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Demonstration of Low Latency 25G TDM-PON with Flexible Multizone-based ONU Activation for Time Critical Services

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Abstract *We successfully demonstrate the flexible multizone-based ONU activation to reduce effectively a quiet window in TDM-PON. The total time for 64 ONUs registration is reduced to 74.3 %.*

Introduction

TDM-PON is attractive solution to accommodate ever increasing traffic in access network since we can have easy optical connectivity to end-user anywhere in the network. As a result, its application area is expanding from traditional FTTH services such as web-browsing and over-the-top (OTT) media services to time-critical applications such as 3D augmented reality, tactile internet, remotely controlled robot, and smart factory [1]. Thus, the low latency as well as high capacity in TDM-PON are critically important for the accommodation of brand-new applications.

The large upstream-latency in TDM-PON is mainly caused by competition of multiple ONUs in shared medium, dynamic bandwidth allocation (DBA) cycle, and quiet window for ONU discovery and ranging process. The competition of multiple ONUs and/or DBA cycle could resolve by enhanced DBA with multiple bursts per 125-µs cycle [2-3] or cooperative DBA (CO-DBA) by exchanging scheduling information between mobile and optical equipment [4]. However, the quiet window induced latency is inevitable in TDM-PON since discovery and registration of new ONU is required. To make ONUs joining to the system, as shown in Fig. 1, OLT repeatedly pauses the upstream transmission with a quiet window of 250-µs and 450-µs duration for 20 km and 40 km fibre distance, respectively. This waiting time affects to latency in time-critical service. Recently, there are a few demonstrations to reduce quiet window induced latency increase such as whispering ranging and dedicated activation wavelength (DWA) [5-6]. Although these methods significantly reduce time for quiet window, additional wavelength for quiet window or modified PON transceiver for whispering is required.

In this paper, we experimentally demonstrate low-latency 25G TDM-PON with multizone-based ONU activation for the accommodation of time-critical applications. The simple multizone-based ONU activation process neither require additional wavelength nor modification of PON transceiver to reduce the quiet window. The quiet window for ONU activation significantly reduced by 102-µs and the total time required to register 64 ONUs reduced to 74.3% in multiple zone scheme.

Multizone-based ONU Activation

In order to reduce the inevitable pausing period caused by a quiet window, multizone-based ONU discovery and registration is utilized according to ONU distance, as shown in Fig.2. The zone could be flexibly configured such as 5 km, 10km, or 20 km according to the location of ONUs. For example, in the case of 20 km zone distance, OLT opens a quiet window of 250-µs to discover ONUs like typica TDM-PON. A 20 km zone distance could be used when the applications accommodated in the ONU have no latency issue such as non-time critical applications. On the other hand, when time-critical applications are needed in the TDM-PON, a short quiet window of 102-µs could be used needed in PON. These zones open in units of 5 km area. For example, zone 4 is used for ONU discovery within a distance of 15 km to 20 km. This means that all ONUs within the zone could be discovered and

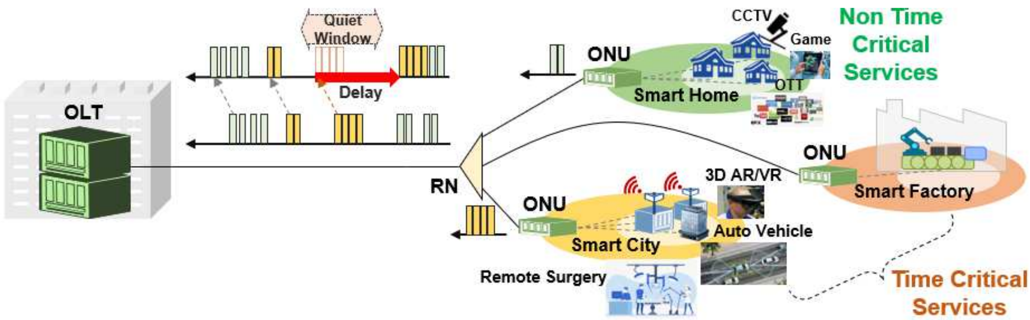

Fig. 1: Co-exitence of non-time critical and time-critical services at the same ODN in TDM-PON

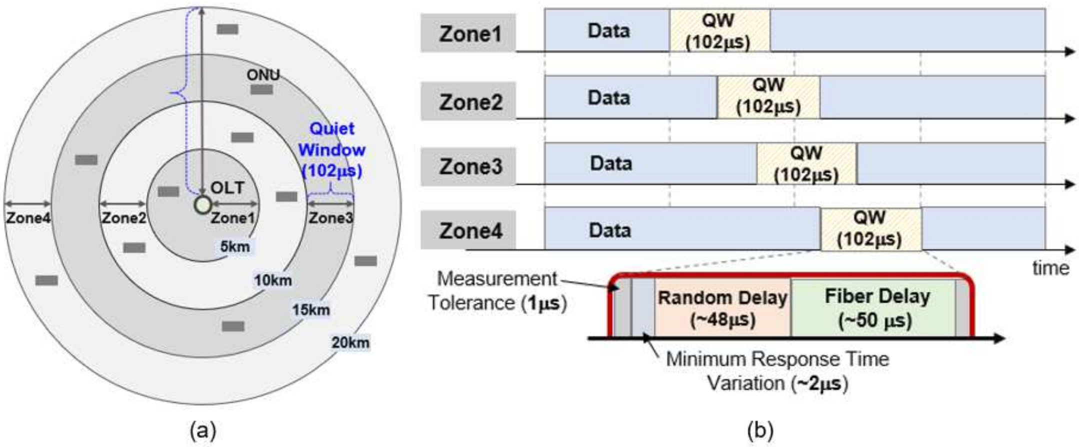

Fig. 2: Multizone-based ONU activation (a) multi-zone configuration with 5 km (b) time for quiet window in each zone

registered through the quiet window of 102-µs. The zone distance with 10 km to register ONUs is also possible configured with 152-µs window. The inevitable pausing time caused by a quiet window can be effectively reduced through the flexibly configured multiple zone.

Each zone is distinguished by different unassigned ONU-ID unlike the legacy PON. The ONUs within the same zone have the same unassigned ONU-ID. Thus, OLT can transmit a serial number (SN) grant with unique unassigned ONU-ID for a specific zone. If SN grant for zone 4 is transmitted, other zones does not response to this request except for zone 4. However, when SN grant with unassigned ONU-ID of 0x03FF is transmitted, all ONUs should be responded to this request. Thus, the legacy and multizone-based ONUs can co-exist simultaneously in TDM-PON. The ONU location could be identified through OTDR measurement in the field site. Fig. 2(b) shows the open time of quiet window in each zone. The quiet windows are opened at different times depending on the distance. As shown in Fig.2(b), the quiet windows include the minimum response time variation of 2-µs, random delay of 48-µs, one-way fiber delay of 50-µs or 100-µs depending on zone distance, and measurement tolerance of 2-µs. This tolerance can cover the difference of 100-m in boundary of the zone. The unused quiet window of 148-µs can be assigned to ONU requiring time-critical service.

Experimental setup and results

Fig. 3(a) shows the experimental setup for the demonstration of low latency 25G TDM-PON with flexible multizone-based ONU activation for time-critical services. It is implemented based on HDL in FPGA with 25GS-PON and ITU-T G.9807 standard. The low latency-oriented DBA assigns an upstream bandwidth to ONUs with a period of at least 125-µs cycle. And it allocates high priority bandwidth to ONU1 for time-critical services and low-priority bandwidth according to status report from ONU2 for non-time critical services. The 25-Gb/s and 10-Gb/s Ethernet ports of packet analyzer was connected to OLT and ONUs for latency measurement. The OLT and ONUs connect with a 20 km SMF and 32-way splitter.

Fig.3(b) show the functional simulation result of ONU activation for registration of a new ONU through multizone-based quiet window. In-service ONU transmits an upstream traffic every 125-µs cycle. OLT periodically attempts a ONU activation to discover new ONU, and then sends the SN grant with specific unassigned ONU-ID for each zone. After then, OLT opens the quiet window of 102-µs to search new ONU. As a result, the latency of 102-µs is occurred into in-service ONUs. We can see that an upstream transmission from in-service ONU is paused, and SN response is received at quiet window of 102-µs. After then, OLT assigns ONU-ID to discovered ONU and performs the ranging process. OLT sends the ranging grant with assigned ONU-ID and again opens the quiet window of 54-µs except for random delay of 48-µs. When registration is received from discovered ONU, OLT assigns an equalization delay (EqD) and finishes the ONU activation. From this result, we can confirm that the quiet window of 102-µs is used during the ONU activation.

Fig. 3(c) shows the measured latency variation when ONU activation is performed according to legacy quiet window scheme. The measured latency is obtained through a packet analyzer in upstream direction. Before the ONU activation process, the maximum latency for upstream traffic transmission for ONU1 and ONU2 is measured to be 196.16-µs and 735.87-µs, respectively. This is because ONU1 is assigned for time-critical applications and ONU2 is assigned for non-time critical applications. On the other hand, when we performed the ONU

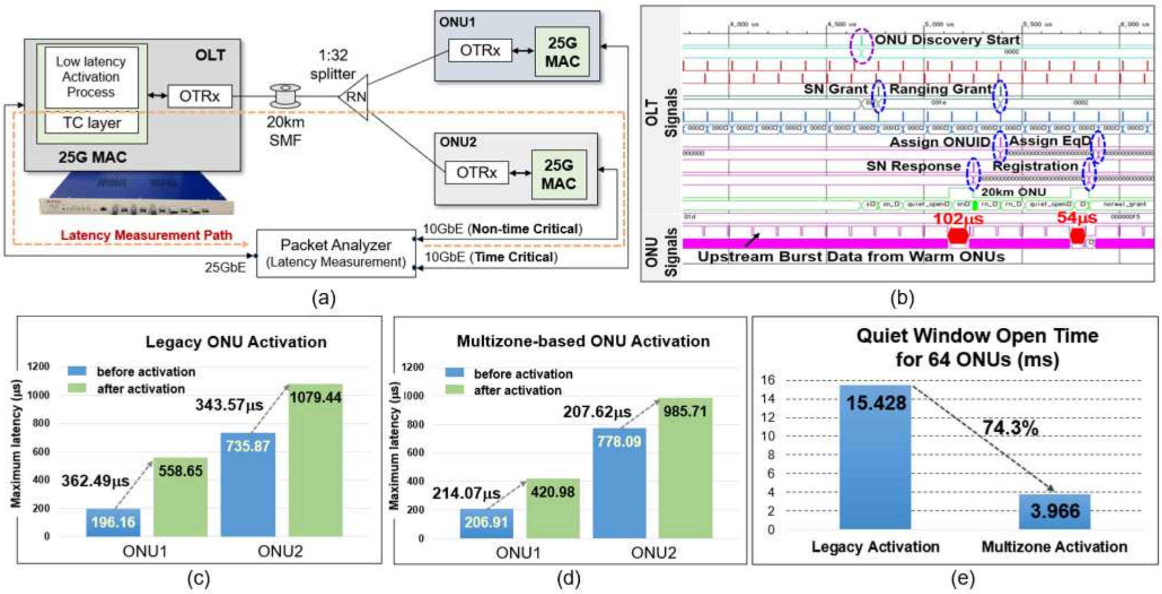

Fig. 3: Expeimental setup and results (a) real-time demonstration setup (b) logical simulation of multizone based ONU activation (c) maximum latency for legacy activation (d) maximum latency for multizone based activation; (e) total time required for opending 64 ONUs

activation process, the latency for each ONU is increased to 558.65-µs and 1079.44-µs by ONU activation, respectively. The increased latency of 362.49-µs and 343.57-µs in each ONU is mainly caused be the quiet window of 250-µs and fibre delay of 100-µs.

Fig.3(d) shows the measured maximum latency in real-time traffic transmission when ONU activation is performed by multizone-based quiet window scheme. The measured maximum latency for ONU 1 and ONU2 is initially 206.91-µs and 778.09-µs, respectively. After ONU activation, the maximum latency increased to 420.98-µs and 985.71-µs for each ONU. In this result, we can observe that the latency of each ONU is only increased to 214.07-µs and 207.62-µs by quiet window of 102-µs. Therefore, the latency caused by ONU activation is significantly reduced from 362.49-µs to 214.07-µs for time-critical service.

Fig.3(e) shows the result of total quiet window open time to discover 64 ONUs. To complete ONU registration, in legacy method, quiet window time for discovery and ranging are typically required 250-µs and 202-µs, respectively. The several ONUs are found through random delay in a single discovery window, and a single quiet window for ranging is need for each ONU. Therefore, an open time is as much as 15.428 ms for 64 ONUs. On the other hand, in the case of multiple zones scheme, total time for discovery and ranging is as short as around 3.9 ms because we used short quiet window, which results in the reduction of total time to 74.3 %.

Conclusions

We experimentally demonstrated low-latency 25G TDM-PON with multizone-based ONU activation for the accommodation of time-critical applications. The real-time measurement with 25G TDM-PON over 20 km of SMF and 1:32 splitter show that the time for discovering and registering new ONU could be significantly reduced by 59.2% through multiple zone scheme. In addition, the total time required for register 64 ONU reduced to 74.3%.

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