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Analytical Power Consumption Modeling For EPON-WiMAX Integrated Networks

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Abstract: **Research on energy consumption and bandwidth allocation scheme is the basis for achieving the standard of service and fairness requirements for various traffic classes within the integrated optical-wireless access network which is crucial as the energy consumption issue is increasingly vital nowadays. The access segment of both optical and wireless networks is well-known for its domination over total network power consumption. In this research paper, the full power consumption and energy efficiency of integrated Ethernet Passive Optical Network (EPON) and two wireless technologies, namely, Worldwide Interoperability for Microwave Access (WiMAX) and Long-Term Evolution (LTE) with a unique EPON-based semi-dynamic bandwidth allocation (SD-DBA) is evaluated. A semi-analytical power consumption model is proposed and applied within the simulation model for energy performance evaluation. Furthermore, various parameters that will affect the energy performance like split ratio, femtocell base station (FBS) range, analysis of broadcast elements, and modulation schemes are considered. The obtained results prove that, the EPON-WiMAX with SD-DBA has better energy efficiency performance compared to EPON-LTE with SD-DBA that offers the best data rates.**

***Keywords**: EPON; WiMAX; DBA; QoS; throughput; time delay; energy efficiency; LTE; power consumption.*

I. INTRODUCTION

Integration of optical and wireless networks might be a promising solution to boost both delay and throughput problems because of their complementary features of wide bandwidth and user mobility, respectively. The optical access network consumes 60-80% of the full power consumed by wired networks [1-4] where the facility consumption is dominated by the Optical Network Units (ONUs). On the opposite side, the wireless access network consumes 9% of (ICT) power consumption whereas 80% of the ability is consumed by the bottom Stations (BSs) [5-6]. The existence of assorted optical and wireless technologies ends up in several different combinations which could support a reliable and efficient (FiWi) architecture [7]. Some architecture for an integrated optical-wireless access network has been proposed in [8, 9]. These include independent architecture, hybrid architecture, unified connection-oriented architecture, and microwave-over-fiber. While independent architecture is simple to be integrated with the existing architecture because the Optical Network Unit (ONU) and Base Station (BS) are integrated without special requirements being met, the hybrid architecture integrates all functional modules ONU and a BS in a single system box. Power consumption measurements in optical and wireless networking devices have rarely been performed in the past. This, in turn, led to unrealistic and/or oversimplified models getting used in simulations. Although integrated optical and wireless access networks have received considerable attention for future broadband access networks, energy/power consumption for this network remains unexplored. In PON, most of the related researches found in the literature used an analytical approach [1, 10-12] within the modeling of the energy consumption. The consumption ability is firstly modeled by defining the generic structure of various equipment that located at both network provider and user premises, i.e. OLT and ONU. Then, the consumption ability per network element is calculated that supported the consumption values of the defined generic structure. In wireless access, analytical power consumption models for wireless access are presented in [13, 14]. An analytical approach of modeling power consumption was also presented for integrated optical-wireless access [15, 16].

In [16], the authors focused their research on different types of (RoF) wireless BS incorporating different wireless signal transport schemes which are named based over fiber, RF over fiber, IF over fiber digitized IF over fiber, and digitized RF over fiber. Since all the processing in RoF is moved towards the CO, extra propagation delay might occur thus degrading the system performance. Additionally, a possible failure inside the (CO) will endanger overall service availability. There are several existing researches [17, 19] that have presented the empirical power consumption models for wireless access networks. In [17], the authors focus their analysis on the new IEEE 802.11n standard which employs a big selection of experiments. This work provides us with insights on the facility consumption of one wireless interface instead of the system as a full. In [18], the authors targeted the energy consumption of a wireless network as a full through presenting a joint experimental evaluation of energy consumption and performance in an IEEE 802.11-based WLAN using both 802.11a and 802.11n operating modes. However, no power consumption model is provided in the meantime, authors in [19] have presented a measurement-based methodology for characterizing the energy consumption behavior of networked wireless devices and concluded that the facility consumption of the considered access devices exhibits a linear dependence on the traffic until saturation is reached. In [20], an in-depth measurement of the facility consumption of an ad femtocell base station was reported. In their analysis, they considered the effect of varying traffic load and datagram size on the consumption-ability of the femtocell base station [21].

From one perspective, EPON is viewed as a promising solution for the leading edge fiber-based access method, not only as a fast and economically familiar, but it is also a versatile. The remote access procedure is additionally steadily redesigning its transfer speed, versatile capacity, and nature of administration support. The new-age WiMAX has now been regulated and passed on. The upsides of bandwidth advantage and portability highlights result in the incorporated EPON and WiMAX design in Fig. 1 [22].

EPONs [23, 24] and IEEE 802.16e/WiMAX [25] have shown a remarkable assurance within the improvement of new-age wired and remote access advances [26]. Due to the limited extent of their bandwidth, unwavering quality,

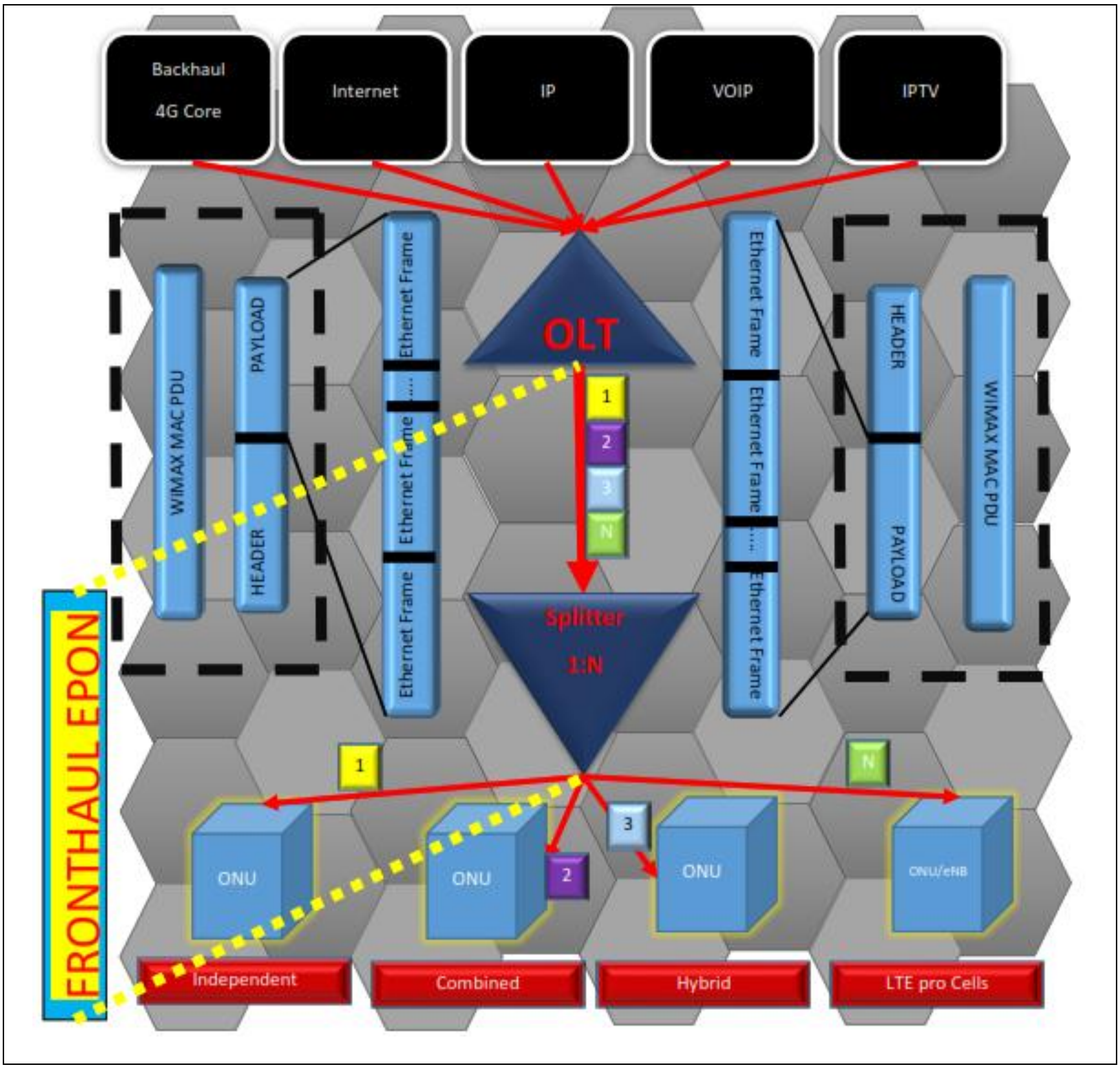


Fig. 1. EPON & WiMAX/LTE integration structure

adaptability within the placement, and system costs are mostly Internet service providers (ISPs) view EPONs as an appropriate choice within the provides backhaul management to connect other things scattered WiMAX base stations (BSs) [26-29]. In any case, EPONs and WiMAX are dependent upon various norms specializing in various system situations. Along these lines, different enormous issues must be settled before they will be adequately coordinated. The noteworthy point within the reconciliation of EPON/WiMAX systems is that the booking instrument ensures that the heterogeneous progression of traffic (through the Ethernet and also the WiMAX) gets a good amount of the accessible upstream data transmission. Many planning instruments are proposed to assist transfer in coordinated EPON/WiMAX frameworks [27-29]. In [27] and [28], centralized-scheduling-based (CS) DBA was proposed to assist the transmission of WiMAX traffic over a coordinated EPON/WiMAX arrangement. Despite the way that these endeavors eliminate delays, generally speaking, system throughput is diminished, because each kind of traffic is solely a pre-dispensed measure of information transfer capacity, which cannot be reallocated to transmit another quiet traffic despite the way that it's not conclusively utilized.

In [29], a system hooked into the 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 try and do intra-scheduling capacities. Although the OLT distributes bandwidth reasonably between the Ethernet and WiMAX, this examination fails to deal with the problem of QoS. The EPON has the benefits of high bandwidth, low cost, and various services support [30-32]. In this paper, a semi-dynamic bandwidth allocation (SDBA) algorithm is introduced obsessed with the auction process, no doubt; that the dynamic bandwidth allocation is crucial 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 required to see the stress for every user, but there's no must repeat the auction process on the bandwidth in consecutive short times, especially the demand for several regular users doesn't change quickly or suddenly and is approximately constant for every profile. Therefore, during this research, we propose a modified dynamic bandwidth allocation, which may be a hybrid or mixture between dynamic and static bandwidth allocation “semi-dynamic”.

The model was adapted in our work to estimate the ability consumption of the femtocell base station connected to the EPON backhaul with a unique hybrid bandwidth allocation algorithm supported auction process, where the dynamic bandwidth allocation is employed within the beginning to work out the demand for every user, and also the auction process is repeated cyclically each 5 cycle to avoid any mistakes or any unanticipated change in user demand. This protects time and avoids mistakes resulting from repeating the auction process in very short times like demand and grant misalignment. Thus, the system is going to be a static system for five cycles and a dynamic system at the moment, and this can be repeated periodically. Therefore, we name the proposed system a semi-dynamic system. It’s demonstrated to be prosperous compared with the prevailing DBA methods of integration between EPON and WiMAX technologies ST, CO, VOB [33], IPACT, and FSD-SLA [34].

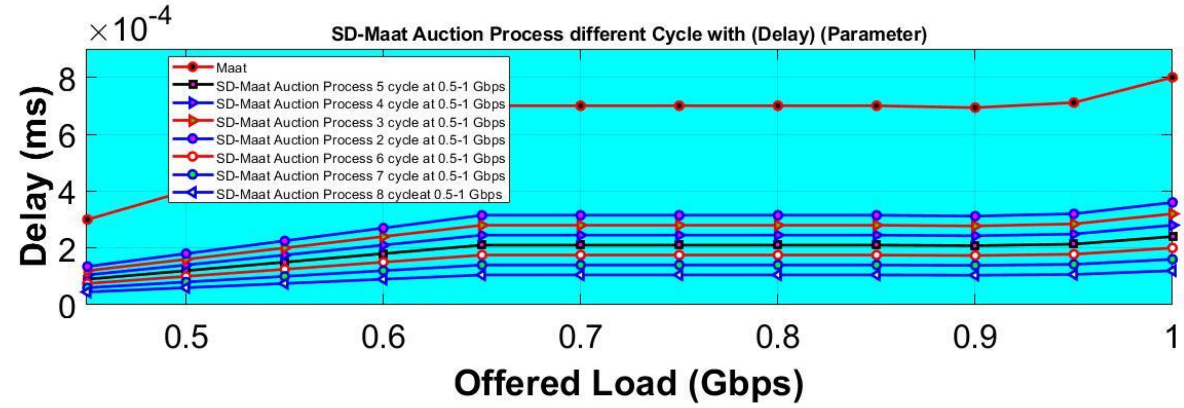
The remaining of the paper is organized as follows: Section II presents the bandwidth allocation of WiMAX/LTE and EPON. Methodology of the power consumption Modeling and SD-Maat is presented in Section III. The evaluation method and simulation parameters are presented in Section IV. Numerical results and discussions are presented in Section V. Comparison and selection of optimum DBA algorithm are presented in Section VI. Finally, Section VII provides the Concluding remarks.

II. THE BANDWIDTH ALLOCATION OF WIMAX/LTE AND EPON

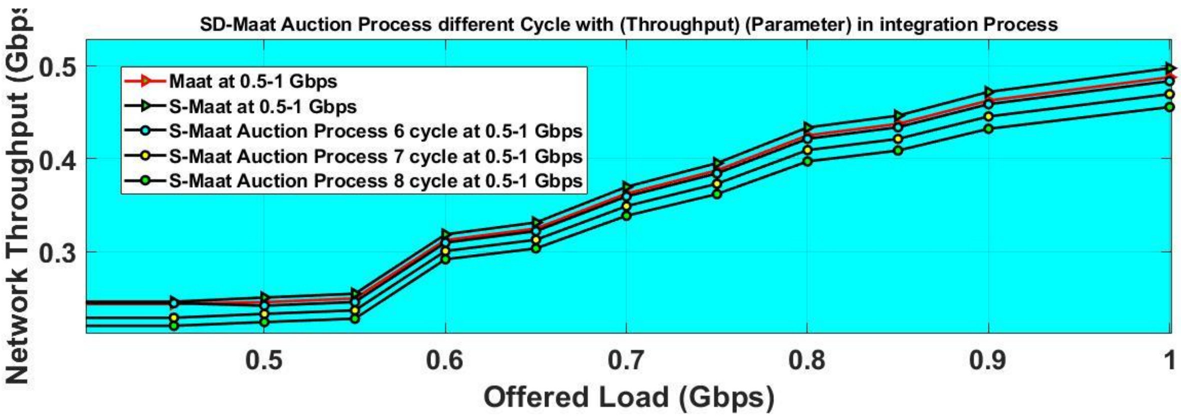
Both WiMAX and EPON use a non-exclusive survey/demand/award component; that's, a central station (OLT or WiMAX BS) surveys a far off-station (ONU or SS) on bandwidth demands. The focal station at that time awards bandwidth. The high similarity empowers the combination of bandwidth designation and QoS support within the incorporated access structures. In any case, there's a personal difference in specific nuances. EPON upholds QoS in a very DiffServ mode, under which bundles are portrayed, grouped, and put aside in precedence queues. Then again, irrespective of the way that the services of WiMAX are ordered to assist various degrees of QoS, WiMAX could be a connection-oriented technology, which primarily seeks after an integrated service (IntServ) model [47]. Subsequently, for incorporation, a desirable approach is the best approach to create possible changes between (DiffServ) and (IntServ) services. Also, it's moreover exquisite to perceive how the end-to-end QoS may be upheld after these two frameworks are incorporated. As a problem of hugeness, we should always stress the bandwidth allocation features of WiMAX and EPON systems. WiMAX demands bandwidth for each association premise, yet assigns bandwidth on a per-SS basis [48]. Upon being granted bandwidth, each SS settles on nearby choices to allocate the bandwidth and time-tables parcel transmission for every association. It supports two kinds of bandwidth allocation modes: unsolicited and upon request. WiMAX groups the knowledge traffic into five QoS levels extending from undesirable grant service (UGS) to best effort (BE) [49-64]. Integrating wireless and optical communications provides pervasive network access to any or all subscribers. The mix of the high capacity of the foremost promising optical technologies, namely Passive Optical Networks (PONs), with the mobility and suppleness of state-of-the-art cell network technologies, like LTE (Long Term Evolution) and WiMAX, enables the formation of efficient hybrid FiWi (Fiber-Wireless) networks. Possible solutions for the optical domain involve versions of PONs standardized by ITU (International Telecommunication Union) and IEEE (Institute of Electrical and Electronics Engineers).

III. Methodology of the Power Consumption Modeling and SD-Maat Method

While EPON-based DBA is utilizing the auction process. OLT is in control of the auction process, which might react during a successful thanks to bandwidth demands from ONUs compared with their needs and also the last time they're stand-by to induce their requested bandwidth. Besides, the auction cycle repeats itself once every five cycles of the bandwidth allocation process calculated by mathematical iteration. We choose five cycles, which achieve the remarkable lead to time delay and throughput, simultaneously. Fig. 2 represents the various numbers of cycles with relevancy time delay and throughput performance.



(a)



(b)

Fig. 2. (a) Comparison between the different numbers of cycles from the iteration process concerning the throughput parameter. (b) Comparison between the different numbers of cycles from the iteration process concerning the time delay parameter.

First step: Reporting the method 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 foremost magnificent holding uptime of an ONU to induce a service, alluring bandwidth, and priority.

Third step: Investigating the obtained demands from ONUs, figuring the offer qualities followed by the determination of

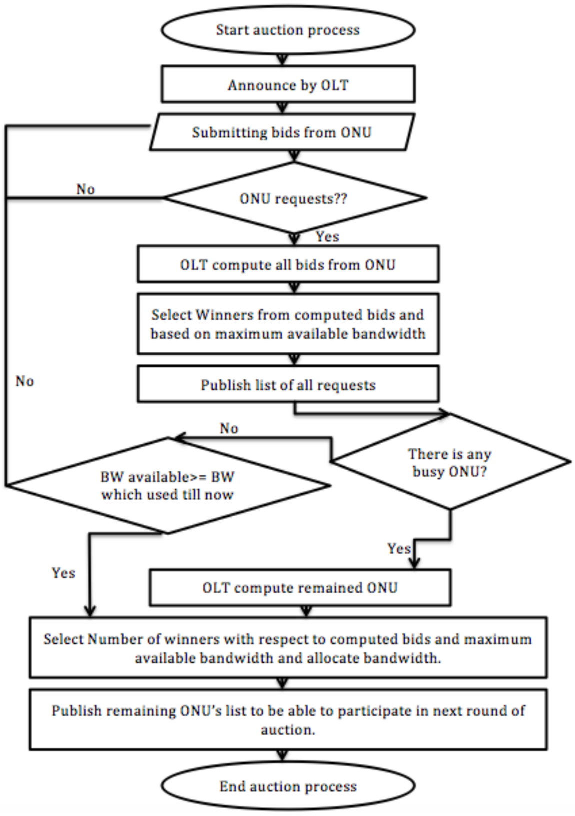


Fig. 3. Schematic diagram of the overall process in the S-MAAT method

the simplest bidders, and producing sub-records from the primary rundown of ONUs.

Fourth step: Assigning bandwidth to the foremost noteworthy bidder ONUs, and managing the employment of the bandwidth.

Figure 1 shows the architecture of the considered integrated EPON and wireless access network with femtocell application. EPON is a backhaul of the integrated network while WiMAX or LTE are considered for the wireless front-end. The users are connected either by using wired or wireless networks. The proposed simulation model will firstly dimension the network then the whole power consumption for every network element is calculated supported by the facility consumption model. In the meantime, the user demand is additionally considered so that, the achievable data rates are

Fifth step: Recurrence of the complete cycle from the primary step once every five cycles of the bandwidth allocation process. The overall process is illustrated schematically in Fig. 3.

determined using SD-Maat. Considering the computed total power consumption and achievable rate, the energy efficiency can be calculated. The proposed simulation model for evaluating the energy performance of the integrated EPON and wireless network is shown in Fig. 4.

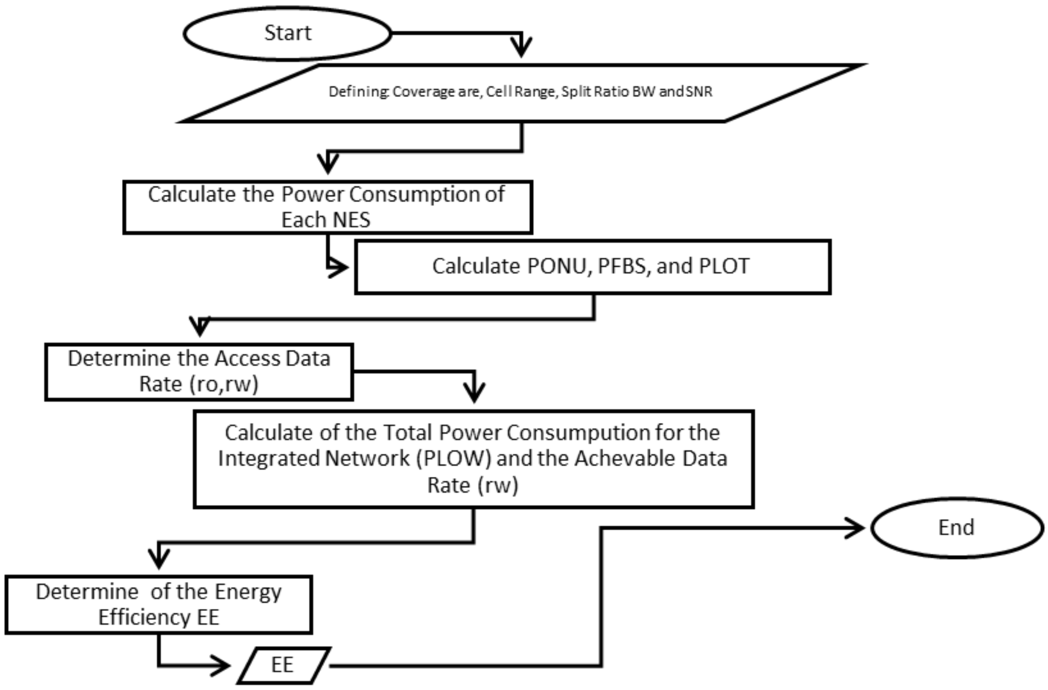


Fig. 4: Overview of the simulation model

IV. EVALUATION METHOD AND SIMULATION PARAMETERS

In this section, the mathematical models used to calculate the delay/throughput for various DBA algorithms within the integration process under test are extracted from the literature. The evaluation method is predicated 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 within the integration process between EPON/WiMAX is presented, targeting the simplest option to enhance the mixing process, algorithm performance, and IPACT delay, which is calculated as follows:

$$P_{Low} = \sum_{i=1}^{M} P_i^{OLT} + \sum_{i=1}^{N} (P_i^{ONU} + P_i^{FBS}) \qquad (1)$$

where M and N are the numbers of OLT and IOB respectively, P_i^{OLT}, P_i^{ONU} and P_i^{FBS} are the power consumption of OLT, IOB, ONU, and FBS respectively. The power consumption of each network element namely the OLT, ONU, and FBS is as follows. For the OLT, the power consumption model is expressed as [42]:

$$P_i^{OLT} = \left(P_{ports} + P_{control} + P_{UL}\right) \times \frac{1}{\eta_{\frac{DC}{DC}}} \times SF \qquad (2)$$

where P_{ports}, $P_{control}$, and P_{UL} are power consumption of OLT PON ports, general OLT function, and uplink ports respectively, $\eta_{DC/DC}$ is power conversion efficiency SF and is the site factor. The power consumption of the ONU was modeled based on its dependence on the traffic loads. The power consumption of the ONU was experimentally measured by using a real GPON testbed in which we utilized an Arduino-based energy meter for power monitoring and measurement. Based on the obtained results, we model the power consumption of ONU as [43]:

$$P_i^{ONU} = \alpha_o r_o \times \gamma_0 \qquad (3)$$

where α_o is the power consumed by the ONU to transmit or receive 1 bit of information, r_o is the average access data rate per ONU and γ_0 is the power consumption of the ONU when idle.

The power consumption model for FBS used in this study is based on the work previously reported in [20]. They used a similar approach as our modeling for the ONU which is the power consumption for the FBS is measured by using an Arduino- based energy meter. For the FBS, the power consumption model is as follows:

$$P_i^{FBS} = \alpha_W r_W + \gamma_W \qquad (4)$$

where α_W Is the power consumed by the FBS to transmit 1 bit of information, r_W is the average data rate of wireless users and γ_W is the power consumption when FBS is idle.

$$D_{elay\ IPACT} = D_{elay\ POLL} + D_{elay\ GRANT} + D_{elay\ QUEUE} \qquad (5)$$

where,
Delay POLL: time between packet arrival and the next request sent by the ONU.
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.
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 the space-time and is not significantly contrasted to the previous two fragments.
FSD-SLA Delay:

$$D_{FSD-SLA} = C_{ycle-Time} + D_{elay\ GRANT} + D_{SLA} \quad (6)$$

where,
Dcycle –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.
Delay GRANT: time interim from an ONU solicitation for a transmission window until the beginning of the scheduled opening in which this casing is to be sent. This deferral may traverse numerous cycles, contingent upon the number of frames in the line at the hour of the new arrival.
DSLA: checking the delay of the essential and optional SLA requests.

Maat Delay:

$$D_{Maat} = D_{elay\ Announce} + D_{elay\ Auction-Process} + D_{elay}\ \text{Allocation} \quad (7)$$

where,
Delay Announce: time to commence the auction process and present the parametric offer.
Delay Auction – Process: time that auction procedure is running.
Delay Allocation: time to distribute the bandwidth to the most noteworthy bidders.

$$\text{Throughput rate}_{TR} = \text{Info}_{Total-Recv} / \text{Time}_{Take-To-Recv} \quad (8)$$

Info Time–Recv: time that the cooperative data conveyed between end-focuses.
Time Take– to –Recv: time taken to accomplish recovery.

In the meantime, the user demand was also defined which can be accustomed to determine the achievable rate. We consider broadcast service for GPON with a broadcast factor of 0.2 [32], [42] whereas for both wireless technologies, we assume the channel bandwidth of 10 MHz and 16-QAM modulation format. For WiMAX, the SNR value as defined in IEEE 802.16 standard was used. On the opposite hand, for the LTE, the SINR utilized in the simulation relies on the SINR mapping presented in [44]. An implementation margin (IM) is included which considers the difference in SINR requirement between theory and practicable implementation. Table 3 summarizes the parameters considered for the determination of the achievable rate. Finally, the tip product would be the energy efficiency which is obtained by dividing the resulting rate by the full network power consumption.

The simulation parameters used are extracted from the published work in this field [65]. The values of these parameters are as follows:

TABLE I. SIMULATION PARAMETERS

Parameter	Value
1. For All Algorithms:	
Number of ONUs	Around 16
Packet size	= 15000 byte
Ethernet overhead bits	=304 bits
Upstream bandwidth	= 1 Gbps
Maximum cycling time	= 2 ms
Buffer size	= 10 Mbyte
Two-way fiber delay	= 200 µs
Guard time	= 5 µs
Traffic type	Poisson Distribution
IPACT condition	Fixed
2. The bit rate for ONU to OLT Other algorithms	= 5 to 57.5 (Mb/s) Mbits/s for Maat & SD-Maat
	= 62.5
3. Window size for report message (Byte)	= 64
4. Request message size (bits)	= 570 bit
5. Maximum transition window (Packets)	= 10 for Maat & SD-Maat
Coverage Area, s	100 Km^2
Split ratio, SR	32
Cell radius, R	30 m
OLT PON port power	41.5 W
OLT general function power	33.3 W
OLT uplink port power	2.3 W
OLT power conversion efficiency	0.9
OLT site factor	1.7
ONU idle power	11.51 W
ONU power per 1 bit	0.00208 W/Mbps
FBS idle power	7.83 W
FBS power per 1 bit	0.0792 W/Mbps
EPON Broadcast factor	20%
WiMAX Bandwidth	10 MHz
WiMAX Modulation and coding scheme, MCS	½ 16-QAM
LTE Bandwidth	10 MHz
LTE Modulation and coding scheme MCS	½ 16-QAM
LTE bandwidth efficiency	0.83
LTE Fudge factor	0.9
LTE SNR efficiency	1 dB

V. 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 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 the 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 Figures.

B. Time Delay Performance

The methodology of the study of throughput performance is repeated here for time delay performance. Figure 7 presents the time delay performance versus the offered load. Table II presents the order of DBA algorithms in keeping with their time-delay performance as a function of the offered load as extracted from Fig. 7, 8, 9, and 10. Fig. 11 shows the connection between total power consumption moreover as energy efficiency and also the considered parameter variations. The values of split ratio considered within the simulation are 16, 32, and 64, the variation of FBS range is from 20m to 40m with 10m gaps, the share of information rates reserved for broadcast factor are 20%, 50%, and 80% and therefore the modulation & coding scheme considered for the evaluation of power consumption is ¾ QPSK, ½ 16-QAM, and 2/3 64-QAM. The combination between GPON and LTE includes the potential to extend the energy efficiency of the access network because of the upper average access rate it offers. However, WiMAX has higher SNR than LTE considering similar MCS leading to lower achievable data rates for the LTE. as an example, the system with 1/2 16-QAM, the info rates of 54.8 MHz is achievable for WiMAX whereas the LTE achieved data rates of 25.12 MHz, Although LTE offers higher theoretical peak data rates than WiMAX, the lower SNR makes LTE less energy efficient than WiMAX. Therefore, from the obtained results it's evident that EPON-WiMAX always surpasses EPON-LTE in terms of total network power consumption and energy efficiency. For parameters variation consideration, it seems that variations in split ratio, FBS range, broadcast factor, and modulation scheme have impacts on the facility consumption yet as the energy efficiency of the integrated access network. Increasing the split ratio features the potential to cut back the full network power consumption and increase the energy efficiency thanks to the improved equipment sharing. Further, an extended FBS range can significantly reduce the overall power consumption and also increase energy efficiency. However, careful measures must be considered so the longer range doesn't affect the standard of the signal. On other hand, the smallest amount of impact on the general power consumption is found for the variation of the printed factors within which it doesn't show much difference in both total power consumption and energy efficiency. Lastly, the variations in modulation schemes, although it exhibits a small impact on total network power consumption lead to a significant increase in the energy efficiency with a high constellation.

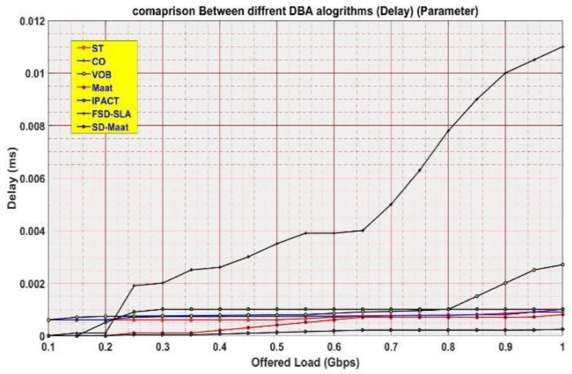
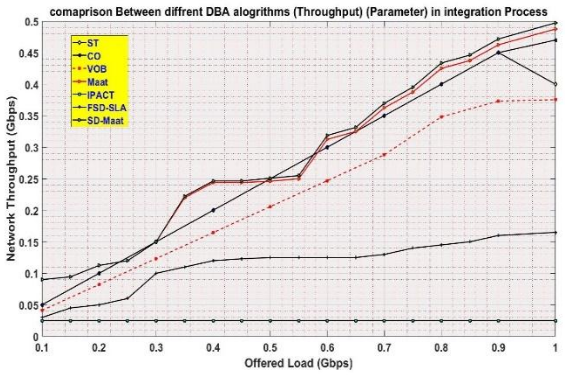


Fig. 5. Network throughput for different DBA algorithms in the integration



process between EPON and WiMAX.

Fig. 6. Network time delay for different DBA algorithms in the integration process between EPON and WiMAX

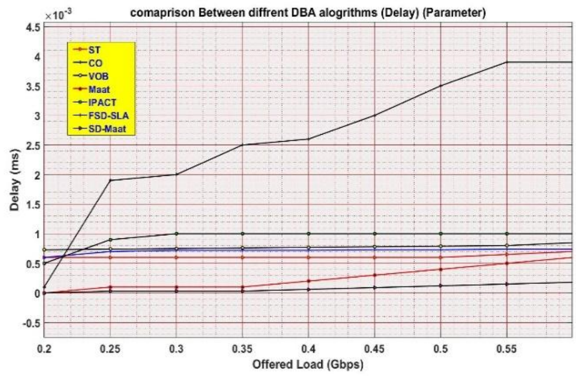


Fig. 7. Performance comparison from 0.2 to 0.55 Gbps.

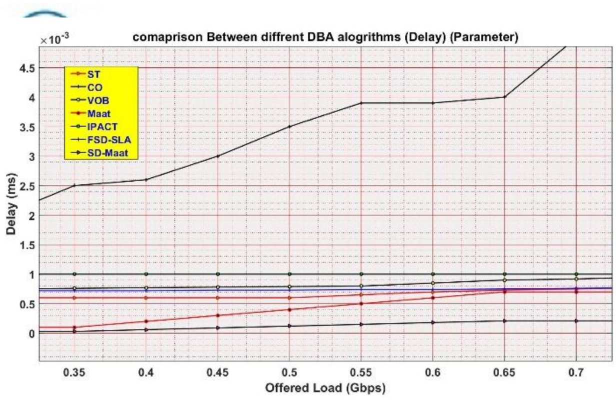


Fig. 8. From 0.4 to 0.75 Gbps.

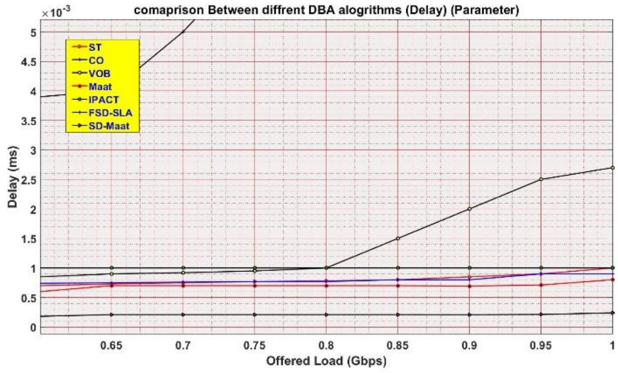
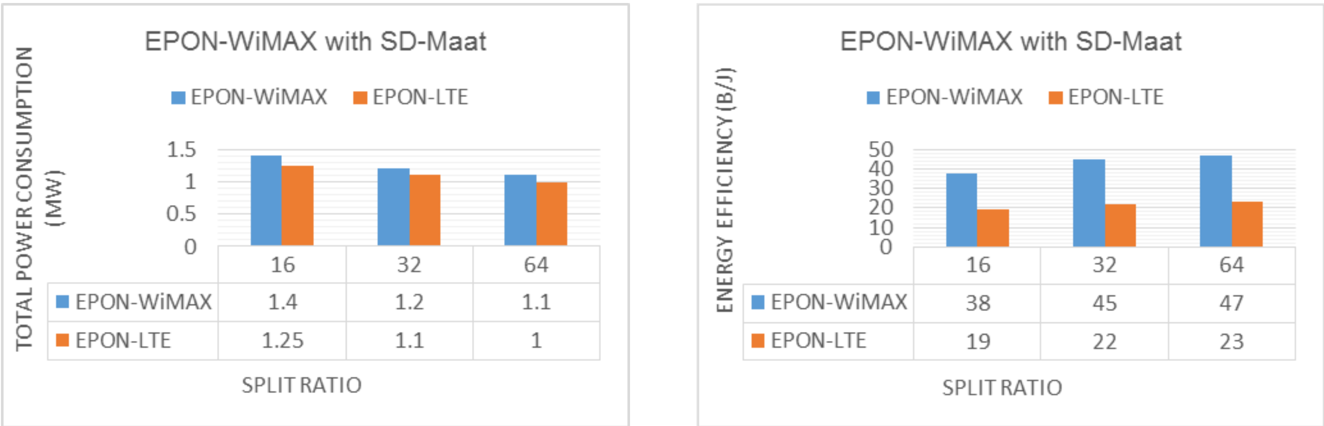


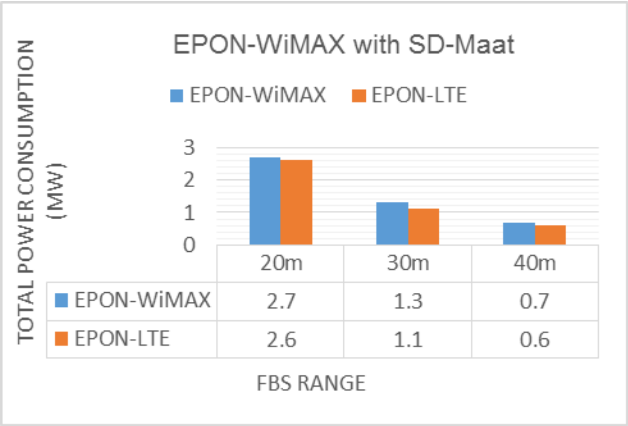
Fig. 9. Performance comparison from 0.65 to 1 Gbps.



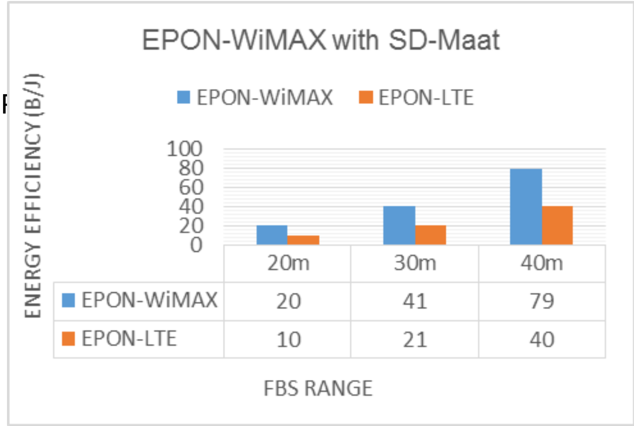
	16	32	64
EPON-WiMAX	1.4	1.2	1.1
EPON-LTE	1.25	1.1	1

	16	32	64
EPON-WiMAX	38	45	47
EPON-LTE	19	22	23

(a) (b)



(C)



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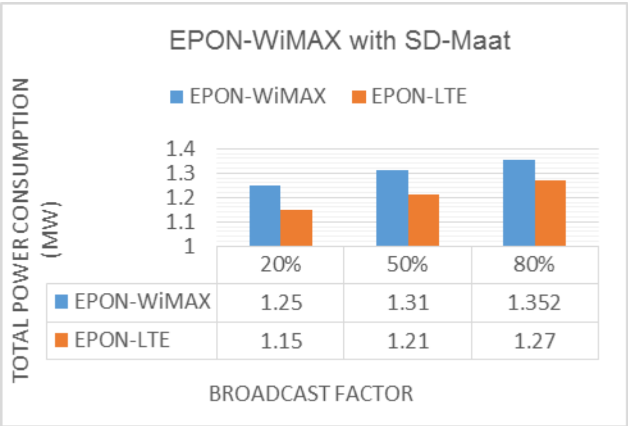

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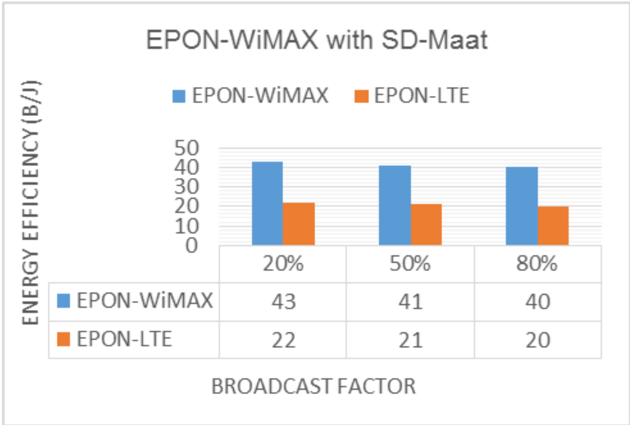

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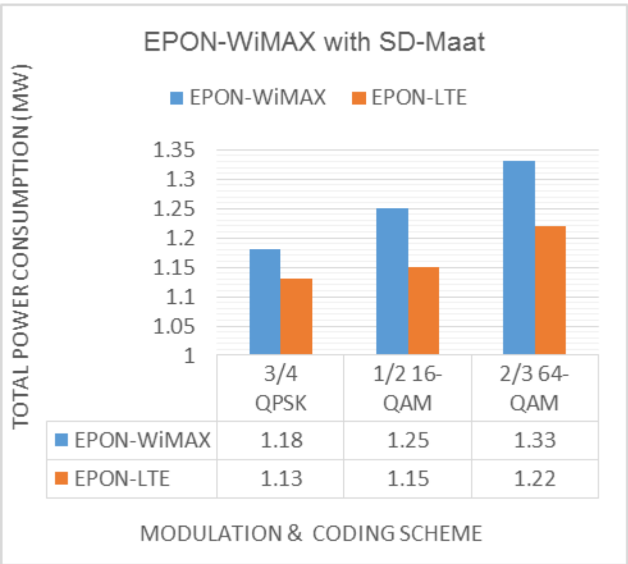

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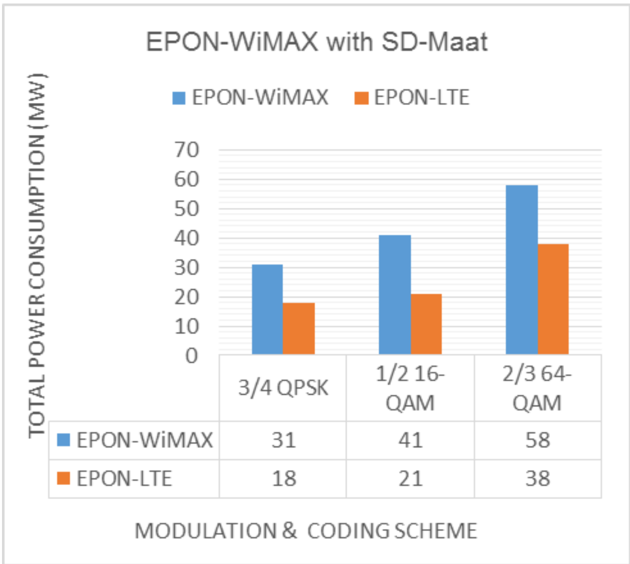

(h)

Fig. 10 Impact of different split ratios on the a) total power consumption and b) energy efficiency of EPON-WiMAX and EPON-LTE c) total power consumption and d)energy efficiency of EPON-WiMAX and EPON-LTE e) total power consumption and f) energy efficiency of EPON-WiMAX and EPON-LTE g) total power consumption and h) energy efficiency of EPON-WiMAX and EPON-LTE

TABLE II. DBA ALGORITHMS ACCORDING TO THROUGHPUT PERFORMANCE IN 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	SD-Maat	0.1300013	SD-Maat	0.24327	SD-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	SD-Maat	1.5×10^{-5}	SD-Maat	1.457142×10^{-4}	SD-Maat	2.1624×10^{-4}

VI. COMPARISON AND SELECTION OF OPTIMUM DBA ALGORITHM

Based on the illustration ends up in Figs. 5, 6, 7, 8, 9, and 10, the target now is to match the optimum DBA algorithm that achieves acceptable throughput and time delay performance with efficient power consumption modeling simultaneously for more processing. Two crucial observations about the proposed algorithm are extracted from Table II. Firstly, it's difficult to get a transparent order for DBA algorithms that achieve remarkable throughput and time delay performance with efficient power consumption modeling simultaneously, because the DBA algorithms that produce a

remarkable throughput performance have lower quality for time-delay performance and contrariwise. Secondly, the DBA algorithms in time delay and throughput performance are very close, which makes the choice operation harder. However, we can try to extract the optimum DBA algorithm that may achieve acceptable instead of remarkable throughput and time delay performances with efficient power consumption modeling simultaneously. Accordingly, the choice is the proposed SD-Maat algorithm [66], with efficient power consumption modeling. Percentage of the enhancement in time delay, throughput, and power consumption modeling are considered.

VII. CONCLUSION

The consumption ability and energy efficiency are associated with several parameters that supported the properties of the optical and wireless technology itself. In this paper, the consumption ability and energy efficiency of the integrated EPON and two different wireless access technologies supported femtocell application, namely WiMAX and LTE with auction semi-DBA technique, that utilizing the coordinated WiMAX/EPON innovation with a dynamic determination of ONUs by OLT have been proposed. The considered optical parameters are split ratio, and broadcast factor whereas the considered wireless parameters are FBS range and modulation and coding scheme. The consequences of these parameters to the whole power consumption and energy efficiency of the EPON-WiMAX and EPON-LTE are investigated. It was found that, split ratio and FBS range give a significant impact on both total power consumption and energy efficiency. On the other side, the results in variations of broadcast factor and modulation schemes to the overall power consumption are lower. However, the high constellation in modulation schemes gives a significant impact on the energy efficiency despite its less effect on the total power consumption. 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.

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