Design of Control Plane Architecture Based on Cloud Platform and Experimental Network Demonstration for Multi-domain SDON

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Abstract. With the features of network virtualization and resource programming, Software Defined Optical Network (SDON) is considered as the future development trend of optical network, provisioning a more flexible, efficient and open network function, supporting intracconnection and interconnection of data centers. Meanwhile cloud platform can provide powerful computing, storage and management capabilities. In this paper, with the coordination of SDON and cloud platform, a multi-domain SDON architecture based on cloud control plane has been proposed, which is composed of data centers with database (DB), path computation element (PCE), SDON controller and orchestrator. In addition, the structure of the multi-domain SDON orchestrator and OpenFlow-enabled optical node are proposed to realize the combination of centralized and distributed effective management and control platform. Finally, the functional verification and demonstration are performed through our optical experiment network.

1. Introduction

Due to the emergence and rapid development of the big data, the cloud computing, the internet of things and video surveillance and other services, the more flexible and efficient optical network interconnection between these remote and geographically distributed data centers are in demand to carry these massive amounts of data, and therefore SDON with centralized management and control arises as the times require [1]. With the dynamic adaptive ability to support high burst traffic, the flexible scalability of network and the elastic adjustment ability of bandwidth, SDON leads the future development direction of optical network [2, 3]. However, the scalability of SDON is limited by the computing and storage capacity of a single SDON controller and the independent path computing element and traffic engineering database are indispensable to assist in the implementation of the control functions, in which case the deployment and operation of the control node become complex. Moreover, the frequent and massive traffic between distributed controllers are increasing, which will result in the burden of network bandwidth.

With converged infrastructure and shared services, cloud computing and cloud storage not only become an important part of information technology, but also are an effective solution to network demands [4]. Through services of cloud, subscribers can access resources on demand from shared infrastructure, such as computing, storage, and networking [5].
The combination of traditional SDON and SDON-supported cloud computing and cloud storage makes full use of powerful computing, management, storage and transaction processing ability in cloud platform, so that the equivalence and coordination of distinct controllers as well as the intraconnection and interconnection of data centers, can be implemented. In addition, the collaborative management, control and path computing ability of SDON are enhanced further, and the interoperability between multi-domain heterogeneous networks is improved, which achieves a high degree of unity of the application, management and control, simplifies the complexity of network facilities and reduces the cost of operation and maintenance. Consequently, a multi-domain SDON optical network architecture based on cloud platform and the centralized and distributed control mechanism are proposed in this paper, the signaling process is detailed, and the functional verification and demonstration are performed in our experimental network.

2. SDON architecture based on cloud control platform

The SDON architecture based on Cloud Control Platform (CCP) is shown in Figure 1, which is the coordination of traditional SDON and cloud platform. The model of SDON based on CCP is divided into three planes, namely, Infrastructure Plane, Cloud Control Plane and Application Plane. The difference with the traditional SDON structure is that the orchestrator and cloud services are added to the cloud control plane, and geographically distributed controllers are gathered in data centers of cloud service. The hierarchical structure of control plane and distributed peer-to-peer architecture of cloud service data centers are reserved to achieve highly integrated distribution and concentration as well as effective management and control. The concentrated orchestrator and controllers in data centers improve the efficiency of data processing and network management and control, while the distributed architecture of the cloud platform data centers also provides a great scalability for the network.

From the vertical perspective, the centralized management and control structure can achieve the local and global optimal control. And from the horizontal point of view, the distributed management and control can overcome the disadvantages of the heavy task, low efficiency, complicated management system and database, which is caused by the centralized management and control. The hierarchical centralized control is realized in the CCP architecture. When a local controller has an enough capability to handle the request effectively, the higher level controller or orchestrator will not interfere. The higher level controller or orchestrator deal well with multi-domain requests only if the management and control task is not borne by a local controller. Meanwhile, hierarchical management systems play different roles to coordinate effectively. In this way, the scale of global management and control database, the time of enquiring and the amount of traffic management information are decreased significantly. These functions can be easily implemented by the efficient computing, management and storage of the cloud platform. This structure is suitable for a large scale, heterogeneous network interconnection, and geographically distributed network.

2.1. Three planes in the CCP architecture

The function of the CCP architecture is realized by three planes. The Infrastructure Plane is a layer in which all types of devices and resources from different vendors are interconnected. The optical network is mainly composed of optical nodes in geographically distributed multi-domains. Optical nodes include OF-switches, optical cross-connectors (OXC) and optical add/drop multiplexers (OADMs), etc. Each domain, which is divided by different geographical location or other characteristics, is controlled by a single SDON controller. The difference between controllers brings inconvenience for the unified control over multi-domain optical networks. Therefore, the multi-domain SDON orchestrator is introduced into the Cloud Control Plane to solve the problems caused by the difference between controllers.
In the Cloud Control Plane, the data center is the component element. Data centers are capable of providing basic functions, such as transmission, computing and storage systems. The data center in Cloud Control Plane provides powerful computing capacity and data storage, which solves the capability limit of single control node. PCEs and DBs are corresponding to an individual controller, to handle the requests in respective domains. Meanwhile, parent PCE and parent DB are introduced into the Cloud Control Plane corresponding to the orchestrator, to deal with requests across multi-domain. In a data center of Cloud Control Plane, the controllers from distributed domains are gathered under the control of an orchestrator, which simplifies the complexity of updating and deployment, and reduces the cost of operation and maintenance. In addition, an orchestrator is employed to coordinate different controllers and deal with different protocols, and responsible for the management of global information and resources. The interactive communication between orchestrators from data centers can be implemented by application programming interfaces (APIs). Meanwhile, the information of data center can be exposed to authorized users and other data centers in the form of API.

The Application Plane consists of a plenty of vendors and third-party applications. All applications are supposed to interact with the Cloud Control Plane through the northbound interface (NBI). The graphical user interface (GUI) as an application provides users with a more personalized service experience, while the network management system is also recommended to communicate with the Cloud Control Plane through northbound interfaces, which reflects the openness of the CCP architecture.

**Figure 1.** Cloud Control Platform architecture.
2.2. Signaling process in the CCP architecture

Figure 2 illustrates the signaling process of two kinds of operation from the Application Plane, which are the requests sent through GET method and POST method of the REST API, respectively. In Scenario 1, Application Plane sends a GET request to the Cloud Control Plane to obtain information, in which case the Infrastructure Plane is not involved. The process is as follows: the app of client in the Application Plane sends out the request to the Cloud Control Plane through the NBI; the orchestrator in the Cloud Control Plane updates information from the controllers and the PCE/DB; the collected information returns to the app through the NBI. In Scenario 2, the Application Plane sends a POST request through transmitting a request of traffic to the Cloud Control Plane, which carries the information of source and destination nodes for traffic requests, and changes the flow table information of optical nodes in the Infrastructure Plane. The process is as follows: the app sends traffic information to the Cloud Control Plane orchestrator; the orchestrator asks PCE/DB for the path information according to the source and destination of the traffic, then sends requests respectively to the relevant controllers; the controllers change the flow tables of the switch in the Infrastructure Plane with the OpenFlow protocol; after receiving the responds of controllers, the orchestrator replies to the app in the Application Plane.

3. Experimental demonstration of CCP architecture

The function of the proposed architecture has been validated in our SDON experimental network. The overall structure is shown in Figure 3(a). The Application Plane interacts with the Cloud Control Plane through the NBI, while the Infrastructure Plane is controlled by the Cloud Control Plane through the southbound interface (SBI). More detail of the Cloud Control Plane and the Infrastructure Plane is shown in Figure 3(b). OpenStack cloud platform of Juno version is deployed in the IBM Linux server with Intel Xeon E5-2620v2 and 32Gbits RAM as a simplified version of data center. OpenStack platform provides computing nodes, storage nodes and virtual machines (VM), which run as the orchestrator and two SDON controllers (e.g., Floodlight and OpenDaylight). Two controllers are connected to the optical nodes from two respective domains. The structure of optical node is detailed in Figure 3(c). The OpenFlow Agent in the optical node contains Open vSwitch (OVS), which communicate with the controller through OpenFlow protocol. The Protocol Adaptor translates the orders from the OVS into the protocols that can be recognized by the optical devices to response to the instruction from controllers.
OpenFlow Protocol
SNMP/TL1/
user-defined
Optical Node

Figure 3. Experimental network scenario
(a) Abstract architecture. (b) Cloud Control Plane and Infrastructure Plane. (c) Optical node structure.

Figure 4. Experiment process. (a) Topology information from the orchestrator in Postman plug-in. (b) HTTP packet in Wireshark. (c) FLOW_MOD packet in Wireshark. (d) Ping process between hosts.
In the process of our experiment, the request of the topology information is sent to the Cloud Control Plane by the client. The topology information provided by the orchestrator is returned to client in the form of JSON. Figure 4(a) presents the HTTP request and the JSON information in the REST API plug-in, named Postman. The orchestrator of Cloud Control Plane enquires the PCE/DB for the solution to the traffic, and then, sends path requests to controllers respectively, and finally returns the replies to the client in terms of controllers. A request captured by Wireshark from the orchestrator to controller 1 through its NBI is shown in Figure 4(b). Figure 4(c) indicates that the controller sends a FLOW_MOD packet in OpenFlow protocol to the OVS of optical node. Finally, in Figure 4(d), the host receives the ping replies from another host in the Infrastructure Plane, which validates the success of the client request in the CCP architecture.

4. Conclusion
SDON represents the future development direction of the optical network, with dynamic adaptive ability to support high burst traffic, flexible scalability of the network and elastic adjustment ability of bandwidth. Cloud platform can provide powerful computing, storage and management capabilities. In this paper, a new type of SDON control plane architecture based on the coordination of cloud platform and traditional SDON is proposed, the structure of the multi-domain SDON orchestrator and OpenFlow-enabled optical node are presented, the efficient management and control in hierarchical centralized structure are realized, and the feasibility and availability of optical network are validated in our experimental network.

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