Disaggregated, Sliceable and Load-aware Optical Metro Access Network for 5G applications and Service Distribution in Edge Computing

Bitao Pan, Xuwei Xue, Fu Wang, Eduardo Magalhães, Nicola Calabretta

Institute for Photonic Integration, Dept. of Elec. Eng, Eindhoven Univ. of Technology, PO Box 513, 5600MB Eindhoven, The Netherlands

A disaggregated, sliceable metro-access ring with SDN control is experimentally assessed with the use case of service distribution in the edge computing nodes. The results show less than 300us delay for virtualized network function chains in a distributed network scenario.

Introduction

Together with Network Functions Virtualization (NFV) and Software-Defined Networking (SDN), edge computing is recognized as one of the key emerging technologies for 5G networks, which will leverage more programmable approaches to software networking and use IT virtualization technology extensively within the telecommunications infrastructure distributed in network edge. Edge computing helps advance the transformation of the mobile broadband network into a virtualized world and contributes to satisfying the demanding requirements of 5G in terms of expected programmability, latency, scalability and automation [1,2]. Recent study on edge computing and NFV are focused on the software architecture and orchestrator. However, as the traffic carrier of edge computing and 5G access, the optical metro access network (MAN) works an important role and should be redesigned to support the upcoming edge computing services like virtualized network function (VNF) distribution and 5G front haul. First, the infrastructure of the optical MAN should be disaggregated and able to be controlled by the uniform SDN controller for dynamic network reconfiguration to adapt to the heterogenous network application and traffic. Second, the networking devices of the optical MAN should be aware to the possible network conditions and able to fast interact with control plane to optimize network performance. By combining dynamic

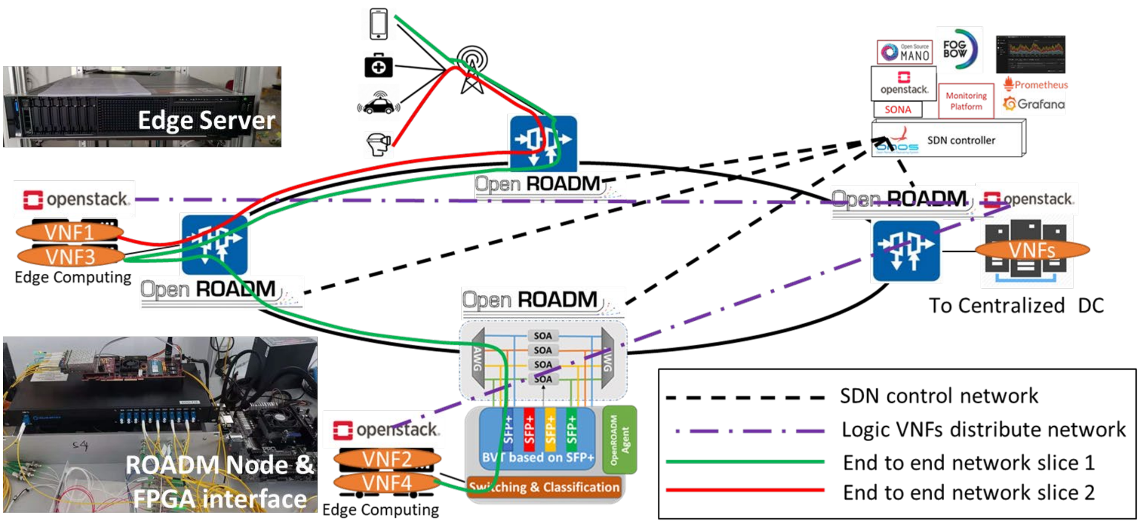

Fig .1. Disaggregated and sliceable optical metro access network

SDN control and programmable traffic monitor, the optical MAN will be able to establish capacity adapted and latency optimized optical and traffic path for the connected 5G access points and edge computing nodes where VNFs are installed [3].
In this paper, we present an experimental investigation of a disaggregated, sliceable and load-aware optical metro access network for service distribution and VNF chaining in metro edge computing. Network slicing and load monitoring are implemented in the FPGA based traffic classification and aggregation optical-electrical network interfaces. The network performance is studied with dynamic service distribution from centralized DC to the edge computing nodes and VNF chaining in the metro access edge computing.

System Operation of the Fully Disaggregated Optical Metro Access Network

The schematic of the metro access ring network is depicted in Fig. 1. Each node consists of a low-cost SOA based 2-degree ROADM with the function of switching and amplification, a FPGA based optical-electrical interface for traffic slicing and network status monitoring, a powerful server as the edge computing, a centralized SDN controller and NFV orchestrator. The metro access network employing disaggregated low cost 2-degree add-drop wavelength blocker (WBL) switch based on SOAs, which provide power amplification, removing high cost EDFA. The SOA gates inside the ROADM can be turning on and off by the FPGA based optical-electrical interface to make each single wavelength pass/stop or drop&continue. Each node can add traffic on a wavelength only if the wavelength is free or was blocked by the node itself. More details of the SOA ROADM can be found in [3]. The SDN controller is responsible for assigning wavelength connections between different nodes. The network is fully disaggregated and all communications between the SDN controller and the metro-access node are performed through NETCONF protocol. The adopted YANG model for the node is derived from the OpenROADM YANG model, specifically enhanced and adapted to account for hardware controls. The network controller is based on ONOS [4] where specific drivers have been implemented to support the metro-access node through the NETCONF protocol. The PC based OpenROADM agent with Netconf server extracts the command information of NETCONF packet and further converts it to PCIE data flow. The FPGA will then map the PCIE data flow to logical high or low signals to drive SOAs. Besides driving SOAs, the FPGA interface is also working as traffic classifier, monitor and BVT controller. The incoming traffic is sliced by the FPGA based interface according to its type. Traffic of different VNF chains will be destined and sent to different nodes. In addition, the FPGA controls the disaggregated BVT implemented here as multiple 10Gb/s transceivers (SFP+) directly plugged on the evaluation board of the FPGA (see Fig. 2b). The SDN controller could assign more wavelengths controlling the FPGA to increase the transmission bitrate at the BVT to get higher throughput for the current node as required by the applications and data traffics. On top of physical and datalink layer, an OpenStack based application orchestrator is running in centralized datacenter (DC) and connected with edge computing nodes on network layer for virtualized hardware management and service distribution. By cooperating with the centralized orchestrator in DC, the computing, storage and networking resource in edge computing nodes can efficiently be used by all the clients in the metro region. Moreover, disaggregated network functions in different edge nodes can be chaining together in an optimized way by the network services provided by the SDN and VNF orchestrator. The presented metro access network

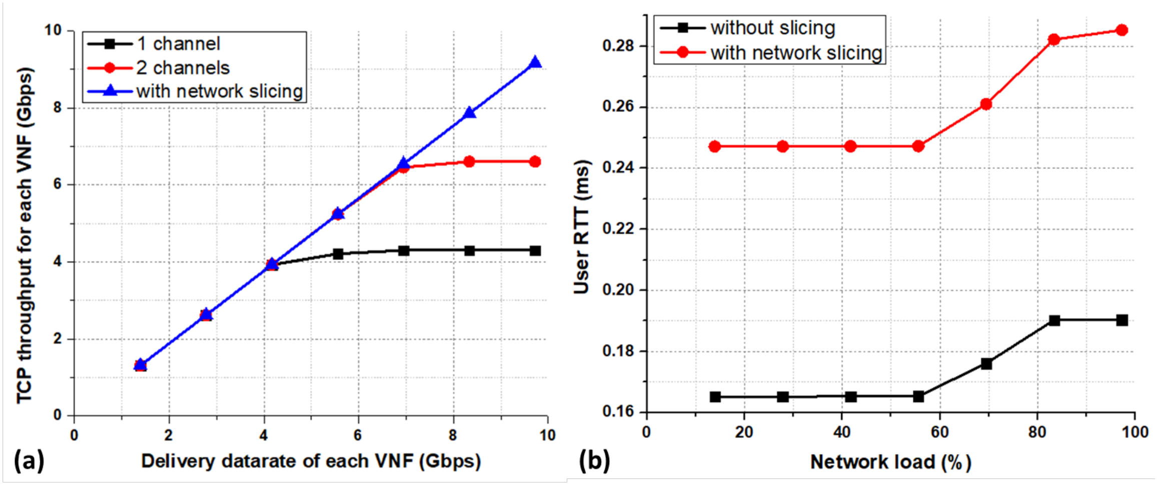

Fig.2 (a) TCP throughput of each VNF versus the delivery datarate (b) User experienced RTT in different network operation case

is fully disaggregated and sliceable thank to the programmable and disaggregated infrastructure and automatic service orchestrator and SDN controller.

Experiment Setup and Results Analysis

The experiment setup is shown in fig. 1. It is composed by a ring network including four metro access nodes. Each node is equipped with an SOA-based 2-degree ROADM, a Xilinx UltraScale FPGA with O/E/O interfaces, and a powerful server with a 4X10Gbps network interface card (NIC) as the edge computing. Additionally, a PC motherboard is used as the OpenROADM SDN agent. Each FPGA is equipped with four 10Gbps SFP+ transceivers (ITU Ch21, 23, 25, 27) to emulate the disaggregated BVT by dynamically turning ON/OFF of each TRX. The I/O FIFOs inside FPGA for both RXs and TXs paths are set to 8192Bytes (1024 x 8Bytes). In the experiment, we make the node one works as the centralized DC, node two and three work as edge computing nodes. Node four is used for generating network request as the subscribers. The idea of this experiment is to present and study the performance of a dynamic network operation for network service distribution and VNF chaining in the proposed fully disaggregated and sliceable optical metro edge computing network in terms of latency and available TCP/UDP bandwidth. At the DC side, we use the server NIC to generate TCP traffic to the edge to emulate the service or VNF distribution from the central to edge. At the user side, we generate and receive TCP/UDP traffic to/from the other nodes to emulate the operation of guaranteed or best effort network services in the metro edge computing network. The destinations of packets are generated to emulate the VNF chaining operation. The iperf and ping functions are used for recording the TCP bandwidth and roundtrip time (RTT) of the network connection.

Fig. 2(a) shows the TCP throughput of each VNF as the function of the delivery datarate. We use two 10G ports of node one to emulate the two servers where two different VNFs are stored. When the transmission datarate of VNFs is lower than 4Gbps, the VNFs can get the full transmission throughput in the case of one wavelength available for the connection between DC and the edge nodes close to end users. Further increasing the transmission datarate of VNF will cause network congestion and buffer overflow. FPGA interface detects the buffer fill ratio and triggers a signal to SDN for requiring more bandwidth. SDN assigns another wavelength for the current connection after it receives the request from DC node. When the delivery datarate of VNFs rises over 7Gbps, two wavelengths connection cannot support full throughput transmission anymore. The SDN then slices the network by distributing two VNFs to different edge nodes. With network slicing, both of the VNFs can have maximum throughput. Fig. 2(b) shows the user RTT of two different VNF chains (the transmission delay is not considered). In the first case, the DC node has only deployed VNFs in edge computing node 1. The average user RTT is lower than 200us since the VNFS are installed in one site. In the second case, network is sliced and VNFs are deployed in different edge computing nodes. Less 300us user RTT can be achieved in this case.

CONCLUSIONS

We have experimentally investigated fully disaggregated and sliceable metro access ring network with edge computing and low-cost ROADM. The results show successful SDN orchestrated and load monitoring-based network slicing functionalities for QoS guaranteed network service distribution. Less than 300us round trip delay has been achieved between metro edge computing nodes.

References

[1] A key technology towards 5G. ETSI white paper. Online Available: https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp11_mec_a_key_technology_towards_5g .pdf.

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

[3] Pan, B., Calabretta, N, et al. Experimental Assessment or SDN Controlled Metro Access Network with Network Slicing and Edge Computing under 5G Applications. In 2019 24th OECC and 2019 PSC (pp. 1-3). IEEE.

[4] ONOS - https://www.opennetworking.org/projects/onos/