TOWARDS SDN FOR OPTICAL ACCESS NETWORKS

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Abstract

The SDN (Software Defined Network) concept has made impressive progress in both enterprise and transport networks. The core idea behind SDN is the separation of control and data forwarding planes. However, the SDN concept is still in an early stage of penetrating optical access networks, especially passive optical networks. A major difficulty of SDN for PON (Passive Optical Network) is how to separate control and forwarding planes in optical access networks. In this paper we discuss the first step towards SDN for optical access networks – determining the control plane of optical access networks, and separating it from the data forwarding plane. We will first discuss SDN for Active Optical Network (AON) and then discuss SDN for PONs.

1. INTRODUCTION

The SDN concept has become a new paradigm for modern communication networks. It has made impressive progress in both enterprise and transport networks in recent years. The core idea behind the SDN is the separation of the control plane from the data forwarding plane. The SDN controller has an updated view of the entire network topology. In principle, through virtualization the SDN controller using OpenFlow or other protocols, can make routing & forwarding decisions based on dynamic multiple layers of network resource availability information. There are two major benefits of SDN. The first benefit is that SDN can more efficiently use network resources. Since the centralized SDN controller has a dynamic global view of the network topology, it can more effectively route traffic through the network. Secondly, SDN/NFV (Network Function Virtualization) can lower network CAPEX and OPEX costs by separating the control plane from the forwarding plane. That in turn makes the network forwarding elements simpler and less costly.

At conception, the SDN was initially developed for packet based enterprise networks where the control plane is separated from the data plane. A vendor agnostic interface is defined between the control and the data planes of the network forwarding elements (switch and routers), and a logically centralized SDN controller is also defined.

Transport SDN has been introduced recently as an effort to more effectively use network resources in optical transport networks. It can be viewed as the natural extension of ASON (Automatically Switched Optical Network) and ASTN (Automatically Switched Transport Optical Network), which were standardized at ITU-T in mid 2000. ASON and ASTN introduced a control plane with distributed path computation on top of the optical transport network that perfectly fits the idea of separation of control plane and data plane in SDN, and enables a holistic view of the network. Centralization of path computation is a novel idea in transport SDN. Through virtualization, the SDN controller can make routing & forwarding decisions based on multi-layer network availability information.

The passive optical networks (PON), including IEEE EPON family (EPON, 10G EPON, 100G EPON) and ITU-T GPON family (GPON, XG-PON, XGS-PON, NG-PON2), are becoming the most promising technologies for FTTH (Fiber to the Home). However the SDN concept is still in an early stage of penetrating access networks, especially passive optical networks. A major challenge of SDN for PON is how to separate the control plane and data forwarding plane. That raises the question of where the SDN boundary should extend to, OLT or ONUs. The PON control and forwarding functions, regardless of EPON family or GPON family, are vertically integrated in a mostly closed system between the OLT (Optical Line Termination) and ONUs (Optical Network Unit). In this paper we discuss the first step towards SDN for PON – the separation of control planes of optical access networks from their data-forwarding planes. We propose a novel method to separate the control plane of the PON from its data plane. We will first discuss SDN for Active Optical Network (AON), and then discuss SDN for PON.

2. CURRENT OPTICAL NETWORK ARCHITECTURES

Active Ethernet is shown in Figure 1 (a). Although Ethernet in the optical access network has point-to-multipoint fiber topology viewed from the Central Office (CO) or Head-end (HE), it is a point-to-point network from the MAC (Multiple access control) layer. Active Ethernet consists of a P2P trunk fiber from a Central-office to an Ethernet aggregation switch in the field location, and multiple P2P (Point-to-Point) fiber terminations from the Ethernet switch to the subscribers. The active Ethernet OSP infrastructure can be easily converged to PON ODN (Optical Distribution Network) by replacing the Ethernet switch in the field with a passive optical power splitter as shown in Figure 1 (b). TDM (time division multiplexing) PON is the most deployed technology for FTTH.

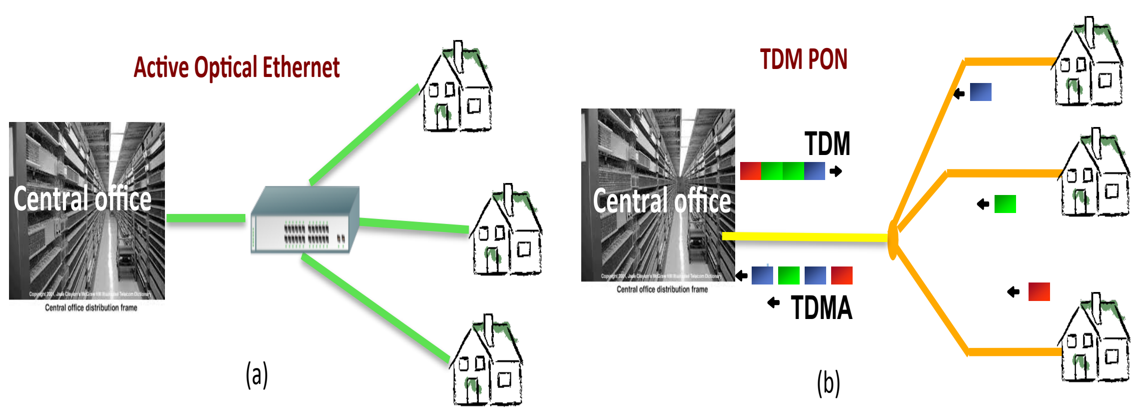

Fig. 1 Active and passive optical Networks, (a) Active optical access network and (b) Passive optical network

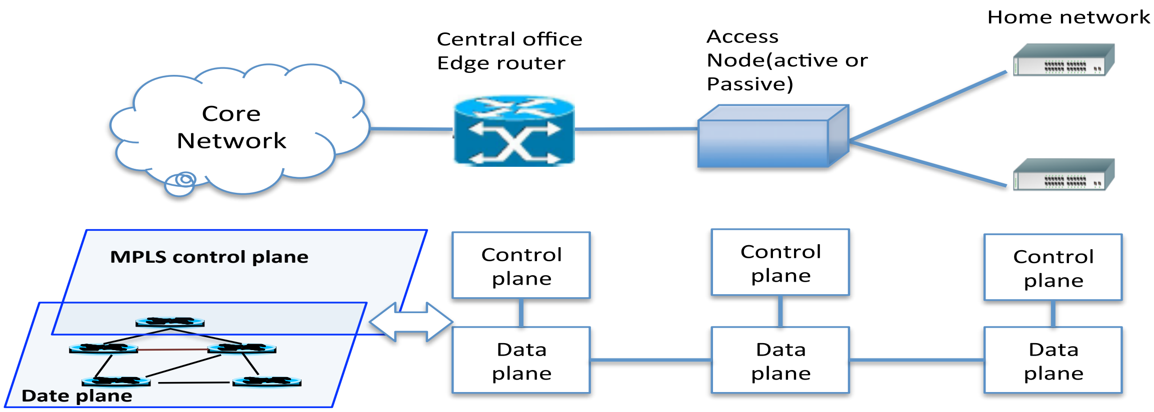

Fig. 2 Current optical access network architecture

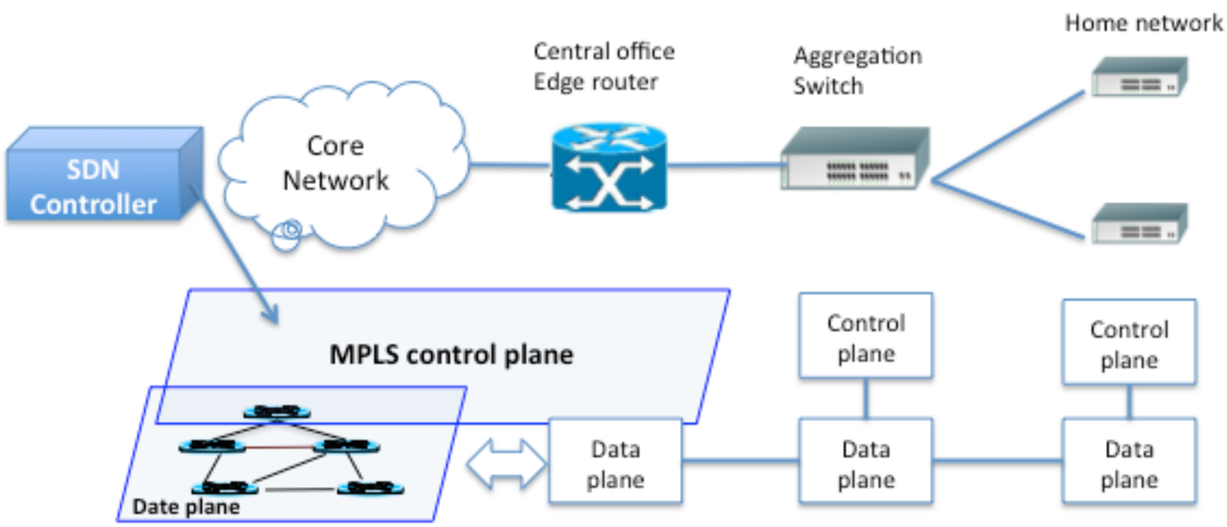

Fig. 3 Extends MPLS/GMPLS control plane to edge router

The current optical network architecture from core optical networks to optical access networks is shown in Figure 2. Most of the core optical networks already have a separated control and data plane. The control plane of the core network is built on MPLS and/or GMPLS, and the data plane runs distributed routing protocols.

The edge router at the service providers' Control-office or Head-end can be viewed as the gateway, for example, the the BNG (broadband network gateway) of the access network to core network. The control plane of BNG can be separated from its data plane using SDN concepts. Therefore, the MPLS/GMPLS control plane of the core optical network can be extended to the edge router in the central-office, as shown in Figure 3.

A SDN control plane then extends its control to the edge router, or BNG. Then the problem remaining is the separation of control and data planes in optical access networks. We will first discuss the Active Optical Network for access.

3. SEPARATE CONTROL AND DATA PLANES OF AON

The access network attached to the BNG shown in Figure 3 is active Ethernet. The IEEE 802.1D Ethernet physical layer topologies can be point-to-point or mess. Using the spending tree protocol, the Ethernet topology can be viewed as tree and branch, as shown in Figure 4. The 802.1Q introduced VLAN and the 802.1ad introduced customer VLAN (C-VID) and service provider VLAN (S-VID) concepts.

With 802.1Q and 802.1ad, Ethernet can be virtualized into VLANs. The virtualization of Ethernet provides a way to separate the control and data planes for Ethernet. Instead of discussing the control plane for forwarding based on Ethernet source and destination addresses, we can now introduce a control plane for VLANs. The multiple VLAN control protocol (802.1ak Multiple VLAN Registration Protocol-MVRP) can be used as one of the multiple VLAN control protocols for the virtualized the Ethernet data plane, as shown in Figure 5.

MVRP is a layer 2 protocol that creates and manages the VLANs. Other Multiple VLAN control protocols include Rapid Spanning Tree protocol, Shortest Path Bridge, Multiple Spanning Tree protocol, etc. With multiple VLAN control protocols as the Ethernet control plane protocols, the SDN controller can then extend its control to both MPLS control plane for core optical networks, in addition to Ethernet control plane in optical access networks.

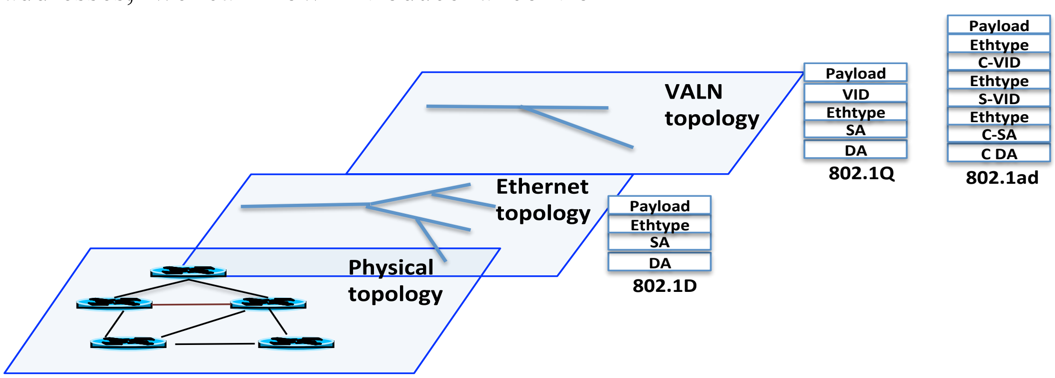

Fig. 4 Ethernet and topology and virtualization

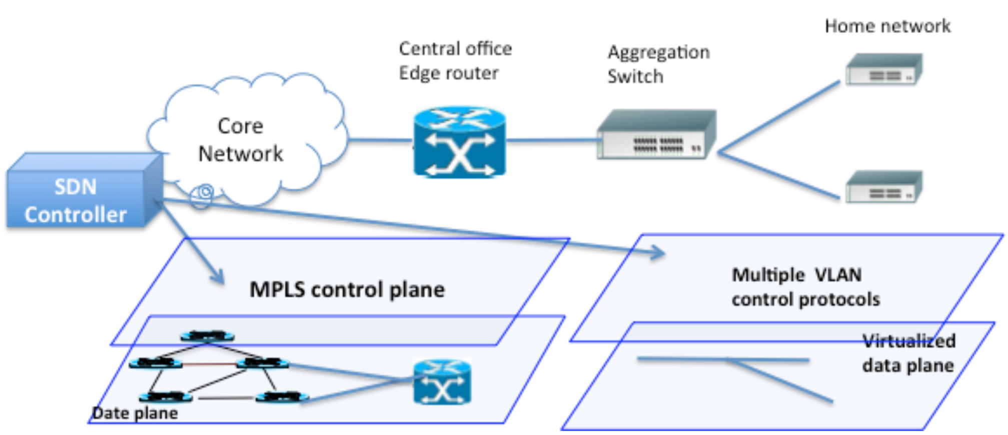

Fig. 5 Ethernet control plane and data plane

4. SDN VIEW OF CORE NETWORK AND AON

When the Ethernet control plane and data plane are separated based on VLANs as proposed, a unified SDN based control plane can be created to control both core networks and access networks. The SDN view of the entire network is shown in Figure 6. The SDN control plane interfaces with network switching and forwarding elements via southbound switch APIs to achieve the first layer of abstraction. It abstracts away the vendor specified hardware interfaces [1]. The SDN controller also has the global view of the network topology. In this global common map abstraction, the Ethernet access network portion is represented by VLAN topology.

The SDN control plane interfaces with the application layer via northbound APIs. Together, the unified SDN control plane extends automated provisioning to the Ethernet access networks and optimizes the use of the network resources across the entire network. Using OpenFlow, the flow forwarding decisions can be based on L2 to L4 information, for example any combination of MAC addresses, VLAN tags, IP addresses, TCP ports, UDP ports, etc.

5. SEPARATE CONTROL PLANE AND DATA PLANE FOR TDM PON

The access network attached to the BNG shown in Figure 3 in this case is PON. There are several literatures on SDN for TDM PON. It is proposed in literature [2] for an OpenFlow controller to replace Dynamic Bandwidth Allocation (DBA) in GPON. There are many problems to link SDN with DBA. First, DBA is a mechanism to enable more efficiently use upstream resources for the EPON family or GPON family. Although DBA controls upstream bandwidth allocation, it is hard to qualify it as a control plane protocol. It is not related to services creation. Second, DBA is a closed protocol between OLT and ONUs in a TDM PON. Take GPON for example, in state report-DBA, the ONUs report their transmission buffer depths to OLT and OLT grants upstream transmission time slots accordingly. It is not feasible for moving the DBA function to an external OpenFlow controller because of delays. Thirdly, the service creations are controlled by LLID (Logical Link identifier) in EPON family and GEM/XGEM Port-ID in GPON family. The LLID and GEM/XGEM Port-ID are also closed parameters between OLT and ONUs in EPON family and GPON family respectively. It is hard to move them to an external OpenFlow controller.

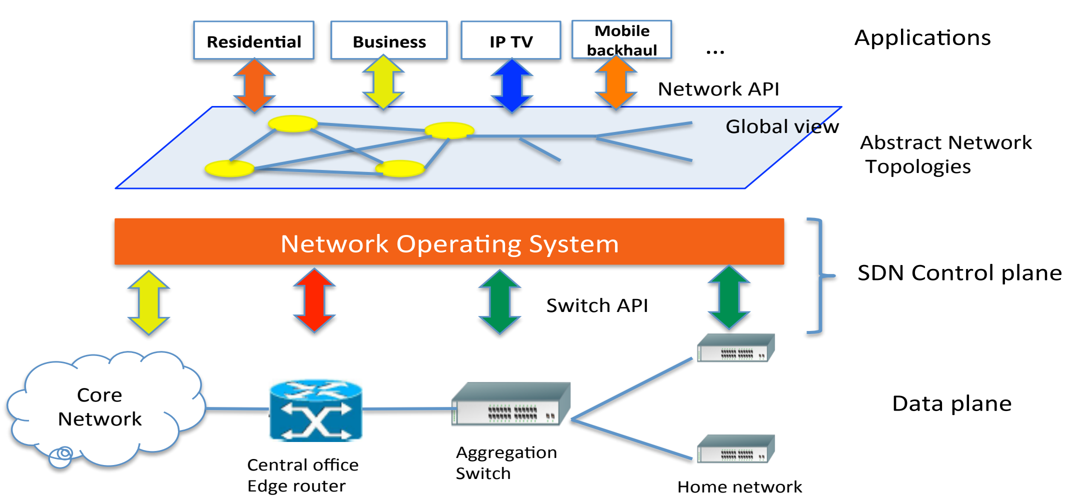

Fig. 6. SDN view of core network and active Ethernet access network

Since DBA, LLID, GEN/XGEM Port-ID are closed between OLT and ONUs in EPON family and GPON family, they should not be visible to the SDN controller. The TDM PON can be viewed as an N+1 ports distributed Ethernet switch: one port for OLT, N ports for ONUs, as shown in Figure 7. This distributed Ethernet switch can be virtualized using VLAN. For this distributed VLAN switch, the control plane and data plane can be separated as discussed in section 3 using MVRP. In this way, a common SDN controller can control both core networks and PON based access networks. Therefore the discussions in section 4 apply to PON based access networks as well.

6. CONCLUSIONS

VLANs can be used to virtualize Ethernet based optical access networks, and the control plane and data plane of active Ethernet based optical access networks can be separated using MVRP. The TDM PON based optical access network can be viewed as a distributed VLAN switch, and therefore the control plane and data plane for TDM PON can be separated using MVRP as well. As a result, a unified SDN control plane can control the optical access network and the core optical network.

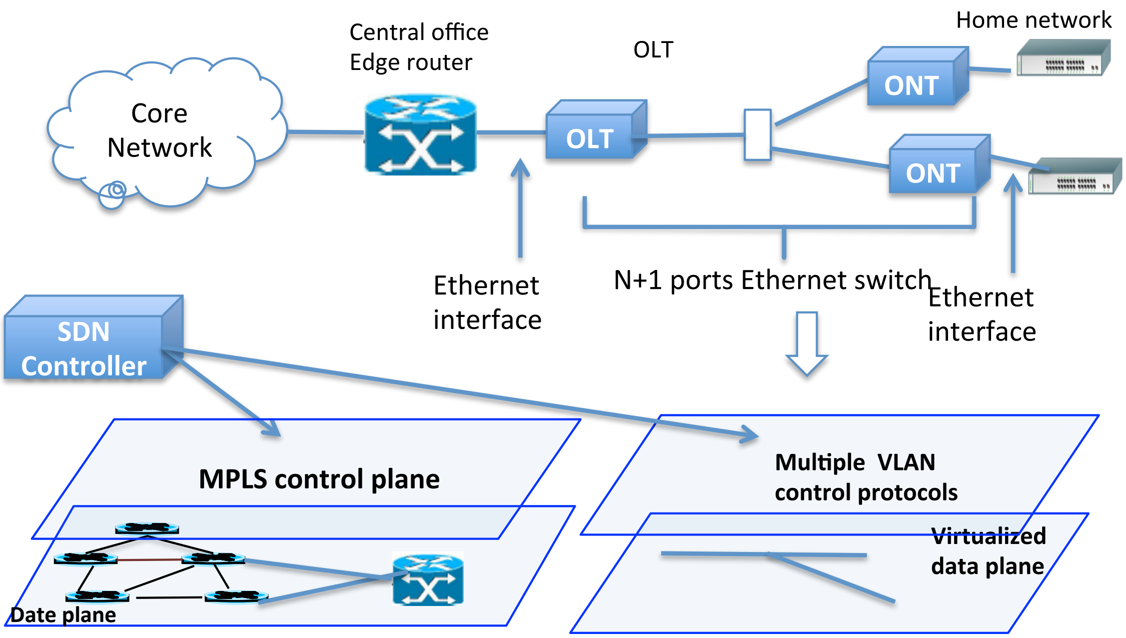

Fig. 7. Separate control plane and data for TDM PON

7. REFERENCES

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[2] Hagen Woesner, Daniel Fritzsche, "SDN and OpenFlow for Converged Access/Aggregation Networks", OTu3E.4, OFC/NFOEC Technical Digest 2013