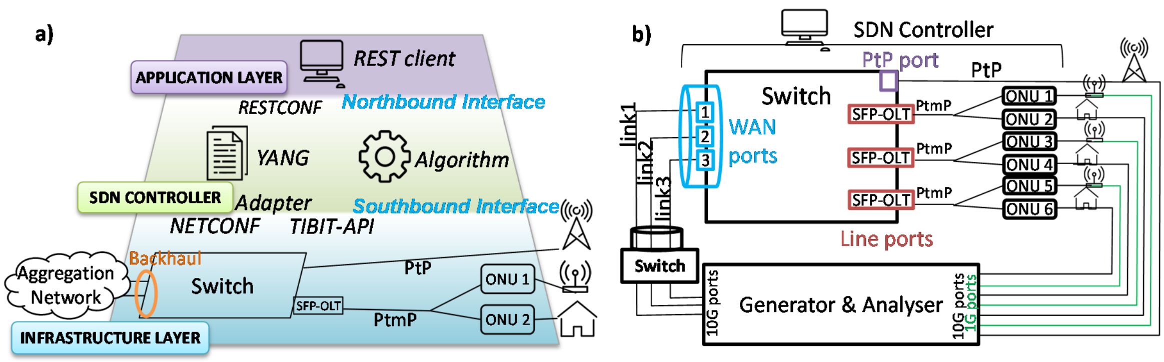

Fig. 2 : a) Proposed architecture with SDN controller b) Experimental setup

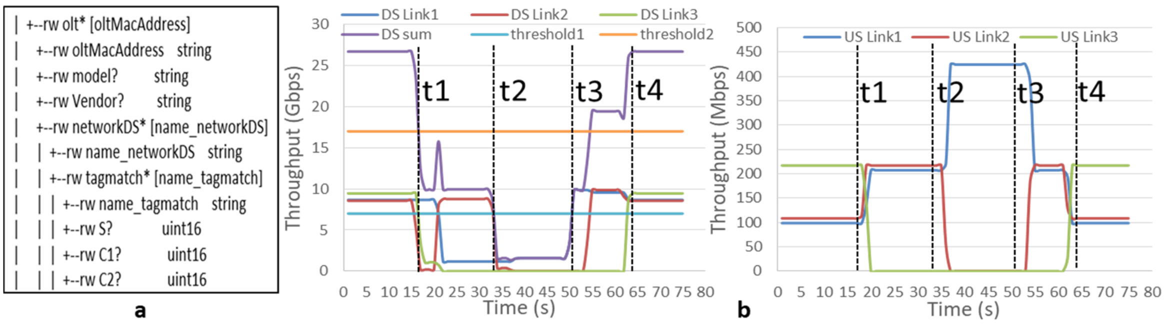

Fig. 3 : a) OLT YANG model example b) Backhaul ports' DS and US bitrate variation in time

OLTs embedded in an SFP+ [14] are inserted in the switch ports (in red in Fig.2b) with each of them connected to two ONUs. Three 10Gbps ports (in blue in Fig.2b) are available as OLT backhaul ports. The regular switch plus SFP+/OLT form a fully-fledged OLT that is more scalable than a traditional OLT chassis since it could evolve in a pay-as-you-grow strategy.

The SDN controller abstracts and controls the previously described hardware. When the application layer interrogates the current configuration on the physical layer, the SDN controller communicates on its southbound interface with the switch and SFP-OLT via Netconf protocol[15] and an Application Programming Interface (API) respectively. The adapter collects physical parameters, as traffic flow, and updates the YANG data structures. Then, on its northbound interface, the SDN controller exposes the network configuration through a programmable RESTConf interface based on the unified YANG model partially shown in Fig.3a. Any web client can then read and modify the disaggregated OLT configuration (switching and DBA parameters) through the unified and generic data model.

The dynamic management of OLT backhaul ports algorithm is triggered by the REST client in the orchestration layer on top of the SDN controller. We defined two operation modes on the algorithm: "regular" mode and "intelligent" mode. The "regular" mode corresponds to an operational regime where no energy savings in the OLT are applied. The "intelligent" mode deallocates or reallocates the backhaul ports dynamically to adapt the data plane bitrate and save energy by doing so. Thus, an optimization of backhaul ports in real time is applied to system based on the OLT-ONU traffic of the different PON optical distribution networks (ODN). Here, we set two thresholds for DS backhaul capacity. Those will trigger an action of opening or closing a 10G backhaul port of the switch. A probe, developed in our controller, interrogates the SFP+/OLTs in average each 800ms to read the total bitrate of all PtMP line ports.

Results

Fig.3b shows DS and US throughput of all backhaul ports on the switch that includes the total traffic of one PtP client and six PtMP ONUs over time. DS and US throughput of three backhaul port links over time are given in Fig.3b with four remarkable time stamps t1, 2, 3, and 4.

At the beginning, all backhaul ports are opened that have a max capacity of 30Gbps in DS and US. The total traffic of PtMP and PtP users is 27Gbps in DS and 420Mbps in US. A decrease of DS bit rate from PtMP users before t1 causes a decrease of the total DS bit rate on Fig.3b (DS sum line). When the DS sum line (purple) crosses the threshold2 (17Gbps) at t1, only two backhaul ports are required instead of three. The same phenomenon happens at t2 with threshold1 (7Gbps). Port 3 and port 2 are shutdown at t1 and t2 respectively, so that the DS and the US of Link3 and 2 decrease to zero. Meanwhile, both DS and US that went through Link3 and 2 are automatically redirected to the remaining links thanks to Link Aggregation Group (LAG) applied on all backhaul ports of the switch.

For each link shutdown, we measured that at least 0.001 kWh energy was saved in one hour. Equivalently, when the throughput exceeds the two thresholds from t3, Links2 and 3 are enabled and share the load with Link 1. At t4, all traffic is re-established with all backhaul ports reconnected. For each modification, the whole procedure of network reconfiguration takes around 5 seconds from the moment when a bit rate change above or below the threshold is detected to the moment when all needed configurations are finished.

Conclusions

We proposed an SDN-based management architecture for the entire OLT. We successfully demonstrate dynamic traffic management between PON ports and backhaul ports thanks to a probe and the algorithm implemented in our SDN controller. Next steps will consist in improving our algorithm in order to adapt the real bitrate profile.

Acknowledgements

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

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