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# Analysis of Delay Performance in Efficient DBA with Global Priority for EPON

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## ABSTRACT

In order to accommodate the needs of very high-speed broadband access, the most attractive solution that is being used nowadays is Ethernet passive optical network (EPON). In upstream EPON, dynamic bandwidth allocation (DBA) algorithm is needed to avoid collision. By ensuring global priority inside DBA, bandwidth can be better utilized since we grant the upstream bandwidth to each queue according to the priority. In this paper, we analyze the delay performance of global priority DBA algorithm proposed that we called as EDBAGP and compare it to EDBA and Min's DBA algorithms. We vary the number of ONUs to 16 and 32. We can see that EDBAGP can improve as high as 25.22% for 16 ONUs and 41.35% for 32 ONUs as compared to Min's DBA. It can also improve as high as 20.69% compared to EDBA for 16 ONUs and 28.57% for 32 ONUs.

## KEYWORDS

EPON, DBA, global priority, delay, differentiated services.

## 1 INTRODUCTION

Due to the transition of average bit rates from 10Mbps to 1Gbps in the access network, the telecommunications infrastructure has also shift from a copper-based plant to a fiber-based plant. Since access networks are very sensitive to cost, the implementation of fiber is better deployed in passive optical network (PON) where the fiber is being shared using a passive optical splitter [1]. By sharing fibers, cost in the physical fiber deployment can be reduced and by using passive components, there is no power involved, thus reducing the cost.

Since 90 percent of data traffic originates and terminates in Ethernet frames, Ethernet PON (EPON) reduces the adaptation required to move data between the Local Access Network (LAN) and the access network [2, 3]. Thus, EPON is seen as the most promising network nowadays [4].

EPON has a point-to-multipoint topology, where it consists of an Optical Line Terminal (OLT) that is connected to multiple Optical Network Units (ONUs) via an optical splitter. It has two types of transmission; downstream and upstream transmission.

Downstream transmission is using broadcasting, whereas in upstream transmission packets from ONUs need to share the same fiber from the splitter to the OLT. Thus collision can happen and in order to avoid that, a contention resolution must be performed [5].

Previously, we have proposed a DBA algorithm that we called as Efficient Dynamic Bandwidth Allocation (DBA) with Global Priority (EDBAGP) in [6]. However, the detailed analysis on the delay has not yet been studied before. Therefore in this paper, we further analyze the packet delay in all three types of traffic in EDBAGP.

### 1.1 Related Works

In order to avoid collision in upstream EPON, many DBA algorithms have been developed [7-12]. Some algorithms support only inter-ONU scheduling; while the rest supports both inter and intra-ONU scheduling.

Among the most referenced inter-ONU DBA algorithms is Interleaved Polling with Adaptive Cycle Time (IPACT) [7]. Inter-ONU DBA algorithm means that the bandwidth allocation is centralized only in the OLT. OLT in IPACT polls the ONUs individually in a round-robin fashion to dynamically assign transmission opportunities. However, since inter-ONU scheduling considers each ONU as a whole, with IPACT it is difficult to realize different quality of service (QoS) access within an ONU.

Broadcast Polling (BP) algorithm is another example of inter-ONU algorithm [8]. Before bandwidth is allocated to ONUs in every cycle, OLT in BP algorithm must know all the bandwidth requirements. ONUs in BP algorithm are divided into three classes; Classes 1, 2, and 3. However, the detail about the classification has not been discussed in the paper and there is no limitation for Class 1. This can cause the light load punishment.

An example of algorithm that supports both inter and intra ONU scheduling is the one proposed by Assi et. al [9]. The algorithm is an enhancement of Limited IPACT, where the ONUs are divided into lightly loaded ONUs and highly loaded ONUs. In inter-ONU scheduling, excessive bandwidth is calculated and in intra-ONU scheduling, the excessive bandwidth is divided to the highly loaded ONUs. However at times, highly loaded ONUs can receive more bandwidth than requested. Besides that, QoS is only satisfied within intra-ONU, not in inter-ONU.

These problems can be solved by using the weighted-DBA algorithm [10]. It works in almost the same way as [9], but the distribution of the excessive bandwidth is according to the weight of the buffer. However, light load punishment occurs in real time traffic since the priority categories of the algorithm is according to the arrival of packets rather than the priority of the traffic.

Recently, global priority DBA algorithm has been introduced by Chen et. al where it can support QoS not only in inter-ONU, but also in intra-ONU [11]. Therefore, it utilizes the bandwidth better and further reduces the delay for real-time traffics.

In previous paper [6], we have incorporate global priority with Efficient DBA algorithm [12] and have shown significant results in terms of the bandwidth utilization and the delay. However, we have not yet discussed further on the delay analysis and we only set our number of ONUs until 16 ONUs. In this paper, we are going to study in more details on the delay and the effect of increasing the number of ONUs to the system.

## 3 METHODOLOGY

Efficient DBA with Global Priority (EDBAGP) supports both inter-ONU and intra-ONU scheduling. In both inter and intra-ONU scheduling, traffics are divided into three priorities; high, medium and low priority.

High priority belongs to Expedited Forwarding (EF) that supports voice traffic since it requires bounded end-to-end delay and jitter specifications. Medium priority belongs to Assured Forwarding (AF) that supports video traffic since it requires bandwidth guarantees. Low priority belongs to BE bandwidth that supports data traffic since is not sensitive to end-to-end delay or jitter.

Limitation bandwidth is set to each priority. For queues that have bandwidth lower than the limitation is called as lightly loaded queues and for queues that have bandwidth higher than the limitation is called as highly loaded queues.

In inter-ONU allocation, excessive bandwidth for each queues are calculated and OLT will sum up all the excessive bandwidth together. On the other hand, for intra-ONU allocation, the total excessive bandwidth will be divided to each highly loaded queue as according to the weight of the respective queue.

The packet delay, *d* in EDBAGP is defined as the time interval between the time packet arrive in the ONU and the time packet depart from that ONU. It can be achieved by summing up dpoll, dgrant and dqueue as in Eqn. 1 [13]

$$d = dpoll + dgrant + dqueue \quad (1)$$

dpoll is the polling delay which delay is calculated between packet arrival and next REPORT sent by the ONU. On average, it can be achieved by dividing maximum cycle time, Tmax to 2 as in Eqn. 2 [13]

$$dpoll = \frac{T\max}{2} \quad (2)$$

dgrant is the granting delay which delay is calculated from ONU's request for a transmission window for the packet until the GATE from OLT received. The calculation of dgrant can be shown as in Eqn. 3 [13]

$$dgrant = T\left\lceil \frac{q - Wi, p}{W\max} \right\rceil \quad (3)$$

where T is the cycle time, q is the is the queue size (including the new packet size) at the moment of new packet arrival, Wi,p is the pending GATE size and Wmax is the maximum transmission window.

dqueue is the queuing delay which is the delay calculated after the corresponding GATE from the OLT arrived. It can be achieved as in Eqn. 4 [13]

$$dqueue = \begin{cases} \frac{q}{R_T}, q \le Wi, p \\ \frac{(q - Wi, p) \bmod W\max}{R_T}, q > Wi, p \end{cases} \quad (4)$$

where $R_T$ is the total upstream bandwidth.

## 4 PERFORMANCE EVALUATIONS

In order to validate our theoretical analysis, we simulate the EDBAGP algorithm and compare it with the EDBA and Min's DBA algorithms.

Simulations are conducted using MATLAB and each DBA is using the same parameters for comparison purposes.

In this simulation, we vary the number of ONUs; for 16 ONUs and for 32 ONUs. We fix the Tmax and guard band, Bg to 2ms and 5µs respectively. We chose 60Mbps and 30Mbps as the guaranteed bandwidth respectively for 16 ONUs and 32 ONUs. For maximum bandwidth, we chose 600Mbps and 360Mbps for 16 ONUs and 32 ONUs. The limitation EF bandwidth is fixed to 20%, limitation AF and BE bandwidth to 40%.

We compare the EF, AF and BE packet delay for all three algorithms with the simulation for 16 ONUs and 32 ONUs.

### 4.1 16 ONUs

Figure 1 shows the comparison of EF, AF and BE delay for EDBAGP, Min's DBA and EDBA for 16 ONUs. In all three types of delay, EDBAGP has the lowest delay compared to Min's DBA and EDBA.

In Figure 1a, we can observe that all three algorithms increase at a linear rate as the offered load increases to 20%. EDBAGP has a delay of 0.2 ms when the offered load is at 20% and increases as high as 0.55 ms when the offered load is 100%. Min's DBA has the highest delay of 0.69 ms followed by EDBA with the delay of 0.67 ms as the offered load increases to 100%.

In Figure 1b, all three algorithms have the same delay of 0.33 ms as the offered load increases to 20%. But as the offered load reaches to 100%, Min's DBA and EDBA both have a delay of 1.04 ms, whereas EDBAGP's delay reaches only to 0.87 ms.

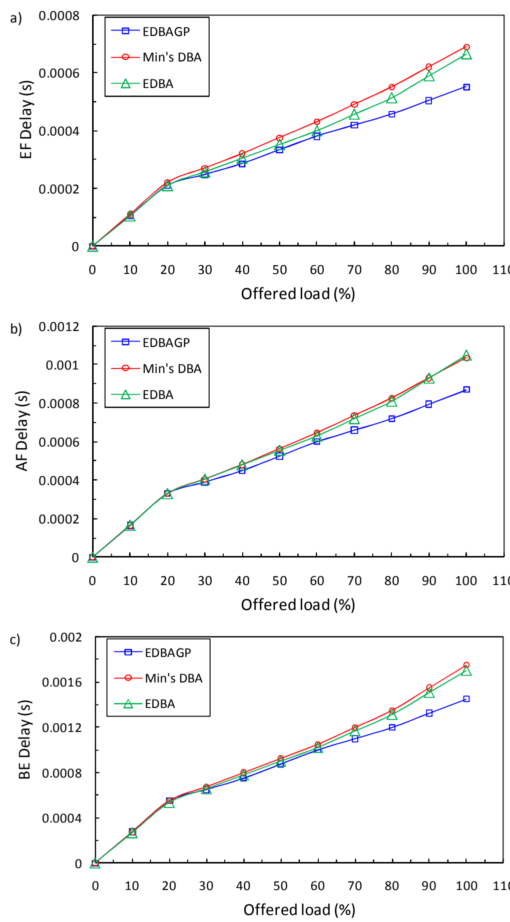


**Figure 1.** a)EF b)AF and c)BE delay versus offered load for EDBAGP, Min's DBA and EDBA for 16 ONUs.

The performance of BE delay is shown in Figure 1c where the delay in EDBAGP remains the lowest; which is at 1.45 ms compared to 1.75 ms and 1.7 ms respectively in Min's DBA and EDBA as the offered load is 100%.

### 4.2 32 ONUs

The comparison of EF, AF and BE delay for EDBAGP, Min's DBA and EDBA for 32 ONUs is shown in Figure 2. The result shows that EDBAGP has the lowest delay among all three algorithms.

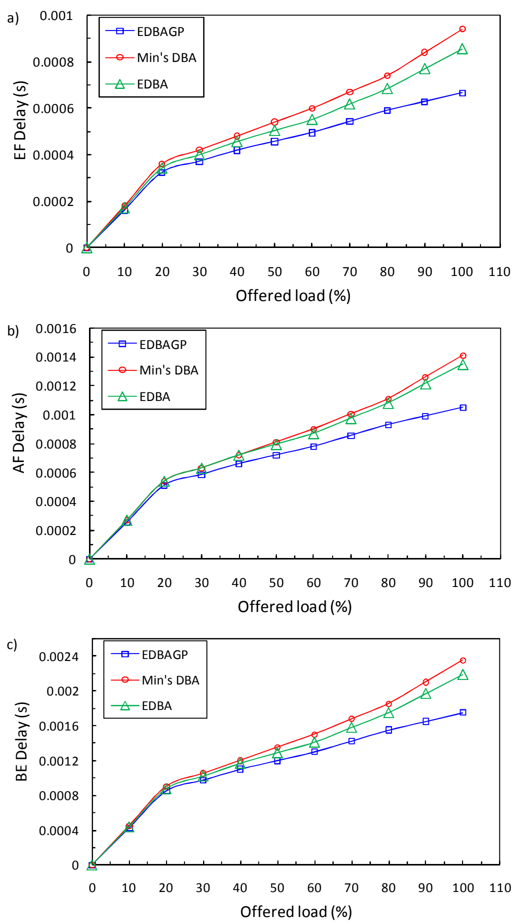


**Figure 2.** a)EF b)AF and c)BE delay versus offered load for EDBAGP, Min's DBA and EDBA for 32 ONUs.

Figure 2a shows that EDBAGP has the lowest EF delay compared to EDBA and Min's DBA. As the offered load reaches to 80%, EDBAGP shows a performance of 0.59 ms whereas EDBA increases to 0.86 ms and Min's DBA further boosts up to 0.94 ms.

In Figure 2b, delay is highest in Min's DBA where it reaches as high as 1.41 ms as the offered load is maximum. EDBA follows closely where it has a delay as high as 1.35 ms and EDBAGP maintains the shortest delay at 1.05 ms.

For BE delay, EDBAGP again has the shortest delay followed by EDBA and Min's DBA. The BE delay in EDBAGP increases at a linear rate from 0% offered load to 20% offered load, where the delay reaches to 0.85 ms. Then, the delay continues to reach as high as 1.75 ms as the offered load is 100%. Min's DBA and EDBA also have the same pattern, where they increase at a linear rate until the offered load is 20%, then increase unboundedly until they reach 2.35 ms and 2.18 ms respectively as the offered load is maximum.

From the simulation results that we have shown, we can observe that for both 16 ONUs and 32 ONUs, EDBAGP has the shortest EF, AF and BE delay compared to EDBA and Min's DBA. EDBAGP has less delay due to the usage of global priority. With global priority, QoS is satisfied globally. EF traffic will be granted first, not only for the queues inside ONU, but also for the queues inside OLT. Since EF traffic is sensitive to end-to-end delay, by reducing the delay will further improve the performance of EPON. After granting all EF traffic, then only EDBAGP will grant the bandwidth to AF and BE traffic. This differs from EDBA and Min's DBA where the priority is granting locally at the ONU level. Since in OLT, QoS is satisfied as according to first in first out, it causes all three types of traffic to have higher delay if compared to EDBAGP.

## 5 CONCLUSION

A delay analysis of EDBAGP has been done in this paper where we explained in details on the formula used to calculate the delay and we vary the number of ONUs to 16 and 32 for the simulation result.

From the result, we can observe that for the case of 16 ONUs, EDBAGP improves upon Min's DBA as high as

25.22% for EF traffic, 18.97% for AF traffic and 20.69% for BE traffic. EDBAGP improves upon EDBA as high as 20.69% for EF traffic and AF traffic and 17.07% for BE traffic.

On the other hand, percentage improvement is higher in the case of 32 ONUs where EDBAGP improves upon Min's DBA as high as 41.35% for EF traffic and 34.29% for AF and BE traffic. Whereas EDBAGP improves upon EDBA as high as 28.57% for both EF and AF traffic and 24.72% fr BE traffic. Delay is longer in 32 ONUs since there are more ONUs and OLT needs longer time to poll for each ONUs in the system.

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