On Demand Network Services Deployment in Optical Metro Edge Computing Network Based on User and Application Requests and Infrastructure Telemetry

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Abstract *We demonstrate an automatic optical metro network based on programmable traffic interface and SOA ROADM. Automatic telemetry assisted network service chains deployment has been experimentally investigated and optimized based on the user request and application requirements. Results shows less than 200us latency for critical application.*

Introduction

The future network system is expected to work in an automatic and flexible way to efficiently serve the upcoming applications with different QoS requirements. It demands the network to be aware of the current status and able to automatically adapt itself to the access requests. Ideally costly IT resources in the network edge known as edge computing [1] should be deployed close to the end users to fulfil the network services with strict requirements such as latency and computational power. However, the deployed IT resources in network edge is usually limited in dimension due to the management and economic considerations. Therefore, the IT resources in the network edge should be optimally allocated for applications with stringent requirements and it is significant to compose a network service chain across multiple edge computing nodes for better utilize the limited resource. The recent studies [2][3] on the network service deployment are concentrated on the IT and optical resource based solutions. The proposed methods, models and algorithms are helpful for network operators to consider the network service deployment from the point view of the resource optimization. However, to really optimize the overall system orchestration, the users and applications requirements have to be considered as well. The precious edge resources should be allocated for the applications with strict performance requirements, otherwise far away resources in datacentre (DC) can be used.

In this work we investigate and demonstrate an on-demand network services deployment based on the user requests and application requirements. The idea is that the telemetry assisted network system automatically deploys more services in the node with higher volume of user traffic from latency sensitive application. Thus, more of the user traffic can be served locally, improving the latency performance. In the meantime, only the latency sensitive network services are deployed in the edge, saving the precious IT resource of the edge network.

User and application oriented Network Services Deployment

To achieve the user and application requests based network service deployment, several network building blocks as shown in fig.1(a) are

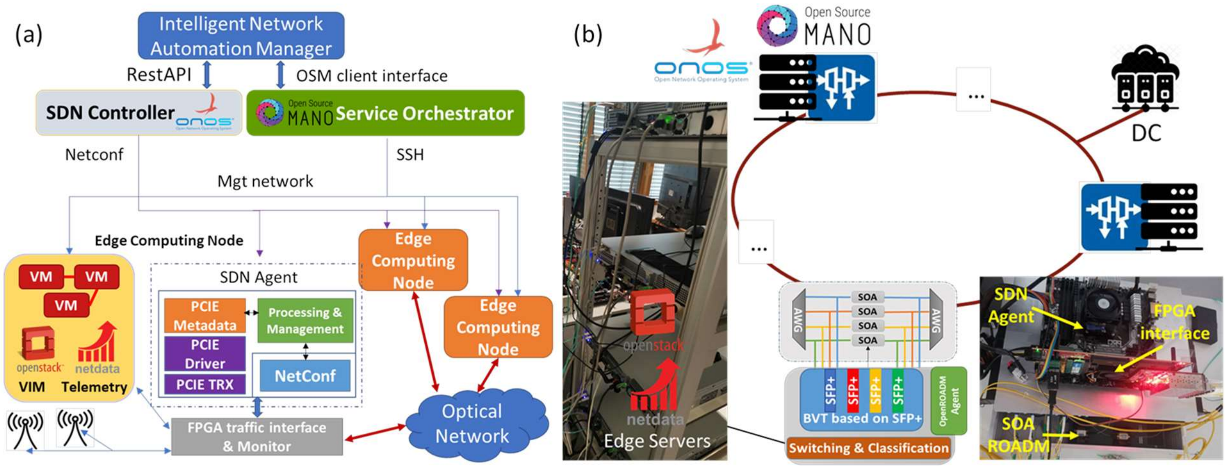

Fig. 1: (a) Network architecture of the metro edge computing network; (b) The experiment setup.

978-1-7281-7361-0/20/$31.00 ©2020 IEEE

2020 European Conference on Optical Communications (ECOC) | 978-1-7281-7361-0/20/$31.00 ©2020 IEEE | DOI: 10.1109/ECOC48923.2020.9333149

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needed. First, each metro node has a traffic access interface (implemented by an FPGA) with the function of switching, traffic classification and monitoring. The FPGA interface is programmed to monitor the latency of each packet and the buffer fill ratio of each transceiver port, which provides the information of the load of each link. The incoming user traffic is first stored at the RX buffer of the receiving port, then forwarded to the target TX buffer based on the processed MAC address. The monitored buffer filll ratio that represents the traffic load is real time reported to the SDN controller through an OpenROADM agent. The OpenROADM agent is derived from the OpenROADM YANG model, specifically enhanced and adapted to account for the hardware control. The ONOS based SDN controller with the adapted hardware driver is employed for controlling the optical network. The monitored information of the FPGA is first sent to the PC based OpenROADM agent by its PCIE interface. The OpenROADM will then forward the information to the SDN through the Netconf connection. The ONOS will further report it to the intelligent network automation manager (INAM) via RestAPI. The INAM is the top layer network manager and responsibe for the information collecting and network configuring. From the FPGA monitoring, the INAM knows the traffic load of each node. There is a mathematical model of the network and a heuristic algorithm is running in the INAM for real time network service deployment. The network model's input is the network status information, the requirements of the application (network services) and the IT resource usage. The objective of the model is to maximize the latency sensitive applications to the edge node with more user requests, and in the meantime forwarding the latency insensitive ones to the remote DC to fulfil the IT resource constraints in the edge. This requires the network having the visibility of the available IT resources in the edge computing nodes. A Netdata based real-time performance and resource telemetry system is employed for the monitoring of the edge servers. It generates the monitoring data in JSON format with the metrics in every one second, which is then sent to the INAM via the management IP network. According to the results generated by the algorithm, the INAM then deploys network services to the target node through the Open Source MANO (OSM) [4] based network service orchestrator and OpenStack based virtualized infrastructure (VIM). At each of the edge computing node, an OpenStack VIM is running for virtualized hardware management. To manage the network services across multiple VIMs, the OSM is employed for orchestrating the services placement and the life cycle in multiple edge computing nodes. All the VIMs are registered to the OSM via SSH link with a valid tenant name and identification information. The INAM commands the OSM to instantiate the network services and configure the virtual network in the target VIM node. The communication between the INAM and the OSM is made by the OSM client interface. In the meantime, the SDN controller configures the optical network between the VIMs in case the service chains have to be composed. By the collaboration of INAM, ONOS, OpenStack, OSM and the telemetry, the network services can be automatically deployed to the network.

Experiment Setup

The experiment setup of the proposed optical metro edge computing network is depicted in fig. 1(b). It is composed by a ring network including four metro access nodes. Each node is equipped with an SOA-based 2-degree ROADM controlled by the Xilinx UltraScale FPGA. The SOA gates inside the ROADM can be turned on and off to pass or block each single wavelength according to the SDN assigned network configuration. The FPGA interface processes the MAC address of the incoming packets in order to forward the packets to the correct destination ports. The relation between packet MACs and target nodes is stored in a look up table and it can be modified by the SDN controller. Each the FPGA is equipped with four SFP+ transceivers (ITU Ch21, 23, 25, 27) that can be dynamically turned ON/OFF. The I/O buffers inside FPGA at both RXs and TXs paths are set to 8192 (1024 X 8) Bytes. The FPGA interface communicates with the SDN agent via its PCIE interface working in direct memory access (DMA) mode. The PCIE data flow containing the information of the buffer fill ratio from the FPGA is packaged to Netconf packets and is sent to the ONOS in real time. The node includes also a server with a 4X10Gbps network interface card (NIC) serving as edge computing. A DC node with 16 servers is connected to the setup for emulating the realistic network operation from the collaboration between edge computing nodes and DC node. The management network is connecting the OSM and OpenStack based VIM. The ONOS, OSM, Netdata and INAM are installed in the edge-node1. For each edge node, there are two 10G NIC employed for emulating the users and generating the traffic with different MAC, which is representing the different applications with different requirements.

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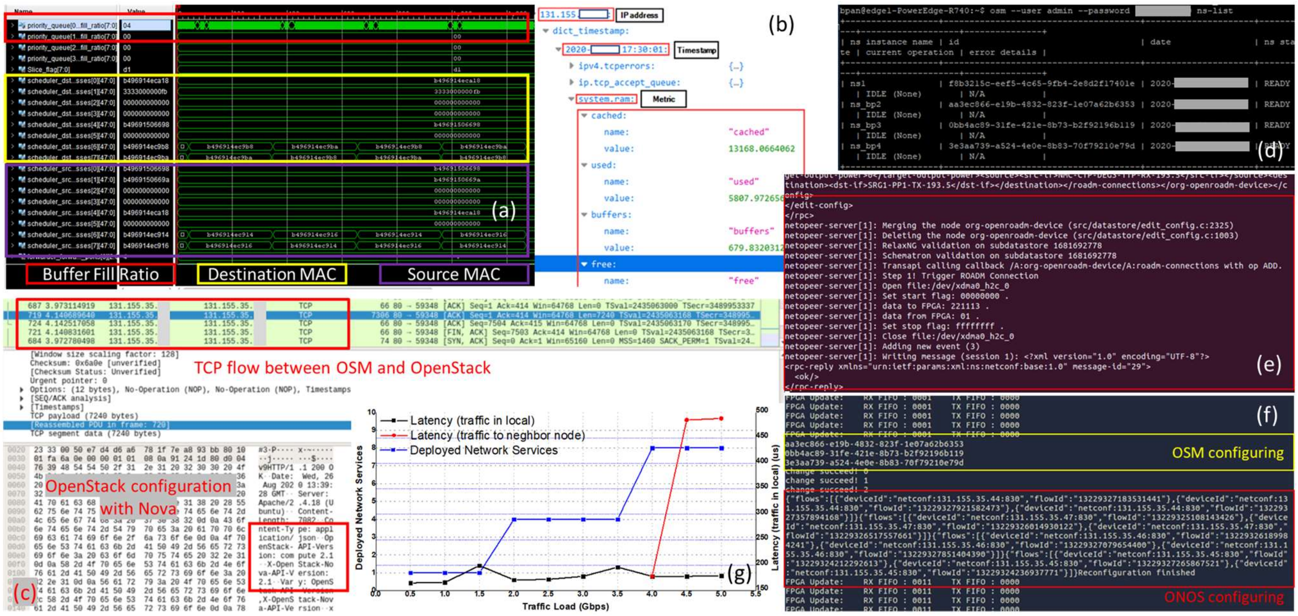

Fig. 2: Results of the user and application based network service deployment.

Results Analysis

Figure2.(a) shows the FPGA monitoring trace of the incoming traffic, from which we can see the MAC address of the packets coming from the server and optical network. The incoming packets from port 0 and 4 are treated as the high priority ones and forwarded to the priority buffer. The fill ratio of the priority buffer is changing with the enqueuing and dequeuing of each 8Bytes cell. This information of the priority buffer is sent to the OpenROADM agent every one second. We can see the communication trace between FPGA and OpenROADM agent from fig.2(e), which shows the Netconf communcation and the data gathering from and sending to FPGA. The gathering data are sent to the SDN cntroller and INAM as shown in fig. 2(f). On the other hand, the server resource usage is monitored by the Netdata, which generates the JSON file of the metrics as shown in fig.2 (b). The JSON metrics from Netdata are packaged in TCP packets and sent to the INAM. The INAM then instructs the OSM to deploy the latency sensitive network services first to the node with highest fill ratio of the priority buffer. If the IT resource of the node is not enough, the services will be deployed to the nearest node with enough resource. The INAM controlled autoamtic network services deployment is shown in fig. 2(f). At the beginning when network traffic is low, there is one network service deployed at node4. The latency (ICMP round trip time) between the local user and edge server is lower than 200us as shown in fig.2(g). With the increasing of the user traffic, the INAM deployes three more VNFs to the node as shown in fig. 2(f). The deployed network services are shown in fig. 2(d). The image of the network services are pre-installed in the VIM. The hardware requirements of the network service instance is set to 4GB RAM, 2 virtual CPU and 10GB storage. Note that here the network services deployed to the edge nodes are treated as the latency sensitives since the latency insensitive network services are all installed in the DC node. Figure 2(c) shows the communication trace between the OSM and OpenStack based VIM. The trace shows that the Nova service of OpenStack is responding to the OSM for instantiating the VNFs at the node. With the further increase of the user traffic, the INAM deploys 4 more services to the current node. However, the node can not host more than 8 network services due to the resource limitation. Therefore the extra required network services are deployed to the nearest neighbour node with enough resource, causing around 500us latency for a part of traffic.

Conclusions

We propose and demonstrate an automatic optical metro edge computing network with the flexible hardware and software components. A novel user and application oriented network service deployment strategy has been investigated. Automatic telemetry assisted network service chain deployment has been achieved. The latency sensitive applications are deployed to the edge node with more user requests and the insensitive ones are deployed to the DC to save the precise edge resource.

Acknowledgements

The authors thank the EU-H2020 project METRO-HAUL (G.A. 761727) and PASSION project (GA 780326) for partially supporting this work.

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References

[1] Shi, Weisong, et al. "Edge computing: Vision and challenges." IEEE Internet of Things Journal 3.5 (2016): 637-646.

[2] Bi, Yu, et al. "Distributed Online Resource Allocation Using Congestion Game for 5G Virtual Network Services." 2019 IEEE Global Communications Conference (GLOBECOM). IEEE, 2019.

[3] Li, Baojia, et al. "Deep-NFVOrch: deep reinforcement learning based service framework for adaptive vNF service chaining in IDC-EONs." 2019 Optical Fiber Communications Conference and Exhibition (OFC). IEEE, 2019.

[4] Mayoral, A., et al. Multi-tenant 5G network slicing architecture with dynamic deployment of virtualized tenant management and orchestration (MANO) instances. In ECOC 2016;

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