Supporting Global Priority in Epon Differentiated Services Upstream Bandwidth Allocation

N. A. M. Radzi¹, N. M. Din¹, M. H. Al-Mansoori², S. K. Sadon¹, M. S. A. Majid¹, M. Yaacob¹
¹Centre for Communications Service Convergence Technologies, Dept. of Electronics and Communication Engineering, College of Engineering, Universiti Tenaga Nasional, 43009 Kajang, Malaysia
²Dept. of Computer and Electrical Engineering, Faculty of Engineering, Sohar University, PO Box 44, Sohar, PCI 311, Oman
¹{Asyikin, Norashidah, Sajaa, mshahmi}@uniten.edu.my; ²mmansoori@soharuni.edu.om

Abstract: This paper introduces a new dynamic bandwidth allocation (DBA) algorithm for upstream Ethernet passive optical networks (EPON) that supports global priority. The algorithm is hierarchical, where it involves the allocation of bandwidth in optical line terminal and optical network units. It supports differentiated services where the excessive bandwidth in this algorithm is allocated fairly according to the global priority. We compare the DBA algorithm proposed with previous DBA algorithms in the literature. The results show significant improvement in terms of bandwidth utilization and overall packet delay.

Keywords – optical network; global priority; EPON; DBA

I. INTRODUCTION

A simple and easily upgradeable technology is needed in access networks since it is cost-sensitive. Passive optical network (PON) is seen as an attractive solution for the first mile communication because it offers a stable communication channel and it is easy to upgrade [1]. PONs can be subdivided into asynchronous transfer mode PON (APON), broadband PON (BPON), gigabit PON (GPON), Ethernet PON (EPON), and 10 Gbit Ethernet PON (10GEAPON). Nowadays, EPON has become an emerging access network technology that provides a low-cost method of deploying optical access lines between a carrier’s central office and a customer site [2].

EPON is a point-to-multipoint optical network which consists of an optical line terminal (OLT) and connected to multiple optical network units (ONUs) via an optical splitter or coupler. The OLT is situated inside a central office (CO) that links up the optical access network to metropolitan area network (MAN) and wide area network (WAN), whereas the ONUs are situated at either end users’ premises or the curb [3].

The two types of transmission in EPON are upstream and downstream. For downstream transmission, OLT will broadcast all packets through a 1:N splitter to every ONU in the system in one wavelength. Each ONU will selectively receive packets that are meant for them based on their medium access control (MAC) address. On the other hand, for upstream transmission, ONUs will transmit the packets to the OLT through N:1 passive combiner using another wavelength. The packets have to share the same fiber from the splitter to the OLT. This can cause collision of packets from different ONUs. In order to avoid this collision, the IEEE 802.3ah standard has developed a multipoint control protocol (MPCP). The MPCP uses two Ethernet control messages, GATE and REPORT. Upon receiving a REPORT message from every ONU, the OLT performs a MAC arbitration mechanism [4-6]. Several approaches such as wavelength division multiplexing (WDM) and Time Division Multiplexing (TDM) have been used for MAC arbitration mechanism.

TDM scheme has been considered as more cost-effective technique to avoid data collision as compared to WDM [7]. The two allocation methods in TDM are known as static bandwidth allocation (SBA) and dynamic bandwidth allocation (DBA). In SBA, bandwidth is fixed to a subscriber, where once we assigned that particular bandwidth to a subscriber, the bandwidth will be unavailable to other subscribers on the network. On the other hand for DBA, the bandwidth is flexible and can be borrowed and pre-empt from one ONU to another. It provides more efficient bandwidth allocation for each ONU to share network resources and offer better quality of service (QoS) for the end users [8, 9].

The crucial issue in ensuring the successful deployment of EPON is to support the differentiated services (DiffServ) [3]. EPON needs to carry diverse QoS requirements such as voice communication that is sensitive to delay and jitter and video that requires bandwidth guarantee. In order to support QoS, packets must be classified into a number of service classes according to their demand and they must be treated as according to their priority. Previously, the priority of the traffics is ensured within the ONUs only.

In this paper, we propose a DBA algorithm that can support global priority to ensure better QoS to EPON. We name this algorithm as Efficient DBA with global priority (EDBAGP). We compare this algorithm with previously developed DBA algorithms, Efficient DBA with local priority (EDBA) and Broadcast Polling (BP). We conduct detailed simulation using MATLAB to study the performance of the proposed algorithm and validate its effectiveness. The bandwidth utilization and delay have been improved by using this algorithm. EDBAGP improves upon EDBA in terms of bandwidth utilization as
high as 11.24% and upon EF, AF and BE delay as high as 23.41%, 17.24% and 14.94% respectively. Also, it improves upon BP in terms of bandwidth utilization as high as 28.41% and upon EF, AF and BE delay as high as 20.69% for all three types of traffic.

This paper is organized as follows. In Section 2, we briefly review the related work on EPON. Then, we further describe our proposed DBA algorithm in Section 3. Section 4 talks about the simulation setup and result. We end our paper with the conclusion in Section 5.

II. RELATED WORK

The literature contains many different DBA algorithms for EPON architectures [10-16]. These algorithms are designed to operate at either inter-ONU level or intra-ONU level. To sum up, we divide these DBA schemes into two categories; single-level and hierarchical.

The most referenced single-level algorithm is Interleaved Polling with Adaptive Cycle Time (IPACT) scheme by Kramer et. al [10, 11]. In this algorithm, the OLT polls the ONUs individually in a round-robin fashion to dynamically assign transmission opportunities. However, IPACT considers each ONU as one without differentiating the traffics as according to their priority. Thus, it makes IPACT difficult to realize different QoS access within an ONU.

BP developed by Xiong and Cao is another example of a single-level algorithm [12]. In BP algorithm, QoS is realized since it divides the ONUs into three classes denoted by Classes 1, 2, and 3, respectively. The OLT has all known ONU bandwidth requirements before bandwidth is allocated to ONUs in every cycle. However, the detail of the classification has not been specified and there is no limitation for Class 1, thus light load punishment is most likely to occur with BP algorithm. Some examples of hierarchical DBA algorithm can be found in [13-15]. Algorithm in [13] divides ONUs to lightly loaded and highly loaded. Excessive bandwidth in lightly loaded ONUs is exploited by fairly distributing it amongst the highly loaded ONUs. Thus, it improves the throughput. But at times, highly loaded ONUs can receive more bandwidth than requested causing a longer delay to the EPON system.

This problem is solved by a weight based DBA scheme that is called as weighted DBA algorithm [14]. As similar to [13], ONUs are divided into lightly loaded and highly loaded, where the excessive bandwidth from lightly loaded ONUs are distributed to highly loaded ONUs. The difference is that the allocation for highly loaded ONUs is based on the weight of the ONUs, which makes the system fairer. However, the priority categories of the algorithm is according to the arrival of packets; for an instance packets that arrive before the time sending the REPORT are given high priority for transmission. This caused light load punishment to the real time traffic.

DBA in [15] is used to overcome the light load punishment by using fuzzy logic and strict priority scheduling. However, this algorithm can only support priority inside the ONUs. Therefore, to resolve the above-mentioned problems and enhance the bandwidth utilization, we propose a new enhanced DBA algorithm that supports global priority. The algorithm is called as EDBAGP and the main focus of the algorithm is to grant bandwidth according to the priority of the traffic. We will distinguish this advantage by comparing the proposed algorithm to the algorithm proposed in [12] and to the ones we proposed previously in [16] that supports only local priority. The reason for comparing algorithm in [12] and [16] with EDBAGP is that all of them support the same number of classes and sophisticated service level agreement (SLA). For comparison, we have used three types of priorities and the same requested bandwidth for all three types of traffic in all three algorithms. All other parameters that have been used, such as maximum transfer window, maximum cycle time, and guard time are also the same.

III. PROPOSED DBA ALGORITHM

As similar to EDBA [16], EDBAGP still has two types of scheduling, inter-ONU and intra-ONU scheduling. But rather than having only one buffer inside the OLT and ONU, there will be three buffers corresponding to the three different priorities of the traffic; high, medium and low priority. Figure 1 graphically describes the scheduling for global priority.

The highest priority is associated with the expedited forwarding (EF) bandwidth because it supports voice traffic that requires bounded end-to-end delay and jitter specifications. Whereas medium priority is given to the assured forwarding (AF) bandwidth that supports video traffic that is not delay sensitive but require bandwidth guarantees. Finally, the low priority is associated to the best effort (BE) bandwidth that supports data traffic and is not sensitive to end-to-end delay or jitter. In EDBAGP, both OLT and ONU will manage the queues. Rather than dividing the ONUs to highly loaded and lightly loaded, this algorithm is dividing the queues to highly loaded and lightly loaded queues.

A. Inter-ONU allocation

For inter-ONU allocation, bandwidths are set for the three types of traffic. We then divide each traffic to lightly loaded and highly loaded queues. If the requested bandwidth is less than limitation, we call it as lightly loaded; else we call it as highly loaded. Then, each queue is granted with the requested bandwidth as long as it does not exceed the limitation bandwidth. This can better be described in (1).
where $Q_{i,j}$ stands for queue for $j$ traffic class in ONU $i$, $R_{i,j}$ stands for requested bandwidth for $j$ traffic class in ONU $i$ and $S_{i,j}$ stands for limitation bandwidth for $j$ traffic class in ONU $i$.

For lightly loaded queues, excessive bandwidth, $B_{e_{i,j}}$ is calculated using (2).

$$B_{e_{i,j}} = S_{i,j} - R_{i,j}$$

The excessive bandwidth for all the queues is then being summed up before proceeding to the intra-ONU allocation.

### B. Intra-ONU allocation

For intra-ONU allocation, lightly loaded queues are granted with as high bandwidth as requested. On the other hand, highly loaded queues are granted with the limitation bandwidth and some part of the excessive bandwidth from lightly loaded queues. This can better be described in (3).

$$B_{i,j} = \begin{cases} R_{i,j} , & R_{i,j} < S_{i,j} \\ S_{i,j} + B_{excess} , & R_{i,j} \geq S_{i,j} \end{cases}$$

where $B_{excess}$ is the excessive bandwidth. The excessive bandwidth from lightly loaded queues is granted to highly loaded queue as according to their weight. It can be better described in (4).

$$B_{excess} = \frac{w_{i,j}}{w_{\text{highly loaded}}} B_{e_{\text{total}}}$$

where $B_{e_{\text{total}}}$ is the total excessive bandwidth from lightly loaded queues. Higher priority traffic is being granted first, followed by the medium and low priority traffic.

### IV. SIMULATION SETUP AND RESULT

#### A. Simulation Setup

This section presents our simulation setup and results. In order to verify our analysis and demonstrate the performance of our proposed EDBAGP, we compare the algorithm with previous BP and DBA algorithms, EDBA without global priority. Both of these algorithms are simulated using MATLAB. We study the bandwidth utilization and packet delay of all three types of traffics. For comparison purposes, the same parameters are used for both algorithms and they can be showed in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ONUs, $i$</td>
<td>16</td>
</tr>
<tr>
<td>Upstream bandwidth</td>
<td>1Gbps</td>
</tr>
<tr>
<td>Maximum cycle time</td>
<td>2ms</td>
</tr>
<tr>
<td>Guard band</td>
<td>5µs</td>
</tr>
<tr>
<td>Buffer size</td>
<td>10Mbytes</td>
</tr>
<tr>
<td>Maximum cycle time, $W_{\text{max}}$</td>
<td>15500 bytes</td>
</tr>
<tr>
<td>Sub-bandwidth $S_{i,EF}$</td>
<td>0.2$W_{\text{max}}$</td>
</tr>
<tr>
<td>AF bandwidth, $S_{i,AF}$</td>
<td>0.4$W_{\text{max}}$</td>
</tr>
<tr>
<td>BE bandwidth, $S_{i,BE}$</td>
<td>0.4$W_{\text{max}}$</td>
</tr>
</tbody>
</table>

#### B. Simulation Result

We evaluate the performance of the DBA algorithm in terms of bandwidth utilization and packet delay. The starting point of our comparison is to look at how the offered load affects the bandwidth utilization of the two mentioned algorithms. The variation is done in every possible condition and in this paper we present the results for rEF and rAF are high and rBE is low as shown in Figure 2 and rEF and rBE are high and rAF is low as shown in Figure 3.

Figure 2. Bandwidth utilization versus offered load for BP, EDBA and EDBAGP algorithms for the variation of rEF and rAF are high and rBE is low.

From the simulation result, we observe that all three algorithms can perform the bandwidth allocation efficiently. However, EDBAGP is proved to be better than EDBA and BP as can be seen in Figure 2. All three algorithms increase linearly as the offered load increases. EDBAGP can reach as high as 87% whereas EDBA can only reach as high as 76% and BP reaches only up to 59% when the offered load increases to 100%.
Fig. 3 shows the performance of bandwidth utilization for EDBAGP, EDDBA and BP algorithm when the condition of rEF and rBE are high and rAF is low. For this variation also, we can prove that EDBAGP performs better as compared to EDDBA and BP. EDBAGP improves the bandwidth utilization to as high as 87% when the offered load is 100%, whereas EDDBA reaches only as high as 81% and BP as high as 84%.

EDBAGP performs better than EDDBA and BP because EDBAGP supports global priority. Rather than dividing the bandwidth to lightly and highly loaded ONUs as what happen in EDDBA, EDBAGP divides the bandwidth to highly and lightly loaded queues. With EDBAGP, excessive bandwidth from lightly loaded queues is granted to highly loaded queues to ensure the global priority. Therefore, there is no specific limitation for each type of traffics as differ from BP algorithm. It makes the performance of EDBAGP to be better than EDDBA and BP, since each queue can be granted with the limitation and the excessive bandwidth from lightly loaded queues.

Figure 4 and Figure 5 show the improved percentage versus offered load for two different conditions. For both conditions, we can observe that EDBAGP improves upon EDDBA and BP at a linear rate as the offered load increases. For the case when rEF and rAF are high and rBE is low, EDBAGP improves as high as 11.24% compared to EDDBA and as high as 28.41% compared to BP. On the other hand, for the case when rEF and rBE are high and rAF is low, EDBAGP improves upon EDDBA up to 6.24% and upon BP up to 3.41% as the offered load increases to 100%.

Figure 6 shows the EF, AF and BE delay versus offered load for EDBAGP, EDDBA and BP algorithms. In all three figures, we can observe that EDBAGP has lower delay than EDDBA and BP. In Figure 6a, we can observe that EDBAGP has the lowest delay, followed by BP and EDDBA. EDDBA took as high as 0.68ms to allocate the bandwidth to EF traffic when the offered load reaches maximum and BP took around 0.67ms. However, EDBAGP only took 0.55ms. Delay is shorter in EDBAGP because all EF traffics in every ONUs are being granted first in the system. Also as compared to BP, there is less unused slot remainder in EDBAGP, causing the delay to be shorter. In EDDBA, only EF traffics in lightly loaded ONUs are granted first. EF traffics in highly loaded ONUs must wait for AF and BE traffics in lightly loaded ONUs to be granted before their turn arrives. Due to this reason, both EDBAGP and BP have shorter delay than EDDBA.

In Figure 6b, AF traffic for all three algorithms show the same delay performance as they reached to 20% offered load. It shows a delay of 0.33ms. As it gets beyond 20%, BP shows longer delay than EDDBA and EDBAGP. The same observation can be seen for BE traffic in Figure 6c, where all three algorithms reach to 0.55ms of delay when the offered load is 20%. Beyond 20%, EDBAGP shows better performance in terms of the delay. EDBAGP can only reach up to 1.5ms when the offered load is 100%, whereas EDDBA reaches as high as 1.7ms and BP reaches all the way to 1.6ms.

EDBAGP has shorter delay than EDDBA due to the global and local priority scheduling. With global priority scheduling, the highest priority traffic is being granted first, followed by medium and lowest. However, with local priority, lightly loaded ONUs are being granted first followed by highly loaded ONUs. In return, only the highest priority traffic in lightly loaded ONUs will be granted first. The highest priority traffic in highly loaded ONUs must wait for all traffics in lightly loaded ONUs to be granted before their turn. Thus, it makes the delay for highest priority traffic in EDDBA to be longer than EDBAGP.
EDBAGP has lower delay than BP algorithm because it makes full use of the excessive bandwidth. There is less unused slot remainder in EDBAGP, which in return causes less delay in all three types of traffic as compared to BP algorithm.

V. CONCLUSION

A global priority DBA algorithm that we called as EDBAGP has been successfully demonstrated in this paper. The proposed algorithm realizes the priority of traffic globally in order to increase the bandwidth utilization and reduce the delay. EDBAGP has been compared with BP algorithm and our previous local priority algorithm, EDBA in two different variations and it shows a better overall performance. EDBAGP improves upon EDBA in terms of bandwidth utilization as high as 11.24% and upon EF, AF and BE delay as high as 23.41%, 17.24% and 14.94% respectively. On the other hand, EDBAGP improves upon BP in terms of bandwidth utilization as high as 28.41% and upon EF, AF and BE delay as high as 20.69%.

REFERENCES