

# Experimental demonstration of PON slicing with slice aware DBA/CTI and virtual OLT for the accommodation of time-critical and non-time-critical services in the same ODN

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**Abstract** We demonstrate PON slicing for fronthaul, business, and residential services coexisting in a single ODN, ensuring independent slice performance, and resource allocation by slice-aware DBA. The latency of fronthaul slice is less than 200  $\mu$ s using Co-DBA/CTI.

## Introduction

As the demand for optical access networks continues to grow, it becomes increasingly important to accommodate the diverse demands such as high-capacity, low latency, and the ability to support on-demand connections for virtual offices, greater video streaming capabilities, and new applications including smart factories, and tactile internet. Time-division multiplexed passive optical networks (TDM-PON) is an attractive technology to handle the ever-increasing traffic cost-effective way and to provide easy optical connection.

Although, TDM-PON has the advantage of easily enabling optical connections, it suffers from significant upstream latency issues. Additionally, managing different types of services within the same optical distributed network (ODN) is a complex task. To meet diverse requirements and application-specific characteristics, it is essential for TDM-PON to provide logical network separation through slicing, flexibility in adding or replacing new functions, and low latency for time-critical applications. As a result, TDM-PON transforms into a more intelligent, simple, and lean optical access network, as shown in Fig. 1.

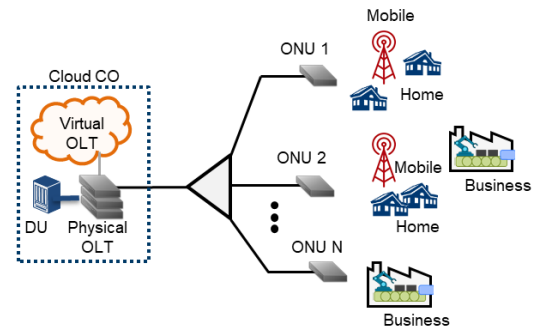
Up to nowadays, there have been substantial efforts to make insentient and simple PON [1-3]. These include PON slicing or advanced-DBA scheme. However, the previous studies have mostly focused on the DBA scheme itself [1], an analytical model to compute optimal virtual PON slice allocation [2], and assigning different slicing per CPU [3]. There have been no experimental demonstrations of PON slicing achieved through the interactions between a disaggregated physical OLT and virtual OLT, as well as the application-specific resource allocation using the slice-aware DBA consisting of CO-DBA and SR-DBA.

In this paper, we demonstrate PON slicing for the coexistence of fronthaul, business, and residential services within a single ODN, for the

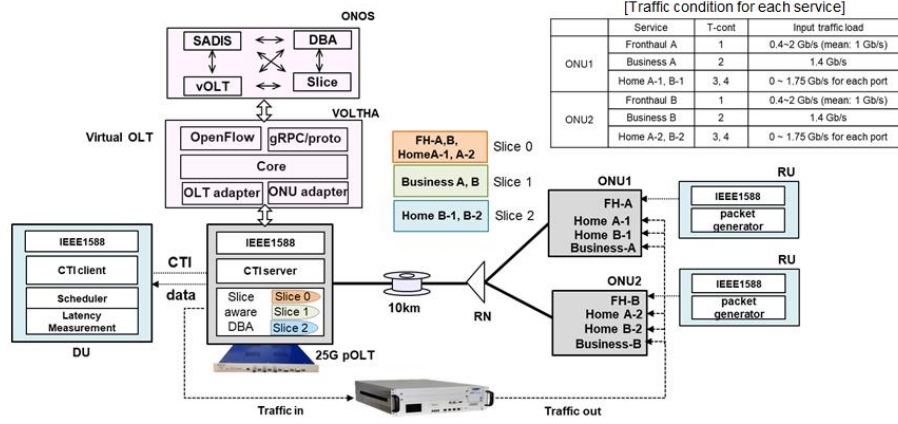
first time to our knowledge. The slicing is accomplished through the interworking of four distinct applications on the open network operating system (ONOS), ensuring that the performance of each slice is unaffected by the traffic conditions of other slices. The allocation of suitable physical resources based on the specific requirements is carried out by a slice-aware dynamic bandwidth allocation (DBA) mechanism. The latency of the fronthaul slice based on TDM-PON is less than 200  $\mu$ s, achieved through the use of Co-DBA/CTI technology.

## Intelligent optical access network and Experimental Setup

Figure 2 shows experimental setup for the demonstration of PON slicing with slice aware DBA and Co-DBA/CTI. The setup comprises a 25G OLT, ONU, virtual OLT, and DU/RU emulator. The physical OLT/ONU is implemented in a single FPGA. The slice-aware DBA consists of CO-DBA and SR-DBA, which allocate different types of network resources optimized for each application. In order to accommodate a fronthaul link in a TDM-PON, the DU and OLT must exchange scheduling information for mobile traffic through a CTI message. The DU contains a traffic scheduler that emulates 5G TDD traffic, a latency measurement module, and a CTI client.



**Fig. 1:** Intelligent, simple, and lean optical access network based on TDM-PON supporting multiple services with one network



**Fig. 2:** Experimental setup for PON slicing with slice aware DBA and CO-DBA/CTI. Fronthaul, business, and residential services are accommodated in the same ODN.

**Table 1:** Measured slice profile by the apps set by virtual OLT for each slice and services.

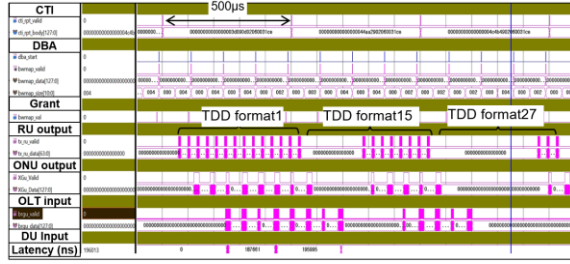
Slice		ONU#	T-cont #	DBA Type	Assigned BW (Mb/s)				
Slice #	BW (Mb/s)				Fixed	Assur	Non guarant	PIR (Max)	
0	2,800	1	1	CO-DBA	10	2,000	0	2,010	FH-A
		1	3	SR-DBA	0	0	1,000	1,000	Home A-1
		2	1	CO-DBA	10	2,000	0	2,010	FH-B
		2	3	SR-DBA	0	0	1,000	1,000	Home A-2
1	2,800	1	2	SR-DBA	0	500	900	1,400	Business-A
		2	2	SR-DBA	0	500	900	1,400	Business-B
2	2,800	1	4	SR-DBA	0	0	3,000	3,000	Home B-1
		2	4	SR-DBA	0	0	3,000	3,000	Home B-2

Each ONU has four UNI ports that are connected to mobile, business, and residential services. The RU which emulates mobile traffic connected to fronthaul port in ONU 1 and 2. The output of a pattern generator are connected to home service 1,2, and business service, respectively. The RU's output packet follows the mobile traffic format set by the DU. The IEEE1588 is used to synchronize the timing of the DU, OLT, ONU, and RU. To emulate ORAN 7-2x function split structure, the RU generates traffic in the range of 0.4 Gbps to 2 Gbps, following TDD traffic patterns, with an average of 1 Gbps. Business traffic is allocated a capacity of 1.4 Gbps, while home A and B are allocated 1.75 Gbps each. T-cont is assigned for each traffic to be accommodated in the PON. The Virtual OLT comprises two main components: the hardware abstraction layer (VOLTHA), which is equipped with open OLT/ONU adapters, and the open networking operating system (ONOS), which has vPON applications (App). PON slicing is accomplished by the interworking of four applications, namely Subscriber/Access Device Information Service (SADIS), vOLT, DBA, and Slicing. The SADIS and DBA apps are used as a database to store provisioning information relevant to subscribers and slice-specific attributes, respectively. By specifying the slice name, PON port, guaranteed bandwidth, and type of DBA, the slice instance can be configured

to meet service types or operator demands in a flexible manner. Whenever a new slice request is received by the slice app, SADIS loads subscriber profiles containing information such as bandwidth profiles, VLANs, and logical device details. The vOLT app then maps this information to the slice profile and provisions the subscriber accordingly. It also installs DBA for the flow and generates an OpenFlow (OF) message with the relevant subscriber information obtained from SADIS, which is subsequently sent to VOLTHA.

## Results and Discussions

First of all, we measured slice profile for each slice, as shown in table 1. PON slicing can be established based on various use cases. A network operator can source one or more services grouped into one or more slices of the same or different types. For this particular experiment, slice 0 was utilized to accommodate fronthaul and home service A, which were located on different ONUs. Slice 1 and 2 were configured for each service type, comprising slices for Business and home, respectively. Controlled by vPON, CO-DBA was set to the fronthaul services, while residential and business was served by SR-DBA with different CoS. Moreover, virtual OLT configured to provide assured bandwidth of 2 Gbps to fronthaul and 0.5 Gbps and 0.9 Gbps of assured and non-guaranteed bandwidth to business, respectively. home service A and B were assigned non-guaranteed (best effort) bandwidth of 1 Gbps and 3 Gbps, respectively. Each slice was assigned a maximum upstream bandwidth of 2.8 Gbps. Since fronthaul have variable traffic patterns, the remaining bandwidth in slice 0 was utilized by home service. It is important to note that even if there is available bandwidth within a slice, it cannot be used by other slices. Therefore, slices

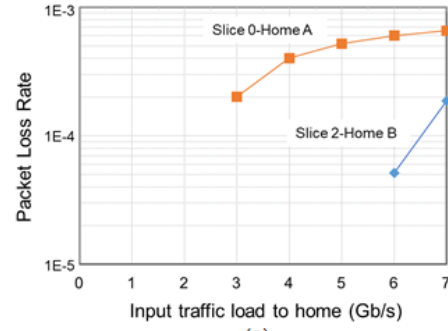


**Fig. 3:** Simulated data pattern at fronthaul link employing CO-DBA/CTI

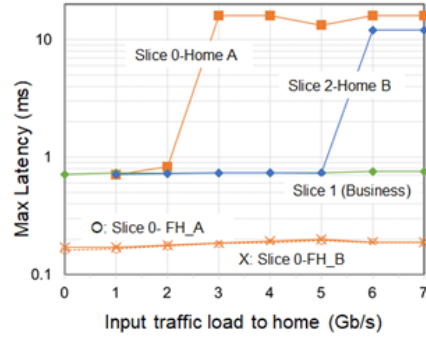
are isolated and logically separated networks.

Figure 3 shows simulated data pattern at the fronthaul link employing Co-DBA/CTI. The TDD data pattern is the same as that of implemented in the RU emulator. The data pattern generated in RU is composed of various variable formats such as TDD format 1, 15, 27, and others. DU sends accurate timing information to the OLT when the upstream mobile will be sent by RU, and accordingly, the OLT allocates upstream transmission in advance within a time window. In other words, the time slots without upstream traffic in the TDD pattern can be used by business and FTTH services. The CO-DBA transmits the current input of mobile traffic that is currently inputted during the duration of PHY frame, usually the same as DBA grant cycle and processed every 125 microseconds, to upstream direction in the next cycle. Thus, the latency is determined by 2 times the grant cycle time plus fibre delay and processing delay. In this experiment, since the DBA grant cycle time was set to 62.5  $\mu$ s, the maximum latency is less than 200  $\mu$ s. If the grant period is set to 1/4 of the 125  $\mu$ s frame length, the latency can be further reduced.

Figure 4 show the measured performance of each slice. In this experiment, we gradually increased the input traffic load from 0 Gbps to 1.75 Gbps for four different home services, resulting in a total input load of 7 Gbps. We measured the packet loss rate and latency of each service. Since home A at slice 0 utilizes the remaining bandwidth used after fronthaul, causing packet drop and latency increase earlier than home B at slice 2. However, no packet loss occurred at fronthaul service at slice 0 and business service at slice 1, and the packet loss/latency was not affected by traffic load variation for home traffic. The maximum latency measured for business and fronthaul services were less than 750  $\mu$ s and 200  $\mu$ s, respectively. This is due to the Co-DBA for fronthaul, which serves traffic within 2 CO-DBA grant cycles, whereas SR-DBA takes seven durations of PHY frame for traffic to arrive from ONU to OLT.



(a)



(b)

**Fig. 4:** Measured performance of each slice (a) packet loss rate (b) and maximum latency

## Conclusions

We have demonstrated PON slicing for coexisting fronthaul, business, and residential services within a single optical distributed network (ODN). The slice-aware dynamic bandwidth allocation mechanism allocates suitable physical resources based on the specific requirements of applications and use cases. Through the use of Co-DBA/CTI technology, less than 200  $\mu$ s latency in TDM-PON based fronthaul slice was achieved. The results confirmed the PON slicing could improve the efficiency and performance of optical access networks, providing a scalable solution for meeting the growing demands in optical access network.

## Acknowledgements

This work was supported by IITP grant funded by the Korea government (MSIT) [2019-0-00452, B5G high speed optical access and slicing technology]

## References

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