ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 7, January 2015

A Comparison of Dynamic Bandwidth Allocation and Costs for EPON and GPON Technologies

Sulaiman Khalifa Yakhlef, Omar Abusaeeda, Ismail sherina
Azzaytuna University, Faculty of Engineering, Tarhuna - Libya

Abstract*— Dynamic bandwidth allocation in passive optical networks presents a key issue for providing efficient and fair utilization of the PON upstream bandwidth while supporting the QoS requirements of different traffic classes. In this paper we compare the typical characteristics of DBA, such as bandwidth utilization, delay, and jitter at different traffic loads, within the two major standards for PONs, Ethernet PON and gigabit PON. We illustrate these differences between EPON and GPON. Industry standards for Passive Optical Network (PON) technology have enabled the initial deployment of Fiber to the Premise (FTTP) services. The ITU-T BPON standard has been embraced in North America while the IEEE 802.3ah based EPON has been chosen as the next step in Japan after close to 2 million BPON, subscribers have been deployed. Regardless of any technology merits, the lowest cost solution will be preferred. With this in mind, this paper also makes a simple costs comparison between EPON and the emerging ITU-T GPON for a given FTTP network.

***Index Terms*—Cost, Dynamic Bandwidth Allocation, EPON, GPON, Fiber to the Premise.**

I. INTRODUCTION

PON standardization activities have been ongoing for the past fifteen years within the ITU-T and IEEE standards bodies. EPON and 10G-EPON are the latest ratified IEEE standards and GPON is the latest ratified ITU-T standard. EPON and GPON both draw heavily from G.983, the BPON standard for their general concepts (PON operation, ODN framework, wavelength plan, and application). Also, both were designed to better accommodate variable-length IP frames at Gigabit line rates. There are, however, significant differences in the approaches used by each. In order to achieve flexible sharing of bandwidth among users and high bandwidth utilization, a dynamic bandwidth allocation (DBA) scheme that can adapt to the current traffic demand is required. Two major standards for PONs have emerged, Ethernet PON (EPON) and gigabit PON (GPON) [6]. Due to significant differences between the EPON and GPON standards (different control message formats, guard times, etc.), there are many implications for the DBA approaches and how an efficient bandwidth allocation scheme should be designed for these two standards. To the best of our knowledge, not much research has addressed a qualitative and quantitative comparison of DBA within EPON and GPON. Therefore, the objective of this paper is to provide insight into the working mechanisms and typical performance characteristics of the DBA schemes under a variety of network conditions in these two competing standards. A key factor in determining the cost effect on a FTTP network is to understand the performance characteristics of the PON technology. Critical cost bearing factors are: PON bandwidth, bandwidth efficiency and split ratio. Table I highlights the performance and operational differences between EPON and GPON.

Table I. Differences between EPON and GPON

	GPON	EPON
Standrad organisation	ITU T	IEEE
Rate	2.488G/1.244G	1.25G/1.25G
Split Ratio	1:64-1:128	1:16-1:32
Carried Service	ATM, Ethernet, TDM	ETHERNET
Bandwidth Efficiency	92%	72%
QOS	Very Good Including Ethernet, TDM, ATM	Good Only Ethernet
Optical Budget	CLASS A/B/B+/C	Px10/Px20
DBA	Standard Format	Self defined
Communication With ONTs	ONT Management Control Interface	Not Supported
Operation And maintenance	ITU-T G.984(Strong)	Ethernet OAM (Weak)

Bandwidth Allocation

The use of TDMA in the upstream direction requires the OLT to schedule each ONT's transmission to avoid collisions. Fundamentally, each ONT receives a grant telling it when to begin and end transmission [8]. In GPON, grants are scheduled per T-CONT; in EPON, per LLID. In the case of GPON, grants are carried in the downstream frame header. A map field within the header specifies the specific T-CONT, start and end {Alloc-ID+Start+End} for each granted upstream window (timeslot). In EPON, grant messages are sent per LLID, as separate MAC-Control client frames (GATEs), between regular Ethernet frames. Each grant specifies the {LLID+Start+Length}.

II. DYNAMIC BANDWIDTH ALLOCATION (DBA)

A DBA profile defines GPON traffic parameters and can be bound to dynamically allocate bandwidth and improve the upstream bandwidth utilization [11]. Dynamic bandwidth allocation can significantly improve network performance, provide a means of flexibly tailoring network responsiveness and enable a service provider to generate more revenue from their FTTH networks without boosting raw bandwidth by increasing the percentage of acceptable over subscription [4].

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 7, January 2015

DBA is controlled by OLT, which allocates bandwidth volume to ONUs. This technique works only in upstream direction, in downstream direction traffic is broadcasted. The Dynamic bandwidth Allocation is shown in Fig 1.

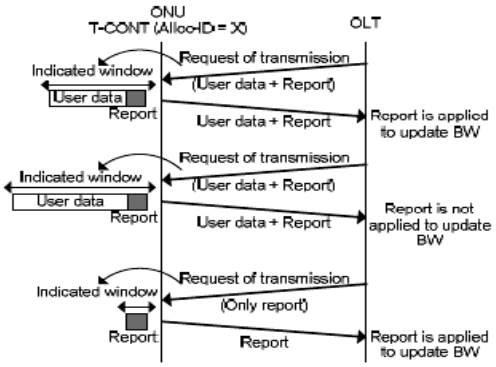

Fig 1. Dynamic bandwidth Allocation

To determine how much traffic to assign to an ONU, the OLT needs to know the traffic status of the T-CONT associated with the ONU. In status reporting method, as part of its traffic status a T-CONT indicates how many packets are waiting in its buffer. Once the OLT receive this information, it can share the allocation to various ONUs accordingly. When an ONU has no information waiting to be transported, upon receiving a grant it sends an idle cell upstream to indicate that its buffer is empty. This informs the OLT that the grants for that T-CONT can be assigned to other T-CONTs. If an ONU has a long queue waiting in its buffer, the OLT can assign multiple T- CONTs to that ONU. DBA algorithms can be divided into two categories: SR-DBA (Status Reporting Dynamic Bandwidth Assignment) provides bandwidth assignment according to report from ONU. NSR-DBA (Non-Status) give bandwidth assignment which does not need report from ONU. However, it provides dynamic assignment by using traffic monitoring by OLT.

III. EPON AND GPON STANDARDS

In this section we compare the two standards, EPON and GPON, which set the framework for the operation of DBA. The two standards embrace different philosophies, with EPON based on a simple standard with looser hardware requirements, and GPON based on a relatively complex standard with tighter hardware requirements and a larger focus on quality of service (QoS) assurance. On a detailed level, the two philosophies boil down to differences in guard times, overheads, and other forms of parameters influencing bandwidth utilization within the two systems. These underlying differences govern how DBA should be designed in order to cope with imposed traffic requirements and fairness policies while still maintaining efficient utilization of the PON's shared upstream channel. Most research to date regarding DBA has addressed EPON [7–8]. However, GPON faces a series of distinct challenges, and new DBA algorithms tailored specifically to the GPON standard need to be developed. In Table 1 the differences related to bandwidth allocation in both standards are listed. The following subsections describe the differences between the EPON and GPON standards in more detail.

A. EPON

In EPON both downstream and upstream line rates are 1.25 Gb/s, but due to the 8B/10B line encoding, the bit rate for data transmission is 1Gb/s. Guard times between two neighboring time slots composed of laser on-off time, automatic gain control (AGC), and clock and data recovery (CDR) are used to differentiate the transmission from different ONUs in a given cycle. IEEE 802.3ah has specified values (class-es) for AGC and CDR. In EPON, Multipoint Control Protocol (MPCP) is implemented at the medium access control (MAC) layer to perform the bandwidth allocation, auto-discovery process, and ranging. As illustrated in Table 1, two control messages, REPORT and GATE, used for bandwidth allocation are defined in [1]. A GATE message carries the granted bandwidth information from the OLT to the ONU in the downstream direction, while the REPORT message is used by an ONU to report its bandwidth request to an OLT in the upstream direction. Their exchange allows the time slots to be assigned according to the traffic demand of the individual ONUs and the band-width available. The size of REPORT and GATE are defined as the smallest size of Ether-net frame (64 bytes).

B. GPON

The GPON standard is defined in the International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) G.984.x series of Recommendations sponsored by the full service access network (FSAN) [9, 10]. Several upstream and downstream rates up to 2.48832 Gb/s are specified in the standard. Here we consider the 1.24416 Gb/s upstream rate to make it comparable with EPON. The GPON protocol is based on the standard 125 µs (~19,440 bytes at 1.24416 Gb/s) periodicity used in the telecommunications industry. This periodicity provides certain efficiency advantages over EPON, as messages (control, buffer report, and grant messages) can efficiently be integrated into the header of each 125 µs frame. In order to efficiently pack Ethernet frames into the 125 µs frame, Ethernet frame fragmentation has been introduced [14]. Within GPON each Ethernet frame or frame fragment is encapsulated in a general encapsulation method (GEM) frame including a 5-byte GEM header [12]. In addition, upstream QoS awareness has been integrated in the GPON standard with the introduction of the concept of transport containers (T-CONTs), where a T-CONT type represents a class of service. Hence GPON provides a simple and efficient means of setting up a system for multiple service classes. Several status reporting modes can be set within GPON. For our comparison with EPON we consider mode 0, the simplest status reporting mode. Hence, our comparison of EPON and GPON is based on a comparable type of communication mode between the OLT and ONUs where the ONUs send REPORT messages or status reports containing

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 7, January 2015

buffer sizes, while the OLT sends the ONUs GATE messages or grants containing the granted time slots [13].

IV. TECHNOLOGY COMPARISON

A key factor in determining the cost effect on a FTTP network is to understand the performance characteristics of the PON technology. Critical cost bearing factors are: PON bandwidth, bandwidth efficiency and split ratio [5]. Table II highlights the performance and operational differences between EPON and GPON technologies.

Table II. EPON and GPON Technologies

Parameters	IEEE 802.3ah (EPON)	ITU-T G.984 (GPON)
Downstream	1250 Mbps	2500 or 1250 Mbps
Upstream	1250 Mbps	1250 or 622 Mbps
Split Ratio	1 : 32	1 : 32, 1 : 64
Downstream Efficiency	72% as a result of: 8B/10B encoding (20%) overhead (8%)	92% as a result of: NRZ scrambling (no encoding), Overhead (8%)
Revenue BW	900 Mbps	2300 Mbps
Security	None specified	AES is part of the standard
Network protection	None specified	Optional 50 ms switching time
TDM transport	Circuit Emulation over Ethernet	Native via GEM or Circuit Emulation over Ethernet
Interoperability	None Specified	FSAN and ITU-T

From Table II, GPON seems better suited for implementation in carrier networks providing the necessary support for interoperability and security, all necessary for large network operation. However, these technical merits alone will not result in an industry endorsement for GPON. For the access network, cost is the final determining factor. Thus, the results of a fair cost comparison with EPON will reveal the viability of GPON technology.

V. BANDWIDTH ALLOCATION FOR GPON AND EPON

Dynamic Bandwidth Allocation (DBA) refers to an optional flexible upstream time slot assignment mechanism used in a PON [2, 3]. It allows a system to assign upstream time slots in real time, based on the instantaneous demand of a given ONT, and hence use the upstream bandwidth more efficiently [15, 18]. In a typical FTTH deployment today where there is ample upstream bandwidth, DBA is not very effective since traffic patterns are still asymmetric and upstream bandwidth demands tend to be relatively low. However, in situations where the upstream demand is relatively high (e,g, FTTB, or emerging gaming services), DBA could be useful. DBA is optional in EPON, and out of scope. The right 'hooks' are supported, however, allowing ONT's to send REPORT messages including multiple queue states, but it's up to the scheduler at the OLT whether, how to interpret this information [16, 17]. GPON uses a very similar scheme, but there the DBA is part of the standard. Elements of the two schemes are outlined in the Table III.

Table III. DBA for GPON and EPON

Parameters	GPON DBA	EPON DBA
Granting Unit	GTC Overhead	MPCP GATE frame
Control Unit	T-CONT	LLID
Identification of control unit	Alloc_ID	LLID
Reporting Unit	ATM: ATM cell/ GEM: fixed length block	MPCP REPORT frame
Reporting mechanism	Embedded OAM	Separate REPORT frame
Negotiation procedure	GPON OMCI	N/A

VI. COST COMPARISON METHODOLOGY

Clearly, there are some distinct differences between EPON and GPON at Layer 2. However, these aren't the only differences between the technologies. Designers will also find differences in terms of bandwidth, reach, efficiency, per-subscriber costs, and management. For per-subscriber costs, the use of EPON allows carriers to eliminate complex and expensive ATM and Sonet elements and to simplify their networks, thereby lowering costs to subscribers. Currently, EPON equipment costs are approximately 10 percent of the costs of GPON equipment, and EPON equipment is rapidly becoming cost-competitive with VDSL. For a simple cost comparison between EPON and GPON, only the total equipment costs for a FTTP network of 10,000 subscribers with a 100% take rate of service will be considered. To keep the analysis uncomplicated, only sustained rate Ethernet based services will be considered since this is the type of service for multiple IPTV and HDTV streams into the home [18]. Given these assumptions, Fig. 2 illustrates the total network equipment cost differences while Fig. 3 provides the cost per subscriber.

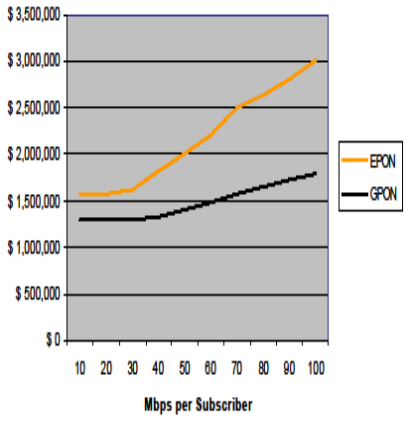

Fig. 2 GPON vs. EPON Total Network Equipment Cost

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 7, January 2015

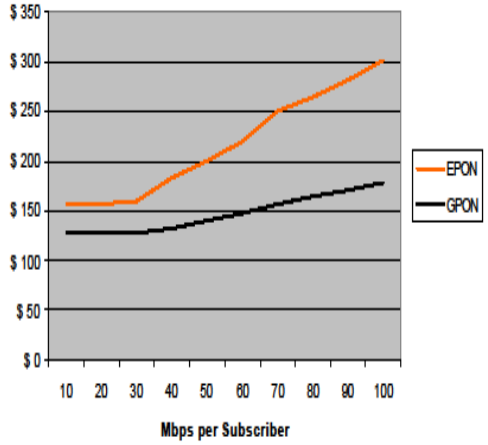

Fig. 3 GPON vs. EPON Cost per Subscriber

GPON's significant cost advantage is simply a result of the reduction in the number of Optical Line Terminators (OLT's) needed. This is because of GPON's higher split ratio, PON bandwidth and bandwidth efficiency. As seen in Table IV and Fig. 2, at 100 Mbps per subscriber, GPON offers up to a 2.6:1 OLT advantage for this network.

Table IV. GPON and EPON Deployment [18]

BW per subscriber (Mbps)	20	40	60	80	100
Number of EPON OLTs	313	455	667	910	1112
Number of GPON OLTs	157	176	264	358	435
GPON to EPON OLT Ratio 1:	2	2.6	2.6	2.6	2.6

VII. CONCLUSION

GPON provide the longer transmission and higher bandwidth. GPON is point to multipoint mechanism and is one of the best choices for the broadband access network. The GPON speed is more than other PON standards. Dynamic bandwidth allocation (DBA) is a methodology that allows quick adoption of user's bandwidth allocation based on current traffic requirements. DBA is controlled by OLT, which allocates bandwidth volume to ONUs. This technique works only in upstream direction, in downstream direction traffic is broadcasted. This simple cost analysis for a given FTTP network highlight's GPON's significant cost advantage over EPON. This is due to GPON's higher split ratio, line rate and bandwidth efficiency which results in a reduction in the amount of OLT equipment.

REFERENCES

[1] C. M. ASSI ET AL., "Dynamic Bandwidth Allocation for Quality-of-Service over Ethernet PONs," IEEE JSAC, vol. 21, no. 9, Nov. 2003, pp. 1467–77.

[2] B. Chen, j. Chen, and s. He, "efficient and fine scheduling algorithm for bandwidth allocation in Ethernet passive optical networks," IEEE j. Sel. Topics quantum elect. vol. 12, no. 4, july–aug. 2006, pp. 653–60.

[3] C. M. Assi et al., "dynamic bandwidth allocation for quality-of-service over Ethernet pons," IEEE jsac, vol. 21, no. 9, nov. 2003, pp. 1467–77.

[4] Mc garry mp et.al —a survey of dynamic bandwidth allocation (dba) algorithmsl ieee communications magazine, vol.42 pp.8–15, 2004

[5] IEEE 802.3ah task force; http://www.ieee802.org/3/efm.

[6] Itu-t g.984.x series of recommendations; http://www.itu.int/rec/t-rec-g/e.

[7] G. Kramer, "interleaved polling with adaptive cycle time (ipact): a dynamic bandwidth distribution scheme in an optical access network." Photonic net. Commun. vol. 4, no. 1, jan. 2002, pp. 89–107.

[8] B. Chen, j. Chen, and s. He, "efficient and fine scheduling algorithm for bandwidth allocation in Ethernet passive optical networks," IEEE j. Sel. Topics quantum elect. vol. 12, no. 4, july–aug. 2006, pp. 653–60.

[9] Itu-t g.984.1, sg 15, "gigabit-capable passive optical networks (g-pon): general characteristics," March. 2003.

[10] Itu-t g.984.4, sg 15, "gigabit-capable passive optical networks (g-pon): ont management and control interface specification," june 2005.

[11] S. Choi and j. Huh, "dynamic bandwidth allocation algorithm for multimedia services over Ethernet pons," etri journal 24, june 2002, pp. 465-468.

[12] Itu-t g.984 (03/2008), gigabit capable passive optical network (gpon).

[13] L. Nicholas, gpon vs. Gigabit Ethernet in campus networking, february 2012.

[14] Trots, joe, an overview of gpon in the access network, presentation for Eriksson, November 2008.

[15] M. Mcgarry, m. Maier, and m. Reisslein, "Ethernet pons: a survey of dynamic bandwidth allocation (dba) algorithms," IEEE communications magazine, vol. 42, august 2004, pp. S8-15.

[16] M. Mcgarry, m. Reisslein and m. Maier, "Ethernet passive optical network architectures and dynamic bandwidth allocation algorithms", IEEE communications surveys & tutorials, vol. 10, third quarter 2008, pp. 46 – 60.

[17] S. Hussain and x. Fernando, "epon: an extensive review for up-to-date dynamic bandwidth allocation schemes", Canadian conference on electrical and computer engineering, 2008. Pp. 000511 - 000516.

[18] D. Parson, gpon vs. Epon costs comparison, light wave journal, September 2005, online: http://www.broadlight.com/e-presenter/media/documents /gpon vs epon cost comparison - broadlight-june 2005.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 7, January 2015

AUTHOR'S PROFILE

Sulaiman Yakhlef (s.yakhlef@it.uot.edu.ly) received his B.S. in telecommunication from Higher Institute of Electronics in 1981 and his MSc. in Communication and Computer Networks from University Putra Malaysia in 2000. His research activities on wireless ATM, computer networks protocols and mobile telecommunications since 2000. Currently, he is Assistant Professor at Azzaytuna University, Faculty of Engineering, Electrical and Electronic Dept. Tarhuna – Libya.

Omar Abusaeeda (abossada@yahoo.com) received his Master degree from University Putra Malaysia "UPM", Malaysia (2004). Since then he joined the department of Computer system engineering at Azzaytuna University working as a Lecturer. He has also obtained his PhD degree (2012) in Applied Imaging from Nottingham Trent University "NTU", UK. Since 2013, He is working as the head of Computer system engineering at Azzaytuna University Tarhuna –Libya. His teaching and area of interest is Digital systems, Signal and Image processing.

Ismail Shrena (ismail1972@yahoo.com) he received his B.Sc. degree in May 1995. In 2002 he received his M.Sc. degree from Informatics-Institute at the Technical University- Clausthal University, Clausthal-Zellerfeld, Germany. From November 2003 to 2006 he was lecturer assistant at the Faculty of Engineering at the Nation Nasser University, in Tarhuna, Libya. In 20012 he received his PhD degree from the Laboratory for Electrical Instrumentation in the Department of Microsystems Technology (IMTEK), University of Freiburg, Germany. Since May 2012 he joined the computer engineering department, Faculty of Engineering at the Azzaytuna University, in Tarhona, Libya. His research interests are in measuring of temperature using SAW Substrate and digital signal processing of sensor signals.