An Enhanced DWBA Algorithm in Hybrid WDM/TDM EPON Networks with heterogeneous propagation delays

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ABSTRACT

An enhanced dynamic wavelength and bandwidth allocation (DWBA) algorithm in hybrid WDM/TDM PON is proposed and experimentally demonstrated. In addition to the fairness of bandwidth allocation, this algorithm also considers the varying propagation delays between ONUs and OLT. The simulation based on MATLAB indicates that the improved algorithm has a better performance compared with some other algorithms.

Keywords: DWBA algorithm; varying propagation delays; hybrid WDM/TDM PON

1. INTRODUCTION

Passive optical networks (PONs) are considered as an attractive access network solution thanks to their low operational costs and huge bandwidth. Nowadays, TDM PONs, such as EPON, GPON and so on [1-3], are widely deployed, but these single channel systems are unable to provide sufficient bandwidth for emerging services like videoconferencing, interactive gaming or video on demand. The increase in user numbers and bandwidth demands triggered by new applications has always posed difficulties for network operators in supporting these unforeseen bandwidth demands during the design and planning period of the network.

Hybrid WDM/TDM EPON is proposed as one of the most promising solutions for smooth upgrading from EPON to satisfy the growing traffic demands in access network. Various dynamic wavelength and bandwidth allocation algorithms have been presented [4-6]. The authors of [5] propose a WDM extension to IPACT that selects the upstream transmission wavelength on a first fit basis. In [6], a new scheduling framework called Just-in-Time (JIT) online scheduling that allows the OLT to have more options for making access decisions without wasting any channel capacity has been proposed. However, with the increase of user numbers and reach distance, the propagation delays between the Optical Network Units (ONUs) and the Optical Line Terminal (OLT) have significant impact on network performance. To the best of our knowledge, these DWBA algorithms don't consider the varying propagation delays between the ONUs and the OLT.

In this paper, we proposed an enhanced dynamic wavelength and bandwidth allocation with heterogeneous propagation delay (DWBA-HPD) which let the lightly loaded ONU be scheduled immediately without waiting for the rest of ONUs to send REPORTs with the consideration of the varying propagation delays between ONUs and OLT to reduce the wasted idle time in the front of the transmission cycle. The simulation is conducted to compare the performance with other algorithms.

2. THE DWBA-HPD ALGORITHM

Hybrid WDM/TDM PON is defined as a PON in which several wavelengths can be used in each direction to establish communication between OLT and ONUs, and each wavelength can be shared by several ONUs whose wavelength assignment can be dynamically changed during operation [7]. To develop the dynamic wavelength and bandwidth allocation (DWBA) algorithm, we assume the ONUs are equipped with the fast tunable laser and can get access to all the

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wavelengths in PON. Therefore, the DBA algorithms in hybrid WDM/TDM PON not only schedule the transmission starting time and duration, but also schedule which wavelength channel the transmission should take place[8].

In [9], the author proposed three offline-based DWBA algorithms (DWBA-1, DWBA-2 and DWBA-3). The DWBA-1 algorithm is completely offline algorithm in which OLT schedules until all the REPORTs are received which will result in an idle time in front of the next transmission. So in DWBA-2, OLT can grant the lightly loaded ONUs in advance and allow them transmit data as soon as the current transmission cycle ends so that the idle time in DWBA-1 can be used to transmit. However, as the algorithm doesn't consider the varying propagation delays between ONUs and OLT, OLT would grant the requested bandwidth to the lightly loaded ONU whose propagation delay may be too large which would also result in an idle time in front of the next transmission cycle as showed in figure 1.

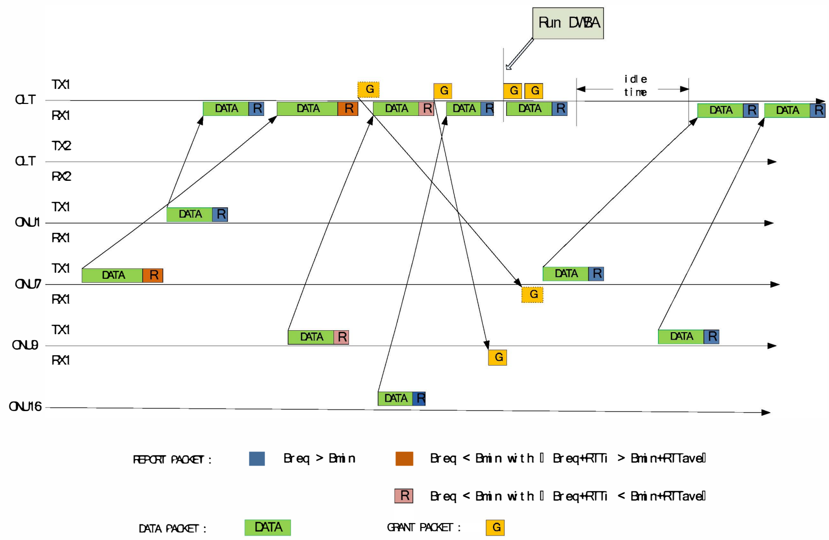


Fig. 1 DWBA-2 protocol

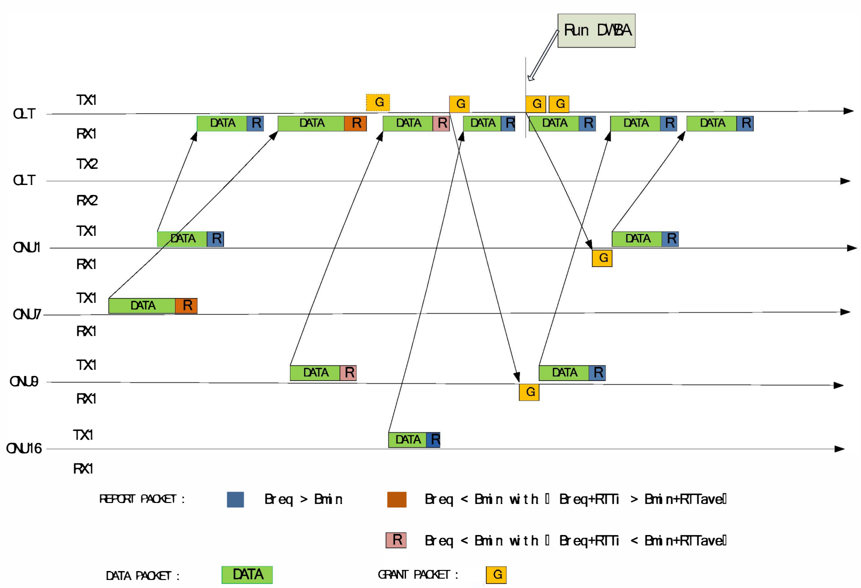


Fig. 2 DWBA-HPD protocol

In order to reduce the idle time, we proposed the DWBA-HPD algorithm in which OLT will grant the requested bandwidth to the ONUs which request a small bandwidth and also have small propagation delays as soon as the REPORT is received by OLT without waiting for the REPORT of other ONUs while the ONUs with large propagation delays should wait to be granted until all the REPORTs are received by OLT as showed in figure 2. We can see the ONU (such as ONU7) with a large propagation delay doesn't be granted in advance while the ONU (such as ONU9) which transmits after it in the current cycle acquires an in-advance grant.

Figure 3 presents the DWBA-HPD algorithm flow. OLT checks if the ONU can be granted in advance until all the REPORTs from ONUs are received. And then OLT grants centralized with the information of the ONUs left. During the centralized scheduling, OLT also consider the varying propagation delay and the requested bandwidth of each ONU in order to reduce the idle time in the next transmission cycle.

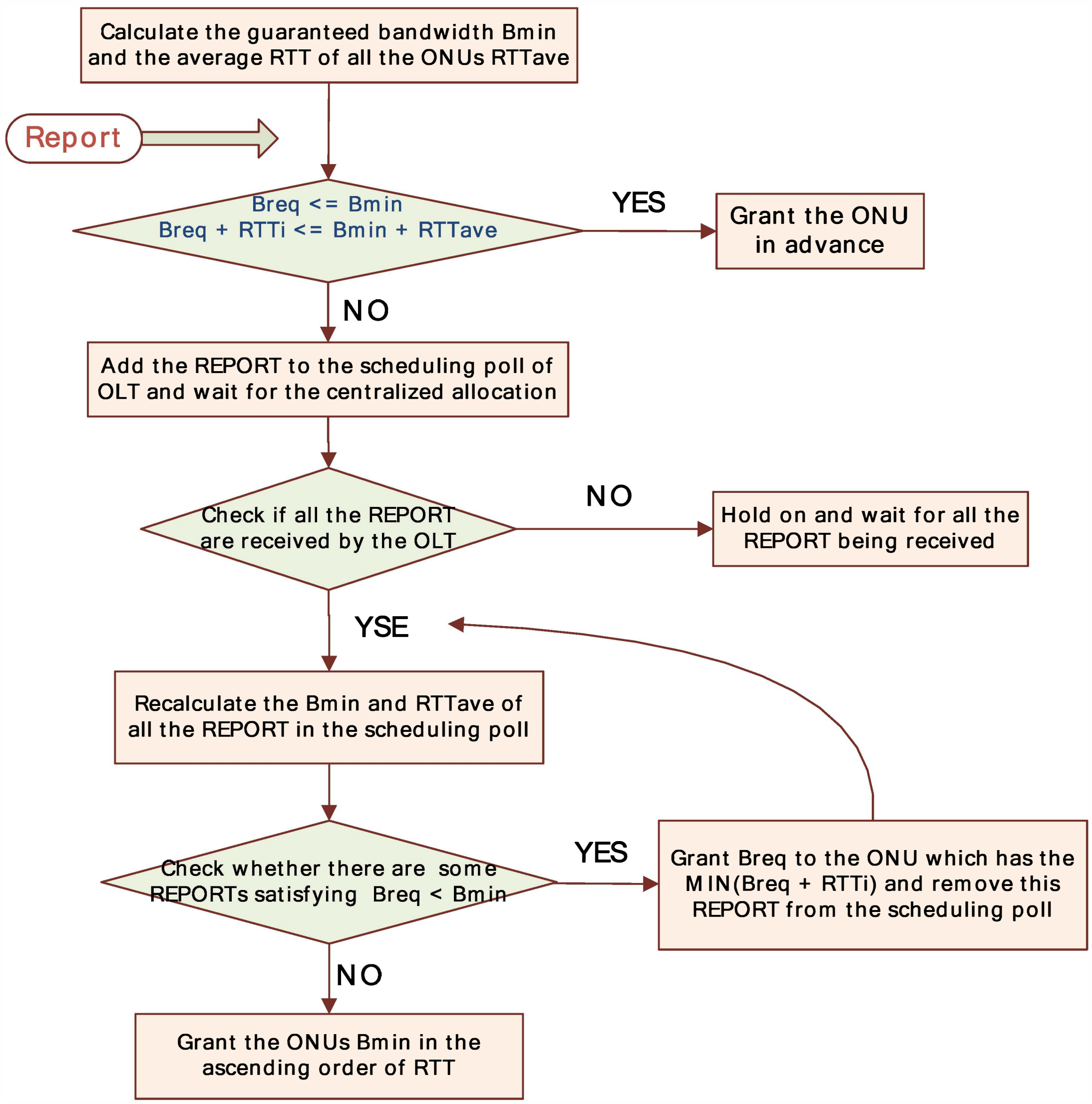


Fig. 3. DWBA-HPD algorithm flow

We consider a hybrid WDM/TDM PON with N ONUs and K wavelength channels. The transmission speed of a single wavelength is R_N.Let T_{cycle} be the grant cycle, during which all the ONU can transmit data to the OLT. T_G is the guard time and ω_i is the bandwidth weight assigned to each ONU. And the DWBA-HPD algorithm is proposed as follows:

1. We calculate the minimum bandwidth guaranteed per cycle the OLT can allocate for an ONU, denoted as B_{MIN}.

$$B_{MIN} = \frac{[(T_{cycle-N\times T_G)} \times K - K \times RTT_{ave}] \times R_N \times \omega_i}{8} \tag{1}$$

In case of no SLA classification, ω_i is 1/N. Thus,

$$B_{MIN} = \frac{[(T_{cycle-N\times T_G)} \times K - K \times RTT_{ave}] \times R_N}{8N} \tag{2}$$

And the average RTT of M ONUs, denoted as RTT_{ave}, can be computed as follows:

$$RTT_{ave} = \frac{\sum_{q=1}^{N} RTT_q}{N} \tag{3}$$

2. Then we check whether $B_{req} \leq B_{MIN}$ and $B_{req} + RTT_i \leq B_{MIN} + RTT_{ave}$. In the case, we will add the REPORT to the scheduling poll of OLT and wait for the centralized allocation. Otherwise, we grant the ONU in advance to reduce the idle time in front of the next transmission cycle.

3. If all the REPORT are received by OLT in current transmission cycle, we recalculate the B_{MIN} and RTT_{ave} of all the REPORT in the scheduling poll with the following formulations.

$$B_{MIN} = \frac{[\sum_{i=1}^{K} T_{left}^{i} - M \times T_G \times K - j \times RTT_{ave}] \times R_N}{8N} \tag{4}$$

$$RTT_{ave} = \frac{\sum_{q=1}^{M} RTT_q}{M} \tag{5}$$

Where we assume that i is the number of the wavelengths in which data is transmitted in advance and j is the number of the other wavelengths (i + j = K). Let M be the number of the ONUs which aren't granted by OLT in advance. The propagation delay between each ONU and OLT is RTT_i.

4. Find the REPORTs that satisfy $B_{req} \leq B_{MIN}$. And then we sort $\left(B_{request}^{i} + RTT_i\right)$ of the ONUs in the ascending order. The OLT grants the minimum one first, and remove the REPORT from the scheduling poll.

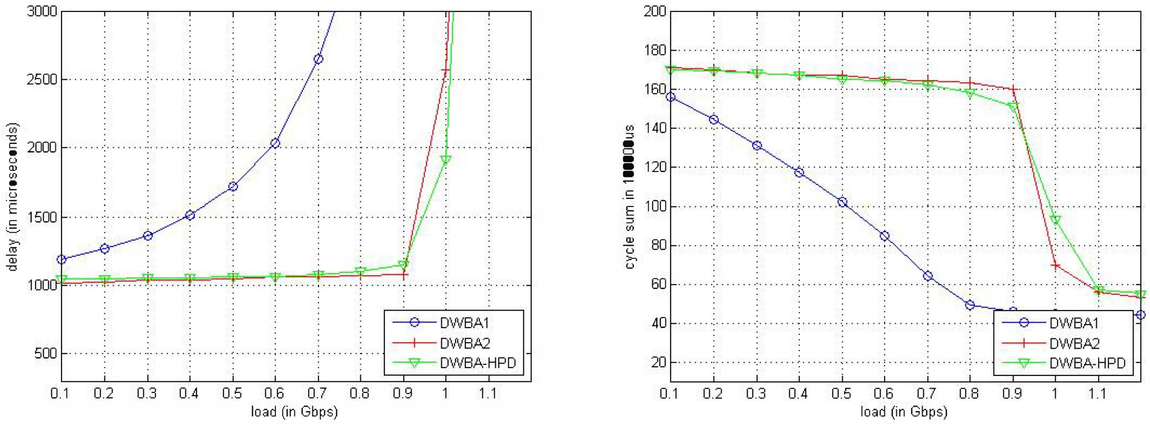
5. Repeat step 3 and 4 in loop until all the REPORTs of the left ONUs satisfy that $B_{req} > B_{MIN}$. And then the OLT just need to grant the B_{MIN} bandwidth to the left ONUs in the ascending order of RTT_i.

In DWBA-HPD, the fairness of transmission is guaranteed as OLT let all the ONU can transmit the B_{MIN} bandwidth at least. In addition, the heterogeneous propagation delay between ONUs and OLT is considered. The algorithm prevents ONU with large propagation delay from being granted by OLT in advance to reduce the idle time in the next transmission cycle.

3. SIMULATIONS AND ANALYZE

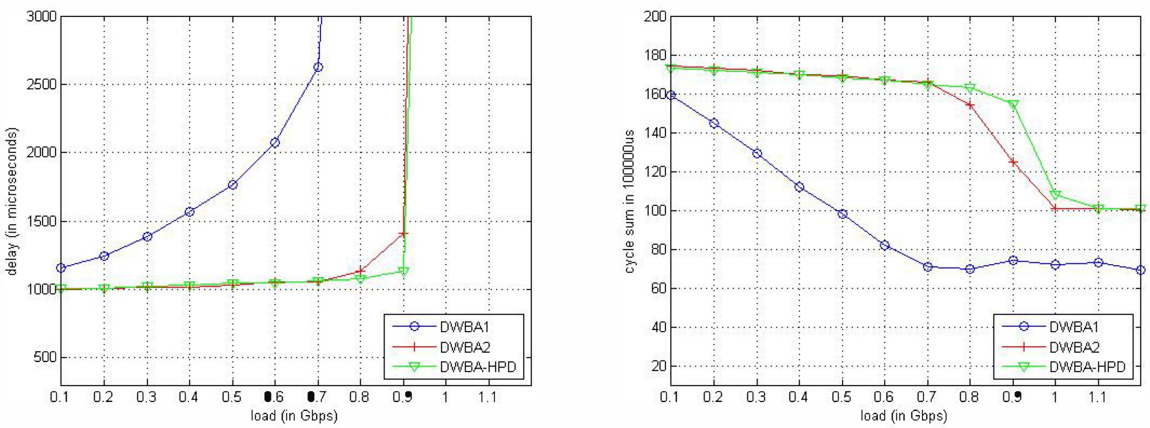
We have developed a simulation using MATLAB in order to compare the performance of DWBA-HPD, DWBA-1 and DWBA-2. We consider the PON architecture with 2 wavelengths and 32 ONUs. The line speed is 1 GB/s and T_G is 1us. We suppose that the RTTs of ONUs are randomly distributed between 10us and 600us. We consider the data packet arrival of the ONUs is a Poisson period. And the sizes of the data packets are randomly distributed between 16B and1518B.

The Fig 4 is the network performance under the condition that the initial transmission cycle is 2ms. We compare the performance of each algorithm on the average packet delay and the number of transmission cycle during 100000us under different loads. And Fig 5 is under the condition that the initial transmission cycle is 1ms.



(a) Average packet delay (b) Sum of the transmission cycle

Fig.4. Network performance when the initial transmission cycle is 2ms



(a) Average packet delay (b) Sum of the transmission cycle

Fig.5. Network performance when the initial transmission cycle is 1ms

From Fig 4, we can see that DWBA-2 and DWBA-HPD have a much better performance than DWBA-1 on both the average packet delay and sum of the transmission cycles. And compared with DWBA-2, DWBA-HPD also has a lower average packet delay and a larger sum of transmission cycles during the fixed time under the network load between 0.9 and 1.1 while DWBA-HPD has approximately the same performance with DWBA-2 under the rest load.

And from Fig 5, we can see that the advantage on average packet delay and sum of transmission cycle achieved by DWBA-HPD compared with other two algorithms is more significant than that of the condition whose initial transmission cycle is 2ms. In particular, DWBA-HPD also has a lower average packet delay and a larger sum of transmission cycles during the fixed time under the network load between 0.7 and 1.0 compared with DWBA-2. This indicates that the DWBA-HPD algorithm is more suitable for the loaded network with a smaller transmission cycle to obtain shorter packet delay.

4. CONCLUSION

In this paper, an enhanced dynamic wavelength and bandwidth allocation algorithm is proposed. The algorithm considers the varying propagation delays between ONUs and OLT in addition to the fairness of the transmission. We grant the lightly loaded ONU in advance to reduce the idle time in front of the transmission cycle to obtain better network performance. Moreover, to evaluate the performance of the proposed scheme, a simulation has been implemented. We compare the performance of each algorithm with different initial transmission cycles. And the results show that the DWBA-HPD algorithm has a better performance on average packet delay and number of the transmission cycles in fixed time.

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