A Hybrid Bandwidth Allocation Algorithm for EPON-WiMAX Integrated Networks Based on Auction Process

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Abstract

Integration of Ethernet passive optical network (EPON) and WiMAX technologies is viewed as a great solution for next-generation broadband access networks. In the systems adopting this strategy, weighty bandwidth allocation schemes are fundamental to fulfil the quality of service (QoS) and fairness requirements of different traffic classes. Existing proposals to overcome the bandwidth allocation problem in EPON/WiMAX networks dismiss collaboration between the self-interested EPON and WiMAX service providers (WSPs). This study presents a novel EPON-based semi-dynamic bandwidth allocation (S-DBA) method that shows points of interest in the integration process. In the proposed algorithm depending on the auction process, the optical line terminal runs an auction to adequately post the optical network unit bandwidth that distributes the most elevated bidders based on the measurement of the accessible bandwidth. Simulation results demonstrate massive upgrades compared with fair sharing using dual-service-level agreements, 'limited service' interleaved polling with adaptive cycle time methods, bandwidth allocation strategy using Stackelberg game, and bandwidth allocation strategy using coalition game regarding the quality of service parameters such as throughput and time delay. This will be extremely helpful for optical system upgrading and improvement with minimal effort.

I. Introduction

With the speedy advancement of new organizations reliant on intuitive media applications, broadband access is mentioned due to extensions in Internet traffic. New structures have been moved from the content, and voice-based administrations to the customer-made intelligent interactive media administrations. Voice over IP (VoIP), Video conferencing, video on demand (VoD), online gaming, and high definition television (HDTV) broadcasting administrations will keep growing shortly to realize extending bandwidth necessities. Due to this fantastic improvement, the focal media transmission frameworks are intended to assist new rising applications with gigantic advancement in data transfer bandwidth and limits.

From one perspective, EPON is viewed as a promising solution for the cutting edge fiber-based access method, as it is not just fast, financially savvy, yet versatile. The remote access procedure is additionally steadily redesigning its transfer speed, versatile capacity, and nature of administration (QoS) support. The new-age WiMAX has now been regulated and passed on. The upsides of bandwidth advantage and portability highlights lead to the incorporated EPON and WiMAX design in Fig. 1 [1]. EPONs [2, 3] and IEEE 802.16e/WiMAX [4] have shown a noteworthy assurance in the improvement of new-age wired and remote access advances [5].

Due to a limited extent to their bandwidth, unwavering quality, adaptability in the arrangement, and low system costs, most Internet service providers (ISPs) view EPONs as a suitable choice in the provision of a backhaul administration for associating different scattered WiMAX base stations (BSs) [5–8]. In any case, EPONs and WiMAX are dependent upon various norms focusing on various system situations. Along these lines, different enormous issues must be settled before they can be adequately coordinated.

The noteworthy point in the reconciliation of EPON/WiMAX systems is the booking instrument, which ensures that the heterogeneous progression of traffic (through the Ethernet and the WiMAX) gets a decent amount of the accessible upstream data transmission. Many planning instruments have been proposed to help transfer in coordinated EPON/WiMAX frameworks [6–8].

In [6] and [7], centralized-scheduling-based (CS) DBA was proposed to help the transmission of WiMAX traffic over a coordinated EPON/WiMAX arrangement. In spite of the way that these endeavors eliminate delays, generally speaking, system throughput is diminished, because each sort of traffic is solely a pre-dispensed measure of data transfer capacity, which cannot be reallocated to transmit another kind of traffic in spite of the way that it is not conclusively utilized.

In [8], a system dependent on game hypothesis was introduced for parleying heterogeneous transmission in an incorporated EPON/WiMAX arrangement.

A bankruptcy game and a bargaining game were utilized to empower each ONU-BS to do intra-scheduling capacities. Although the OLT distributes bandwidth reasonably between the Ethernet and WiMAX, this examination fails to address the issue of QoS. The EPON has the advantages of high bandwidth, low cost, various services support [9–11].

In this paper, a semi-dynamic bandwidth allocation (SDBA) algorithm is introduced dependent on the auction process, no doubt; that the dynamic bandwidth allocation is essential and better than the static bandwidth allocation. But, the dynamic bandwidth allocation is time consuming, which affects the delay time and throughput. The dynamic bandwidth allocation is needed in order to determine the demands for each user, but there is no need to repeat the auction process on the bandwidth in consecutive short times, especially the demand for many regular users does not change quickly or suddenly and is approximately constant for each profile. Therefore, in this research, we propose a modified dynamic bandwidth allocation, which is a hybrid or mixture between dynamic and static bandwidth allocation “semi-dynamic”.

In the proposed system, the dynamic bandwidth allocation is used in the beginning in order to determine the demand for each user, and the auction process is repeated cyclically each 5 cycle to avoid any mistakes or any unanticipated change in user demand. This saves time and avoids mistakes resulting from repeating the auction process in very short times such as demand and grant misalignment. Thus, the system will be a static system for 5 cycles and a dynamic system after that, and this is repeated periodically. Therefore, we name the proposed system as a semi-dynamic system. It is demonstrated to be prosperous compared with the existing DBA methods of integration between EPON and WiMAX technologies ST, CO, VOB [12], IPACT and FSD-SLA [13]. The work in this paper is organized as follows. Introduction is presented in Section I. Related work presented in section II. The bandwidth allocation of WiMAX and EPON is presented in Section III. The proposed S-Maat method is presented in Section IV. Evaluation method and simulation parameters are presented in Section V. Numerical results and discussion are presented in Section VI. Section VII provides the comparison and the choice of the optimum DBA algorithm. Conclusion is given in Section VIII.

II. Related Work

DBA algorithms in EPON can be classified into two categories, centralized [14], decentralized and hierarchical [15]. The framework structure is streamlining well in centralized algorithm due to that OLT has all capacities of bandwidth allocation. While the scheduler and queues located at each ONU caused higher cost in decentralized algorithm. On the other hand, in hierarchical algorithm, each ONU reallocates the bandwidth for its interior queue with diverse sorts of traffic after allocate the bandwidth in OLT. Using the hierarchical algorithm provides an expansibility and proficient resource allocation in EPON. DBA algorithms can be classified according to the distinct network traffic prediction into two categories, prediction based and non-prediction based. Limited bandwidth allocation (LBA) non-prediction algorithm presented in [14], service level agreement (SLA) might be indicates the maximum time slot length $B_{\max}$ which is the upper bounded for the time slot length of each ONU. One of the downsides in LBA is that no more granted bandwidth to ONU which as of now doled out an ensured bandwidth, $B_{\max}$. Under the non-uniform traffic LBA in [16] presented poor and limits forceful competition for the upstream bandwidth.

In order to allocate more granted time slots proficiently and diminish the packet delay prediction based schemes has been considered in organize. In the predictive algorithms, to meet the QoS requirements by overhaul the allocated bandwidth the calculated aggregated traffic has been utilized. In order to avoid over or underestimation the debase in the network performance according to the longer packet delay, accurate traffic predictor is highly required. The credit-based bandwidth allocation (CBA) takes a few point of reference transmitted outlines into thought, and when the OLT allocates the upstream bandwidth it adds a credit into the requirement of each ONU. Some packets do not have to wait for the next grant to arrive; they can be transmitted with the current grant and the average packet delay can be reduced. Author in [17] presents a prediction DBA algorithm based LBA with multiple services (DBAM) which executes expectation agreeing to the straight estimation credit. Because of the prediction model suffer serious inaccuracy is the DBAM for some ONUs with high variations in traffic it leads to that the performance is deteriorated in non-uniform traffic flow.

In [19] based on the requests from SSs and according to the 802.16 standard, BS is mindful for the uplink bandwidth allocation. In spite of, the standard guarantees the QoS for differential services, the detailed scheduling in algorithms still unspecified. In [20–24] schemes have been proposed with many scheduling mechanisms in order to support real time and non-real time algorithms. In this case and according this studies schemes can be classified into two categories, the first one is a one-level scheduling schemes [20, 21] and the second one is a hierarchical scheduling schemes [22, 23]. In [20] Vinay et. Al. presents a one-level scheduling scheme that uses Earliest Due Date (EDD) and Weighted Fair Queue (WFQ) scheduling algorithm in order to deal separately with real-time and non-real time data. In [21] in order to fit the QoS requirements for algorithms, each traffic sorts their benefit queue and each queue uses different scheduling schemes. One of the advantage in the one-level scheduling is the low complexity. However, due to the diverse QoS requirements and the different traffic characteristics it is hard to deal with all varies traffic types well. A hierarchical schedules for different service-classes has been proposed by the authors in [22]. Detailed execution comparisons has been evaluated in [23] between hierarchical and one-

level schedulers and this comparison made it clear that the QoS service more organized in hierarchical than one-level scheduler. Based on the concepts that recommended in [24] a scheduling solution, such as hierarchical scheduling has been presented in [25].

In the integration process between the EPON and the WiMAX networks there are several scheduling mechanisms have been proposed. QoS-based Dynamic Bandwidth Allocation (QDBA) together with the Prediction-based Fair Excessive Bandwidth Allocation (PFEBA) scheme to enhance the system performance in EPONs had been proposed in [25]. WiMAX traffics classified into three priority levels and then mapping into ONU queues, the three queues with the distinctive needs has been handled in each ONU in QDBA. Integrated network has been considered to empower information transmission over optical and wireless networks, and an end-to-end separated benefit for different QoS prerequisites in [26]. This QoS-aware scheme supports bandwidth fairness at the ONU-BS level and class of-service fairness at the WiMAX subscriber station level. In [27] A QoS-aware scheduling mechanism for the integrated EPON-WiMAX network was proposed, but it does not take in the consideration the measure of the ONU queues. A two-level scheduling scheme for the integrated EPON-WiMAX network was proposed that takes into thought the queue length and head-of-line (HoL) delay was proposed in [28].

In [29], the scheme utilized corresponding fairness for the transmissions from SSs over the WiMAX channels and a centralized mechanism at OLT for EPON uplink transmission that connects to multiple WiMAX-ONUs, and it had the great advantage of being autonomous of the EPON convention received. This encourages the sending of EPON-WiMAX systems and increments its benefits. Dynamic bandwidth allocation scheme has been considered in [26] as a benchmark plot providing a QoS-aware transfer speed dissemination system for EPON-WiMAX hybrid systems. In expansion, a hierarchical QoS-aware DBA (HQA-DBA) has been displayed and applied in both OLT and ONU-BS. This scheme appears to diminish the normal network delay and the packet drop probability. In [31], a DBA framework was proposed that extraordinary to extend the channel utilization by restricting the signaling overhead. Authors in [32], tried to converge a multichannel PON with a multi-channel wireless access front-end. Scheme based on game theory approach has been proposed in [33] giving accentuation to the fairness provisioning. A common downside in [26–33] DBA schemes found in the literature is that they disregard the time of the coordination handle as a basic effect on the surveying execution. A prediction-aware DBA scheme has been proposed in in [34], assuming that a FiWi networks consists of an asymmetric (10G-EPON) and WiMAX base stations in the front end. The reader is recommended to review the following research in [35] for more DBA schemes and algorithms.

iii. The Bandwidth Allocation Of Wimax And Epon

Both WiMAX and EPON use a non-exclusive survey/demand/award component; that is, a central station (OLT or WiMAX BS) surveys a far off-station (ONU or SS) on bandwidth demands. The focal station at that point awards bandwidth. The high similarity empowers the mix of bandwidth designation and QoS support in the incorporated access structures. In any case, there is an individual difference in specific nuances. EPON upholds QoS in a DiffServ mode, under which bundles are portrayed, grouped, and set aside in precedence queues. Then again, regardless of the way that the services of WiMAX are ordered to

help various degrees of QoS, WiMAX is a connection-oriented technology, which primarily seeks after an integrated service (IntServ) model [36]. Subsequently, for incorporation, a fascinating approach is the best approach to make possible changes between (DiffServ) and (IntServ) services. Also, it is moreover exquisite to perceive how the end-to-end QoS can be upheld after these two frameworks are incorporated. As an issue of hugeness, we should stress on the bandwidth allocation features of WiMAX and EPON systems. WiMAX demands bandwidth for every association premise, yet assigns bandwidth on a per-SS basis [37]. Upon being granted bandwidth, each SS settles on nearby choices to allocate the bandwidth and time-tables parcel transmission for each association. It supports two sorts of bandwidth allocation modes: unsolicited and upon request. WiMAX groups the information traffic into five QoS levels extending from undesirable grant service (UGS) to best effort (BE) [38–43].

Iv. Proposed S-maat Method

It is an EPON-based DBA utilizing the auction process. In this strategy, OLT is answerable for auction process, which can react in a successful way to bandwidth demands from ONUs compared with their needs and the last time they are stand-by to get their requested bandwidth. Besides, the auction cycle repeats itself once every five cycles of the bandwidth allocation process calculated by mathematical iteration. We chose five cycles, which achieve the remarkable result in time delay and throughput, simultaneously. Figure 2 represents the different numbers of cycles with respect to time delay and throughput performance. The general strides of this technique, which depends on the auction process, are summarized as follows and illustrated in Fig. 3.

First step: Reporting the process by OLT for the allocation of bandwidth to the ONUs also, presenting the underlying states of the auction of the ONUs.

Second step: Analyzing the introductory auction conditions by the ONU that sends the bandwidth demand boundaries to the OLT. These parameters include the most magnificent holding uptime of an ONU to get a service, alluring bandwidth, and priority.

Third step: Investigating the obtained demands from ONUs, figuring the offer qualities followed by the determination of the best bidders and producing sub-records from the first rundown of ONUs.

Fourth step: Assigning bandwidth to the most noteworthy bidder ONUs, and managing the utilization of the bandwidth.

Fifth step: Recurrence of the entire cycle from the first step once every five cycles of bandwidth allocation process.

The overall process is illustrated schematically in Fig. 4.

V. Evaluation Method And Simulation Parameters

In this section, the mathematical models used to calculate the delay/throughput for different DBA algorithms in the integration process under test are extracted from the literature. The evaluation method is based on (OPNET/C++) calculation for these algorithms/models. The parameters are applied to the numerical models. A comparison between DBA algorithms concerning throughput and time delay in the integration process between EPON/WiMAX is presented, targeting the best choice to enhance the integration process, algorithm performance, and IPACT delay, which is calculated as follows:

$$D_{\text{delay IPACT}} = D_{\text{delay POLL}} + D_{\text{delay GRANT}} + D_{\text{delay QUEUE}} \quad (1)$$

where,

$D_{\text{delay POLL}}$: time between packet arrival and the next request sent by the ONU.

$D_{\text{delay GRANT}}$: time interim from an ONU solicitation for a transmission window until the beginning of the timeslot in which this casing is to be sent. This deferral may traverse numerous cycles, contingent upon the number of structures existing in the line at the time of the fresh debut.

$D_{\text{delay QUEUE}}$: delay from the earliest starting point of the timeslot until the start of the frame transmission. This postponement is equal to half of a space time and is not significant contrasted to the previous two fragments.

FSD-SLA Delay:

$$D_{\text{FSD-SLA}} = D_{\text{Cycle-Time}} + D_{\text{delay GRANT}} + D_{\text{SLA}} \quad (2)$$

where,

$D_{\text{Cycle-Time}}$: greatest time cycle length. The scheduler at the OLT may plan bandwidth for the most fabulous time of T in one emphasis on schedule.

$D_{\text{delay GRANT}}$: time interim from an ONU solicitation for a transmission window until the beginning of the schedule opening in which this casing is to be sent. This deferral may traverse numerous cycles, contingent upon what number of frames in the line at the hour of the new arrival.

D_{SLA} : checking delay of the essential and optional SLA requests.

Maat

Delay:

$$D_{\text{Maat}} = D_{\text{delay Announce}} + D_{\text{delay Auction-Process}} + D_{\text{delay Allocation}} \quad (3)$$

Where,

$D_{\text{delay Announce}}$: time to commence the auction process and present the parametric offer.

$D_{\text{delay Auction - Process}}$: time that auction procedure is running.

$D_{\text{delay Allocation}}$: time to distribute the bandwidth to the most noteworthy bidders.

Throughput rate $TR = \text{Info}_{\text{Total-Recv}} / \text{Time}_{\text{Take-To-Recv}}$ (4)

$\text{Info}_{\text{Time-Recv}}$: time that the cooperative data conveyed between end-focuses.

$\text{Time}_{\text{Take- to -Recv}}$: time taken to accomplish recovery.

The simulation parameters used are extracted from the published work in this field [44]. The values of these parameters are as follows:

Table I. simulation parameters

1. For All Algorithms:	
<i>Number of ONUs</i>	Around 16
<i>Distance between OLT and ONUs</i>	= 20 km
<i>Packet size</i>	= 15000 byte
<i>Ethernet overhead bits</i>	= 304 bits
<i>Upstream bandwidth</i>	= 1 Gbps
<i>Maximum cycling time</i>	= 2 ms
<i>Buffer size</i>	= 10 Mbyte
<i>Two-way fiber delay</i>	= 200 μ s
<i>Guard time</i>	= 5 μ s
<i>Traffic type</i>	Poisson Distribution
<i>IPACT condition</i>	Fixed
<i>2. The bit rate for ONU to OLT</i>	= 5 to 57.5 (Mb/s) Mbits/s for Maat & S-Maat
<i>Other algorithms</i>	= 62.5
<i>3. Window size for report message (Byte)</i>	= 64
<i>4. Request message size (bits)</i>	= 570 bit
<i>5. Maximum transition window (Packets)</i>	= 10 for Maat & S-Maat

Vi. Numerical Results And Discussion

The throughput performance and time delay for the DBA algorithms under evaluation are presented to determine the ideal DBA algorithm that accomplishes a noteworthy throughput and time delay performance among all DBA algorithms under assessment in the integration process between EPON/WiMAX.

A. Throughput Performance

In this section, the parameters and their corresponding values are applied to the mathematical models to generate the following throughput performance for the DBA algorithms under evaluation. Figure 5 represents the network throughput performance

TABLE II. DBA algorithms according to throughput performance in a descending order and to their time delay performance in a descending order						
The values are taken around 0.2 Gbps offered load			The values are taken around 0.5 Gbps offered load		The values are taken around 0.9 Gbps offered load	
No.	Algorithm	Throughput (Gbps)	Algorithm	Throughput (Gbps)	Algorithm	Throughput (Gbps)
1	ST	0.1	ST	0.275	ST	0.416
2	CO	0.1	CO	0.275	CO	0.44
3	VOB	0.082312	VOB	0.226358	VOB	0.3424198
4	Maat	0.13	Maat	0.2385	Maat	0.463125
5	IPACT	0.025	IPACT	0.025	IPACT	0.025
6	FSD-SLA	0.04625	FSD-SLA	0.1236	FSD-SLA	0.155
7	S-Maat	0.1300013	S-Maat	0.24327	S-Maat	0.4723875
No.	Algorithm	Delay (ms)	Algorithm	Delay (ms)	Algorithm	Delay (ms)
1	ST	6×10^{-4}	ST	6.614×10^{-4}	ST	8.66×10^{-4}
2	CO	6.44×10^{-4}	CO	7.35×10^{-4}	CO	8.34×10^{-4}
3	VOB	7.04×10^{-4}	VOB	8.15×10^{-4}	VOB	1.925×10^{-3}
4	Maat	5×10^{-5}	Maat	4.85714×10^{-4}	Maat	7.208×10^{-4}
5	IPACT	4.8×10^{-4}	IPACT	1×10^{-3}	IPACT	1×10^{-3}
6	FSD-SLA	8.2×10^{-4}	FSD-SLA	3.483×10^{-3}	FSD-SLA	9.66×10^{-3}
7	S-Maat	1.5×10^{-5}	S-Maat	1.457142×10^{-4}	S-Maat	2.1624×10^{-4}

versus offered load for different algorithms. Due to the high bandwidth demand required by modern life applications and personal digital assistants (PDAS), this work will focus on the high offered load (i.e., 0.8-1 Gbps) scenario, and this reveals superiority of the S-Maat algorithm.

Tables II represent the order of DBA algorithms according to their throughput performance as a function of the offered load as extracted from Fig. 5.

B. Time Delay Performance

The methodology of study of throughput performance is repeated here for time delay performance. Figure 6 presents the time delay performance versus the offered load.

Table II presents the order of DBA algorithms according to their time-delay performance as a function of the offered load as extracted from Fig. 6, 7, 8, and 9.

Vii. Comparison And Selection Of Optimum Dba Algorithm

Based on the illustrated results in Figs. 5, 6, 7, 8, and 9, the target now is to compare between the four optimum DBA algorithms that achieve acceptable throughput and time delay performance simultaneously for more processing. Two crucial observations about the proposed algorithm can be extracted from Table II. Firstly, it is difficult to obtain a clear order for DBA algorithms that achieve remarkable throughput and time delay performance simultaneously, because the DBA algorithms that produce a noteworthy throughput performance have lower quality for time-delay performance and vice versa. Secondly, the DBA algorithms in time delay and throughput performance are very close, which makes the selection operation more difficult. However, we can try to extract the optimum DBA algorithm that can achieve acceptable rather than remarkable throughput and time delay performances, simultaneously. Accordingly, the selection will be the proposed S-Maat algorithm. Table III provides the percentage of enhancement in the time delay and throughput for the different offered loads.

Table III. Percentage of the enhancement in time delay and throughput.

Proposed S-Maat Algorithm						
Parameter	Percentage of increase in throughput			Percentage of decrease in time delay		
Offered Load (Gpbs)	0.2	0.5	0.9	0.2	0.5	0.9
(ST)	30.0013%	-11.538%	13.5546%	97.5%	77.9688%	75.03%
(CO)	30.0013%	-11.538%	7.3607%	97.67%	80.1749%	74.0719%
(IPACT)	More than 100%	More than 100%	More than 100%	96.875%	85.428%	78.376%
FSD	More than 100%	96.82%	More than 100%	98.17%	95.816%	97.7614%
(VOB)	57.9372%	7.47%	37.9315%	97.869%	82.1209%	88.7667%
(Maat)	0.001%	2%	2%	70%	70%	70%

Viii. Conclusion

A novel and successful auction semi-DBA technique has been proposed utilizing the coordinated WiMAX/EPON innovation with a dynamic determination of ONUs by OLT. This strategy exhibits

significant upgrades in diminishing packet time delay and enhancing throughput with limited service IPACT, FSD-SLA, bandwidth allocation strategy using coalition, bandwidth allocation strategy using Stackelberg, Maat, and VOB methods. This study could be utilized for considering and structuring the cellular automata parametric offer calculation, running settled auctions for better execution and investigation of (Fi-Wi) connect with Long-Term Evolution Advanced (LTE-A) for accomplishing an improved QoS and characterizing the distribution in EPON and LTE.

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Figures

Figure 1

EPON & WiMAX integration structure

(a)

(b)

Figure 2

(a) Comparison between the different numbers of cycles from the iteration process with respect to the throughput paramter. (b) Comparison between the different numbers of cycles from the iteration process with respect to the time delay paramter.

Figure 3

Steps to the proposed method

Figure 4

Schematic diagram of the overall process in S-MAAT method

Figure 5

Network throughput for different DBA algorithms in the integration process between EPON and WiMAX.

Figure 6

Network time delay for different DBA algorithms in the integration process between EPON and WiMAX

Figure 7

Performance comparison from 0.2 to 0.55 Gbps.

Figure 8

From 0.4 to 0.75 Gbps.

Figure 9

Performance comparison from 0.65 to 1 Gbps.