Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2017, 4(9): 668-677

Research Article ISSN: 2394 - 658X

Dynamic Bandwidth Allocation in Fiber-Wireless (FiWi) Access Networks

Uma Rathore Bhatt, Alpa Sharma, Vijendra Mishra and Raksha Upadhyay

Department of Electronics and Tele-communication,
Institute of Engineering and Technology, Devi Ahilya Vishwavidyalaya, Indore, India
uvrathore@gmail.com

ABSTRACT

Fiber wireless access (FiWi) network is a category of hybrid network, which cumulates the advantages of optical network and wireless network at frontend and backend respectively. FiWi is one of those networks which are capable of providing high bandwidth as well as great flexibility. In today's world of high speed applications demand of spectrum is increasing rapidly, hence it becomes critically important to utilized available bandwidth efficiently. Therefore, many dynamic bandwidth allocation (DBA) algorithms have been proposed in recent years for FiWi network which can improve the utilization of bandwidth. DBA algorithms can be classified as DBA at PON, DBA at wireless and hybrid DBA depending upon the implementation of DBA at backend or frontend or both respectively. In this paper, a detail study of DBA at frontend and backend is done; separately as well as simultaneously. Considering bandwidth utilization as most important parameter, its literature and brief explanation is also provided. DBA algorithms are generally categorized in three types of services i.e. limited service DBA, fixed service DBA and gated service DBA. Simulation of these services of DBA is also done in the paper which helps us to analyze the effectiveness of different DBA services by comparing them to each other.

Key words: Fiber wireless **(**FiWi), Dynamic Bandwidth Allocation (DBA), Limited Service (LS), Fixed Service (FS), Gated Service (GS)

INTRODUCTION

The access networks are mediator between subscribers and service provider; it is one of the most promising last mile technologies. Access networks mainly have two categories wireless and wired. Wireless access networks provide more flexibility, easy installation, and low cost but not suitable for high bandwidth applications. Wireless fidelity (Wi-Fi), wireless interoperability microwave access (WiMAX), wireless mesh network (WMN) are some of the example of wireless access network. Optical and copper cables come under wired access network, which provide high bandwidth and long range communication but its deployment from home to home is difficult and costly. Fiber-wireless (FiWi) access network, which is the combination of optical networks at the back end and wireless networks at the front end have brought together to fulfil the demands of applications which require high bandwidth and more flexible communication system [1,2]. Both these wireless and optical technologies have large number of well-developed standards, FiWi networks can be integrated by using a standard of optical with a standard of wireless.

Backend of the FiWi is passive optical network (PON) which consists of central office (CO), optical line terminal (OLT), splitter/combiner, and optical network unit (ONU), where ONUs are connected to OLT through splitter. Beyond ONU in frontend, network is wireless where users are connected to access points (APs) and these APs are connected to ONUs. FiWi architecture represents a tree structure where OLT is at top node, ONUs are connected as different branches and users/subscriber are like sub branches of the tree as shown in fig. 1.

In literature of integrated fiber and wireless, two different techniques are mentioned using which hybrid access network can be created i.e. radio over fiber (RoF) and radio and fiber (R&F). RoF mainly focuses on physical layer implementation. It uses radio signal onto an optical carrier for distribution over optical fiber to different remote antennas. R&F, is integration of both optical and wireless technology both in physical and medium access control (MAC) layer [4]. Different MAC protocols are used for both wireless and optical part. Based on service provisioning orientation, R&F architecture have two different formats. First, hybrid wireless optical mesh network e.g. wireless-optical broadband access network (WOBAN) and second, hybrid wireless optical access network having PON and broadband wireless technology like Wi-Fi, WiMAX.

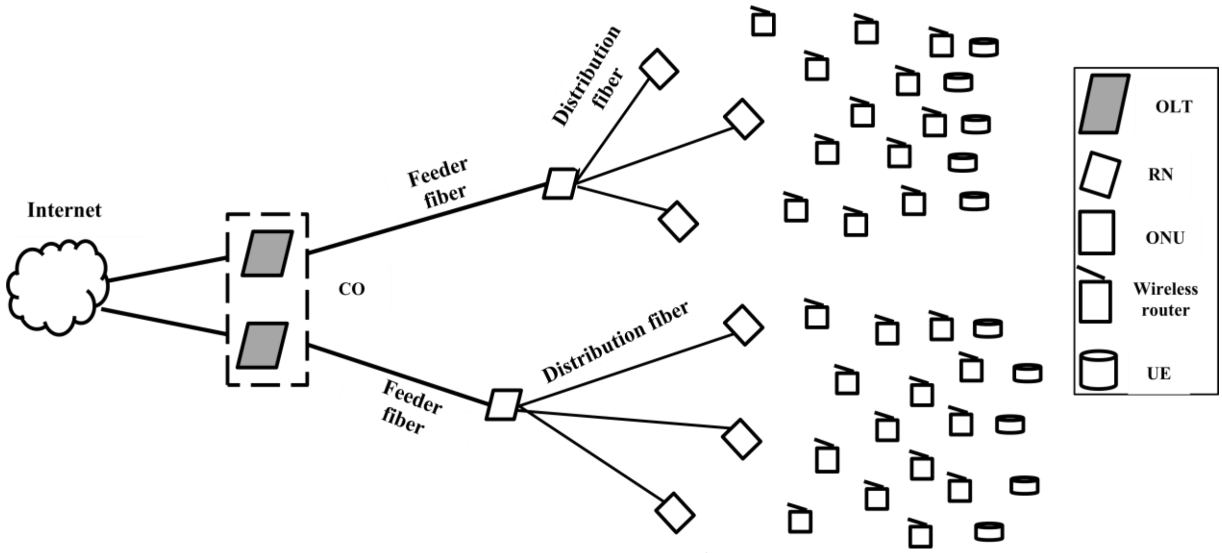

Fig.1 Basic Architecture of FiWi [3]

Since decades both the technologies have been explored to their bottleneck and new standards of these technologies are keep on evolving, but FiWi technology is one of the new area which requires more concern, as it provides advantages of both technologies by showing higher flexibility and better spectrum availability. There are many issues related to FiWi access networks which require researchers' attention [5], like survivability, ONU placement, energy saving and resource utilization. Survivability of a network can be defined as ability of network to provide service during failures, [6] U. Bhatt *et al* have discussed two types of failure in FiWi networks i.e. ONU level failure and OLT level failure. There are many algorithms which are proposed in literature for survivability of FiWi network like delay aware routing algorithm (DARA) [7], risk-and-delay aware routing (RADAR) algorithm [8], ring based protection considering multiple failure (RPMF) [9], wireless rerouting with backup radios (WRBR) [10] etc. ONU placement in FiWi network is critically important because, ONU acts as an intermediate between optical backend and wireless frontend and, is one of the costly component hence optimal ONU placement is important in order to improve networks reliability. There are many algorithms proposed for the placement of ONUs like deterministic approach [11], random approach [12], greedy approach [13] and simulated annealing (SA) algorithm [14], load balancing ONU placement [15], hybrid algorithm [16] etc. Other than ONU placement and survivability issue, Energy saving in FiWi networks becomes critically important nowadays. Considering any issue of FiWi and evaluating its energy efficiency is a trend in present literature. In [17] Y. Liu *et al* have proposed algorithm for improving survivability in FiWi network along with that author have also considered energy saving issue, naming it as Green survivability. In [18] J. Coibra*et al* proposed energy efficient routing algorithm for FiWi network in which along with the routing author have considered energy efficiency as a key issue. Similarly, authors of [6,15] proposed energy efficient dynamic bandwidth allocation (DBA) schemes for FiWi networks, by considering ONUs in sleep and doze mode. Proper utilization of available resources is also one of the key areas of research in FiWi. With increase in users demand and increasing real time traffic, it becomes essential to provide high data rate to users while bandwidth available is almost fixed, so it is very important to efficiently utilize the available resources which is referred as bandwidth allocation. Bandwidth allocation can be done in two different ways i.e. static bandwidth allocation and dynamic bandwidth allocation. Static bandwidth allocation referred as allocating fixed amount of bandwidth to each user while dynamic bandwidth allocation referred as allocating bandwidth to the user depending upon their load.

In this paper, we have provided detailed description of algorithms for dynamic bandwidth allocation in PONs, wireless network, fiber-wireless networks and then illustrated the utilization parameter for existing DBA algorithm for FiWi.

BANDWIDTH ALLOCATION

In Fi-Wi access networks number of ONUs are connected to a single OLT, and users/ subscribers are connected to OLT through these ONUs. In order to fulfil the demands of users and also to maintain the quality of service, OLT needs to have some mechanism through which service can be provided to users both in upstream and downstream direction. In downstream transmission, OLT broadcast its traffic to ONUs through splitter i.e. point-to-multipoint transmission while in upstream it follows multipoint-to-point transmission. In upstream transmission, multiple ONUs tries to access the available band in order to provide services to users. The mechanism of scheduling ONUs so that they can access the available band is bandwidth allocation and, then providing band to ONUs on the basis of their buffered traffic, QoS etc. is Dynamic Bandwidth Allocation. The process of ordering ONUs in which they are served is referred as scheduling [19]. Scheduling can be done in two different ways; Inter-ONU scheduling and Intra-ONU scheduling [20]. In Intra-ONU scheduling, allocation is done directly for users based on the priority of queues maintained by ONUs while in Inter-ONU scheduling band is allocated to ONUs by OLT and further scheduling is done for users by ONUs.

Based on the service provided, DBA can be classified in two types, one which supports quality of service (QoS) and another which does not support QoS. Supporting QoS means ability to provide different priority to different applications or users and guarantee a certain level of service. In order to provide QoS there are different priority levels decided, based on those priority bandwidth is allocated. Main goals of quality of service are to provide dedicated bandwidth, controlled delay and latency.

Fig.2 shows the DBA implementation in MAC layer. MAC layer provides QoS Mapping framework, which addresses QoS diversity of two different technologies connected in backend and frontend. MAC layer uses Multipoint control protocol (MPCP) for EPON in which Gate and Report messages are used as control message for transferring information between OLT and ONU [20]. GATE message is transmitted by OLT, which has information about allocated bandwidth to ONUs and REPORT message is transmitted by ONU to OLT which has information about ONUs current buffer size. In order to provide QoS there are different priority levels for both PON and wireless ends, for example in FiWi network EPON have three priority levels and WiMAX have five different priority levels.

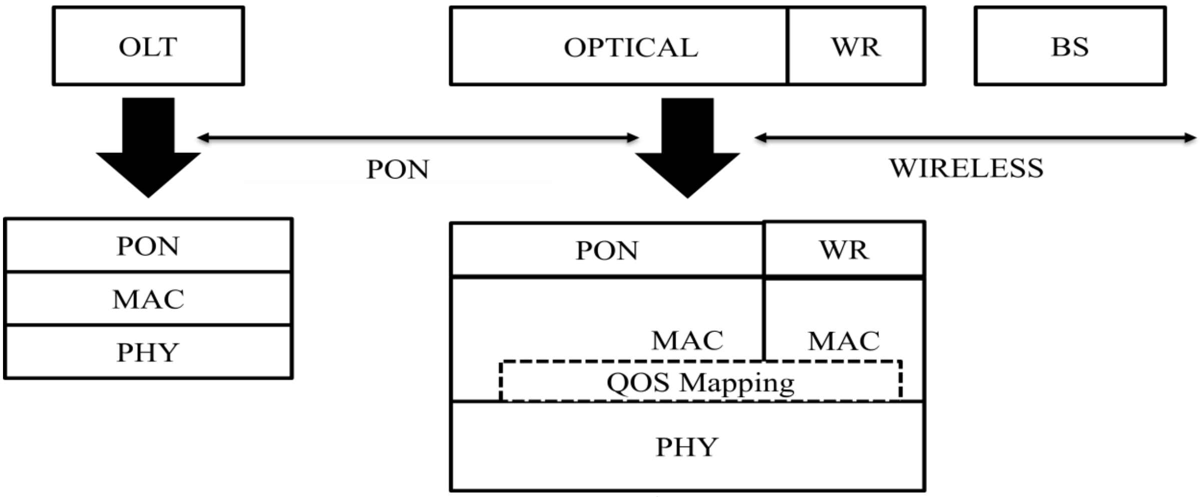

Fig.2 Physical and MAC layer of FiWi access network [21]

Dynamic Bandwidth Allocation in PON

Interleaved polling with adaptive cycle time (IPACT), is one of the basic dynamic bandwidth allocation algorithms [19]. In IPACT scheme band/time slot is allocated in basically three types, fixed allocation, gated allocation and limited allocation. In fixed allocation, irrespective of traffic at ONU, a particular band/time slot will be allocated to each ONU. Duration of slot($L_{\min}$) is decided by the respective DBA scheme. In fixed allocation, there are chances of underutilization of resources and also increase in packet delay for high loaded ONUs. In Gated scheme allocation of band/time slot is done on the basis of demand of ONUs. There is no limit on the allocation window, hence this there is huge of variation in cycle time (T_{cycle}), which leads to increase in packet delay. In limited service, allocated bandwidth is not more thanL_{min}, it is $min\left(B_{req}, L_{min}\right)$ where B_{req}, is the requested bandwidth from ONU. This scheme also shows variation in T_{cycle}but due to limited amount of allocation, variation is less than gated service.

M. Ma *et al* in [22] proposed bandwidth guaranteed polling (BGP) algorithm, in which ONUs are divided in two groups, bandwidth guaranteed ONUs and the non-bandwidth guaranteed ONUs. Bandwidth guaranteed ONUs can have more than one entry in polling table and can allocate band more than one time based on their Service Level Agreement (SLA). Non-bandwidth guaranteed ONUs will be provided with best-effort service without bandwidth guarantee. Probability Density Function Based (PDF) DBA algorithm mechanism is proposed in [23], in which a threshold value for pdf of traffic is set based on PDFs of different ONUs in their previous cycle. If certain ONUs PDF in last polling cycle is less than the threshold value, then in present polling cycle they will not get any priority, and will be scheduled on priority basis in next cycle. The formula to calculate the PDF of the $(n)th$ ONU in the $(T-1)$th cycle is given by:

$$PDF = \frac{grantedbandwidth(n)_{t-1}}{\sum totalbandwidthallocatedin(t-1)} \tag{1}$$

Allocation based on online-offline mode (Half Cycling DBA) is briefly explained by O. Turna*et al* in [24] where online mode stands for allocation of band immediately after receiving the request message and offline mode allocation of band is done after receiving last ONU report message. Author have also discussed intermediate mode between online and offline mode allocation. In low load condition, algorithm switches to offline mode and in high load condition, it switches to online mode. In offline mode, instead of computing bandwidth allocation at the end of cycle, computations are done at half cycle. On the basis of simulation result, it has been found that byte loss ratio and access delay is better in half cycle DBA (hcDBA) in comparison to existing algorithm named prediction hcDBA (p-hcDBA). In intelligent fuzzy logic based dynamic bandwidth allocation (IFL-DBA) [25] OLT does scheduling of ONUs, IFL-DBA is improved version of limited IPACT in which subdivision is performed based on different queues created by ONUs based on fuzzy logic. Maximum window size allocated in limited IPACT is given by –

$$W_{max} = (\frac{T_{max}}{N} - B_g \ ) \ R_t \tag{2}$$

Where, $Tmax$is the maximum cycle time, N is the total number of ONUs, $Bg$is the guard time and R_t is the total upstream bandwidth.In subdivision scheduling, band is allocated according to the request received from all three types of traffic i.e. expedited forwarding (EF), assured forwarding (AF) and best effort (BF). If requests from EF and AF are higher than BF traffic, then instead of putting limitation on EF and AF traffic, limitation will be kept on BF. The decision made in algorithm is based on human reasoning which makes it more dynamic and utilizes the bandwidth better than other approaches. This algorithm increases the utilization by 21% as compared to broadcast polling (BP) algorithm due to less unused slots. Y. Zhu *et al* [26] proposed interleaved polling with adaptive cycle time with grant estimation (IPACT-GE) scheme, which is based on IPACT DBA, in which the amount of traffic arriving between two polling cycles is estimated based on the previous cycle request. Granting additional window based on estimation and grant size will be in accordance with ONU buffer size. In this algorithm, average packet delay can be shortening, which can be evaluated using characteristic of traffic arriving between two polling cycle, which is done by multiplying of observed arrival rate by scan time. By observing the arrival rate and the scan time obtained in n^{th} cycle, packets arriving in $(n+1)^{th}$ cycle can be estimated as follow.

$$E(n+1) \ = \ r(n) \,.\, T_c(n) \tag{3}$$

Where r(n) is real traffic arrival rate and T_c(n) is scan time. Granted window for $(n+1)th$ cycle is given as

$$G(n+1) \ = \ min\,(R(n) \ + \ \alpha.E(n+1)\,, Wmax) \tag{4}$$

Where α is estimation factor.

Adaptive Dynamic bandwidth allocation algorithm supporting multi-service [27] provides QoS by dividing the service in different classes of voice, data and video. On collecting the requests from all ONUs based on the load condition, OLT schedules the orders of ONUs to reduce the delay which can guarantee QoS. OLT calculates maximum transmission window and the minimum guaranteed window and then predicts the incoming EF frames during waiting time. OLT also collects report from all ONUs and obtains V_{EF},V_{AF} and V_{BF}(bandwidth requested by ONUs for EF, AF and BF traffic load) and then OLT predicts incoming EF which is denoted by V_τ. OLT also calculates T_{delay},T_{expect} and then a process of comparison is initiated. If, $T_{delay} < T_{expect}$then order of ONUs will not change and they will transfer data according to previous cycle. If, $T_{delay} > T_{expect}$, then OLT will adjust ONUs in accordance to have least delay.

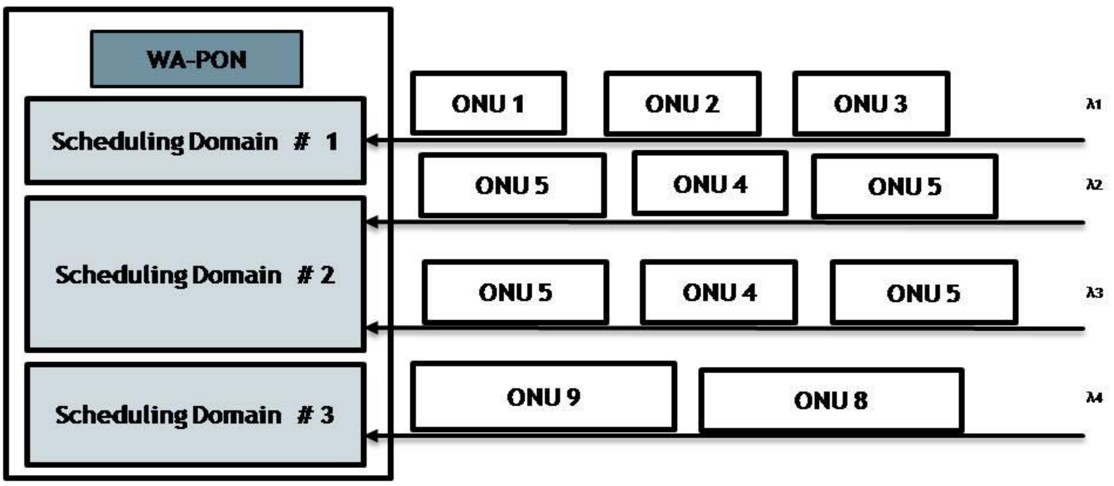

Fig.3 Wavelength-Agile EPON [30]

Service to multiple queue level can be provided in two ways, strict priority (SP) scheduling and weighted fair queuing (WFQ) scheduling. Strict priority bandwidth allocation is used for the real-time application, whereas weighted fair queuing scheduling may not be appropriate for real-time traffic due to high delay. However, in SP higher priority queues will be scheduled first prior to lower priority queues, which may cause increase in packet delay and packet loss. In order to solve problem in SP, author in [28] have proposed improved weighted IPACT (IW-IPACT), in which traffic arrival rate is calculate for each cycle. Then EF virtual buffer queue and the virtual weighted buffer queue of ONUs were established. L. Wang *et al* [29] have proposed an energy efficient dynamic bandwidth and wavelength allocation scheme. In which wavelength-agile EPON (WA-EPON) is used, as shown in Fig. 3. In WA-EPON depending on traffic conditions, single ONU can be allotted with more than one wavelength at a given instant of time and among those wavelengths different time slots can be allocated. For receiving and sending different wavelengths each ONU must have multiple wavelength transceivers, this leads to increase in overall energy consumption of the system. Authors have given water-filling dynamic bandwidth allocation (WF-DBWA) to improve energy efficiency.

Dynamic Bandwidth Allocation on Wireless Access Networks

In wireless networks, the available bandwidth is made allocated to all the users that are connected to the access point, on the basis of certain rule. The process of allocation depends on parameters like traffic type, quality of service, quality of links, and the number of users connected to the network. There has been lot of work done on DBA for WiMAX, WMN, WiFi and LTE to improve utilization parameter of wireless network.

A smart cluster based approach for dynamic bandwidth allocation in wireless networks is proposed [30], in which intelligent clustering technique is used for dynamic bandwidth allocation for variable traffic. To create clusters authors have used K Means clustering algorithm in order to identify potential peak times for every wireless node. Basic steps involved in proposed algorithm are data extraction, data processing, data clustering and data feeding.

A novel approach for bandwidth allocation among soft QoS traffic in wireless networks is proposed in [31], which presents a novel value based optimization model and dynamic bandwidth allocation model that improve QoS in wireless. M. Kamel*et al* have developed an efficient heuristic algorithm to allocate the radio resource block in long term evolution (LTE) network. Authors have discussed about base station schedulers which consider efficient band allocation to different service provider (SP) based on service level agreement (SLA). In heuristic approach, initially the power is allocated equally to all the users and then in next step they use greedy algorithm for the allocation. Pick-best first algorithm helps SP to pick the physical resource block (PRB) which has largest data rate. Their slicing scheme is dynamic and efficient as compared to offline solvers [32]. For providing good quality video service, system requires more bandwidth. In [33] allocated bandwidth is made variable for multicast/broadcast services (MBSs), if fixed allocation is done then it degrades the quality of service and call termination probability will increase. In proposed scheme with variation in network traffic, bandwidth allocation is varied.

Dynamic Bandwidth Allocation in FiWi

Fiber wireless access network is considered to be one the best solution for providing high bandwidth and flexibility to the users, although its ability to utilize bandwidth is not explored to the great extent. FiWi consist of two segments i.e. optical back end and wireless front end, separate DBA algorithm of both the segments can be implemented on FiWi network individually as well as simultaneously. Most of the literature present on DBA algorithms of FiWi have only considered PON segment of FiWi network, seldom work have been done in implementing DBA for both front and back end of FiWi.

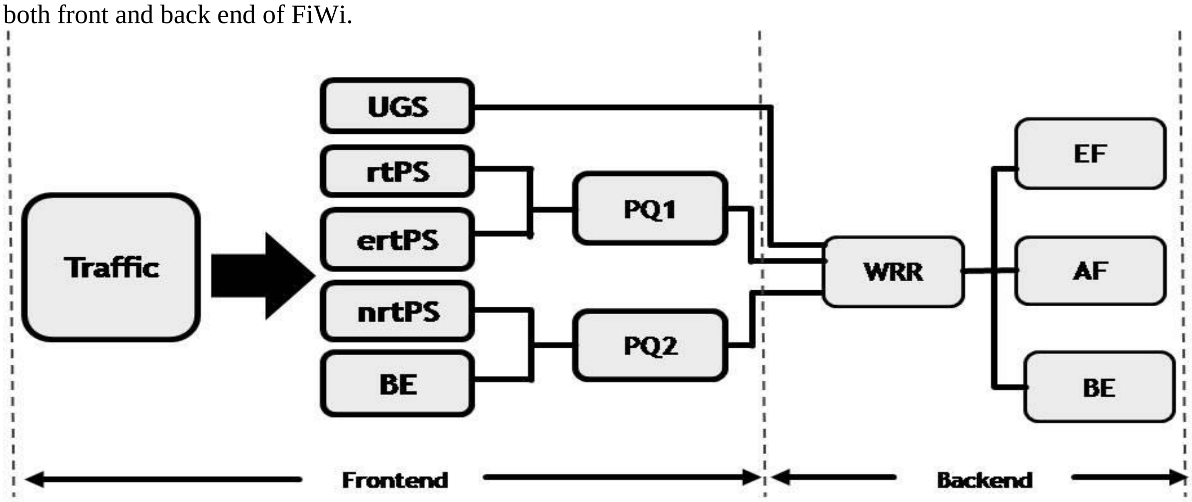

Fig.4 Priority queues [34]

Sarkar *et al* [34] have proposed bandwidth allocation algorithm for FiWi, in which frontend has WiMAX network and backend has EPON network. WiMAX supports connection oriented transmission under which each service flow is allocated with a unique connection ID (CID), then based on connection oriented request, aggregate bandwidth is allocated to each service station (SS). While backend EPON does not support such type of service, in EPON bandwidth requests are queue oriented. Traffic for WiMAX is divided in five different groups based quality of service: UGS (Unsolicited Grant Service), rtPS (real time Polling Service), ertPS (extended real-time Polling Service), nrtPS (non-realtime Polling Service), and BE. Authors have designed two step scheduling in which UGS has highest priority followed by rtPS, ertPS, nrtPS and BE respectively. In EPON there are three priority levels EF with highest priority, AF with medium priority and the BF with least priority. QoS mapping of priority queues is shown in Fig.4. Three different cases are considered for allocation based on buffer status of ONU. First, when ONU buffer is filled less than 40%, then priority ratio of UGS, Priority Queue 1 (PQ1) and Priority Queue 2 (PQ2) is 4:2:1, in second case if buffer is filled between 40% to 80% then priority ratio is 2:1:0 and third, when buffer is filled more than 80% then priority ratio is 1:0:0.

A Traffic-Prediction based dynamic bandwidth allocation algorithm is proposed [35], which consists of two phases of scheduling i.e. inter-ONU scheduling, which does not consider QoS and intra-ONU scheduling which is performed at each ONU and is based on traffic class. In proposed algorithm prediction function F(t), is an increasing function of time that provides the amount of traffic that has been received up to time t. It is used at the base stations for sending summarized information to OLT. A. Ahmed *et al* in [36] have proposed new architecture which is an optical-optical-wireless network, in which ONU and WiMAX base stations (BSs) are merged together, through which users are connected. Bandwidth allocation is done in three levels, first level of algorithm runs at the BS, second level runs at the ONU and third level runs at sub-OLT. OLT located at CO does not need any bandwidth allocation algorithm, only a switching mechanism is sufficient to transfer traffic to sub-OLTs. There are eight priority levels maintained by ONUs, which are as follow UGS, ertPS, rtPS-s-dead queue, rtPS-1-dead queue, nrtPS queue, under-test queue, New-connections queue and BE queue based on QoS and delay. ONU sends its request to subOLT then subOLT assigns band according to their requests, initially subOLT allocates a minimum bandwidth B_{min} to each ONU. Then subOLT assigns remaining bandwidth to lower priority queues.

$$B_{min} = B_{UGS} + B_{ertPS}^{min} + B_{rtPS}^{min} \quad (5)$$

Where, $B_{UGS}, B_{ertPS}^{min}, and B_{rtPS}^{min}$ are bandwidth requested for UGS, ertPS-min and rtPS-c-dead queues.

A dynamic bandwidth allocation in WOBAN is proposed by L. Jiang *et al* [37], in which EPON is at the backend and WiMAX is at the frontend. The proposed scheme supports QoS, in which a fixed amount of bandwidth will be initially allocated to all each ONU, considering their loads being same. Then based on the priority queues, bandwidth will be allocated but there are chances that some ONUs will have light load and some will have high load, hence ONUs with light load have some amount of bandwidth unused, so the unused band will be allocated for other priority services.

Most of the literature mention above only considered DBA in backend, but when DBA is implemented for both front and back end then analysis of bandwidth utilization can be extended for the complete FiWi network which can further improve the associated utilization parameter for the network. But while executing DBA at both the segments of FiWi simultaneously, parameter like upstream delay and synchronization becomes very crucial because handshaking messages now has to be transfer between station and OLT through ONU, which can increase the upstream delay and on the other hand synchronization need be executed regularly between stations and OLT.

BANDWIDTH UTILIZATION ANALYSIS IN DBA FOR FIWI

Implementation of dynamic bandwidth allocation algorithm generally affects some network parameters, which ultimately affects the overall network performance. Energy saving, mean packet delay and utilization of available bandwidth are some of the parameters which can get affected by DBA. There is always a trade-off between different parameters of network like, bandwidth utilization and delay of network, in literature many predictions based schemes were proposed in order to minimize overall delay of the network, but with reduction in delay there are chances of under-utilization of bandwidth. Hence bandwidth utilization is considered to be the crucial parameter for DBA.

High utilization is one of the key goals of Dynamic Bandwidth Allocation algorithms, which is generally calculated for upstream channel, because in upstream direction number of ONU share common channel hence utilization can be achieved to its bottleneck. Utilization is defined as ratio of data transmission time to total cycle time. In upstream direction, it is difficult to get utilization of 100% due to the presence of overheads bits, gate message, report message, guard time and some idle time. In heavy load condition utilization is mostly high and it does not depend on the DBA scheme used, where as in medium and light load condition utilization depends on the DBA scheme used.

$$U = \frac{T_{data}}{T_{cycle}}, \quad (6)$$

Where, $Tdata = (totalbandgranted - Hreport - Husl)$
$Hreport = reportmessagesizeofMPCPprotocol, Husl = unusedslotsleftinanyONU.$
$Tcycle = totalcycletime.$

With variation in DBA algorithms, utilization factor also varies, in [38] using interleaved polling with adaptive cycle time (IPACT) and fixed allocation DBA is achieved, in which allocated window is fixed irrespective of load at ONU. So, there are chances that some ONU are light loaded and some ONUs are heavy loaded, in light loaded ONU some amount of bandwidth will be left unused, this will reduce overall utilization of the network. For Fixed allocation, utilization ranges between 50-60% which means around 40% of the bandwidth is wasted. In [22] IPACT is used with gated service, in which amount of bandwidth allocated to each ONU is always equals to its requested window size. In this case utilization will be maximum but delay will be high, because cycle time varies according to the load condition of ONUs. Jiunn-Ru *et al* [39] proposed high utilization dynamic bandwidth allocation algorithm in which sorting of report messages is done based on the request of each ONU. Dividing all the report message request in two different groups, first group consist of ONUs with request greater than minimum window (L_{min}) and other group have ONUs with request less than L_{min}. Bandwidth is allocated to ONUs of different group on priority basis such that overall utilization can be increased. Excess bandwidth left from light loaded ONUs is allocated to heavy loaded ONUs. For light load condition when there are no such ONUs whose request greater than $Lmin$, in such case author have proposed insertion process, using which utilization factor of 99.11% is obtained, which is highest among all the compared scheme. In [40] network utility model is proposed for resource allocation in passive optical network in which a model is presented for bandwidth allocation in PONs and long-reach PON. A fair excess-dynamic bandwidth allocation (FEx-DBA) is proposed [41], in which cycle time is fixed based, and bandwidth is allocated to each ONU multiple times in a single polling cycle. Allocation of bandwidth is based on the excess bandwidth available in the current cycle and traffic load of ONUs. Initially allocated window to each ONU depends on the SLA of the particular ONU. Since allocation of band is done in online fashion hence it also improves delay performance.

SIMULATION AND ANALYSIS OF DBA ALGORITHMS IN FIWI

The MPCP is the mechanism used for DBA, which supports time slot allocation to the ONUs. The MPCP provides a framework which consists of GATE and REPORT messages intended to provide bandwidth allocation in backend of FiWi for upstream data transmission. At the end of a transmission cycle, ONU provides its queue status to the OLT by sending a REPORT message. The OLT evaluate the granted window for the next cycle depending upon the received REPORT message. There are three different DBA disciplines for granting window size to ONUs, depending upon their REPORT message, which are fixed service DBA, gated service DBA and limited service DBA. In fixed service DBA, OLT ignore the REPORT message information and allocate a maximum window to all ONUs, which causes underutilization of bandwidth but it provides constant cycle time and delay. In gated service DBA, their no limit on the size of window which is allocated to ONUs. ONU is always allowed to transmit the amount of traffic it had requested, but it leads to increase in cycle time and delay with increase in load. While in limited service DBA, ONU is granted with amount of requested bandwidth but not more than a maximum limit. In this approach cycle time is variable but maintained under a limit.

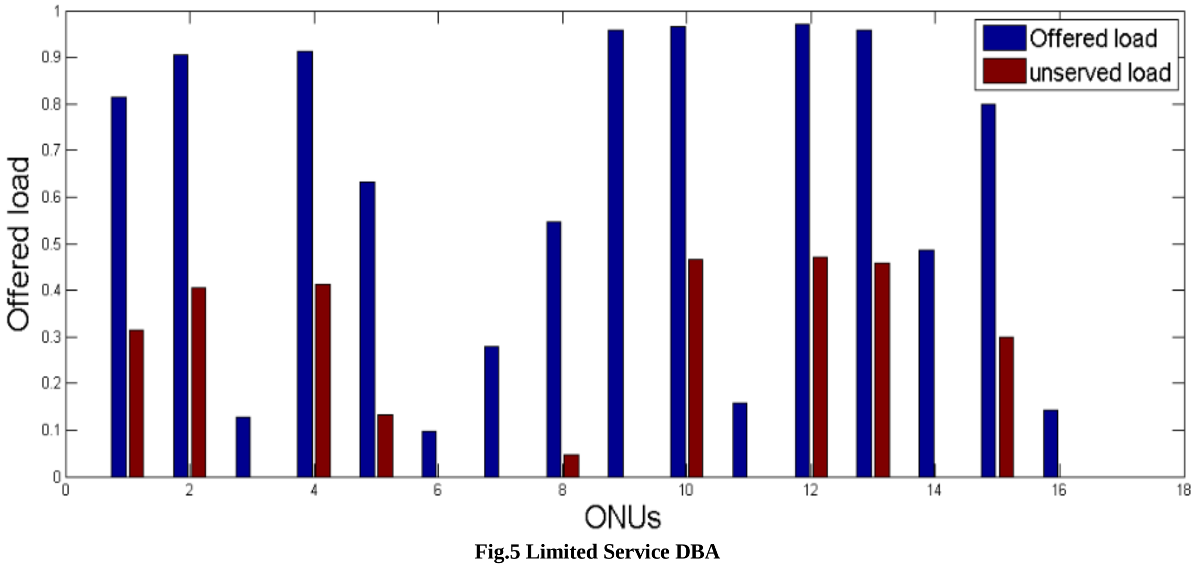

Fig.5 Limited Service DBA

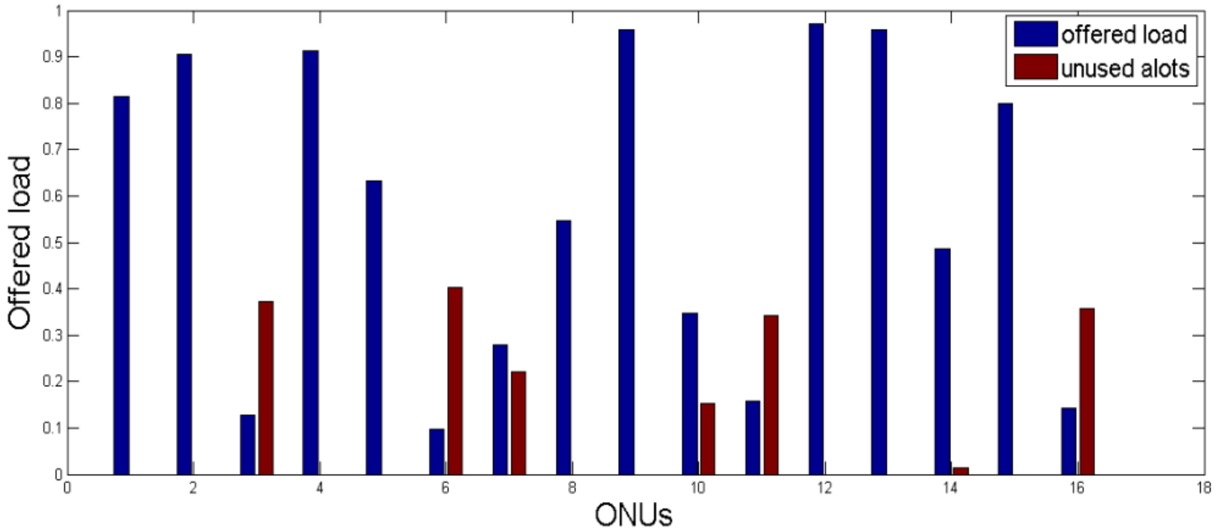

Fig.6 Fixed Service DBA

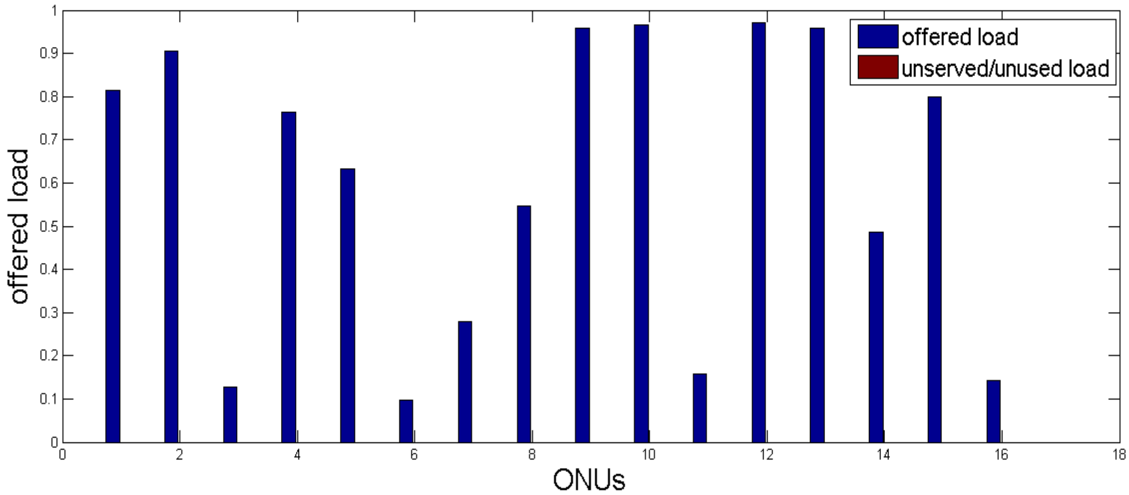

Fig.7 Gated Service DBA

For simulation purpose a test FiWi network is considered in which EPON is at backend and WLAN is at frontend. Traffic arriving at the ONUs through base station is served in real-time manner. OLT is connected with 16 ONUs, Guard time (Tg) between two consecutive window is 1μ sec, round trip time (RTT) is 200 μ sec and uplink data rate is considered as 1Gbps.Fig.5, Fig.6, Fig.7 shows the simulation of limited, fixed and gated service DBA, which is showing the used and unused slot for different ONUs. From these figures, it is clear that unserved/unused load left in gated service DBA is negligible in comparison to limited and fixed service DBA. But due to variation in polling cycle time delay in gated service DBA will be more than delay in limited and fixed service DBA.

CONCLUSION

In this paper, a comprehensive study of DBA is done for complete FiWi network which enable us to understand the importance of DBA. It is understood that, DBA can be implemented at both frontend and backend of FiWi separately but its effectiveness can be improved by implementing DBA at both end of FiWi simultaneously. A thorough study of already existing DBA is also performed for optical frontend and wireless backend network. To further clarify the understanding of DBA mechanisms and its advantages, three different categories of DBA services i.e. fixed service DBA, limited service DBA and gated service DBA are explored and their simulation is performed. It is found out that, fixed and limited service DBA is providing some amount of unserved load which is affecting bandwidth utilization while in gated service DBA there is no unserved load but it will produce increment in cycle time which leads to increase in delay.

REFERENCES

[1] RQ Shaddad, AB Mohammad, MA Elmagzoub, A Survey on Access Technologies for Broadband Optical and Wireless Networks, *Journal of Network and Computer Applications*, **2014**, 41,459-472.

[2] Martin Maier, Fiber-Wireless (FiWi) Broadband Access Networks in an Age of Convergence: Past, Present, Future, *Advances in Optics*, **2014**, 2014, 1-23.
[3] Y Liu and L Guo, Green Survivability in Fiber-Wireless (FiWi) Broadband Access Network, *Optical Fiber Technology*, **2012**, 18 (6), 68-80.
[4] T Tsagklas and F Pavlidou, A survey on Radio-and-FiberFiWi network Architecture, *Journal of Selected Areas in Telecommunication (JSAT)*, **2011**, 1(3), 18-24.
[5] H Win and A Pathan, On the Issues and Challenges of Fiber-Wireless (FiWi) Networks, *Journal of Engineering*, **2013**, 2013, 1-11.
[6] UR Bhatt, N Chouhan and R Upadhyay, Hybrid Algorithm: A Cost Efficient Solution for ONU Placement in Fiber-Wireless (FiWi) Network, *Optical Fiber Technology*, **2015**, 22, 76-83.
[7] S Sarkar and S Dixit, A Noval Delay-Aware Routing Algorithm (DARA) for a Hybrid Wireless-Optical Broadband Access Network (WOBAN), *IEEE Network*, **2008**, 22 (3), 22-28.
[8] S Sarkar and S Dixit, RADAR: Risk-And-Delay Aware Routing Algorithm in a Hybrid Wireless-Optical Broadband Access Network, *Optical Fiber Communication and The National Fiber Optic Engineers Conference*, Anaheim (USA), **2007**.
[9] Y Liu, L Guo and BGong, Ring-Based Protection Scheme for Survivable Fiber-Wireless (FiWi) Access Network Considering Multiple Failures, in proceeding of *IEEE International Conference on Communication Network and System in China: Optical*, **2012**, 285-290.
[10] Y Liu and Q Song, Protection Based on Backup Radios and Backup Fibers for Survivable Fiber-Wireless (Fiwi) Access Network, *Journal of Network and Computer Applications*, **2013**, 36 (3), 1057-1069.
[11] S Sarkar and B Mukherjee, Towards Global Optimization of Multiple ONU Placement in Hybrid Optical-Wireless Broadband Access Networks, in proceeding of Optical Internet and Next Generation Network, **2006**, 65-67. doi: 10.1109/COINNGNCON.2006.4454489.
[12] P Chowdhury and B Mukherjee, Hybrid Wireless-Optical Broadband Access Network (WOBAN): Prototype Development and Research Challenges, *IEEE Network*, **2009**, 23 (3), 41-48.
[13] S Sarkar and S Dixit, Hybrid Wireless-Optical Broadband Access Network (WOBAN): A Review of Relevant Challenges, *Journal of Lightwave Technology*, **2007**, 25 (11), 3329-3340.
[14] S Sarkar and H Yen, Hybrid Wireless-Optical Broadband Access Network (WOBAN): Network Planning and Setup, *IEEE Journal of Selected Areas in Communications*, **2008**, 26 (6), 12-21.
[15] Y Liu, Q Song, B Li and R Ma, Load Balanced Optical Network Unit (ONU) Placement in Cost-Efficient Fiber-Wireless (FiWi) Access Network, *Optik*, **2013**, 124 (20), 4594-4601.
[16] UR Bhatt, N Chouhan and R Upadhyay, Hybrid Algorithm: A Cost Efficient Solution for ONU Placement in Fiber-Wireless (FiWi) Network, *Optical Fiber Technology*, **2015**, 22, 76-83.
[17] J Coimbra, GSchutz and N Correia, Energy Efficient Routing Algorithm for Fiber-Wireless Access Networks: A Network Formation Game Approach, *Computer Network*, **2014**, 60, 201-216
[18] B Lannoo, L Verslegers and M Pickavet. Analytical Model for the IPACT Dynamic Bandwidth Allocation Algorithm for EPONs, *Journal of Optical Networking*, **2007**, 6 (6), 677-688.
[19] RQ Shaddad and AB Mohammad, A Survey on Access Technologies for Broadband Optical and Wireless Networks, *Journal of Network and Computer Applications*, **2014**, 41, 459-472.
[20] W Lim and P Kourtessis, QoS Mapping for LTE Backhauling Over OFDMA-PONs, *Transparent Optical Networks (ICTON)*, Coventry (USA), **2012**, 14.
[21] M Ma, Y Zhu and T Cheng, A Bandwidth Guaranteed Polling MAC Protocol for Ethernet Passive Optical Networks, *Twenty-Second Annual Joint Conference of the IEEE Computer and Communications*, San Francisco (USA), **2003**, 22-31.
[22] S Sharma and ASinghal, A PDF Based Dynamic Bandwidth Allocation Algorithm Using Last Recent Polling Table, *International Journal of Application or Innovation in Engineering and Management*, **2013**, 2 (7), 174-180.
[23] O Turna, M Aydin and A Zaim, A New Dynamic Bandwidth Allocation Algorithm Based on Online-Offline Mode for EPONs, *Optical Switching and Networking*, **2015**, 15, 29-43.
[24] M Awad and A Abuhasan, A Smart Clustering Based Approach to Dynamic Bandwidth Allocation in Wireless Networks, *International Journal of Computer Networking & Communication (IJCNC)*, **2016**, 8, 73-86.
[25] N Asyikin, M Radzi and M Mansoori, Intelligent Dynamic Bandwidth Allocation Algorithm in Upstream EPONs, *Optical Communication Networks*, **2010**, 2, 148-158.
[26] Y Zhu, IPACT with Grant Estimation (IPACT-GE) Scheme for Ethernet Passive Optical Networks, *Journal of Lightwave Technology*, **2008**, 26, 2055-2063.
[27] X Le and L Dan, Adaptive Dynamic Bandwidth Allocation Algorithm Supporting Multi-Services over Ethernet Passive Optical Network, *optik*, **2013**, 124, 287-291.
[28] F Xiao, Z Zhang and X Yin, An Improved Weighted IPACT Algorithm of EPONs in Smart Distribution Networks Based on the Requirements of Relay Protection, *International Transactions on Electrical Energy Systems*, **2016**, 26(10), 2107–2122.

[29] MAwad and A Abhasanand, A Smart Clustering Based Approach to Dynamic Bandwidth Allocation in Wireless Networks, *International Journal of Computer Networks and Communication,* **2016**, 8, 73-86.
[30] L Tan, Z Zhu and M Tornatore, Dynamic Bandwidth and Wavelength Allocation Scheme for Next-Generation Wavelength-Agile EPON, *Optical Communication Network*, **2017**, 9, B33-B42.
[31] L Tan, Z Zhu and C Yuan, A Novel Approach for Bandwidth Allocation Among Soft QoS Traffic in Wireless Networks, *Transaction on Emerging Telecommunications Technologies*, **2014**, 25, 5, 479-484.
[32]M Kamel, L Le and A Girard, LTE Multi-Cell Dynamic Resource Allocation for Wireless Network Virtualization, *IEEE Wireless Communications and Networking Conference*, New Orleans (USA), **2015**, 966-971.
[33] M Chowdhury, Tuan Nguyen and Y Kim, Radio Resource Allocation for Scalable Video Services Over Wireless Cellular Networks, *Springer Science*, **2013**, 74(3), 1061–1079.
[34] I Shyan and Z Shyu, Advanced Dynamic Bandwidth Allocation and Scheduling Scheme for the Integrated Architecture of EPON and WiMAX, *International Conference on Mobile Data Management: System, Service and Middleware*, Taipei (Taiwan), **2009,** 10.
[35] MMirahmadi and AShami, Traffic-Prediction-Assisted Dynamic Bandwidth Assignment for Hybrid Wireless Optical Networks, *IEEE wireless communication and mobile computing conference (IWCMC)*, Istanbul (Turkey), **2011**, 7, 2103-2108.
[36] A Ahmed and A Shami, A New Bandwidth Allocation Algorithm for EPON-WiMAX Hybrid Access Networks, *IEEE Global Telecommunication Conference*, Miami, FL, USA,**2010**.
[37] L Jiang, M Fu and Z Le, Hierarchical QoS-Aware Dynamic Bandwidth Allocation Algorithm for Wireless Optical Broadband Access Network, *International Conference on Electronics, Communications and Control*, Ningbo (China), **2011**, 4329-4332.
[38] B Lannoo, LVerslegers and D Colle, Analytical Model for the IPACT Dynamic Bandwidth Allocation Algorithm for EPONs, *Journal of Optical Networking*, **2007**, 6, 677-688.
[39] J Lai and Wen-Ping Chen, High Utilization Dynamic Bandwidth Allocation Algorithm Based on Sorting Report Messages with Additive-Polling Threshold in EPONs, *Optical Switching and Networking*, **2015**, 18, 81-95.
[40] NMerayo, J Aguado and F Burrull, Fair Bandwidth Allocation Algorithm for PONs Based on Network Utility Maximization, *Optical Communication Network*, **2017**, 9, 75-86.
[41] Y Cao and K Leung, Bandwidth-Guaranteed Fair Scheduling with Effective Excess Bandwidth Allocation for Wireless Networks, *IEEE Transaction on Wireless Communication*, **2008**, 7 (6), 2094-2105.