A Field Trial of 50G TDM-PON Based 5G Small Cell Backhaul

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Abstract: We demonstrate a field trial of 50G TDM-PON based small cell backhaul. Multiple user equipment are connected to two 5G base stations simultaneously. The maximum download speed of each user equipment reaches nearly 1000 Mbps.

1. Introduction

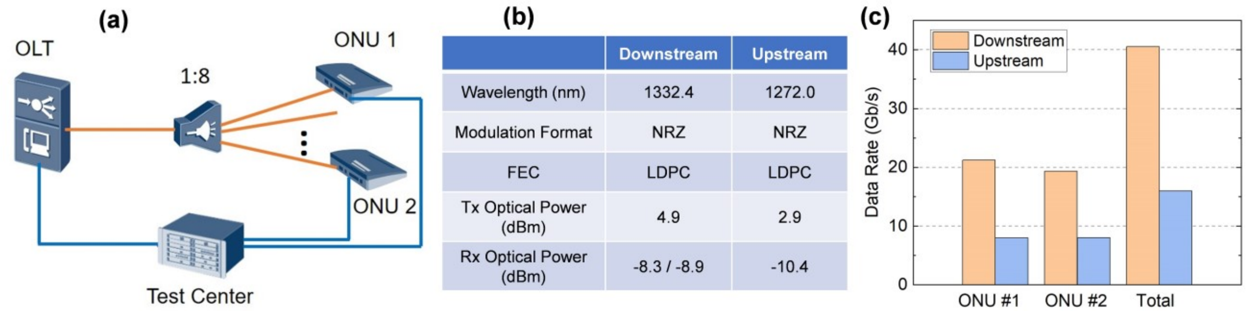
In the 5G era, in order to meet the requirement of ever-growing wireless traffic capacity, both operators and vendors agree that the number of small cell base stations (BSs) and the total bandwidth must be dramatically increased [1]. Also, the latency of the single BS should be less than 1 ms. Since the deployment of distributed radio access networks (D-RANs) requires a huge amount of both fiber resources and transmission equipment, it poses a financial challenge on operators, given the high cost of deployment and maintenance of a large amount of active devices over metropolitan areas [2]. It is necessary to find a way to evolve to a denser small cell deployment while minimizing the cost. In most of the urban areas all over the world, fiber-to-the-home (FTTH) access networks have already been widely deployed. The passive optical network (PON) shows unique advantages, including high reliability, low operational cost, large bandwidth support and long distance reach [3]. In the case that the existing optical distribution network of PON can be reused, using PONs to support BS traffic can reduce the total cost of network construction and minimize the additional optical fiber that needs to be deployed. However, the existing ten gigabit symmetric (XGS)-PON doesn't have enough bandwidth for 5G small cell backhaul in many scenarios.

50G time-division multiplexing (TDM)-PON has been defined by international telecommunications union (ITU) to be the next generation PON system beyond 10G. The most significant upgrade is that its downstream data rate is increased by 5 times. 50G PON has been intensively investigated recently, and several impressive results have been reported so far. In [4], by using externally modulated laser (EML) with semiconductor optical amplifier (SOA) at the optical line terminal (OLT) side, and 25G-class avalanche photodiode (APD) with digital signal processing (DSP) technology at optical network unit (ONU) side, an E2-class power budget with 20-km fiber downstream transmission was realized. Recently, the first real-time 50G PON prototype was also demonstrated [5]. Its downstream and upstream capacity are 50 Gbps and 25 Gbps, respectively. The first version of ITU-T G.9804 standard series for 50G PON has been approved recently, and so now it is the best time to explore their potential application scenarios.

In this paper, we demonstrate for the first time a field trial of 5G small cell backhaul based on a 50G TDM-PON prototype which is compatible with a commercial PON chassis. Two ONUs are connected with two individual BSs, and four 5G cellphones are registered to the small cells simultaneously. The OLT is capable of layer 2 (L2) and layer 3 (L3) networking. Key wireless communication parameters including download speed and latency are characterized for both cases.

2. Characterization of the 50G TDM-PON system

The experimental setup for the characterization of our 50G PON system is shown in Fig. 1(a). The OLT is connected to a 1:8 optical power splitter. Two of the eight ports are connected to the ONU devices. The 50G PON is designed to be an asymmetric type: the maximum downstream speed is 50 Gbps while the maximum upstream speed is 25 Gbps. In downstream direction, a 50G-class EML is used at the OLT side, but a 25G-class APDs is used at the ONU side. After the receiver, additional signal processing is needed to compensate for the limited receiver bandwidth. In upstream direction, the 25G burst-mode (BM) TIA and CDR is used in the OLT receiver. A Spirent test center (SPT-N4U) was used to connect the OLT and two ONUs and send data streams in both directions simultaneously. The optical parameters of the 50G PON system is shown in Fig. 1(b). The downstream and upstream operation wavelengths are 1332 nm and 1272 nm, respectively. The modulation formats we used in both directions are NRZ signal and we applied LDPC FEC for both directions. In downstream direction, the launched optical power from OLT transmitter is 4.9 dBm, and the optical power received at two ONUs are -8.3 dBm and -8.9 dBm. Similar results are observed for the upstream direction. Since the total fiber length is less than 100m, the power loss mainly comes from the splitter and fiber connectors. It is noted that the maximum power budget our system can achieve is 22dB with 20-km fiber transmission, which can be further improved by using SOA and optimizing the DSP. We measured the data rate of both directions, and the results are shown in Fig. 1(c). The two ONUs are configured in a similar way, and both BER and frame loss rate are zero in both directions. The total downstream payload data rate is 40.6 Gb/s, close to the theoretical maximum value of 50G PON, which is 41.75Gb/s. The total upstream data rate is 16.0 Gb/s. Because the upstream signal is in burst mode, more preambles are required which reduces the payload data rate.



	Downstream	Upstream
Wavelength (nm)	1332.4	1272.0
Modulation Format	NRZ	NRZ
FEC	LDPC	LDPC
Tx Optical Power (dBm)	4.9	2.9
Rx Optical Power (dBm)	-8.3 / -8.9	-10.4

Fig. 1. (a) Experimental setup for the characterization of the real-time 50G TDM-PON, (b) optical parameters of the 50G PON prototype in both downstream and upstream transmission, (c) measured results of data throughputs of two ONUs for both downstream and upstream.

3. Field trial of 5G small cell backhaul

We carried out a field trial of 5G small cell backhaul using the 50G TDM-PON in Jiangsu province of China. The uplink interfaces of the 50G PON OLT are connected to the metro transport network, namely 5G slicing packet network (SPN) switching node. It is further connected to the 5G core networks (5GC) of China Mobile. All the SPN protocols are supported on the 50G PON equipment, and the OLT can be configured for either L2 or L3 networking. Each of the two ONUs is connected with a 5G small cell base station (BS) that contain a base band unit (BBU) and a remote radio unit (RRU) antenna. Their functions are exactly the same with 5G distribution unit (DU) and active antenna unit (AAU), capable of carrying 5G services. The two BBUs are located in a same equipment room as PON system, but the two RRUs are located in two different floors within the same building. The interface between each BBU and its ONU is 10G Ethernet. Traditional XG(S)-PON cannot support more than one BS when operating at full speed. We turned on four user equipment (UEs) that are 5G cellphones, and connected them to the two BSs. Each cellphone is registered to an individual BS. The Speed Test Application of the four cellphones were run simultaneously to measure the downstream speed and latency.

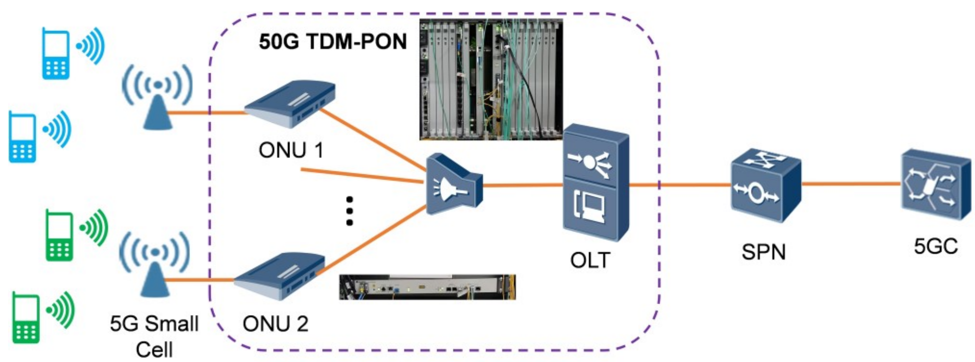


Fig. 2. Schematic setup of the field trial of 50G PON based small cell backhaul.

In the first test, the OLT was configured to provide L2 networking. The whole end-to-end network structure is shown in Fig. 3(a) together with the IP addresses of each equipment. In this case, both the OLT and ONU are working at L2, and the data streams travel through the 50G PON based on their VLAN and MAC addresses. The red arrow shows the transmission path of data stream. The transmission between the BBU and ONU is based on Xn interface for 5G communications [6]. The L3 switch is realized by the SPN node, which sets a default route to each BBU. The IP address of each BBU is in the same segment as its corresponding SPN port. The maximum download speed of four UEs was measured over half an hour, and the results are shown in Fig. 3(c). Cellphone 1 and 2 are registered at BBU 1, and the other two are registered at BBU 2. We can see that the download speeds of all UEs are between 800 Mbps to 1000 Mbps for most of the time, and occasionally they can even exceed 1000 Mbps. The average speed of cellphone 3 and 4 are slightly lower because the measurement was conducted at a busy time. There were some other users on the same floor that shared the RRU, which caused the speed difference. Our 50G PON can simultaneously support around 40 UEs under single PON interface while maintaining the same speed.

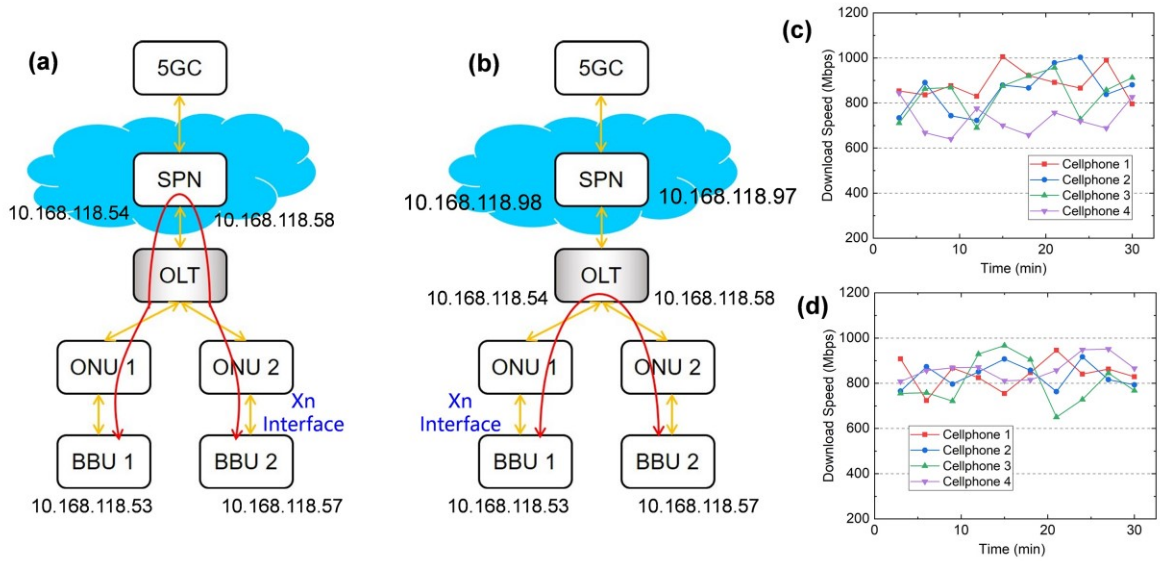


Fig. 3. The network structure for the 50G PON based small cell backhaul accompanied with IP addresses of each equipment when OLT configured at (a) L2 and (b) L3, and the measured download speed of each UEs using (c) L2 and (d) L3 PON networking.

In the second test, the OLT was configured for L3 networking. This time the OLT provides the L3 routing of the data stream, as the red arrow shows. The IP address of each BBU is in the same segment as its corresponding OLT ports. The SPN will only configure the default route to the OLT, rather than to each BBU. The IP addresses for two BBUs of the SPN device are in the same segment. The results of UEs download speed of OLT L3 network are shown in Fig.3(d). There is no obvious decrease compared to the L2 case. The download speed of all four cellphones ranged between 800 Mbps to 1000 Mbps. We also characterized the latency properties of our system. The measured average delay of 50G PON downstream and upstream were only 27.5 us and 73.9 us, thanks to the dedicated activation wavelength technology. Including the latency of BS itself, it was still less than 1 ms, which fulfills the requirement of 5G small cell backhaul. We also measured the round-trip delay of the entire system, compared to the result of BBUs directly connected to the SPN node without PON equipment, the delay increases only 0.3 ms, which proves the low-latency fashion of our 50G TDM-PON.

4. Conclusion

We have successfully carried out a field trial of 5G small cell backhaul based on a 50G TDM-PON prototype. Two ONUs are connected with two 5G base stations, and four 5G cellphones are registered to the two BBUs simultaneously. We configured the OLT for L2 and L3 networking. The measured maximum download speed of each cellphone ranges from 800 Mbps to 1000 Mbps for both cases. This work paves the way of future applications of 50G TDM-PON in 5G wireless communications.

5. References

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