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다중 OLT를 갖는 PON 시스템에서 하향 동적대역할당 알고리즘에 관한 연구

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A Study on Downstream Dynamic Bandwidth Allocation Algorithm in Multi-OLT PON System

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요 약

한 개의 PON 시스템을 이용하여 여러 종류의 서비스 혹은 여러 서비스 공급자를 수용할 수 있도록 하는 Multi-OLT PON 구조를 제시하였다. 또한 이런 PON 구조에 적합한 동작 프로토콜 및 동적 대역할당 기법에 대하여 설명하였다. 성능 분석을 통해 제안한 구조의 PON 시스템이 매우 효율적이며, 향후 초고속 PON 시스템에서 효과적으로 이용될 수 있음을 알 수 있었다.

Key Words : Passive Optical Network, multi-OLT (Optical Line Terminal), DBA (Dynamic Bandwidth Allocation)

ABSTRACT

A multi-OLT PON architecture is proposed to accommodate several types of services or multiple service providers economically in a single PON. The operation protocol and a dynamic bandwidth allocation scheme appropriate for two-OLT structure are proposed. Performance analysis shows that the proposed system is very efficient and can be used in the upcoming higher speed PON system.

Ⅰ. Introduction

Since its first deployment in the 1990s PON (Passive Optical Network) systems have been used to carry many different types of data including internet, multimedia data, CATV, wireless internet, sensor network, etc. Recently, it is observed that wireless traffic increase during the last two years reached 10 times with the appearance of smart mobiles. PON has played an important role in breaking the bottleneck of traffic[1]. But unfortunately, there are quantitative and qualitative aspects related to the traffic growth. The quantitative side relates to the increasing number of internet users and the qualitative side involves to changed behavioral patterns of usage. Users are using more bandwidth-intensive applications and services than ever before[2]. So, the service providers are in strong competition to give the best facilities. Single-OLT (Optical Line Terminal) PON system, however, allows only one service provider, and subscribers don't have the right to choose the most appropriate

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service provider for themselves. By the way, to install multiple PONs at a subscriber premises is an expensive solution while it allows versatile choices to users.

In this study, we propose a design and analysis of a PON architecture that uses the time-division multiplexing (TDM) approach to deliver data encapsulated in Ethernet packets between several central OLTs and a collection of ONUs (Optical Network Units) over a single PON access network. The upcoming 10 Gbps or 40 Gbps PON systems[3] can be used to implement this multi-OLT single PON system.

Two OLTs in two separate PONs shown in Fig. 1(a) need an additional photo-detector (PD) at each ONU and additional fibers between Remote Nodes (RN) and ONUs. Thus, it is difficult to expand the number of OLTs. However, two OLTs in a single PON shown in Fig. 1(b) do not need any additional PD. It only requires an additional fiber between the added OLT and the remote node. Therefore, this structure is economical and easy to expand the number of OLTs using existing PON systems.

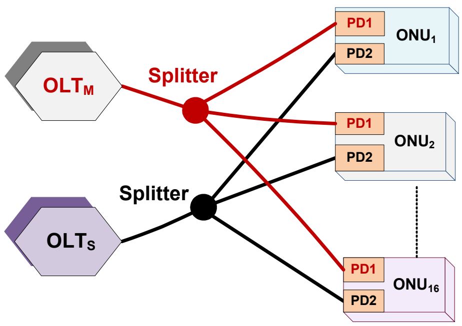
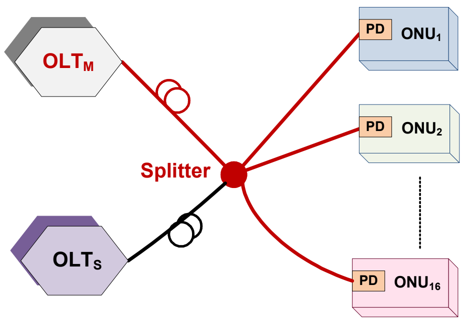


Fig. 1. (a) Two separate PON systems for two OLTs.



(b) Proposed architecture of a single PON with two OLTs.

Three main challenges in implementing multi-OLT PON system are the avoidance of packet collision, bandwidth allocation and security of data in both directions. In this paper, we propose appropriate ways to solve these problems. We also discuss a method to measure the RTTs (Round Trip Time) between multiple OLTs and ONUs, respectively. In addition to this, a dynamic bandwidth allocation scheme for downstream transmission is suggested and its performance is analyzed.

The rest of this paper is organized as follows. Section II introduces data transmission sequences in the PON system with multiple OLTs. RTT measurement procedures is described in Section III. In Section IV, we discuss the proposed GLDBA (Guaranteed Limited Dynamic Bandwidth Allocation) scheme and present it's performance improvement with respect to FBA (Fixed Bandwidth Allocation). Finally, Section V concludes our work.

Ⅱ. PON with Multiple OLTs

Downstream and upstream data transmission sequences in the multi-OLT PON are shown in Fig. 2 and 3, respectively. For convenience, only two OLTs, master OLT (OLT_M) and subsidiary OLT (OLT_S) and sixteen ONUs are assumed in these figures. Since two OLTs share the same PON as in Fig. 1(b) they should know the other OLT's transmission time and RTT to avoid packet collision. Procedures of RTT measurement are described in Section Ⅲ. Transmission start time of OLT_S is calculated using two RTTs and packet length (L_K) transmitted from OLT_M as in eq. (1). The same principle should be applied to ONUs during the upstream transmission.

$$T_{begin}\ of\ OLT_S = T_{begin}\ of\ OLT_M + L_K + \frac{1}{2}RTT_M - \frac{1}{2}RTT_S + T_{guard}\ of\ OLT \quad (1)$$

Fig. 2 shows that OLT_M and OLT_S transmit buffered packets in sequence. Transmission slot size of each OLT is decided according to the bandwidth

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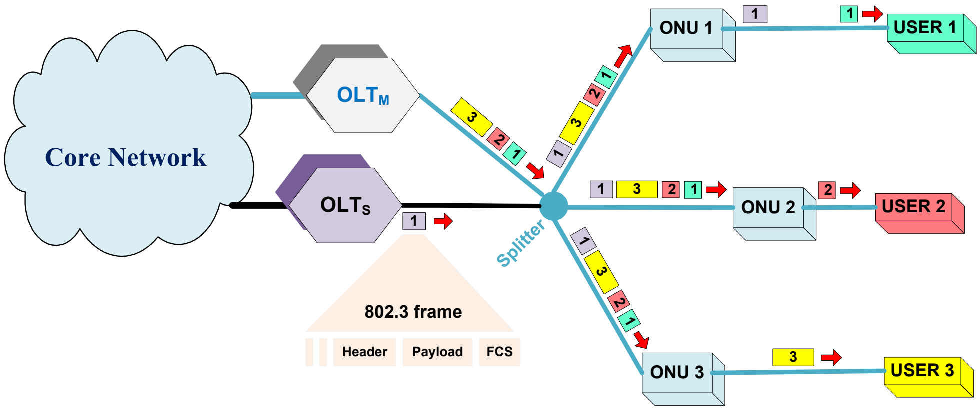

Fig. 2. Downstream transmission in the proposed multi-OLT PON network

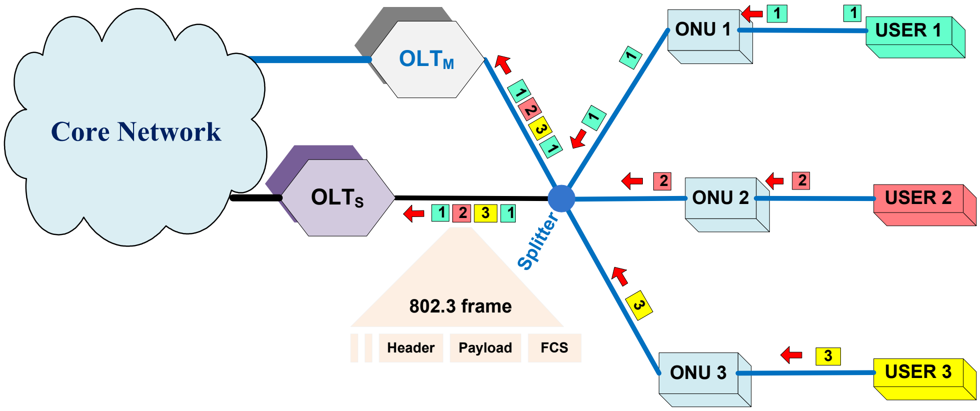

Fig. 3. Upstream transmission in the proposed multi-OLT PON network

allocation scheme. User 2 and user 3 receive data packets only form OLT$_M$ because they choose only this OLT as their service provider. On other hand user 1 choose service from both OLT. Upstream transmission time in Fig. 3 is calculated by both OLTs so that each ONU sends their packets in sequence without any collision. Since packets sent by all ONUs are received at both OLTs, an appropriate encryption algorithm[4] should be used in order to provide secure data transmission for users.

Ⅲ. Principles of the RTT Measurement

The simplest way to measure RTT (Round Trip Time) is to send a message from the OLT and request an ONU to echo it back[5].

Fig. 4 shows the exchange of messages for RTT measurement of OLT$_M$ and OLT$_S$ with respect to ONU 1. OLT$_M$ sends a message (GATE), which is time-stamped with it's local time. ONU 1 receives it and sets it's local time to the arrived time-stamp. When the local clock of the ONU 1 reaches the start time of it's slot (also delivered in the GATE message), it transmits a message (REPORT). It contains a time-stamp representing ONU's local time of the REPORT message delivery. Both the OLTs receive this REPORT message.

Now, according to Fig.4, OLT$_M$ can measure its RTT using eq. (2).

$$T4 - T1 = T3 - T2$$
$$RTT_M = (T5 - T1) - (T3 - T2) = T5 - T4 \quad (2)$$

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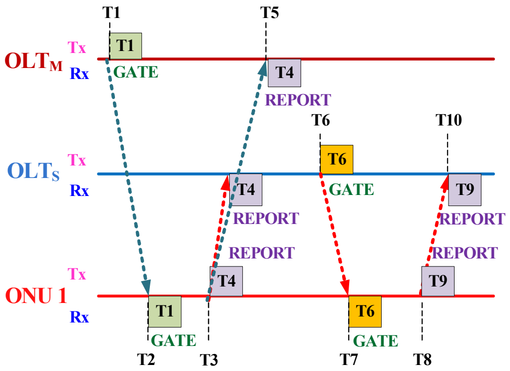

Fig. 4. Round-trip time measurement in the proposed multi-OLT PON network

OLT_S also receives the REPORT message and sets it's local time to the arriving time-stamp. So, it's time is synchronized with OLT_M. Then it sends back a GATE message containing time-stamp T6 to ONU 1. When the local clock located at the ONU 1 reaches the start time of it's slot, it again transmits a REPORT message. It contains a time-stamp representing the local time of Report message delivery. This time only OLT_S receives it and calculates own RTT using eq. (3).

$$\begin{aligned} &T8 - T7 = T9 - T6 \\ &RTT_S = (T10 - T6) - (T8 - T7) = T10 - T9 \end{aligned} \tag{3}$$

Once each OLT knows own RTT, it sends this information to ONU 1 in the next cycle. Then ONU 1 retransmits them to the other OLTs so that they know each others RTT, which are used in the calculation of transmission time.

Ⅳ. Dynamic Bandwidth Allocation and Performance Analysis

The possible bandwidth allocation among multiple OLTs can range from a fixed scheme to a dynamic adapting one[6]. Although the fixed bandwidth allocation (FBA) scheme is easy to implement, it has some demerits. If the occurred traffic is different from the pre-assigned bandwidth, the delay increases rapidly. As an alternative we propose a Guaranteed Limited Dynamic Bandwidth Allocation (GLDBA) scheme that guarantees the pre-assigned time slot for each OLT. Therefore, it is guaranteed that each OLT can use its own downstream capacity while it can share its unused capacity with the other OLT. The amount of the leased bandwidth is changing dynamically according to the occurred traffic. The amount of exchange is limited so that the pre-assigned bandwidth at each OLT is guaranteed, which is the reason that we have the term 'limited' in the name of the scheme. Fig. 5 shows the flowchart of the scheme.

Let's define that L_m and L_s are loads of OLT_M and OLT_S, respectively, and packet generation ratio G_m and G_s can be calculated as

$$G_m = L_m/(L_m + L_s), \quad G_s = L_s/(L_m + L_s) \tag{4}$$

Each OLT should decide whether it has releasable bandwidth. Assume that R_m and R_s are the ratios of guaranteed bandwidth that are pre-assigned to OLT_M and OLT_S, respectively. If both load and generation are less than the guaranteed bandwidth ratio as in eq. (5), then OLT_M can release a part of its remained bandwidth.

$$L_m < R_m \quad \text{and} \quad G_m < R_m \tag{5}$$

Above conditions are made to guarantee the

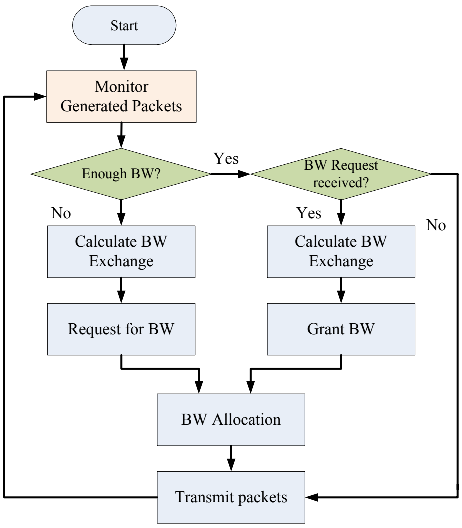

Fig. 5. Flowchart of the proposed GLDBA Scheme

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pre-assigned bandwidth ($L_m < R_m$) and to achieve fairness ($G_m < R_m$) between OLTs. The amount of releasable bandwidth is decided considering appropriate margin at the donar OLT_M as described in eq. (6) and eq. (7).

$$BW_r = BW_m \times (1 - G_m/R_m) \quad \text{for } L \le 1 \tag{6}$$

$$BW_r = BW_m \times \{(1 - L_m/R_m) \times G_s\} \quad \text{for } L > 1 \tag{7}$$

where BW_m is the pre-assigned bandwidth of OLT_M. OLT_S can release the bandwidth in the same manner as eqs. (5)-(7).

We analyzed the downstream transmission performance of the FBA and GLDBA using above algorithms. System parameters used for the analysis are listed in Table 1. Distance between the two OLTs and ONUs are not considered since this study is more focused on bandwidth sharing among OLTs and thus, transmission delay is negligible compared to the queue dalay at each OLT. We ran simulations using Matlab for two different pre-assigned bandwidth ratios for OLT_M to OLT_S; 50%:50% and 70%:30%. Uniformly distributed Ethernet packets are used for the simulation.

Fig. 6 shows the average delay with respect to network load when the two OLTs are assigned the same amount of bandwidth, 50% per each. If the occurred traffic ratio is different from the pre-assigned value, for example 60%:40%, 70%:30% or 80%:20%, then the FBA shows very large delay. The delay is negligible when the load is small, but, it becomes larger for increased load since the downstream capacity is not shared between OLTs. However, it is shown that the delay increase of

Table 1. Simulation environments

Parameter	Description	Value
N	Number of OLTs	2
n	Number of ONUs	16
Q	Buffer Size at OLT	Infinite
q	Buffer Size at ONU	Infinite
T	Cycle-time	2 msec
BW	Total downstream bandwidth	1 Gbps

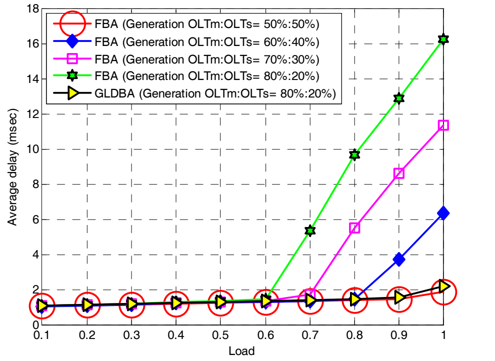

Fig. 6. Delay of 2-OLT PON system (initial BW OLT_M:OLT_S = 50%:50%)

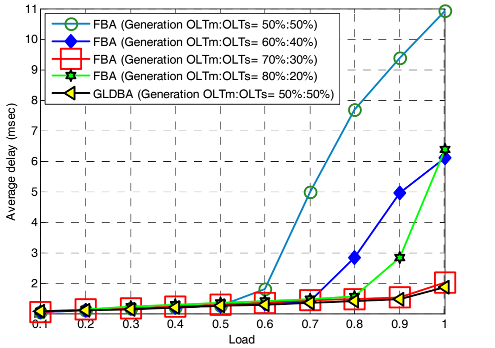

Fig. 7. Delay of 2-OLT PON system (initial BW OLT_M:OLT_S = 70%:30%)

GLDBA is negligible even in the extremely non-symmetric traffic distribution like 80%:20%. Similar results are found in Fig. 7, where pre-assigned bandwidths of 70%:30% are used.

Fig. 8 and 9 show the normalized throughput with respect to network load for the initial bandwidth assignment of 50%:50% and 70%:30%, respectively.

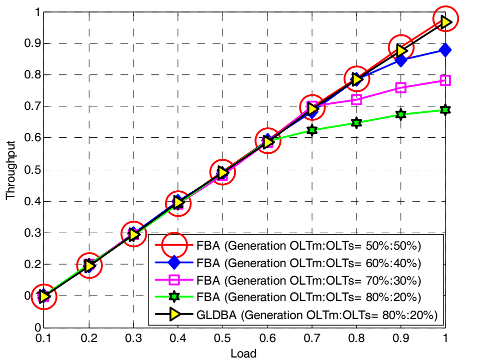

Fig. 8. Normalized throughput of 2-OLT PON system (initial BW OLT_M:OLT_S = 50%:50%)

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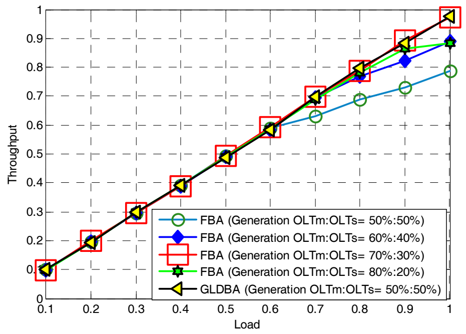

Fig. 9. Normalized throughput of 2-OLT PON system (initial BW OLT_M:OLT_S = 70%:30%)

In both environments the GLDBA scheme results in maximized throughput even when the generated traffic differs a lot from the estimated value.

Delay of each OLT is investigated since just the low average delay doesn't guarantee the performance of all OLTs. Fig. 10 shows the delay of OLT_M and OLT_S in addition to their average value when GLDBA is used. When the generated traffic ratio is the same as the estimated value, delays of both OLTs are the same as expected. However, in the generation ratio of 80%:20% (when generation is far different form the estimated BW) the delay difference is increasing with load. However, the largest delay at load 1.0 is only 2.16 ms, which is tolerable for both OLTs. It is noted that the delays of two OLTs are equal at load 1.0, which is attributed to the complete exchange of unused bandwidth between the two OLTs.

The delay and throughput analysis proves excellent performance of GLDBA scheme. It can

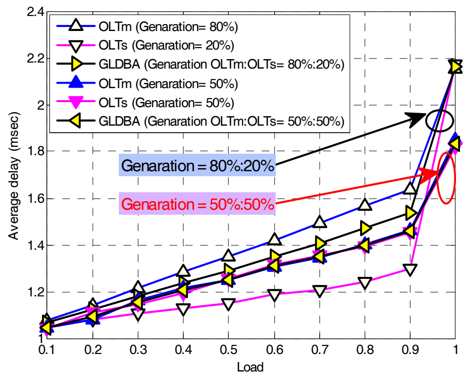

Fig. 10. Delays of two OLTs of 2-OLT PON system (initial BW OLT_M:OLT_S = 50%:50%)

guarantee bandwidth of one OLT while it can help improving performance of other OLT by releasing unused bandwidth.

Ⅴ. Conclusions

In this paper, we presented a novel PON structure that has multiple OLTs in a single PON system and proposed an appropriate operation algorithm for it. This system can help several companies providing their services without deploying another PON. A novel downstream packet scheduling scheme for this PON is proposed and it's performance in terms of packet delay and throughput has been analyzed by simulation. This analysis shows that, the proposed bandwidth allocation scheme is very efficient even when traffic generation pattern is changing very rapidly.

References

〔1〕 Ali Nouroozifar, Hassan Naser, Hussein T. Mouftah, "A delay-based provisioning for Ethernet passive optical networks," AccessNets '07. Second International Conference on Access Networks, pp.1-6, Aug., 2007.

〔2〕 Dave Payne, Russell Davey, "The Future of Fiber Access Systems," BT Technology Journal, vol. 20, no. 4, pp. 104-114, Oct., 2002.

〔3〕 Tim Hills, "Who Makes What: 40- & 100-Gbit/s Systems," www.lightreading.com, July, 2009.

〔4〕 William Stallings, *Cryptography and Network Security*, Prentice Hall, 2003.

〔5〕 Glen Kramer, *Ethernet Passive Optical Networks*, McGraw-Hill Communications Engineering Series, 2005.

〔6〕 Glen Kramer, Gerry Pesavento, "Ethernet Passive Optical Network (EPON): Building a Next-Generation Optical Access Network," IEEE Communications Magazine, pp. 66-73, Feb., 2002.

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