Diallo, T., Farhadi Beldachi, A., Muqaddas, A. S., Silva, R., Nejabati, R., Tzanakaki, A., & Simeonidou, D. (2019). Enabling Heterogenous Low Latency and High-bandwidth Virtual Network Services for 5G Utilizing a Flexible Optical Transport Network. In *2019 Optical Fiber Communications Conference and Exhibition, OFC 2019 - Proceedings* [W1G.7] Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1364/OFC.2019.W1G.7

Enabling Heterogenous Low Latency and High-bandwidth Virtual Network Services for 5G Utilizing a Flexible Optical Transport Network

Thierno Diallo, Arash Farhadi Beldachi, Abubakar Siddique Muqaddas, Renato Souza Silva, Reza Nejabati, Anna Tzanakaki and Dimitra Simeonidou
High Performance Networks Group Department of Electrical and Electronic Engineering, University of Bristol
thierno.diallo@bristol.ac.uk

Abstract: For the first time, we demonstrate a 5G network orchestration system supporting low latency and high bandwidth virtual network services over a flexible time slotted optical transport network.

OCIS codes: (060.2330) Fiber Optics Communications; (060.4250) Networks, (060.4253) Networks, circuit-switched

1. Introduction

5G network requirements and Key Performance Indicators (KPIs) are defined in [1]. Among them, the access network should be able to provide a high density of connected devices (1 million connections/km^2), high bandwidth, low latency ($\leq$ 1 ms), network slicing and flexibility, scalability and elasticity of the network [1,2]. To achieve the requirements and KPIs, the future optical network for 5G should be flexible, scalable, provide connectivity with low latency and high bandwidth. Time Shared Optical Network (TSON) is a technology, which permits to bring the flexibility and scalability in the optical transport network and offers high bandwidth and low latency connectivity [3] to handle some requirements and KPIs of 5G.

To meet its latency requirements a 5G network requires orchestration of both network functions and connectivity resources. In a 5G network, network functions are often virtualized to run in commodity hardware platform (servers) and are enabled through Network Function Virtualization (NFV). Also, in a 5G network, the preferred method of managing network connectivity is vendor and technology-agnostic, enabled by Software Defined Networking (SDN). Therefore, in 5G network, a Management and Orchestration (MANO) systems is required which can orchestrate both SDN and NFV technologies [4]. MANO systems support the deployment of Virtual Network Services (VNSs), consisting of several chained Virtual Network Functions (VNFs) hosted by compute resources, and interconnected by the network resources. For each VNS, MANO creates a network slice of the end-to-end network, where each VNS may have varying resource requirements. To accommodate a variety of VNSs with different network requirements, TSON is a viable optical transport network candidate due to its flexible nature. TSON consists of transmitting a variable number of TDM frames with variable time slot size over an optical infrastructure. This variable nature of TSON allows the accommodation of network services (VNSs) with different granularity of data rates. Thus, throughput and the latency in the TSON network is variable, hence scalability and flexibility in the optical transport network can be achieved by this technology.

In this paper, we demonstrate for the first time TSON with the NFV orchestration, where the latter is responsible for managing and deploying VNFs of a VNS in multiple compute nodes. The underlying connectivity between the compute nodes is enabled by TSON. We show that TSON can support heterogenous virtual network services, and network slicing using orchestration in the optical transport network. We briefly discuss the architecture of TSON, followed by the TSON testbed utilized in our experiment.

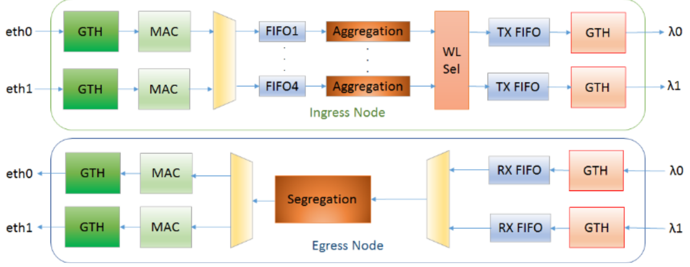
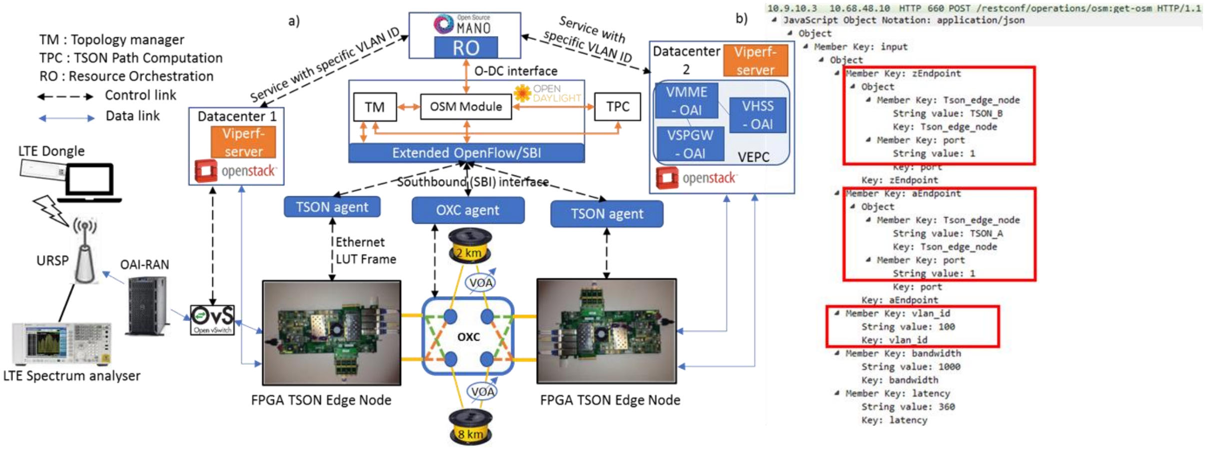


Fig. 1. TSON architecture in the FPGA [3]

2. TSON architecture

TSON is implemented in a Field Programmable Gate Array (FPGA) as shown in Fig. 1 [3]. The implemented TSON edge node has 2 input ports for client ethernet traffic and 2 output ports towards the metro network providing the TSON frame. The ingress node consists of aggregation of multiple frames which fill a particular time slot size. This is followed by a Wavelength Selector (WL Sel) block which selects the appropriate output port with a particular wavelength. At the egress node, the traffic received is segregated into different client ports. The Layer 2 (L2) network slicing is achieved in the TSON node by classifying and selecting the appropriate output according to the VLAN tags of the ingress traffic.

2. Implemented Testbed and Experiment



```
10.9.10.3  10.68.48.10  HTTP 660 POST /restconf/operations/osm:get-osm HTTP/1.1
◢ JavaScript Object Notation: application/json
  ◢ Object
    ◢ Member Key: input
      ◢ Object
        ◢ Member Key: zEndpoint
          ◢ Object
            ◢ Member Key: Tson_edge_node
                String value: TSON_B
                Key: Tson_edge_node
            ◢ Member Key: port
                String value: 1
                Key: port
            Key: zEndpoint
        ◢ Member Key: aEndpoint
          ◢ Object
            ◢ Member Key: Tson_edge_node
                String value: TSON_A
                Key: Tson_edge_node
            ◢ Member Key: port
                String value: 1
                Key: port
            Key: aEndpoint
        ◢ Member Key: vlan_id
            String value: 100
            Key: vlan_id
        ◢ Member Key: bandwidth
            String value: 1000
            Key: bandwidth
        ◢ Member Key: latency
            String value: 360
            Key: latency
```

Fig. 2. SDN and NFV over TSON optical transport for 5G: a) Testbed b) Wireshark capture of message on O-DC interface

In this section, we present the implemented testbed for the integration of MANO with TSON as shown in Fig. 2a. Indeed, two VNFs of the same VNS located in two different datacenters can communicate via TSON, where each VNS uses one slice in the optical transport network identified by the VLAN tag. Open Source MANO (OSM) is used [5] for orchestration and OpenDaylight (ODL) SDN controller is used to manage the TSON network. OSM manages the deployment of different VNSs where the VNFs are hosted in datacenter managed by OpenStack. In this test, two VNSs are deployed. The first VNS is composed of 2 VNFs, where each VNF has "*Iperf"* tool installed (to measure the performance of the transmission between two VMs over TSON); and both VNFs are in two different datacenters. Also, an LTE network, as the second VNS, is implemented in parallel to emulate the backhaul traffic. The different components of EPC for LTE are virtualized using OpenAirInterface (OAI) [6] which is an open source LTE emulator. OAI combined with a Universal Software Radio Peripheral (USRP) is used here to emulate a Radio Access Network (RAN). An LTE dongle is connected to a computer to emulate the User Equipment (UE). The interface between OSM and ODL controller is a RESTCONF interface, where OSM sends a request to configure the end-to end connectivity in the TSON network to the ODL controller. This request specifies the information about the TSON edge node, the entry points of the TSON node (input ports), the VLAN tag which slices the TSON network, the bandwidth, and the latency. This request is shown in the Wireshark capture in Fig. 2b, during the deployment of a VNS.

In ODL, an API called *OSM Module*, which receives the request to configure the optical transport nodes, has been developed. This module gets the TSON network topology from the Topology Manager (TM) to configure them. Another TSON Path Computation (TPC) has also been developed external to ODL. TPC calculates the path in the TSON using the shortest path algorithm, utilizing the optical transport topology obtained from TM. The result of the path computation provides the outputs of the TSON nodes and the ports of the optical cross connection (OXC) switch to configure. The TPC sends the results to the OSM module which configures the different nodes by using an extended OpenFlow (OF) protocol developed to set the parameters of TSON node and the OXC switch. Concerning the southbound interface in Fig. 2a, the TSON agent and the OXC agent have been developed to receive the OF messages from ODL to translate them for configuring the TSON node and the OXC.

Since the TSON latency depends on the size of packets (64 bytes or 1500 bytes), the number of the time slices (TS), the data throughput (relative to the size of the TSON frame) and of the interleaved distribution of the TS [7,8], an empirical model to evaluate the latency has been built (Fig. 3) to provide the weight of the TSON edge nodes used to perform the shortest path algorithm. For a given data rate, to minimize the latency, a continuous distribution with 62 time slices has been considered [7,8]. Furthermore, to estimate the latency in real transmission, the size of the generated packets to build this empirical model is randomly selected between 64 bytes and 1500 bytes. To evaluate the performance of data plane, the LTE VNS is deployed from OSM which has a 1Gb/s bandwidth, 360 µs latency and VLAN ID 100 where the input TSON port is 1. The second VNS for “iperf” has 1 Gb/s bandwidth, 500 µs latency and VLAN ID 101 where the input TSON port is 2. 2 km of optical fiber is allocated to the LTE VNS and 8 km of optical fiber is allocated to iperf VNS. Also, the UE in the LTE network service uses iperf tool to measure the performance of the mobile backhaul network based on TSON.

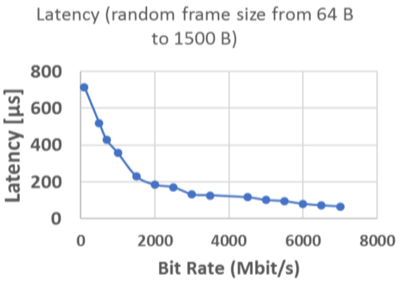


Fig. 3. Latency result using by the TPC

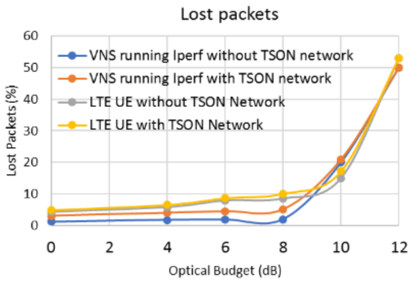


Fig. 4. End-to-end lost packets

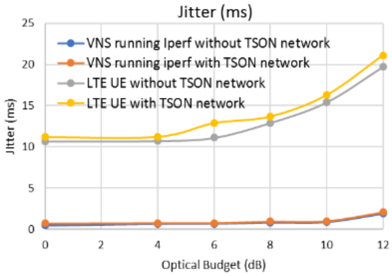


Fig. 5. End-to-end lost jitter

3. Data plane performance result

To show the impact of TSON, the result for the case without TSON where the two ends of the datacenters are connected only via OXC is also computed and compared with the case where TSON is used. Figs. 4 and 5 show the performance of the data plane vs. the optical budget about the lost packets and jitter respectively. The average of the difference between the result of with and without using TSON is about 2% for the “iperf” VNS and about 1.1% for the LTE VNS for the lost packets. The average of the difference in case of jitter is about 0.1 ms for the “iperf” VNS and about 0.9 ms for the LTE VNS. This slight increment of the lost packet and jitter is due to the data processing performed by the FPGA.

Also, the radio performance is measured by connecting the Radio Frequency (RF) output port of the USRP to an LTE spectrum analyzer. The TSON network does not have any influence on the quality of the radio signal. Indeed, for an LTE Bandwidth of 10 MHz the data transmission rate is constant and equal to 12 Mbit/s for the UE. In addition, the Error Vector magnitude (EVM) is 1.2 % on the RF downlink and 1.8 % on the RF uplink.

4. Conclusion

In this paper, we demonstrate for the first time, the orchestration of heterogenous virtual network services over a TSON. The different interfaces between the OSM and TSON SDN controller, and between the TSON SDN controller and the data plane elements are discussed. The TSON path computation based on an empirical method to estimate the latency has been developed. The presented architecture brings flexibility and scalability by reconfiguring the TDM features of TSON via the implemented SDN controller which includes the extended OpenFlow protocol in order to control the data plane. Network slicing is enabled for various network services by classifying the traffic based on VLAN tag. In addition, the TSON does not have any impact in the performance on the RAN and does not introduce much latency and jitter in the optical transmission.

5. Acknowledgment

This work has been supported by EU H2020 5G-PICTURE and Metro-Haul (grant agreements 762057, 7617727), and EP/L020009/1 “TOUCAN”.

6. References

[1] 5GPPP, “5G Vision,” available on https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf
[2] Azahar Machwe et. al “D2.1 5G and Vertical Services, use cases and requirements,” available on : https://www.5g-picture-project.eu/download/5g-picture_d21.pdf, 2018.
[3] A. F. Beldachi et. al, “Experimental Demonstration of 5G Fronthaul and Backhaul Convergence based on FPGA-based Active Optical Transport,” ECOC 2018
[4] S. Abdelwahab et. Al, “Network Function Virtualization 5G,” IEEE Communications Magazine, vol 54, no 4, pp. 84-91, 2016
[5] Open Source MANO, available on https://osm.etsi.org
[6] Open Source OpenAirInterface, available on http://www.openairinterface.org/
[7] K. Kondepu et al. "Fully SDN-enabled all-optical architecture for data center virtualization with time and space multiplexing," *JOCN 2018*
[8] Zervas, Georgios S., et al. "Time Shared Optical Network (TSON): a novel metro architecture for flexible multi-granular services," *Optics Express* 19.26 (2011): B509-B514.