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A proposal for an SDN-based SIEPON architecture

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A B S T R A C T

Passive Optical Network (PON) elements such as Optical Line Terminal (OLT) and Optical Network Units (ONUs) are currently managed by inflexible legacy network management systems. Software-Defined Networking (SDN) is a new networking paradigm that improves the operation and management of networks. In this paper, we propose a novel architecture, based on the SDN concept, for Ethernet Passive Optical Networks (EPON) that includes the Service Interoperability standard (SIEPON). In our proposal, the OLT is partially virtualized and some of its functionalities are allocated to the core network management system, while the OLT itself is replaced by an OpenFlow (OF) switch. A new MultiPoint MAC Control (MPMC) sublayer extension based on the OpenFlow protocol is presented. This would allow the SDN controller to manage and enhance the resource utilization, flow monitoring, bandwidth assignment, quality-of-service (QoS) guarantees, and energy management of the optical network access, to name a few possibilities. The OpenFlow switch is extended with synchronous ports to retain the time-critical nature of the EPON network. OpenFlow messages are also extended with new functionalities to implement the concept of EPON Service Paths (ESPs). Our simulation-based results demonstrate the effectiveness of the new architecture, while retaining a similar (or improved) performance in terms of delay and throughput when compared to legacy PONs.

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1. Introduction

1.1. EPON networks

Ethernet Passive Optical Networks (EPON) [1] are used in broadband access. These networks follow a tree topology with a central office located at the root node (Optical Line Terminal, OLT), a set of passive optical splitters, and the customers are connected to the leaf nodes of the tree (Optical Network Units, ONU). This architecture uses time-division multiplexing (TDM) as the medium access control (MAC) to deliver data encapsulated in Ethernet packets (following the IEEE 802.3 standard) from the ONUs to the OLT. Due to the directional properties of the optical splitters, the OLT broadcasts data to all ONUs in the downstream channel. Each ONU in the upstream channel must use a specific TDM channel to avoid collisions (since all ONUs share the transmission medium). To optimize channel utilization, the TDM channels are changed dynamically by the OLT in response to the bandwidth demands of the ONUs, using dynamic bandwidth allocation (DBA) algorithms.

The Multipoint Control Protocol (MPCP) controls the point-to-multipoint fiber network in the upstream channel. MPCP provides the signaling infrastructure to coordinate the data transmission from the ONUs to the OLT. It also performs the operations of auto-discovery, registration, bandwidth assignment and ranging calculation (round-trip-time computation) for newly added ONUs. Two types of messages are used to facilitate arbitration: GATE and REPORT. The OLT uses GATE messages to issue transmission grants, which contain the transmission start time and transmission length of the corresponding ONU; while ONUs use REPORT messages to report bandwidth requirements to the OLT.

1.2. SIEPON architecture

The IEEE 1904.1 Service Interoperability in Ethernet Passive Optical Networks (SIEPON) standard [2,3] creates an open system-level specification to provide plug-and-play interoperability, transport, and control planes in a multi-vendor EPON and GPON [4] environment. The scope of SIEPON standardization includes physical (PHY), MAC, and upper layers to support functions related to the data path: such as multicast delivery, tunnels, VLANs, and quality-of-service (QoS) management.

The architecture model of SIEPON is separated into: (1) Line OLT (L-OLT)/Line ONU (L-ONU) with functions covered by the IEEE 802.3

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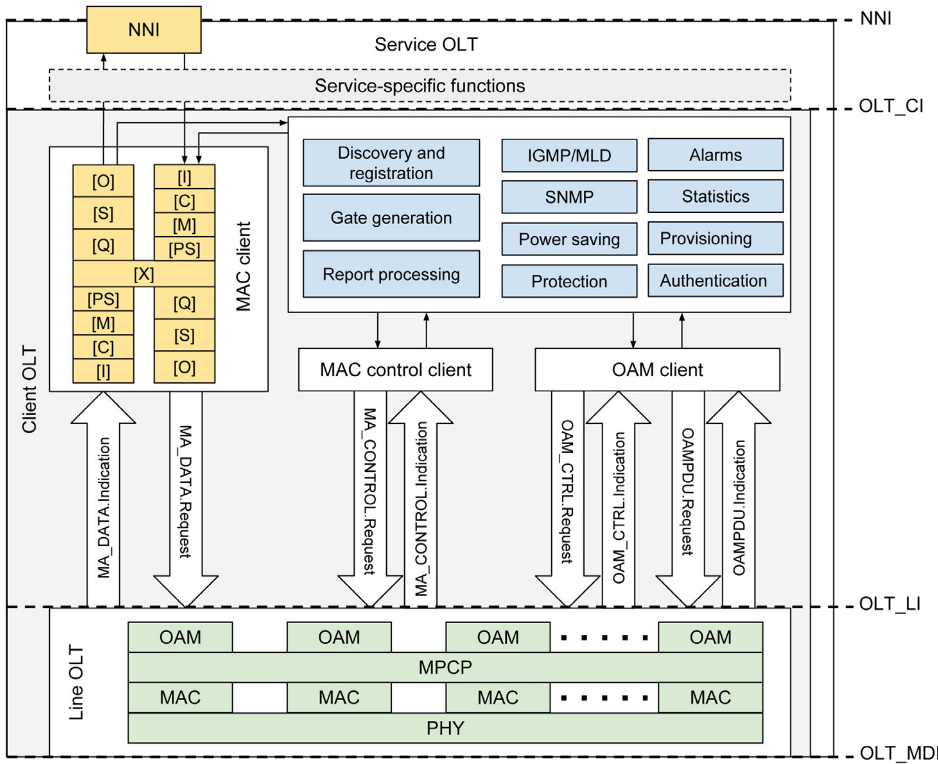

Fig. 1. OLT SIEPON architecture (based on [3]).

standards; (2) Client OLT (C-OLT)/Client ONU (C-ONU) with functions covered by the SIEPON standards; and (3) Service OLT (S-OLT)/Service ONU (S-ONU) with additional functions defined by operators or vendors. Fig. 1 shows a detailed view of the SIEPON OLT internal architecture and interfaces.

The MAC client reference model describes the connectivity and how performance may be ensured for frames traversing the client OLT or client ONU. SIEPON defines EPON service paths (ESPs) as the conceptual path followed by a frame through the functional blocks of the MAC client. The ESP traversed by a frame fully determines the connectivity-related and QoS-related treatment of the frame by the OLT or ONU. Connectivity is controlled by classification based on header fields (MAC address, IP address, VLAN tag, etc.) and by modifying the values of some fields. Performance guarantees are ensured by enforcing the QoS parameters that control the way frames are queued, prioritized, and scheduled. The basic functional blocks in ESPs that provide data forwarding in OLTs and ONUs are: Input [I]; Classifier [C]; Modifier [M]; Policer/Shaper [PS]; Cross-connect [X]; Queues [Q]; Scheduler [S]; and Output [O]; as shown in Fig. 5. Each of these blocks may include multiple independent instances that act on different traffic flows.

1.3. SDN architecture

Software Defined Networking (SDN) [5] has gained a lot of attention in recent years, because it addresses the lack of programmability in legacy networking architectures and enables easier and faster network innovation. Network administrators can manage services through the abstraction of lower level functionalities, by decoupling the system that makes decisions about where traffic is sent (the control plane) from the underlying systems that forward traffic to the selected destination (the data plane). Moving the control plane out of the data plane elements enables both planes to function independently, thus introducing many advantages such as: programmability; global optimization of network operations (such as load balancing, for example); high flexibility; and the possibility of realizing a centralized network view (and thus opening the way to the optimization of network operations).

The control plane communicates with the data plane through a southbound interface. OpenFlow (OF) was the original southbound API and remains one of the most common protocols. It allows a remote controller to specify the path followed by packets through the network of switches, using the flow concept to manage network traffic based on predefined match rules which are (statically or dynamically) adjusted by the controller. OF enables the network manager to define a set of rules to match against packet headers, and define the actions to execute on the matched packet (such as forward to a certain port, modify content or headers, or drop the packet).

1.4. State of the art of SDN applied to PONs

Several works have already addressed the topic of how to apply the SDN architecture in PON networks: however, the focus was on facilitating the deployment of SDN-based services and so service interoperability remains unexplored in detail. [6] is a good survey of the most recent efforts in the field of SDN applied to optical access networks, classifying them into the categories of control layer, infrastructure layer, application layer, and orchestration of multi-layer and multi-domain networking. We now discuss the main relevant contributions by other authors.

In [7] an SDN-based architecture for PON networks is proposed with an extension of OF to provide traffic mapping and forwarding capabilities without affecting the latency of the data link layer (L2). The authors of [8] proposed a meta-MAC algorithm for applying SDN principles to the optical access and mobile backhaul networks, which enables coordinating the medium access control algorithms of different PON technology and physical layers. [9] presents a control plane architecture for SDN-driven converged metro-access networks. The SDN controller maintains communication with the network orchestrator, and exports an abstracted network view to the controllers. In [10] a new software-defined optical access network (SDOAN) architecture is proposed. A service-aware flow scheduling strategy (SA-FS) is introduced to efficiently and flexibly allocate network bandwidth resources. An

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