Field Trial of OTN Flexible Control Scheme and Protocol for Cloud Service

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Abstract *This paper proposes new flexible control scheme and protocols based on OTN network. The field trial results show that the technical solution proposed enables OTN to fast respond, flexibly carry end-to-end cloud services, and effectively improve the service quality, reduce the service delay. ©2023 The Author(s)*

Introduction

With the continuous development of services, industries such as government, finance, and education gradually migrate their production systems and core systems to cloud resource pools, which brings a large number of end users' requirements for cloud access [1]. As the requirements of cloud access services on the network are increasing, the basic network needs to have features such as low latency, high reliability, high security, and diversified bandwidth granularities. In addition, the basic network needs to have a flexible scheduling capability, so as to meet the requirements of users for flexibly accessing cloud [2, 3].

Generally, most users access cloud resources over IP networks. The IP network has flexible routing and scheduling capabilities, due to the statistical multiplexing mechanism, it is hard to meet the low latency and high reliability requirements of some high-level users.

Users who have high requirements on network latency, reliability, and security usually prefer OTN networks to carry services [4, 5]. The OTN network features low latency, high reliability, and hard isolation, and can provide diversified connection granularity options. The OTN network adopts centralized control, and no Layer 2/Layer 3 routing protocol (such as OSPF) runs between nodes. Therefore, one client-side physical port or VLAN port is mapped to one OTN connection. Route selection and scheduling based on Layer 2/Layer 3 address are not supported. So that OTN networks are usually used to provide point-to-point private lines. To enable a single user to access multiple cloud resources through OTN network, the CE (Customer Edge) must connect to the OTN device through multiple ports and lease multiple private lines to different directions as shown in Fig. 1 (a). This requires the CE to occupy a large number of physical or VLAN ports, and the cost is too high, it is difficult to apply on a large scale. It requires OTN to have flexible control capabilities to meet the connection scheduling requirements [6,7].

This paper proposes new flexible control mechanism and protocols based on the OTN. By cooperating with the centralized controller and the new control protocols, the OTN network can sense and identify client-side service information, schedule resources to match service requirements, supports automatic connection creation and service mapping. OTN resources can be flexibly scheduled based on information such as destination address of client-side service, and routing protocols are not required to run in the OTN network. Services are carried by using end-to-end OTN connections, and Layer 2 and

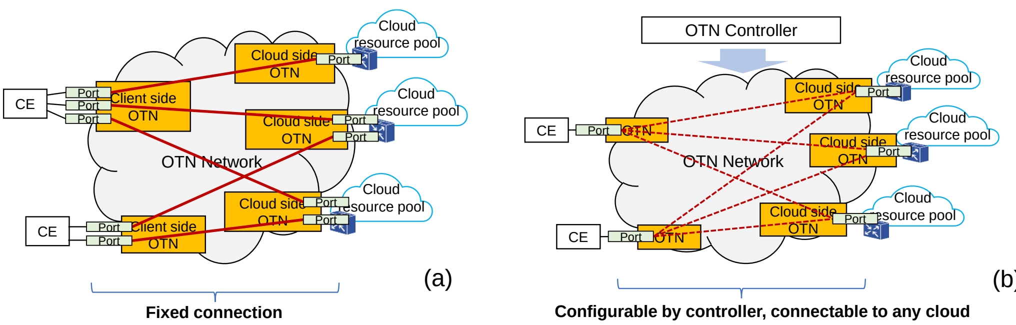

Fig. 1: Networking architecture of OTN carrying cloud services (a) in traditional OTN situation CE connects to the OTN device through multiple ports, (b) by the proposed mechanism, services from one port can be flexible dispatched according to the destination address.

Layer 3 switching is not required on intermediate OTN nodes. This keeps the hard pipe features of the OTN network and provides flexible E2E quality cloud access services for high-level users as shown in Fig. 1 (b).

Technical solution

Based on the OTN centralized and distributed cooperative control architecture, this paper proposes a service oriented OTN control scheme, and protocols named OSP (Optical Service Protocols). The OSP protocols enable efficient interaction between OTN devices and centralized controller, or between different OTN devices, enabling client-side service address awareness, quick connection creation, and flexible service mapping.

The core protocol of OSP is constructed based on the PCEP (Path Computation Element Communication Protocol) protocol [8]. The PCEP protocol includes PCE and PCC. The PCE can be deployed on a controller or a core node on the network. In this document, the PCE is deployed on a controller and the PCC is deployed on OTN nodes by default.

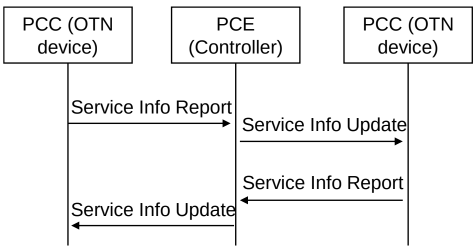

Fig. 2: OSP protocol mechanism.

Based on the original PCEP messages, two PCEP message types are extended: Service Info Report (SIR) and Service Info Update (SIU). After the PCEP session is established, the PCC (OTN device) and the PCE (controller) may exchange messages, that is, the OTN device sends an SIR message to the controller, and the controller sends a SIU message to the OTN device as shown in Fig. 2.

Main content of the SIR message are as follows:

- Client-side service information including VLAN, source or destination IP address, source or destination MAC address,
- OTN UNI (User-network Interface) port information, where the service come from.

The SIR message may report OTN client-side service information in real time, so that the controller obtains service address connected to UNI ports of each node in the OTN network and forms a client-side address table (CSAT). In addition, based on the client-side service destination address reported by the SIR message, the controller can query the client-side address table to determine the destination node of service, and select or create a corresponding end-to-end OTN connection.

Tab. 1: service mapping table.

Service matching items	Network matching item
SVLAN	OTN connection ID
CVLAN	
Source MAC	
Destination MAC	
Source IP	
Destination IP	

To achieve centralized address learning, the SIU message is sent from controller to the OTN device to create or set the service mapping table (SMT) which is shown in Tab. 1, service can be matched to OTN connection through one or multiple items. The SMT identifies the mapping relationship between a client-side service and an OTN connection, so as to transmit services to different directions through corresponding OTN connections. Fig. 3 (a) shows the centralized address learning mechanism.

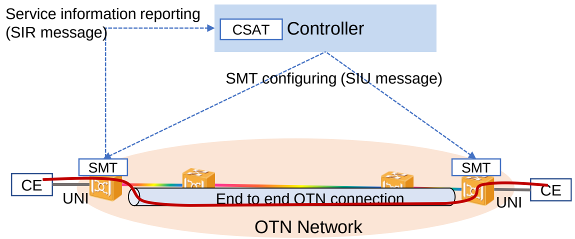

Fig. 3: Centralized address learning mechanism.

Application effect

In the field trial, OTN devices supporting the OSP protocols, and a centralized controller are deployed. Two VR servers are deployed at machine room C and D. VR terminals converged by a router access the CPE (Customer Premise Equipment) OTN through one UNI port at machine room A to run VR games, as shown in Fig. 4. IP addresses are used to identify servers and terminals.

The CSAT is initialized by SIR messages. When a user initiates an application request through a VR terminal, the OTN device detects the client-side service, obtains the source and destination addresses of the service, and reports the service address to the controller through SIR message. Based on the service destination address, the controller queries CSAT to determines the A, Z ends of the service, calculates routes and creates the end-to-end OTN connection. Then controller delivers SMT to the CPE OTN device through SIU message. Figure 5 shows the OSP protocols messages interaction process and implementation.

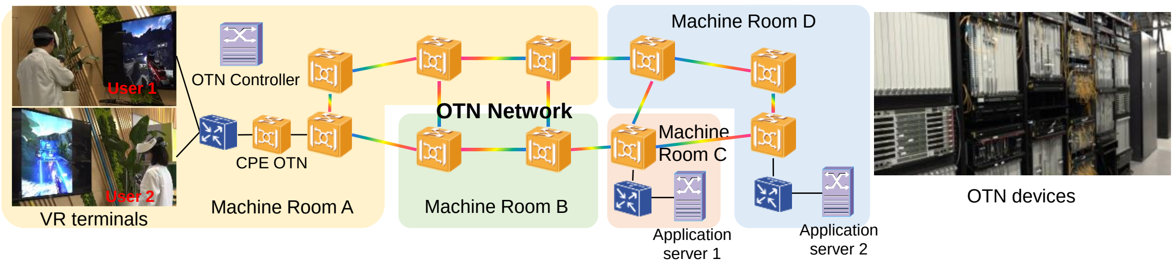

Fig. 4: Experiment setup of OTN flexible control scheme and protocol for cloud service.

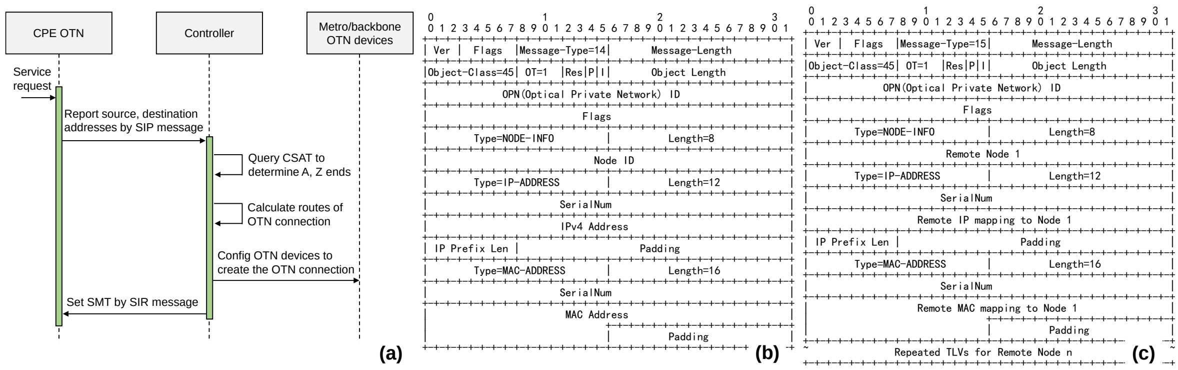

Fig. 5: OSP protocol messages interaction process and implementation (a) interaction process, (b) TLV format of SIP message, (c) TLV format of SIR message.

Through VR game applications, the scheme and protocols proposed and the effect of OTN network end-to-end service bearing are verified. The two VR terminals can access different services respectively through the same OTN port.

Tab. 2 lists the service response time (VR game users go online) accessing the two application servers respectively.

Tab. 2: service response time.

Service	Server 1		Server 2	
	User 1	User 2	User 1	User 2
response time	4 s	1 s	5 s	1.5 s

Compared with the traditional hop-by-hop packet switching solution, E2E OTN network can effectively improves user experience. Tab. 3 shows the E2E service delay and packet loss ratio of OTN E2E solution, hop-by-hop packet switching solution with light network load, and hop-by-hop packet switching solution with heavily loaded (80% traffic).

Tab. 3: Service quality (average traffic of service: 130 Mbit/s).

	OTN E2E	Hop-by-hop (light loaded)	Hop-by-hop (heavily loaded)
Average delay	75 us	204 us	9 ms
Maximum delay	81 us	1817 us	163 ms
Minimum delay	73 us	123 us	0.1 ms
Packet loss rate	0	0	2.84%

Experiment results show that the scheme and protocols proposed in this paper enables client-side services to be carried over end-to-end OTN connections, providing cloud access services with quick response, high reliability, and low latency. Based on the OSP protocols, OTN network can quickly respond to user service requests, meeting users' requirements for flexible and fast access to cloud services.

The service access capability of the client-side port on the OTN network depends on the board capacity, system control board processing capability, and data communication network throughput, etc. Based on the capabilities of the existing OTN devices, it is estimated that a single OTN UNI port can access about 100,000 services.

Conclusions

In this paper, a service oriented OTN control scheme and new protocol are proposed. Field trial results show that the technical solution proposed enables the OTN network to carry and flexibly schedule cloud services, and effectively improve the service quality, reduce the service delay. In the future, we will further discuss the possibility that carriers could provide cloud access services through OTN private lines, so as to provide more options for high-level users to flexibly access multiple clouds.

Acknowledgements

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