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Service-oriented Software Defined Optical Networks for Cloud Computing

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Abstract. With the development of big data and cloud computing technology, the traditional software-defined network is facing new challenges (e.g., ubiquitous accessibility, higher bandwidth, more flexible management and greater security). This paper proposes a new service-oriented software defined optical network architecture, including a resource layer, a service abstract layer, a control layer and an application layer. We then dwell on the corresponding service providing method. Different service ID is used to identify the service a device can offer. Finally, we experimentally evaluate that proposed service providing method can be applied to transmit different services based on the service ID in the service-oriented software defined optical network.

1. Introduction

With the development of new network services (such as high-definition video push service, cloud computing, content delivery networks (CDNs), grids, distributed storage, video on demand), the optical networks are expected to have the characteristics of dynamic flexibility and service adaptability. Meanwhile, Software Defined Optical Network (SDON) and Network Function Virtualization (NFV) has been proposed to maximize the network resource utilization. SDON can be considered as extension of Software Defined Network (SDN) in optical networks. By separation of control plane from data plane, and the standard application programming interface (such as OpenFlow) between these two planes, software defined optical network (SDON) leads to a more flexible control manner for optical networking via software programming [1]. With the help of centralized controller, the SDON controller (e.g., NOX, ODL, RYU) can have a global network view and make strategies in an optimum way. The potential benefit of SDON paradigm is that SDON offers a convenient platform for experimentations of new techniques in optical network.

Network Function Virtualization (NFV) has also attracted a lot of attention in the last years [2] [3]. Traditional telecom services are highly dependent on physical topology graph and vendor specific hardware. NFV uses highly mature virtualization techniques to virtualize the entire classes of network node functions [4] [5]. In this regard, NFV aims to implement network functions that are typically deployed in specialized hardware as software instances running on commodity servers. Besides, with network virtualization, infrastructure providers can offer different virtual optical network (VON) for tenants who have a variety of different demands for physical resources, such as different physical interfaces, bandwidth requirements etc.

The current expansion of cloud computing follows mainly from several recent IT trends, including the “dot-com boom,” which started an explosion of interest in outsourcing IT services; the popularity, maturity, and scalability of the present Internet; and the appearance of large data centers developed by companies such as Google, Amazon, and Microsoft [6]. There are three major types of services



provided in cloud computing systems: Infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS). However, a transport network is an indispensable element of the cloud computing model since it provides connectivity between distributed computing resources. Current transport networks are not efficiently designed to meet the needs of cloud environments for the optical network is still treated as a blind pipe without considering the various cloud computing requirements. Besides that, the separated ownerships for cloud facilities and backbone networks also raise the difficulties of deep cooperation between the two parts.

However, in order to cope with this problem, we can focus on two aspects. First, combining the SDON and NFV technologies to enhance dynamic flexibility. As mentioned above, SDON paradigm offers a unified control plane but it faces the problem of dedicated hardware without a standardized northbound interface. NFV can improve resource utilization by partitioning and abstracting the network infrastructure but it should also be noted that various virtualization network functions may lead to scheduling difficulties [7]. Applied to this context, the combining of SDON and NFV can highly improve the network flexibility in the global network view. With the unified control plane, the virtualization network functions scheduling problem should be processed in the most optimal way. Second, abstract services from the network nodes to extend service adaptability. Different nodes can provide different services. For example, the all-optical switches may have low latency while the flexi-grid optical network devices may have the potential ability to realize the required capacity on demand.

The rest of this paper is organized as follows: Section II presents the proposed service-oriented software defined optical network architecture. Then a service function variable optical node and the service providing method are described in Section III. Section IV is the experimental demonstrate. Finally, Section V concludes the work.

2. Service-oriented Software Defined Optical Networks architecture

Protocol independent transmission method in SDON is proposed in our former work [8]. Based on this method, optical layer functions like Power Equalizer (PE), Dispersion Compensator (DC) and Multicast can be defined as a network services which can be call by upper layers. A service-oriented software defined optical network architecture is proposed based on various optical networks, as shown in Figure. 1. The legacy DWDM and flexi-grid optical network can be regard as transparent network, while the optical consists of O/E/O nodes can be regard as opaque network. In order to realize the service defined optical network, four layers are presented to realize the required function.

The service-oriented software defined optical network architecture include a resource layer, a service abstract layer, a control layer and an application layer. The resource layer consists of all the optical network resources and each optical device logically associated with its own OpenFlow Agent. However, different devices can provide different services. For example, the basic service which the devices in transparent optical network can offer is all-optical switching. But in opaque optical network, with the help of O/E/O convert, the basic service function is the 3R (Reamplification, Reshaping and Retiming). All the information of optical devices will be collected to the service abstract layer through the extended OpenFlow protocol.

Control layer provides different service-oriented virtual optical networks according to the requests from the application layer. The request can be denoted by $R=(s,d,w,q)$, where s is the source node and d is the destination node for the request. w is the bandwidth request by R and q is the service ID. First, according to the service ID, take the $q=2$ for example, the control layer selects nodes from the all-optical switching pool to generate service-oriented virtual optical network. Second, the control layer checks whether the s and d can be mapped into the virtual optical network. Finally, if mapping successful, a path will be calculated for the request based on the w .

The top of the architecture is an application layer. The application layer consists of various third-party applications including graphical user interface (GUI). Cloud computing services requests can be triggered via the Restful API.

The service abstract layer bridges the control layer and resource layer. This layer abstract services from optical nodes via the extended OpenFlow protocol messages. We have defined some services such as all-optical switching, asymmetric spectrum assignment (ASA), low latency, quality of service (QoS),

which is shown in Table I. Thus, according to the service ID, the services a node can offer will be collected and a lot of resource pools can be built for the control layer

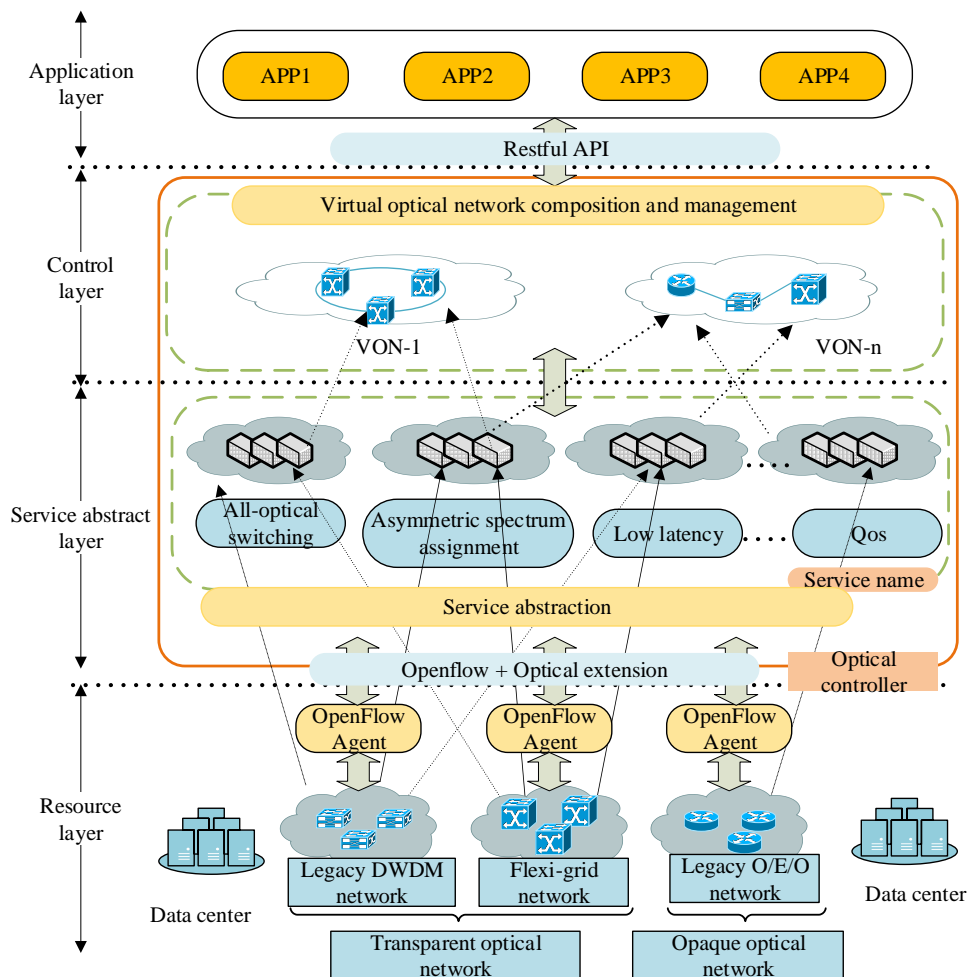


Figure 1 Service-oriented Software Defined Optical Networks architecture

3. Service Variable Optical Node And Service Providing Method

As mentioned above, in service-oriented software defined optical network architecture, it is very important to abstract the services from the hardware. In this section, we designed a service variable optical node (SVON) to provide various services. Its implementation structure is shown in Figure. 2. However, the SVON is composed of three micro-electro-mechanical systems (MEMSs) primarily. Among these MEMSs, various devices are deployed, such as EDFA, DC and optical coupler. As shown in Figure 2, the SVON can provide services function such as PE, DC and Multicast. Only one service can be enabled at a time. A proprietary OVS has been designed for this SVON. In order to realize the service-oriented software defined optical network, a new OFP_SERVICE_MOD message is designed to control devices based on service ID, which is shown in Figure.3. The Service ID is used to identify the service and the Command type will be set to $0x0000ffff$ if the service is requested. Spectrum slot ID is designed for the flexi-grid node.

According to the service ID, the SVON can provide different services. For example, when service ID turns to 4, route 4 will be select and route 2 will be choose if all-optical switching is needed. In our early study [9], we have proved that the PE service is an effective solution for adaptive adjustment of transmission performance on optical path.

Table 1 Service Id And Service Name

Service ID	Service
0	None
1	PE without O/E/O
2	All-optical
3	DC
4	Multicast
5	ASA
6	PE with O/E/O
7	Low latency
8	Low BER (QoS)

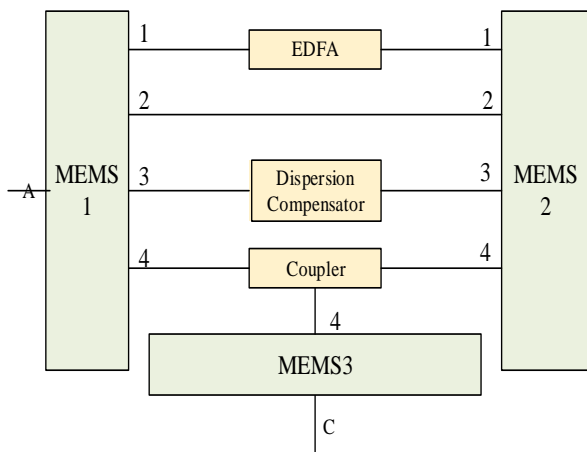


Figure 2 The structure of SVON

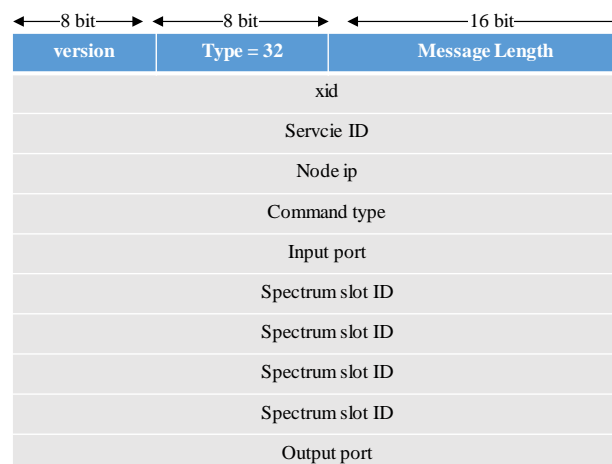


Figure 3 OFF_SERVICE_MOD message

4. Experimental Setup And Results

The experiment testbed is shown in Figure. 4. We construct the optical network based on two OpenFlow-enabled ROADMs (OF-ROADMs), a SVON node, a OpenFlow-enabled OXC and a OpenFlow switch (OF-switch). These nodes offer two paths for traffics. Path1 go through OF-ROADM1~OF-switch~OF-ROADM2 and path2 go through OF-ROADM1~SVON~OF-OXC~OF-ROADM2. All the nodes have the all-optical switching ability except the OF-switch. All the devices are controlled by ODL through OVSs. A High-definition (HD) camera is used to provide the serial digital interface (SDI) high-definition video.

The internet control message protocol (ICMP) is simulated by ping packages between PC1 and PC2 and it is the traffic 1. The carrying wavelength is 1550.67nm. HD camera is used to provide supervisory signal with centre wavelength 1553, 17 nm and it is the traffic 2. However, if a traffic does not apply for any service, the traffic will go through the path1 for path1 is shorter than path2. As traffic2 is a SDI signal without compressing, the traffic cannot pass the OF-switch and the terminal TV cannot receive any signal. Therefore, we set $q=2$ for traffic2. It is means that the all-optical switching service is required and the experiment result is show in Figure. 4, Figure. 5 and Figure. 6.

From the experiment result, we observe that only ICMP signal go through path1 and the SVON offer the all-optical switch service successful, which is shown in Figure. 4. As the SVON is very special and then it does not have the ability to dynamically adjust the bandwidth, only three fields (Service ID, Node ip, Command type) are needed. Figure. 5 shows OFF_SERVICE_MOD message issued by the controller and Figure. 6 shows that both the traffic1 and traffic 2 are fully accepted.

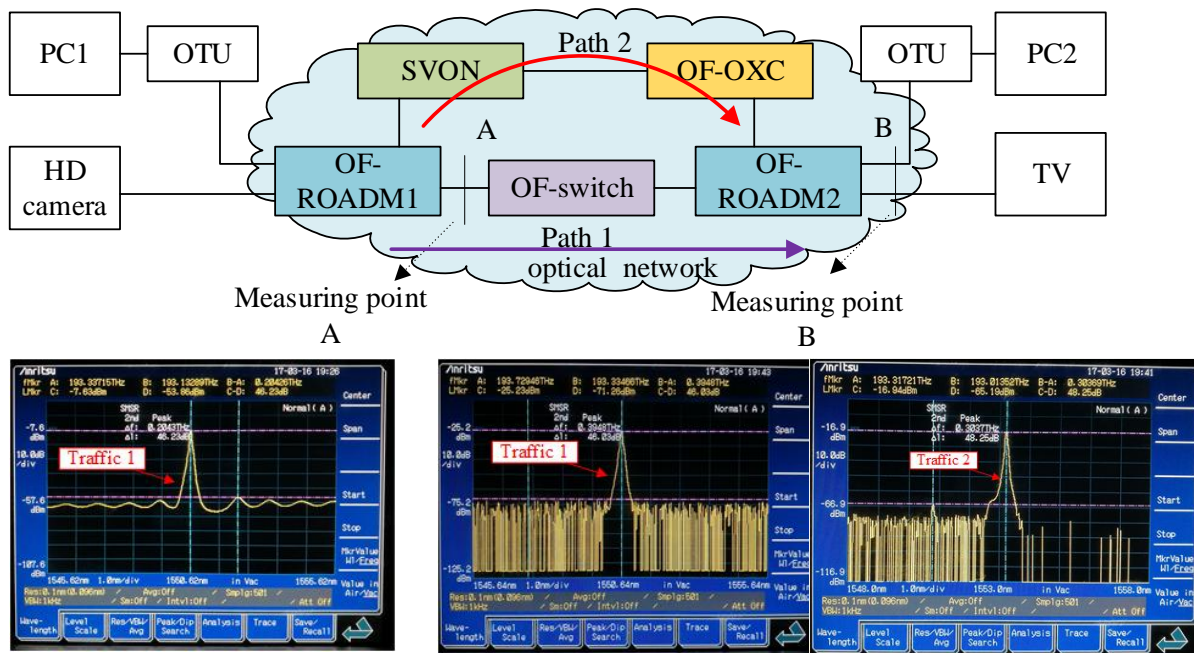


Figure 4 Experiment network architecture

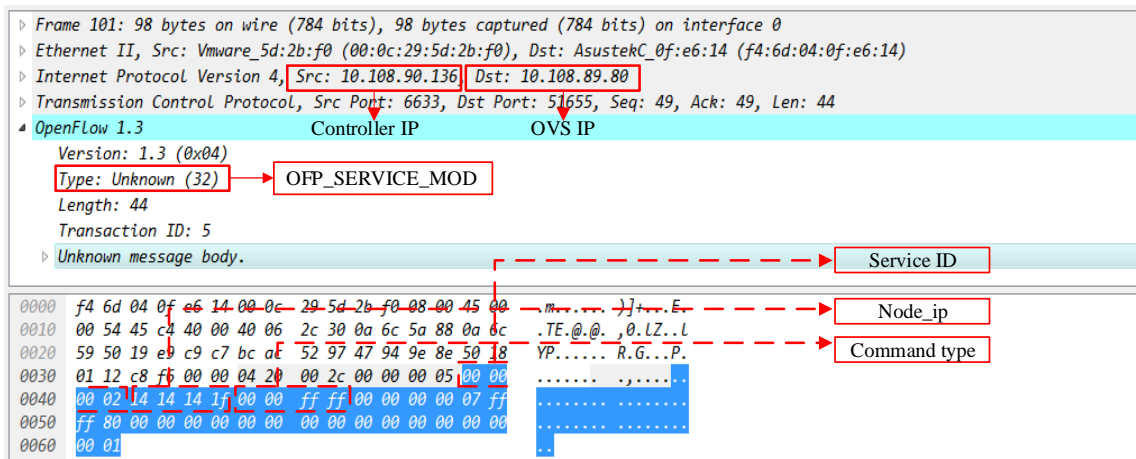


Figure 5 The “OFP_SERVICE_MOD” message issued by the controller and captured by Wireshark

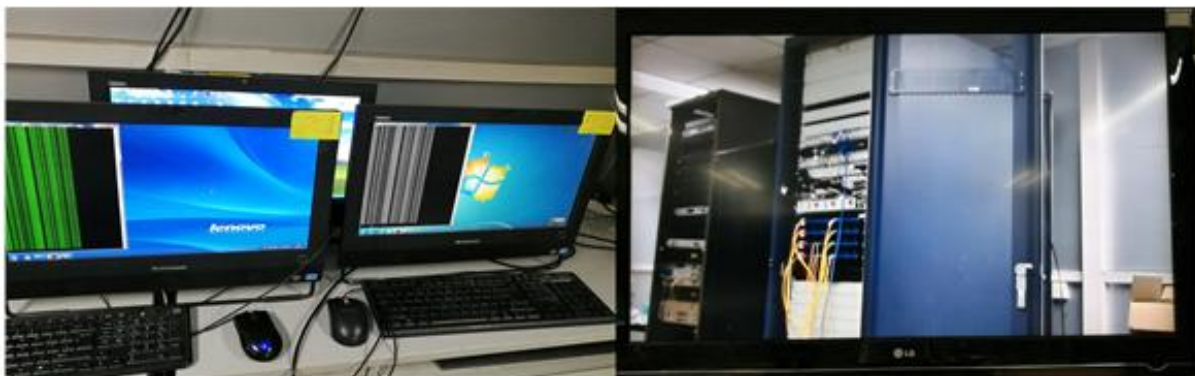


Figure 6 Transmission effect of traffic1 (left) and traffic2 (right)

5. Conclusions

In this paper, we have proposed a service-oriented software defined optical network architecture by utilizing combination of SDN and NFV technologies. The proposed architecture and technologies were experimentally validated and demonstrated. The service-oriented SDON provide a method to enhance the dynamic flexibility and service adaptability. Some optical layer functions such as PE, DC and Multicast are defined as services which can be called by SDN controllers, and as a result, clouding service with different physical interfaces can be adapted directly into optical networks, and less O/E/O transitions are needed which can reduce the network delay and cost shapely.

6. Acknowledgment

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7. References

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