iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** XII **Month of publication:** December 2023

DOI: https://doi.org/10.22214/ijraset.2023.57744

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue XII Dec 2023- Available at www.ijraset.com

An Improved Polling Mechanism for Dynamic Bandwidth Allocation of XGPON Networks

Patel M. C.[1], Mandloi A. S[2]
[1, 2]Department of Electronincs Engineering,S. V. National Institute of Technology, Surat

Abstract: One of the most well-known technologies that offers a large range of services at user's fingertips without requiring the least amount of infrastructure is passive optical networks. This can be due to a particular component known as the passive optical spiller. In order to facilitate time division access for individual ONUs on a single optical fiber, the appropriate dynamic bandwidth allocation mechanism must be present at the OLT with the advent of user support. For bandwidth assignment by DBA, it is essential to determine the precious upstream bandwidth demand, and can be aided by the more frequent polling mechanism. The more frequent polling mechanism lead to erroneous bandwidth report problem, become more serious when the mechanism is employed in larger coverage area network (specifically larger channel delay). This IBR problem lead increase in upstream delay at higher load condition, it's because of improper assignment of bandwidth and waste of bandwidth. The IBR issue is resolved by the improved polling and scheduling method presented in this paper. Instead of transmitting the bandwidth allotment in each downstream frame, the OLT uses this scheduling technique to send it all at once to a TCONT (i) of ONU (i) for the duration of the SI period. To counteract the channel delay impact, a unique polling technique is also presented that use the hybrid methodology in which the OLTs sends polling mechanism once per the Service interval but According to the simulation study's findings, the suggested system reduces mean upstream delay for type 2, 3, and 4 traffic classes by 62% when compared to the EBU scheme and by up to 20% when compared to the XGIANT design.
Keywords: Polling and Scheduling, Dynamic Bandwidth allocation, XGPON networks, TDM

I. INTRODUCTION

Excessive internet traffic demand is increasing in recent years has prompted more research on advanced networks that can handle the high bandwidth demands of enterprises, public sector organizations, single individuals, and the mobile industry. A technology called passive spillter/combiner [1] of passive optical networks has proven a promise and demonstrated its significance in offering high throughput, scalability, and energy efficiency in the direction of a highly reliable bandwidth infrastructure. Upstream speeds of 2.5 Gbps and downstream speeds of 10 Gbps are supported by XGPON [2]. However, because of the symmetrical broadcast access mechanism, the line-rate can approach Gbits for individual users, but because of the time division based bandwidth-sharing mechanism employed in upstream, it cannot reach Gbits for individual users. The point-to-multipoint architecture of XGPON network is depicted in the figure 1, along with the various components that represent a network system. For example, An Optical Line Terminal(OLT) serves as the central controller, the Optical Line Unit(OLU) acts as the router at user ends, the passive spillter distributes signals to each ONU in a passive manner, and the upstream unit functions as a combiner, combining all of the signals from ONUs into a single optical signal that can be received and processed by a single OLT.

A four types of transmission container types (TCONTs) with provisioned allocation policies and quality of services have been recommended by the XGPON standard [2]. Each ONU with different traffic class is assigned a unique Allocation Id, which might be useful in classifying each of them separately. Each of the TCONTs has a corresponding type of bandwidth associated with it, such as fixed bandwidth for TCONT- T1, ensured bandwidth for TCONT-T2, non-assured and best effort for TCONT-T3 and TCONT-T4. To support with various traffic container, the various with their supported application with their operational service parameter is given in Table I. In XGPON, the synchronous frame has been standardized, with value of 125 µsec for both the downstream and the upstream. The OLT obtained the queue status report from the ONUs via Dynamic Bandwidth Report Upstream (DBRu) field in upstream direction. Following to save a scheduling operation for Granting of bandwidth is carried out and delivered back to ONUs via field BWmap to avoid the collision during the data transmission in upstream direction. This process is carried out at a instance called the service interval (e.g. SImin, SImax). The duration of this service interval (SI) is integer multiple of frame duration.

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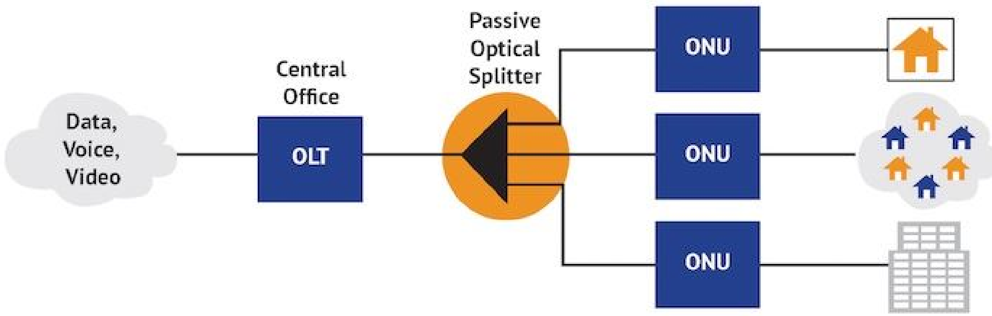

Fig. 1. Architecture of Passive Optical Networks

The XGPON compliant DBA has two types of polling mechanisms: one that schedules grant for each alloc − ID as well as, polls them once during a service interval (SI); the other that schedules grant for each alloc − ID during every downstream cycles as well as polls them in every DS cycle. The first method having a problem improper reporting of buffer occupancy and lead to improper assignment of bandwidth to individuals. This cause the higher uplink delay and larger frame loss specifically the lower priority traffic class. To combat larger delay and frame loss of first method, the other method is suggested. the performance of lower priority class is improved at low load condition but at higher load situation the bandwidth assignment is become more severe and inefficient, lead to higher delay and larger frame loss for the all the traffic class. The second method having a problem of lack of bandwidth, it's because of more frequent assignment of polling field called DBRu. Nevertheless, no specific polling method is suggested for DBA, that may be used for small or large Chanel delay e.g. 100µSec, 600µSec for 20km, 60km coverage respectively. More attention has been paid to appropriate and effective polling methods for the XGPON system.

TABLE I
VARIOUS TRAFFIC CLASS WITH THEIR OPERATIONAL PARAMETERS

Traffic Class	Supported Application	Bandwidth	Operational Service Parameters
TCONT-1	Leased Line	Fixed Bandwidth	$SImax, ABmin$
TCONT-2	Basic Video Service	Assured Bandwidth	$SImax, ABmin$
TCONT-3	VoIP	Assured Bandwidth	$SImax, ABmin$
TCONT-3	Web Surfing	Non-Assured Bandwidth	$SImin, ABsur$
TCONT-4	File Transfer	Best Effort	$SImin, ABsur$

In this work, a Modified EBU for XGPON is present that improve the scheduling and polling mechanism of existing state of art DBA scheme called Efficient bandwidth utilization (EBU). EBU grant phase suffers from Borrowed-Refund problem and polling phase suffer from the static report inconsistency, and increased delay for all traffic class at high loads and bandwidth waste at lower priority traffic loads. The BR problem result in reduced bandwidth assignment to T3 and T4 class and T4 is severely affected its delay and frame loss increase. Modified EBU resolve the both issues and improve the performance of all the traffic class. However, the packet loss is slightly increasing because of solving the problem of BR. The flow of rest of this paper is as: section II is covered related works and existing works is reviewed. The section **??** covers the polling methodology used in proposed method and modified scheduling methodology have been explained in section III-B. The results are presented in section IV and the conclusion is presented in last section.

II. RELATED WORK

In 2006 [3], the first standard compliant DBA for GPON network was introduced. The MAC operation is divided in two phases that this DBA is working on are the Guaranteed Part of Allocation (GPA) and the Surplus Bandwidth Part of Allocation. The SPAs' allocation for TCONT-2 is done as guaranteed bandwidth allocation; TCONT-3 allocates a portion of non-assured bandwidth; and TCONT-4 allocates one word in order for DBRu to be function for buffer occupancy of ONUs. In SPA, remaining portion non-assured bandwidth is carried for TCONT-3, and in in the end, for TCONT-4's remaining non-guaranteed bandwidth.

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The aforementioned type of scheduling order is implemented using the AB provisioned counter, as Table I illustrates for each traffic class. With an operational value of 5 to 10, the other parameter known as the SI is introduced in this DBA named Timers/Down Counter and maintained for each alloc−ID of each traffic class maintained. The polling and scheduling operation is carried out once the SI value reaches to 1, where the SI is recharged to its initial value irrespective to the request size. The granting mechanism follows the gated policy as; min (Request, AB, FB), where FB is called the Total Frame Bytes of upstream burst. The major problem of this DBA is ideal channel time, it because of polling is scheduling is carried out once the SI expiry; lead to higher upstream delay.

The Immediate Allocation with Colorless Grant (IACG) algorithm [4] provides a solution to the ideal time delay problem. The available byte counter (V B) was added for every traffic class's alloc − Id. It stores the bytes allotted for each DS frame cycle and decremented them according to the bytes granted for each frame action as; min (Request, V B, FB). This V B stores the AB once the SI expire. And same is carried out once in every SI. Finally, by adding extra TCONT-5, the unused bandwidth in each grant process is allotted to each ONU without any polling operation. However, some bandwidth that is not being used during the grant operation is still available which may not be used by other types of alloc − ID.

Later in 2013, the EBU [5] had been proposed with Borrow Refund policy to allocate such unused bandwidth of individual traffic class. For borrowing, the possibilities of negative value for V B is suggested, means the requested bandwidth is higher than available byte counter value. In an update operation, the common counter counterfeits the return of such a borrowed byte. A novel polling methodology is introduced in it, where the DBRu slot is assigned to each alloc − ID irrespective their queue size and additional DBRu can be allocated whose grant size is higher than zero. Still the problem is persisting in EBU that if there is no bandwidth allocation in common counter than it leads to reduce the bandwidth allocation in least priority traffic class. One accessible byte counter for each traffic class was used to address the deficiency of EBU in a Simple and Feasible DBA (SFDBA) [6]. One of the byte counters may exhaust the common counter, preventing other service classes from using the services of other classes. For the purpose of resolving such a difficulty, the DBA known as the High Utilization algorithm (DBAHU) [7] was proposed as an updated version of SFDBA using a concept of BR of EBU. The grant policy is carried out based on the min (report, A, FB), where A is called common maximum allocation byte of same traffic class.

In subsequent year 2015, X-GIANT algorithm was introduced by author [8]. A problem of zero unused bandwidth, which may have affected the next cycle allocation is solved by allocating the bandwidth irrespective of expiry of Down counter. Author proposed smaller SI value to reduce the ideal channel timing of XGPON, e.g. SImin = 2, and SImax = 1. The priority order among the TCONT class is maintained via proposing a GIR:PIR ratio to 0.4, which reflect in their upstream delay result. The polling is occurred in every frame duration for TCONT-2, TCONT-3 and TCONT-4, while twice frame duration for TCONT- 3 and TCONT-4. The performance of TCONT-3 is much better up to certain load due to excess grant allocation to TCONT-3.

The main challenge is as the polling carried out each frame duration for TCONT- 2, it leads to overhead allocation for T2 traffic class. The latter the enhance polling and scheduling mechanism was introduced in DBA called Enhanced Bandwidth utilization (IBU) [9].

The priority to TCONT-2 and TCONT-3 in assignment the delay of least container TCONT-4 is increased. The Comprehensive Bandwidth Utilization (CBU) [10] is useful in improving the ICAG and EBU scheduling policy and polling policy. This improve the delay for TCONT-4 but fails to TCONT-3 and TCONT-2 traffic as compared to that of EBU. The CBU introduced the polling frequency in every ODD frame duration e.g. 8, 5, 2. However, the clear justification was not explained for the same.

The memory mechanism was introduced in EBU to counterfeit the static report inconsistency problem due to larger coverage areas. It was suggested that it required to store the at least three granted bytes that need to subtract from the reported bandwidth for 20km operation. This may increase to eight cycle for the larger coverage operation. The latter in 2022, the more efficient bandwidth allocation algorithm was introducing namely EEBU [11]. This polling was carried out once per SI based on Polling flag value. This polling flag in reset once when the Down counter value to zero value unlike to that of EBU where the PF flag may reset to zero once the grant to the particular alloy − ID is greater than zero.

The goal of this algorithm is improvising the utilization of remaining bandwidth in the available Byte counter. The problem of Static report inconsistency still present in this algorithm. All together, the most fundamental algorithm known as XGIANT [8], GIANT [3], ICAG [4], and EBU [5] serves as the foundation for the improvement of other DBA mechanisms. This work developed a novel technique, named MEBU, to solve the issue of static report inconsistency with better polling approach, utilizing the unused bandwidth totally and without any more complexity.

III.MODIFIED EBU

A bandwidth is allocation in MEBU is illustrated in figure 2, according to service interval SI. The SI duration is divided into total 10 frame duration, C0, C1,…C9 cycles, in order to easily understand the polling mechanism. Every one of them is 125uSec in duration. Round-trip time is another crucial aspect in polling, and it is calculated using the Ranging technique [2]. The term” time to allocated bandwidth reached to specific ONUs” or” obtaining the DBRu value from the ONUs” refers to RTT/2. By equalization timing, ONUs receive the given DBRu field once it has been assigned. Equalization time plus processing time equals the total polling time. The ONU processed the Queue Occupancy report after receiving the DBRu and transmitted it to OLT. Following reception of the buffer report, OLT processes it and determines the bandwidth demand by factoring in the time required for OLT processing as well as bandwidth allocation. The grant is distributed to each ONU by the DBA using BWmap; the total amount of time required is known as the dynamic bandwidth allocation time.

As explained above, Upstream frame delay (DUS) depends upon four factor as given by (1).

$$DUS = QD + PD + TD + Tpoll \qquad (1)$$

The amount of time in this instance, QD, that the frame needs to wait before receiving upstream bandwidth. PD represents the process lag time that the OLT went through while handling the bandwidth assignment. Upstream delay, called TD, typically accounts for half of round-trip time. The amount of time required by the OLT to regularly deliver the bandwidth allotment to ONUs is called Tpoll. With an increase in traffic volume, the QD is rising. Due to the imbalance in service and arrival rates as well as the growing queening delay, this has to occurred.

A. *Polling Mechanism of MEBU*

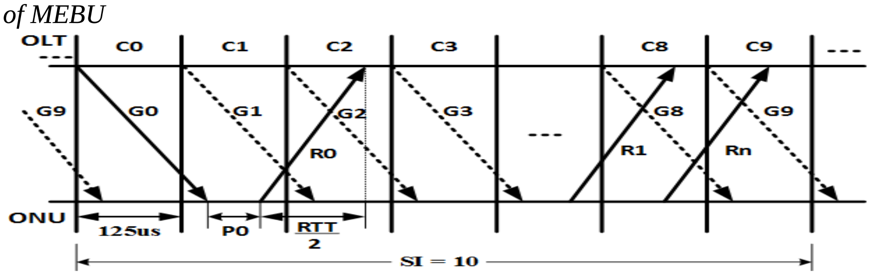

Fig. 2. Polling Process for the collection of Queue Report

The polling mechanism required the allocation DBRu field to get the response from the ONUs. The individual $PolFlag_{ij}$ is initiated for each of $TCONT$ and it $DBRu_{ij}$ is assigned with $PolFlag_{ij}$=0. Once the $DBRu_{ij}$ is assigned the value the $PolFlag_{ij}$=1. These $PolFlag_{ij}$ is reset to 0 once the Down counter FNj has expired. The $TCONT$ has chance to receive the $DBRu$ field once the per the Service interval SIj. In EBU the same is carried out multiple times per SI which increase the bandwidth resource overhead as the $DBUuSize$ is 4 bytes for each $alloc-ID$. This may be much higher with higher number of ONUs. The ICAG suggested the polling to be done once per service interval but the true reporting of ONUs is not guaranteed and problem of static report is still persistence. To optimize the static report inconstancy problem and bandwidth overhead problem, MEBU suggested a polling is carried out once per SI as well as in the ODD number of frame e.g. 1, 3, 5, 7, 9 for TCONT-4. The polling algorithm is given in as below.

```
// k = ONU number
//j = TCONT Type
i = stop = LastPol_j while (1) do
{ DBRu_ij =0
if (PolFlag_ij =0 && Frame_Byte>0) then
{ Frame_Byte = Frame_byte - DBRuSize; PolFlag_ij = 1;
DBRu_ij =1; }
else if (polling_end_flag =0 && Frame_Byte=0) then
{ LastPol_j = i ; polling_end_flag=1;} i++
i= i mod N
if (i == stop) then BREAK; } }
```

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B. Scheduling Mechanism of MEBU

In MEBU follows parameters of EBU e.g. SImax, Smin, ABmin, ABsur for following the scheduling of TCONTs queue. however, the polling parameter for T4 is change little to get true reporting. For such DBA the first cycle GPA is executed which is same as standard compliant EBU. During this phase, scheduling priority is highest for the T1 TCONTs with fixed bandwidth followed by assured bandwidth to T2 TCONTs. After this, assured bandwidth to T3 TCONTs and surplus bandwidth to T3 TCONTs. Finally, surplus bandwidth assigned to T4 TCONTs. The Remaining Bandwidth is re-calculated at end of SPA allocation phase. This bandwidth is equally assigned to individual alloc-Id of all class.

The detailed scheduling algorithm of MEBU is follows the conventional Service level agreement. The detailed flow chart of the same is given below:

```
i = stop = SMj while (1) do
{ if (Frame_Byte>0 && VBj>0 &&) then
{ Gij = min (VBj, Rij, Frame_Byte) Rij= Rij - Gij
FB = FB - Gij
else if (allocation_end =0 && Frame_Byte=0) then
{ SM_j = i and allocation_end_flag = 1} FNj = FNj -1;
if (FNj=0) then
{ FNj = SIj VBj = ABj PFij =0 }
elseif (mod (FNj,2)!=0 && j=4)
{PFij=0} % For additional Polling mechanism i++, i = i mod N
if (i = stop) then Break;
}
}
```

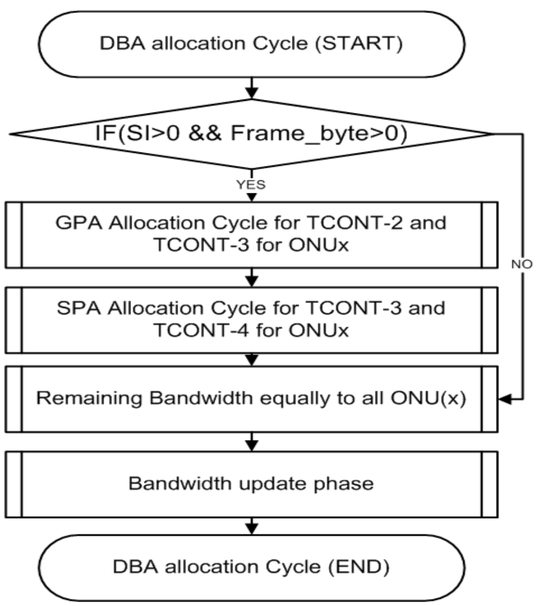

Fig. 3. Flowchart of MEBU

IV. RESULT OF MEBU

As already explained in previous chapter, the same simulation parameter is considering for performance evaluation. The evaluation is carried out in terms of Throughput, packet delay, UBM, Aggregate date rate.

As seen in figure 4, The delay performance of TCONT-2 for RR is increasing with increased in traffic load. However, after the saturation point (100% of Traffic-load) there is exponential increased in RR. This is due to packet drop at ONU due to buffer over-flow and secondly it is because RR consider each fairness among each ONU-Ids irrespective of their priority class. The same is case with EBU. However, in EBU the allocation is carried out based on demand. So more borrowed bandwidth by TCONT-3 class lead to increase in Queuing Delay.

The XGIANT is standard compliant algorithm. Its gives more priority in assigning bandwidth to T2 class. So due to higher priority of T2 among all the XGIANT is still performing well after reaching the saturation points. The XGIANT is similar to that of MEBU in T2 case the Mean Queuing delay remain intake after network saturation point also.

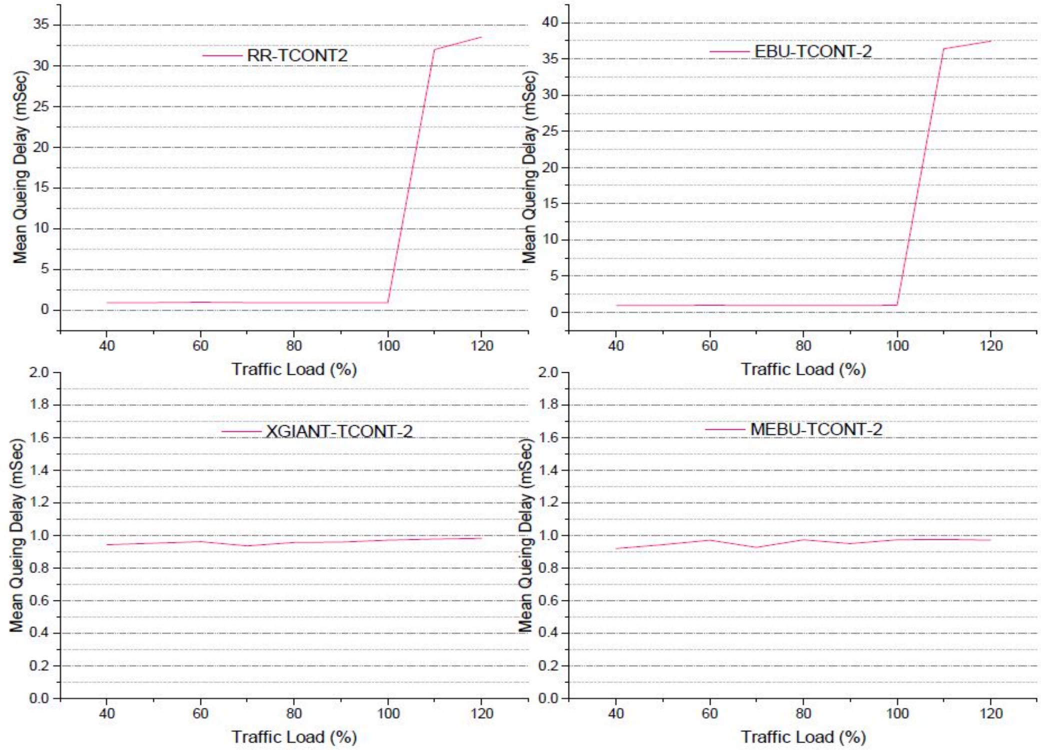

Fig. 4. Mean Queuing Delay for TCONT-2

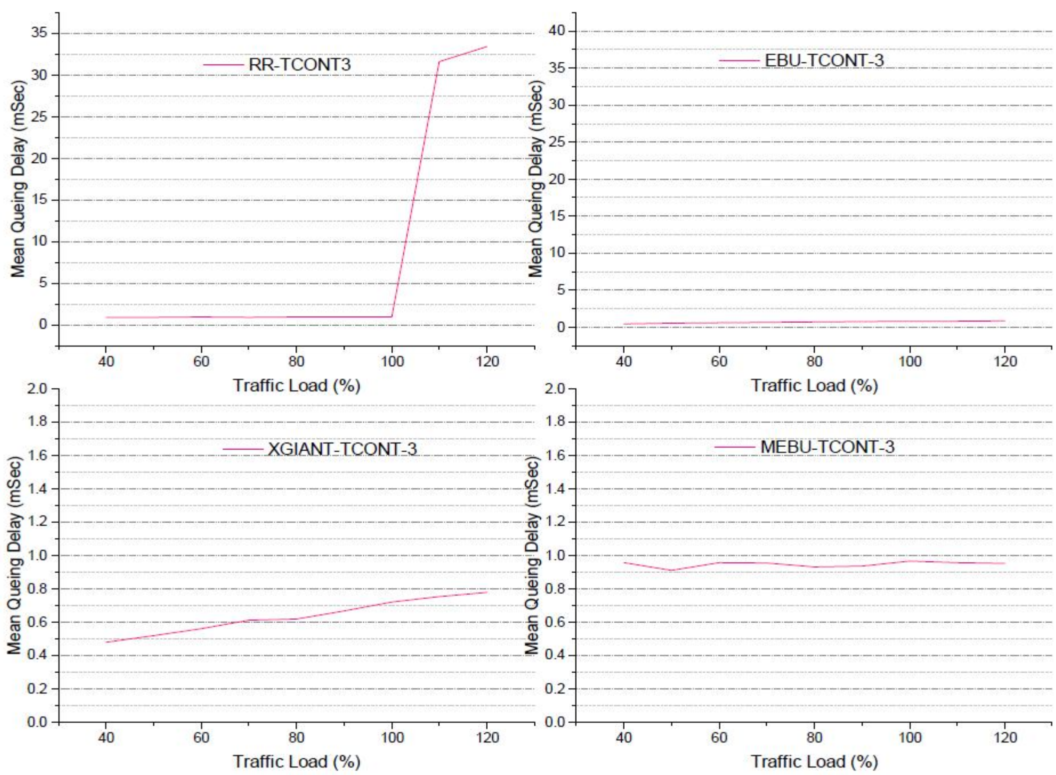

Fig. 5. Mean Queuing Delay for TCONT-3

For TCONT-3, the Queuing delay performance is at-most comparable as seen in figure 5. The basic fundamental reason is the more allocation cycle is given to TCONT-3 in EBU, and XGIANT too. However, the RR Queuing delay is increased once network saturation point is reached. The more opportunity to T3 class in SPA allocation lead to more bandwidth resource allocation. and performance of TCONT-3 is well bounded within permissible time bound delay for video traffic (5mS).

The results of TCONT-4 for all the algorithm is given in figure 6. As expected the at higher load state the TCONT-4 sacrifices the bandwidth grants. For RR the Queuing Delay is much less as compared to that of other algorithms. This is because the T4 is equally scarifies that of the other TCONT class. The EBU is fails impartially after the network saturation point. This saturation point near about 107% of traffic load. The XGIANT gives the little improvement as compared to that of EBU. This fails the traffic load near to 112% to 114%. The last MEBU have improved the performance in terms of network saturation point. Here it is around 120% which is higher as that of EBU and XGIANT. PLR at higher load condition.

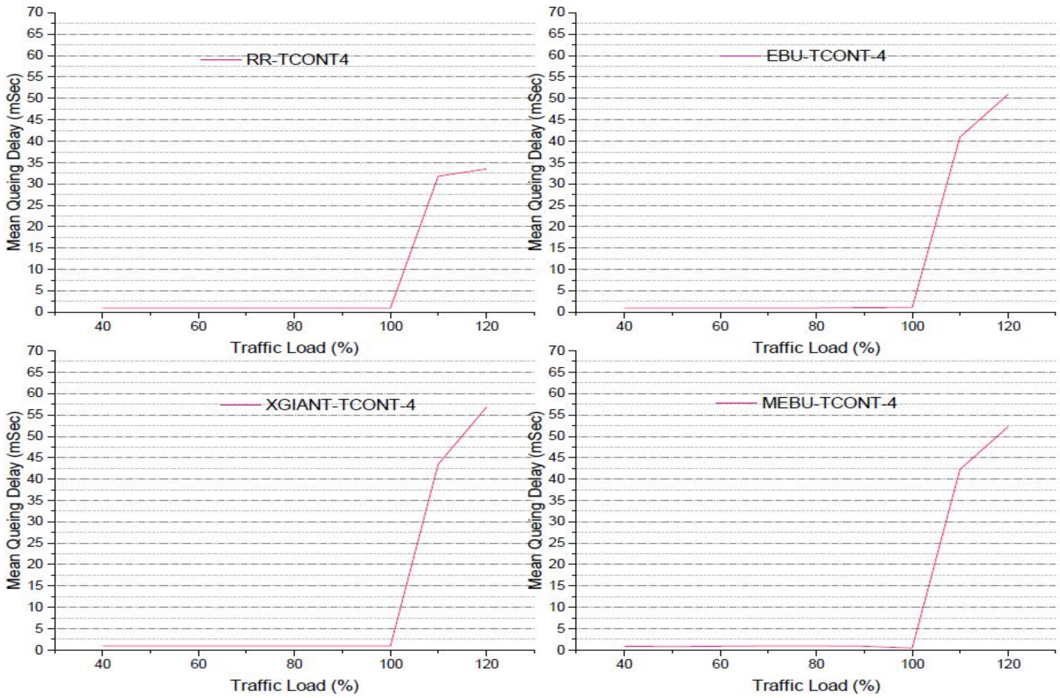

Fig. 6. Mean Queuing Delay for TCONT-4

This saturation point near about 107% of traffic load. The XGIANT gives the little improvement as compared to that of EBU. This fails the traffic load near to 112% to 114%. The last MEBU have improved the performance in terms of network saturation point. Here it is around 120% which is higher as that of EBU and XGIANT. PLR at higher load condition.

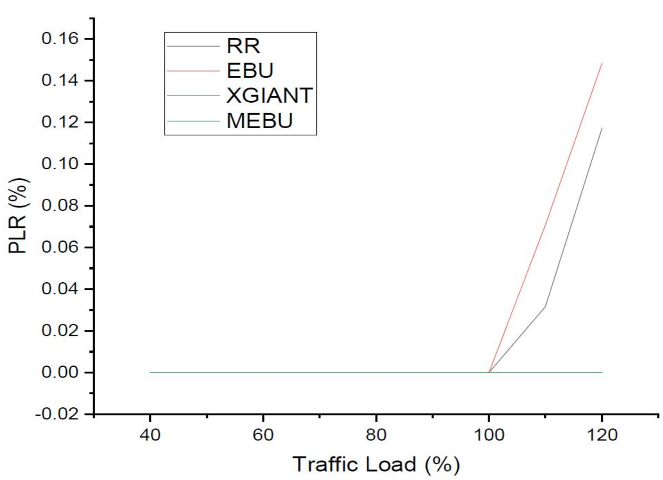

Fig. 7. PLR for TCONT-2

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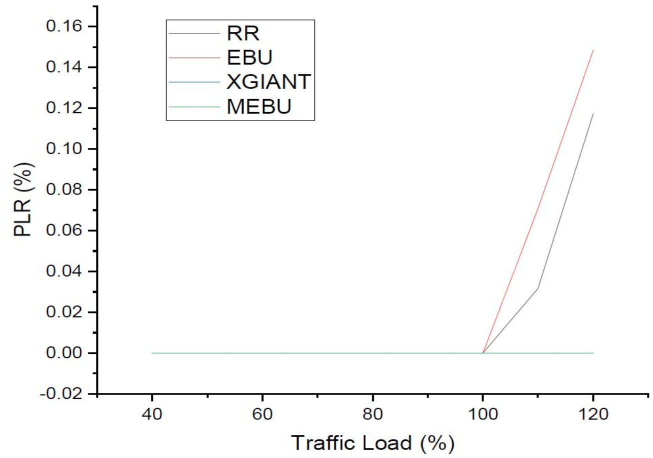


Fig. 8. PLR for TCONT-3

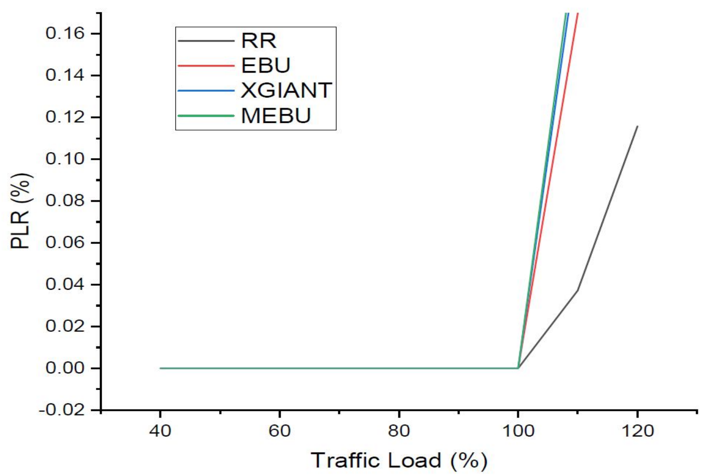
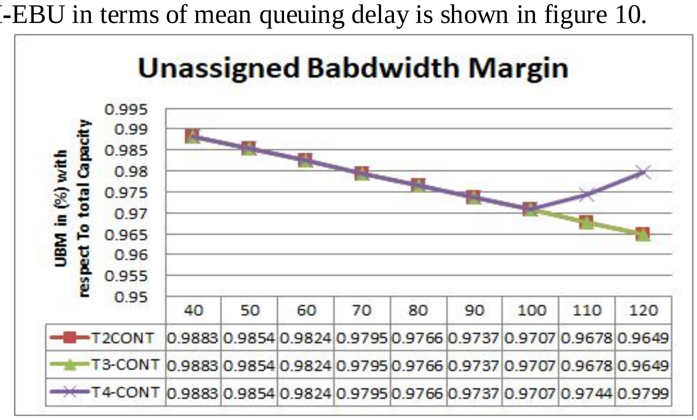


Fig. 9. PLR for TCONT-4

The one of the observation is that The UBM margin is improved as compared to XGIANT due to additional sub-cycle. The UBM value is decreasing as load increasing, it is because as traffic load is increasing more buffer occupancy is reported by each class of Alloc-id, and new algorithm is able to provide more additional bandwidth to needy alloc-Id. The UBM result show that this scheme is able to provide almost equal opportunity to individual class. The aggregate data rate is increasing as traffic load is increasing. Even the percentage share of individual t-cont class is at-most equal and even it is improved as compared to that of XGIANT. The performance of M-EBU in terms of mean queuing delay is shown in figure 10.



	40	50	60	70	80	90	100	110	120
T2CONT	0.9883	0.9854	0.9824	0.9795	0.9766	0.9737	0.9707	0.9678	0.9649
T3-CONT	0.9883	0.9854	0.9824	0.9795	0.9766	0.9737	0.9707	0.9678	0.9649
T4-CONT	0.9883	0.9854	0.9824	0.9795	0.9766	0.9737	0.9707	0.9744	0.9799

Fig. 10. PLR for TCONT-4

T2 class mean queuing delay well with range the decreasing delay performance at higher load is due to higher priority assignment in GPA cycle as well as additional cycle. T3 have constant delay performance due to GPA, SPA and additional cycle. T4 performance is also decreasing at higher load condition, this is unusual case. To refine this additional refinement has been suggested in M-XGIANT.

V. CONCLUSION

The performance XGPON network is improvement in terms of supporting higher traffic load. The Mean queuing delay improvised as compared to that of RR, EBU and XGIANT. For T2 the performance improvement is 3% to 5% for T2 Class, 5% to 7% for T3 class and 2% to 4% for T4 class. However, with fixed assignment scheme the performance of MEBU is well bounded event at higher traffic load. It is best suits for the bounded delay application like 5G communication, the bounded delay specification for Best effort traffic is within 10mS. So this novel algorithm is best suits for the application like FTTh, FTTb and backhaul communication networks.

VI. ACKNOWLEDGMENT

I would like to express my deepest gratitude to my supervisor for his valuable suggestion and guidance. Without his immense support, this work would not be possible to happen on time.

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