The Supporting Mechanism for Realtime Traffic in 10G EPON

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Abstract

The high speed network becomes an important indicator of national power in information society. The bandwidth of LAN and WAN are over the Gbps but bandwidth of subscriber access network is dozens of Mbps. Task Force team for IEEE 802.3ah has accomplished the standardization of EPON which is one of next generation subscriber access networks but it doesn't still have the bandwidth wide enough to support the new service which demands high bandwidth. Therefore IEEE 802.3av Task Force studied 10G EPON technology. It expanded the updown bandwidth range of 1G EPON 10 times in order to support a next generation multimedia service demanding high bandwidth and which is proceeding the standardization of physical layer in IEEE 802.3av Task Force. This paper has designed the model which can accommodate IEEE 802.1 AVB traffics smoothly in 10G EPON and suggesting the Intra-ONU scheduling model which makes this model operate effectively.

Keywords: *10G EPON, QoS, DBA Algorithm*

1. Introduction

The high speed network becomes an important indicator of national power in information society where the demand for multimedia service based on internet is increasing. Because of this reasons, many developed countries are accomplishing a number of projects in order to construct high speed networks. As the communication network, there are two types. One is the Local Area Network(LAN) which is composed of terminals, switches and links in short distance. The other is the subscriber access network which connects countries or LANs with the backbone network. In order to construct high speed communication network, all the above mentioned LAN, subscriber access network and backbone network should be able to transfer high bandwidth. As the backbone network, its speed has been increased up to Tbps class. The transfer rate of LAN has reached to 100Gbps class due to Carrier Sense Multiple Access/Collision Detection (CSMA/CD). However, as the subscriber access network, many researches have been studied but actual transfer rate is just a couple of tens of Mbps class. The construction of FTTH is still in the early stage due to the high cost for large scale network and approaching in various ways according to the communication environment of each country. These ways include xDigital Subscriber Line (DSL), cable modem, Fiber-to-the-Curb/Cabinet (FTTC), Fiber-To-The-Building (FTTB) and Gigabit Ethernet (GE)/10GE technologies.

The Final goal of Ethernet over Passive Optical Network (EPON) which appeared on the way to FTTH, is next generation subscriber access network [1]. The EPON has started the Ethernet in the First Mile Study Group which is targeted for the deployment of Ethernet in the First Mile (between house of a subscriber and a neighboring station or neighboring connecting nodes). The concept of EPON is low price subscriber access tool accommodating the general subscriber in IEEE 802 LMSC (LAN/MAN Standards Committee). In May 2004, the Task Force of IEEE 802.3ah completed the standardization of EPON, the next generation subscriber access network.

The EPON has been set up in many places in the world as a new alternative for subscriber access network, but it doesn't still have enough bandwidth to support new services such as the HD level IPTV which needs a high bandwidth, and the Video On Demand (VoD), video conferences, IP Video surveillance systems and online games which demands higher interaction [2]. Additionally the demand for Tripe-Play Service which can support internet service along with broadcast data and voice data is so high that the service to secure sure delay and jitter should be provided in order to satisfy the demand [3][4].

The 10G EPON has a maximum bandwidth up to 10Gbps, it covers the drawback of 1G EPON due to a bandwidth shortage. It can perfectly support strict realtime service based on IEEE 802.1 AVB which is the protocol operating based on reservation and acceptance control [5]. Because it basically communicates data between OLT(Optical Line Terminator) and ONU (Optical Network Unit) using optical fibers on the physical layer as one type of FTTH, there is no weakness for distances. Also it can permit various multimedia services that have their strict characteristics as its MAC layer to adopt the proper bandwidth allocation algorithm.

So we propose the effective Bandwidth Allocation Algorithm in order to support IEEE 802.1 AVB in 10G EPON. We introduce the basic concept of PON in chapter 2, the configuration and bandwidth allocation algorithm of 10G EPON to support IEEE 802.1 AVB traffic explained in chapter 3 and the experimental results of the scheduling method described in chapter 4. Finally, chapter 5 will summarize the result of this paper.

2. 10G EPON

2.1. The Structure of the EPON

We explain the fundamentals of the operation in EPON. Figure 1 shows the EPON system structure, as suggested by the IEEE 802.3 EFM SG [6]. The OLT and the ONU are located at the End Point of a Passive Star Splitter (PSS), each of which is connected by an optical fiber. The PON is either distributed into several identical optical signals or united into one signal according to the transfer direction of the optical signal. PSSs are economical as they have low construction, maintenance, and repair costs, plus since a PSS is a passive component, it does not require any extra power supply. In addition, between the OLT and the ONU are connected by a Point-to-Multipoint form, the installment cost of the optical fiber is lower than that of a Point-to-Point form [7].

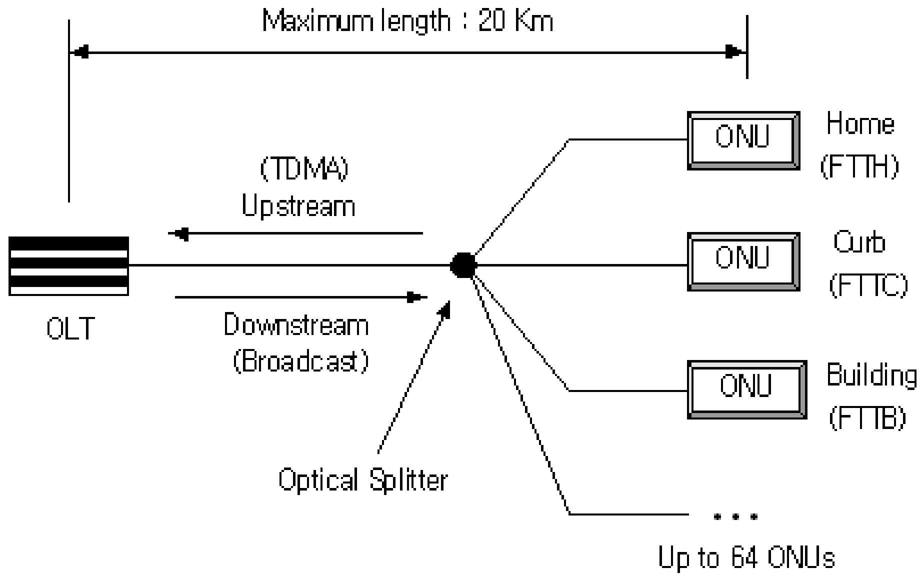

Figure 1. The Structure of Ethernet PON is Proposed in IEEE 802.ah

2.2. 10G EPON

The 10G EPON is a next generation subscriber access network with 10 times faster speed in the upstream and downstream than 1G EPON. So it can transmit easily multimedia data which requires a high bandwidth using its improved data transmission rate without shortage of the bandwidth such as installation cost and adaptability from the aspect of its simple structure and operation than Wavelength Division Multiplexing PON (WDM-PON) which allocates ONU's bandwidth for each wavelength [6].

Although the physical layer of 10G EPON is different from the physical layer of 1G EPON, because both MAC layers have analogous functionalities, 10G EPON can use the control protocol and MAC protocol of 1G EPON without the modification. But the existing Dynamic Bandwidth Allocation (DBA) algorithms of 1G EPON seem unsuitable to accommodate 802.1 AVB traffic with the strict time-sensitive property. This paper suggests a DBA algorithm that consists of Inter-ONU scheduling and Intra-ONU scheduling to support 802.1 AVB traffic. Inter-ONU scheduling allocates each ONU's bandwidth and Intra-ONU scheduling allocates a bandwidth for each traffic class consists of voice, video and data. The bandwidth of each traffic class is allocated by priority of transfer as you can see in Figure 2. The 10G EPON uses the traffic class 4, 5 and each priority queue for IEEE 802.1 AVB traffic while it introduces and utilizes the scheduling structure used in 1G EPON.

As for bandwidth allocation method, there are two types. One is the single level model which allocates bandwidth by reporting the scheduling information of each queue to ONU through GATE message. The other is the hierarchical model in which ONU makes notice to the length of the entire queue to REPORT and arranges the priority through the queue scheduler of its own bandwidth allocated in the DBA of OLT. The single level model provides convenience for maintenance because all the information can be controlled in OLT by reducing the load of the queue scheduling in ONU. However it can't cope with input traffics while each ONU transfers REPORT message and receives GATE message. On the other hand the hierarchical model can flexibly deal with input traffics in the queue of ONU between REPORT message and GATE message even though the price of ONU goes up due to scheduling function.

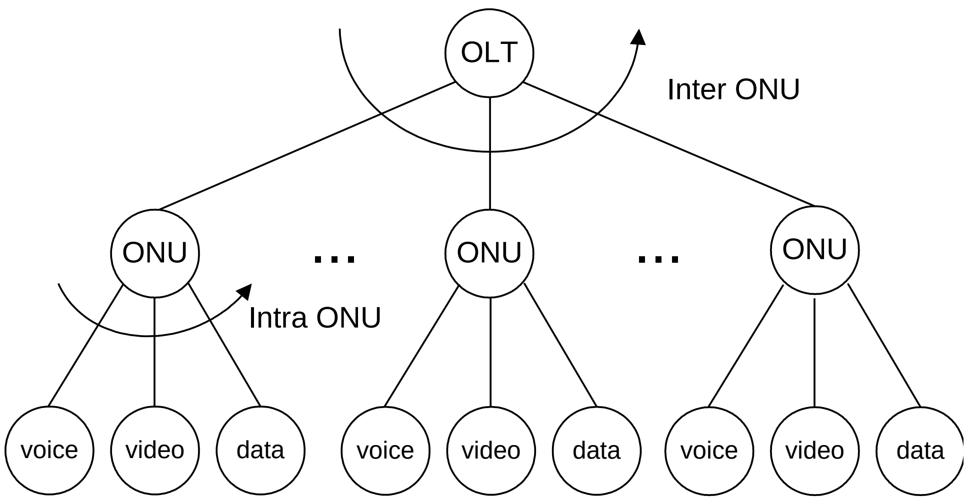

Figure 2. The Structure of Queue Scheduling in EPON

2.3. The Studied DBA Algorithms in the 1G EPON

In McGarry et. al. assorted the study of DBA algorithm into statistical multiplexing method and Quality Of Service (QoS) guarantee that is divided again absolute guarantee and relative QoS guarantee [7]. However the study for acceptance control to handle IEEE 802.1 AVB traffic and the DBA based on resource reservation was not accomplished. In Kramer et. al. assorted Interleaved Polling with Adaptive Cycle Time (IPACT) with statistical multiplex method [8]. Kramer suggested fixed bandwidth allocation method and polling method based on OLT in order to improve the decrease of availability rate due to fixed bandwidth allocation method [8, 9]. Basically IPACT operates in the way of polling the following ONU before the transfer of prior ONU is completed. The polling method is not adequate to the service delicate to delay and jitter because of variable polling cycle time although it enables the statistical multiplex and has excellent capability. As for bandwidth allocation by polling, there are Fixed, Limited, Gated, Const, Linear and Elastic method. Fixed method is the static allocation method which allocates the same bandwidth to every ONU and Limited method allocates bandwidth which each ONU demands within the range not beyond maximum transmission window. Gated method allocates all bandwidth ONU demands. Const method allocates fixed credit to demanding bandwidth by adding the time slot and Linear method decides the size of credit according to demanding bandwidth. Finally Elastic method is the one which transfers bandwidth of ONU to demanding ONU which requires smaller amount than MTW does beyond the maximum bandwidth.

Ma and Zhu suggested the bandwidth guaranteed polling which shares upward traffic based on SLA between Internet Service Provider (ISP) and subscriber [10]. This algorithm provides the best effort service to general subscribers while it guarantees bandwidth to premium subscribers who contracted SLA. This model classifies ONU in network into two types of class. One is ONU to which bandwidth guarantee service is secured and the other is ONU to which the best effort service is secured. In Kramer et. al. minimum bandwidth is secured and the bandwidth beyond limitation is distributed fairly [11]. However it takes quite a few times to receive GATE message because allocating is possible only after bandwidth of all ONUs are reported. Therefore this study decreased the time between receiving of REPORT message and GATE message by dividing them into 2 groups but it was not solved perfectly. So it has limitation to provide QoS to traffic arriving during the time between REPORT message and GATE message.

3. The Method for Supporting Synchronous Ethernet

3.1. The Studied DBA Algorithms in the 1G EPON

For the traffic transmission, IEEE 802.1 AVB reserves resource reservation path before sending the traffic from the talker (service provider) to listener (service user). This work is started when the AVB network group declared. If the host wants to set a group, host broadcasts Multiple Registration Protocol Data Unit(MRPDU) which includes group Media Access Control (MAC) to all other devices. This message is sent to each device and devices determine whether the participants will be registered in this group. After the registration step is completed, talker knows that the group is generated by listener's reservation message. When the path setup is complete, the talker which hopped the traffic and sends it to listeners based on Stream Reservation Protocol (SRP) defined in the IEEE 802.1 Qat [12]. SRP is sent to the listener from the talker and the simplex protocol is defined as in Figure 3.

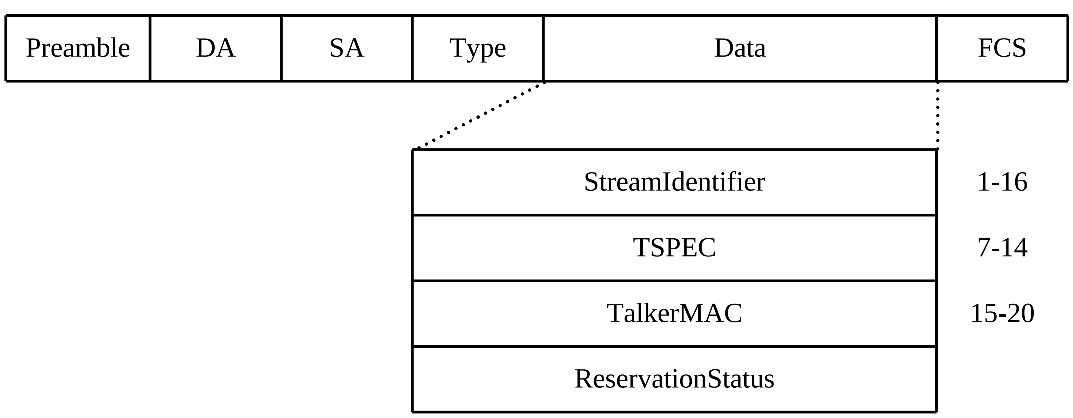

Figure 3. SRPDU

When ONU receives Stream Reservation Protocol Data Unit (SRPDU) from IEEE Ethernet network, TSPEC field in the SRPDU can be scheduled to determine whether the resources are considered. If there is a shortage on resource distribution, the predetermined distribution would fail in ReservationStatus field, then a REPORT message would be sent to OLT.

If the reservation resources are sufficient to Traffic Specification (TSPEC), the temporary reserve and assign value of reservation success in the ReservationStatus field, then this is sent in a REPORT message to OLT. OLT receives a REPORT message including the SRPDU, OLT and SLA in the database test condition of TSPEC and Talker MAC address, Then SLA concludes the contract with the resources necessary for a reservation. Namely, response for reservation is processed at high position protocol. However, in this paper, to reduce processing delays caused by resource reservation, we confirm a responce of resource reservaton by receiving GATE message with StreamIdentifier. Figure 4 and Figure 5 show REPORT message and GATE message with including SRPDU.

	Octets
Destination Address	6
Source Address	6
Length/Type = 88-08	2
Opcode = 00-02	2
Timestamp	4
Number of Queue Sets	1
Report bitmap	1
Queue #0 Report	0/2
Queue #1 Report	0/2
Number of SRP PDU	1
SRP PDU #0	21
SRP PDU #1	21
⋮	
Pad/Reserved	0-39
FCS	4

LSB | b0 … b7 | MSB

Figure 4. REPORT Message with including SRPDU

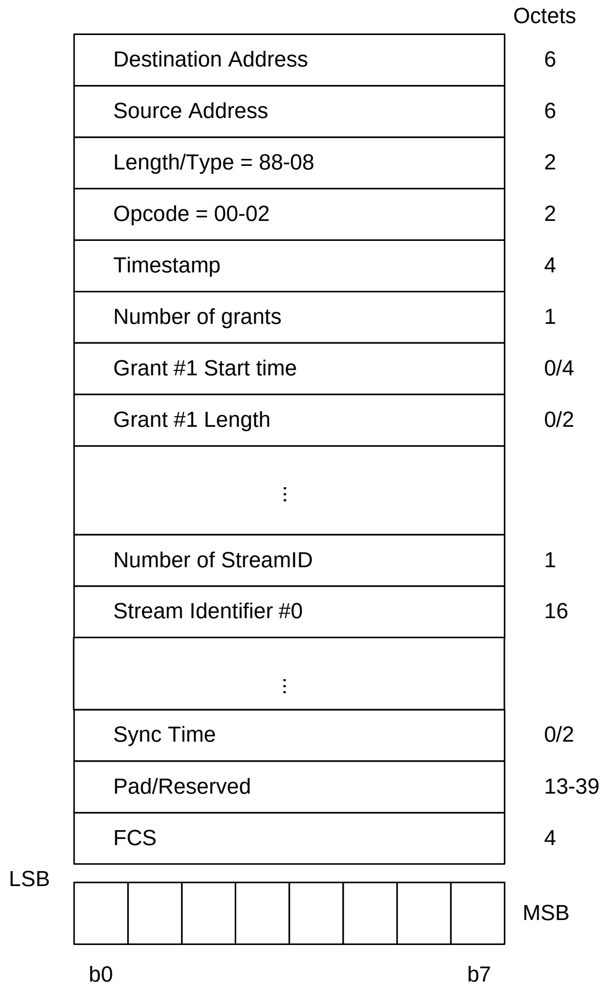

Figure 5. GATE Message with including SRPDU

3.2. Inter-ONU Scheduing

The Inter-ONU scheduler in the OLT will allocate a bandwidth (start time and granted transmission time) within one cycle to each ONU based on REPORT messages. Inter-ONU scheduling can be expressed in (1), at (1) RB_i is required bandwidth as input, GB_i is the Granted Bandwidth as output. RB_i is consists of Booking information (B_i) for the reservation of IEEE 802.1 AVB traffic and Queuing information(R_i) for non-time sensitive traffic. Because AVB traffic is constant, once Inter-ONU scheduler permits B_i to ONU_i, it continues until ONU requests to terminate the connection. So, OLT keeps each ONU's B_i summation. But R_i is a variable per a cycle, therefore each ONU requests R_i every cycle.

$$GB_i = InterDBA(RB_i)$$

$$RB_i \in \{B_i, R_i\}, GB_i \in \{T_i^{start}, G_i\} \quad \textbf{(1)}$$

GB_i that is notified to each ONU is consists of a start time (T_i^{start}) and a transmission duration (G_i). Each ONU initiates to transmit their traffic in queues accodring to their priority and allocated quantities at T_i^{start} in time next cycle and continues to T_i^{stop} as expressed in (2). B_{max} is the maximum transmission rate and equal to 10Gbps in the 10G EPON model.

$$T_i^{end} = T_i^{start} + G_i / B_{\max} \quad \textbf{(2)}$$

Our system must accommodate two kinds of class 4 and class 5 traffic as defined in the IEEE 802.1 AVB to support synchronous ethernet traffic. Each class has constraints of the maximum delay and jitter. The maximum delay of class 4 and class 5 is 1ms and 125㎲ respectively. Therefore we chose the class 5 which is limited to 125㎲ in upstream. One cycle can be expressed in (3). G_{BAND} is Guard Band in expression (3) that transmits data laser transmitter in ONU_i. This is used to prevent ONU_{i+1} transmitting before the nature signal disappeared after a short period. G_{BAND} uses 512ns which is the same in the existing EPON. M_{report} represents bit unit in length of a REPORT message.

$$T_{cycle} = \sum_{i=1}^{N} (G_i / B_{\max} + (G_{BAND} + M_{report} / B_{\max})) \quad \textbf{(3)}$$

Our Inter-ONU scheduler operates in a transmission procedure based on IPACT made by Kramer et. al. IPACT operates as Figure 6. Each ONU reports its queue information and OLT transmits the GATE message to each ONU used by DBA. This process increases the throughput by reducing the bandwidth of the uplink stream. We chose Limit method within IPACT methods to support synchronous Ethernet traffic.

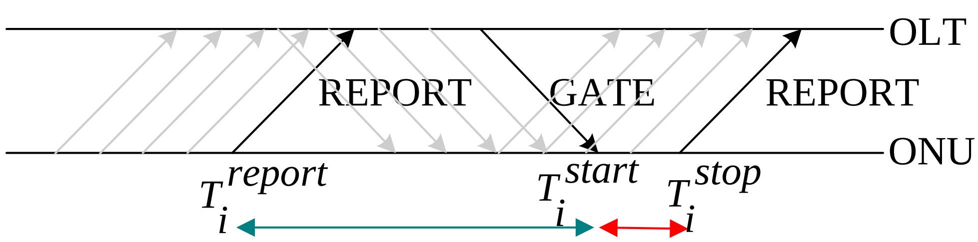

Figure 6. IPACT Mechanism

G_i and T_i^{start} are specified by Inter-ONU scheduler based on equation (4).

$$G_i = \begin{cases} R_i - B_i, & R_i + B_i < W_{\max} \\ W_{\max} - B_i, & R_i + B_i \geq W_{\max} \end{cases} \quad \textbf{(4)}$$

$$W_{\max} = (T_{cycle} / N - G_{BAND}) \times B_{\max} - M_{report}$$

3.3. Intra-ONU Scheduing

Inter-ONU scheduling allocates transmission starting time (T_i^{start}) and transmission allowance quantity (G_i) based on queue information indicated in the REPORT message from ONU so that the conflict between each ONU may not occur. Intra-ONU scheduling is carried out for transmission window (W_i) which is the sum of the bandwidth G_i allocated from OLT and reserved bandwidth B_i in each ONU.

$$W_i = B_i + G_i \tag{5}$$

B_i is classified into class 5 and class 4, which are defined in IEEE 802.1AVB like Equation (6) below.

$$B_i = B_i^{T4} + B_i^{T5} \tag{6}$$

The bandwidth G_i allocated from Inter-ONU scheduler indicates the total quantity of 3 classes which are high, medium and low priority like Equation (7).

$$G_i = W_i^H + W_i^M + W_i^L \tag{7}$$

Intra-ONU scheduling has the queue which has 5 priorities and its structure is like Figure 7. It accomplishes the role of deciding the size of the transmission window and the transmission starting time with G_i which is carried out and allocated in ONU and Bi recorded on resource reservation table. In GATE message, $T_i^{T5,start}$, $T_i^{T4,start}$, $T_i^{H,start}$, $T_i^{M,start}$ and $T_i^{L,start}$ indicates the transmission time while W_i^{T5}, W_i^{T4}, W_i^H, W_i^M, and W_i^L are the size of the transmission window. We described GATE message in the figure 8.

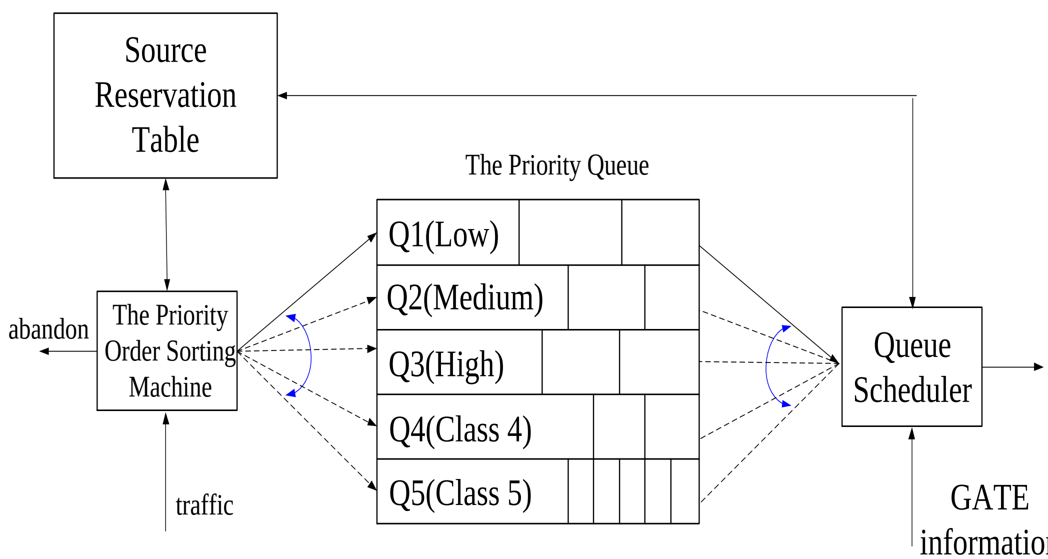

Figure 7. The Structure of Intra-ONU Scheduler

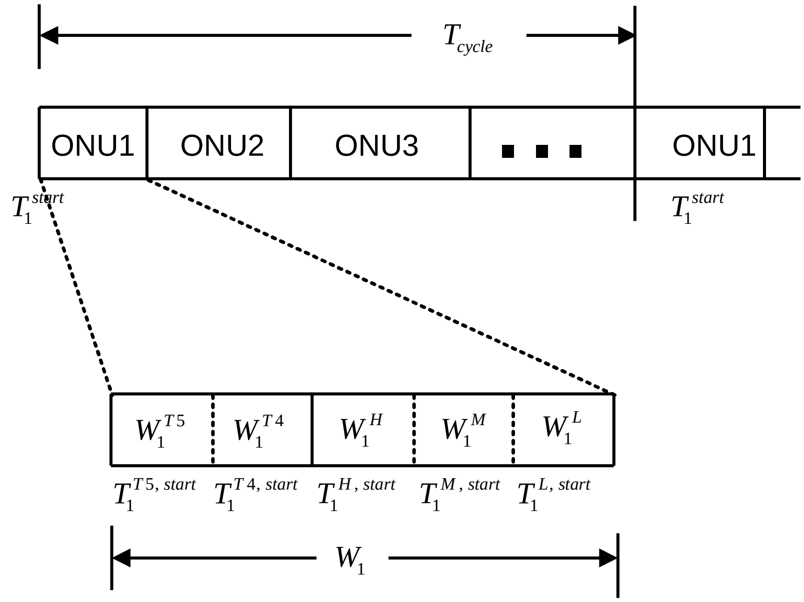

Figure 8. The Example of 5 Classes of Traffic Transmission

Intra-ONU scheduler consists of 5 priority queues, priority manager and queue scheduler. Intra-ONU scheduler sorted each Ethernet frame according to priority and input in the queue matching priority. Priority manager classifies Ethernet frame into 5 priority queues based on Priority code point (PCP) in Virtual LAN (VLAN) tag of input frame.

As IEEE 802.1 AVB frame of class 4 and class 5 operate based on resource reservation, it is considered that the resource for incoming frame is available if there is reservation on resource table. If reservation is success state on resource table, incoming frame is stored in queue, but if reservation is not success, incoming frame is discarded. The transaction time is allocated in order according to priority from high one to low one after bandwidth of synchronous data and IEEE 802.1 AVB data are allocated.

3.4. The Method of Allocating Bandwidth

IEEE 802.1 AVB traffic specifies the resource it requires on the field of TSPEC in SRPDU. As resources are specified variably like minimum and maximum number of frame, ONU makes reservation of resource according to the maximum number. So as the waste of bandwidth can occur because actual traffic doesn't arrive, it calculates bandwidth of synchronous and asynchronous traffic both like Equation (8).

In Equation (8), for the size(B_i^{T5}) and transmission of bandwidth reserved for class 5 traffic, the minimum value of traffic size (Q_i^{T5}) is designated as the transmission window size. Likewise it is applied to traffic of class 4.

The asynchronous traffic transmits the data of subscriber with SLA contract which doesn't support synchronous traffic. It can be classified into 3 types. They are Expedited Forward (EF) class which is high priority traffic, Assured Forward (AF) class which is medium priority and Best Effort (BE) class which is low priority traffic. It is the QoS method which has been studied in 1G EPON and the service that should be provided for exchangeability with conventional EPON. When ONU_i makes REPORT message, the entire demanding bandwidth of asynchronous traffic can be expressed as follows.

$$W_i^{T5}=MIN(B_i^{T5})$$

$$W_i^{T4}=MIN(B_i^{T4},Q_i^{T4}) \quad \textbf{(8)}$$

$$W_i^{NR}=G_i+(B_i^{T5}-W_i^{T5})+(B_i^{T4}-W_i^{T4})$$

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$$R_i = R_i^H + R_i^M + R_i^L \quad \textbf{(9)}$$

After GATE message is received, the status of queue which stores asynchronous data at the transmission start time can be expressed as follows.

$$Q_i^{NR} = Q_i^H + Q_i^M + Q_i^L \quad \textbf{(10)}$$

The reason why Equation (9) and Equation (10) is needed, the packet which arrived during TWT can be delayed for more than a cycle since only the length of packet which arrived during Treport is reported to OLT through REPORT in IPACT method like figure 7. As the load of network is higher, its delay is larger. So quality of high priority traffic which has the lowest delay among asynchronous traffics could be reduced [8].

In order to guarantee QoS of high priority traffic, traffic which arrives during TWT should be transmitted faster than traffic of other class. The most basic method is to use Strict Priority Queuing (SPQ). The shortage of SPQ is that delay is increased for low priority traffic. The second method is the way additional Credit is allocated as expecting high priority traffic during TWT. The shortage of credit is waste of additional bandwidth because Credit method is hard to estimate credit, so entire cycle can increase. As it couldn't accommodate synchronous traffic, high priority traffic must deal first. So the paper was focused on minimizing delay of high priority traffic. However, as 10G EPON can accommodate synchronous traffic, the efficiency of asynchronous traffic like abolition rate of traffic rather than capability of high priority traffic is important. So this paper suggests Adaptive Guarantee Bandwidth Allocation (AGBA) which takes consideration in characteristics of 10G EPON which supports synchronous Ethernet traffic based on WFQ. The WFQ doesn't occur the disadvantage for QoS of high priority traffic. As AGBA is a WFQ method which sets weight dynamically, weight is an important standard for capability. To decide weight, we consider maximum delay, maximum jitter and characteristics of traffic quantity stored in queue of each class.

The maximum delay and jitter of high priority traffic(EF) and medium priority traffic(AF) is defined as 10ms and 100ms in IEEE 802.1Q but there is no definition in low priority traffic(BE). However excessive delay can cause Time out in TCP, a high protocol layer. The value which decides time-out of timer is RTO (Retransmission Time-Out) and it is calculated based on RTT. So it is decided dynamically for each TCP.

In this paper, the maximum delay value of BE is designated 1s, 10 times of AF. The ratio for EF, AF and BE becomes 1:10:100 when considering the max delay time of them. As the max value of cycle in 10G EPON is 125 ㎲, we can conclude that the max delay can be guaranteed only if EF can transmit 80 cycles, AF can do 800 cycles and BE can do 8000 cycles for traffic which arrives within one cycle. Therefore the quantity for traffic of each class, which arrived within a cycle, can be estimated. The period of a cycle is divided into T_{trans} and TWT. Figure 9 showed the structure of Intra-ONU scheduler.

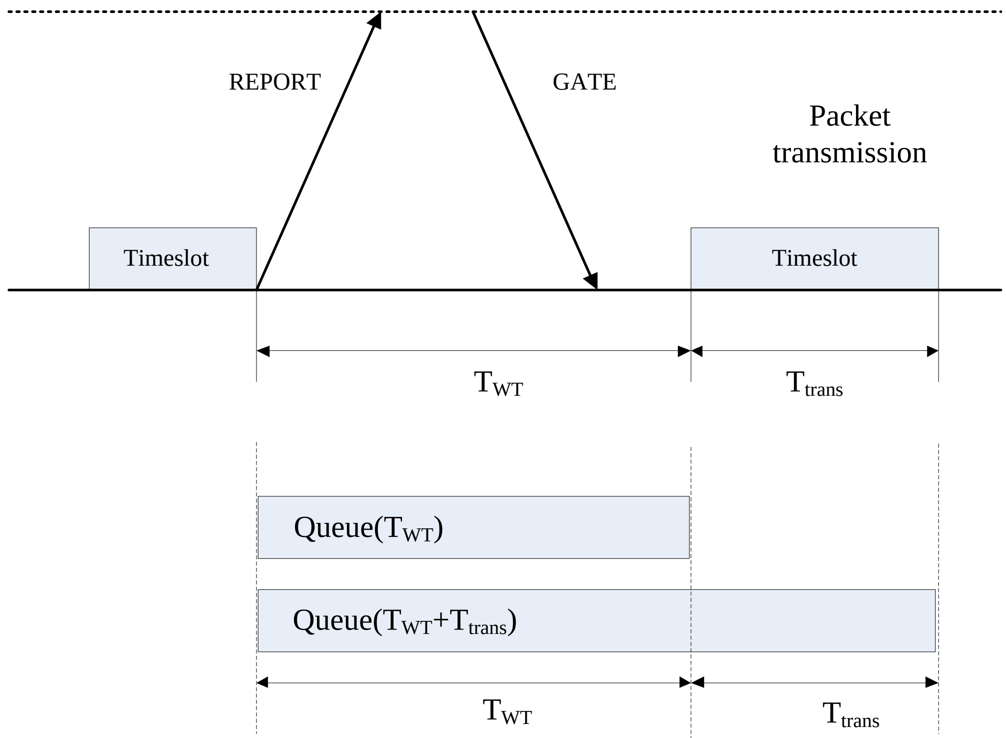

Figure 9. The Structure of Intra-ONU Scheduler

The following 3 cases happen if compare the sum of $W_{i,t}^{min}$ of minimum guarantee bandwidth with allowed bandwidth, G^i before additional bandwidth is allocated. So the additional bandwidth is allocated according to 3 cases.

· $W_{i,t}^{min} = G_{i,t}$: the minimum guarantee bandwidth becomes the size of transmission window.

$$W_{i,t}^{c,add} = 0 \tag{11}$$

· $W_{i,t}^{min} > G_{i,t}$: the minimum guarantee bandwidth of all classes is decreased by the ratio of sum of allocated bandwidth and minimum guarantee bandwidth.

$$W_{i,t}^{c,add} = \left(G_{i,t} - W_{i,t}^{min}\right) \times \frac{W_{i,t}^{c}}{W_{i,t}^{min}} \tag{12}$$

· $W_{i,t}^{min} < G_{i,t}$: Like Equation (13) it calculates out and allocates the additional bandwidth calculated by multiplying average and the ratio in queue on sum of weight for the excess bandwidth which subtracts the sum of minimum guarantee bandwidth from allocated bandwidth like Equation (14).

$$W_{i,t}^{c,\,add} = W_{i,t}^{\alpha} \times \frac{1}{2} \times (Q_{i,t}^{c,\,ratio} + \omega^{c}) \qquad Q_{i,t}^{c,\,ratio} = \frac{Q_{i,t}^{c}}{Q_{i,t}^{NR}} \tag{13}$$

$$W_{i,t}^{\alpha} = W_{i,t}^{NR} - \sum_{\beta \in c} W_{i,t}^{\beta,\,min} \tag{14}$$

4. Experimental Results

This section has implemented the 10G EPON model that supports IEEE 802.1 AVB traffic in order to analyze the capability of bandwidth allocating method this study suggests by use of OPNET, commercial capability analysis tool and is analyzing capability of Intra-ONU scheduling method. Intra-ONU scheduling accomplishes the role to allocate bandwidth allocated by Intra-ONU scheduling method to each class as described in section 3. This experiment compared the Par and DBA2 of the method suggested by this paper with those of SPQ, WFQ, and the Credit method. Each experimental model of the bandwidth allocation system had 3 priority queues [13]. Under asynchronous experiment model, we allocated 30 % of whole traffic produced to synchronous traffic and kept the ratio of EF, AF and BE with 1:1:2 and increased 10 % each time from 10% to 100%. The EF traffic is used transmitting voice data and it is a Constant Bit Rate (CBR) in the ATM network. The AF traffic is video data type such as MPEG-1, MPEG-2 and H.264. It is used by Video on Demand (VoD), video conferencing etc. The AF traffic considers bandwidth of great importance, but it is less sensitivity to delay than EF traffic. The BE traffic is used by legacy Internet services such as web services, e-mail and FTP. The BE traffic doesn’t need real time transmission.

Figure 10 and 11 shows average delay of terminal to terminal and queue size of EF traffic in each bandwidth allocation method. Under load below 70%, delay of terminal to terminal was lower in order of Par, the suggested method, DBA2, SPQ and WFQ method. When traffic load goes over 70%, end-to-end delay changed in order of SPQ, WFQ, the suggested method, DBA2 and Par method. The queue size showed the same order with average end-to-end delay. However SPQ which showed the lowest delay, had no large difference end-to-end delay and queue size while it showed delay low enough to accommodate EF traffic. We have analyzed capability of asynchronous traffic under synchronous allocation system with max end-to-end delay, average end-to-end delay and queue size.

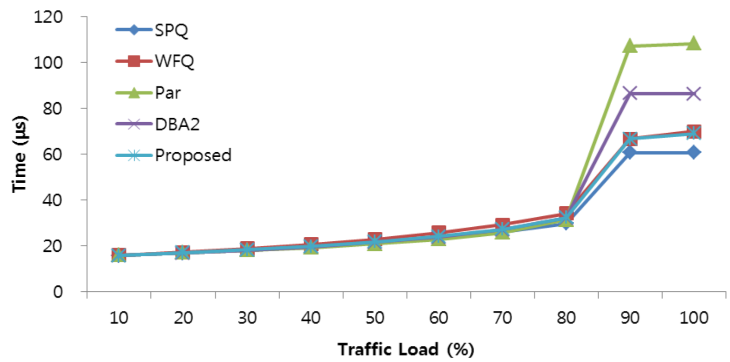

Figure 10. Average end-to-end Delay in EF Traffic

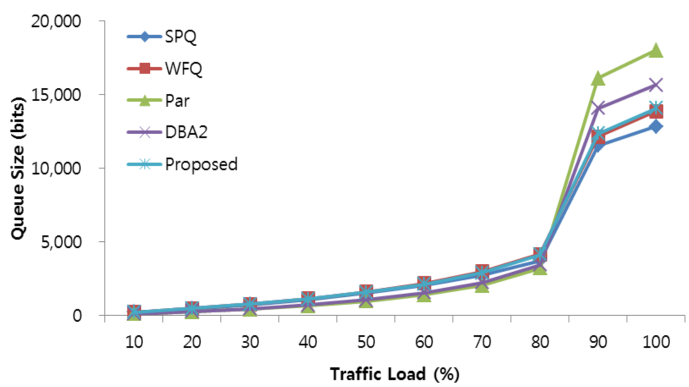

Figure 11. Queue Size of EF Traffic

Figure 12 and 13 shows average delay of terminal to terminal and queue size of AF traffic in each bandwidth allocation method. The priority of AF traffic is lower than EF, so end-to-end delay is longer, and AF traffic is used for video data, that is why AF traffic is bigger queue size than EF.

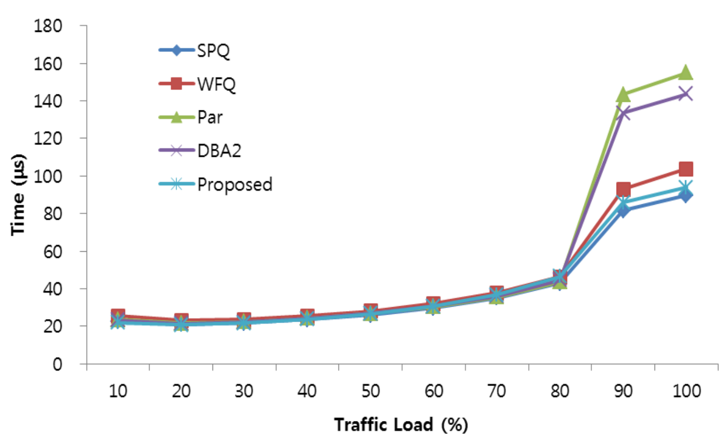

Figure 12. Average end-to-end Delay of AF Traffic

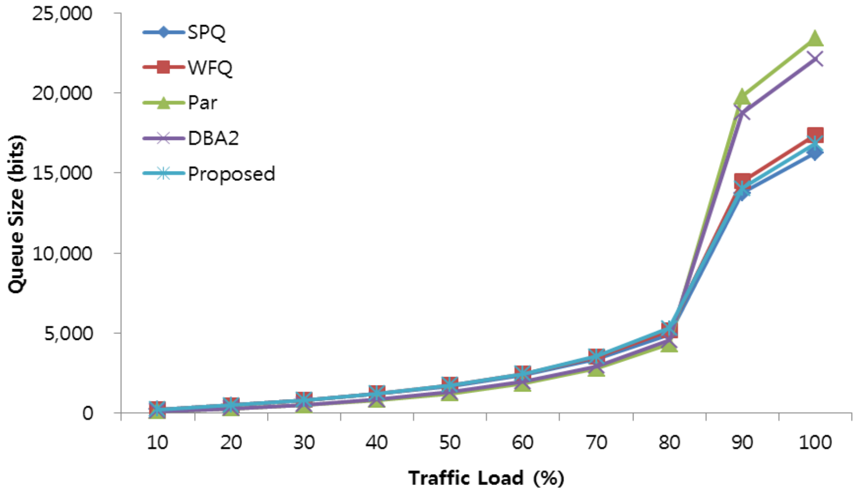

Figure 13. Queue Size of AF Traffic

Figure 14 and 15 shows average delay of terminal to terminal and queue size of EF traffic in each bandwidth allocation method. Because of our method guaranteed minimum bandwidth for BE traffic, the end-to-end delay in low traffic load (10 ~ 40%), but the ratio of minimum bandwidth and BE traffic is high, the performance of our method was lower than others. When traffic load goes over 80%, our proposed method showed lowest end-to-end delay, and smallest queue size. Therefore packet loss ratio of our method is also lowest. We described this in figure 14 and table 1 shows more detailed results for the end-to-end delay of BE traffic.

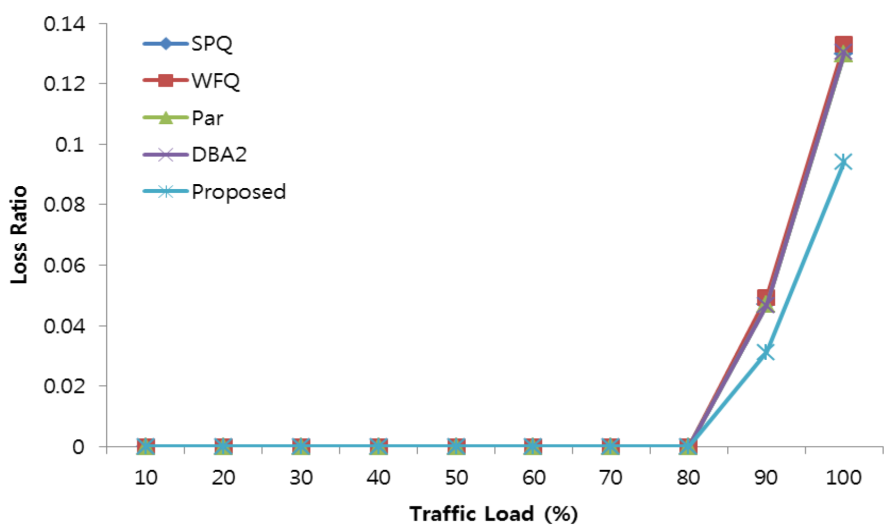

Figure 14. Loss Ratio of BF Traffic

Table 1. Average end-to-end Delay of BE Traffic **(Unit : μs)**

Traffic Load	SPQ	WFQ	Par	DBA2	Proposed
10	22.76	22.80	24.34	23.99	21.76
20	21.45	21.46	22.54	22.28	21.02
30	22.66	22.72	23.79	23.56	22.51
40	25.15	25.30	26.47	26.26	25.21
50	29.06	29.29	30.47	30.30	29.42
60	35.37	35.87	36.72	36.50	36.21
70	46.44	47.46	47.00	46.48	48.53
80	69.42	71.86	67.14	65.27	75.90
90	46843.04	47400.90	46774.23	46943.72	36055.38
100	52035.85	52281.54	51983.60	52035.52	42097.58

5. Conclusion

As the demand for multimedia service increases, many research and investment on bandwidth expansion of network has been accomplished. The backbone network and LAN enabled the transfer of multimedia data with large quantity as it developed a lot as a result of a long time research and investment. However the subscriber access network which connects backbone network and short distance network still remains the area that is insufficient to transmitting multimedia data between high bandwidth of backbone network and short distance network.

In this situation the EPON technology that can provide higher transmission rate than various subscriber access networks appeared. But as its transmission rate is just maximum 1Gbps, its bandwidth is not enough to serve Internet Protocol TeleVision (IPTV) that has more than 100 channels, Video on Demand (VoD) of High Definition (HD) class and online games of large capability in the future. So now 10G EPON is considered to be an alternative. As 10G EPON not only can support high bandwidth but also traffic of IEEE 802.1 AVB that requires strict delay and jitter, it can support all services customers want. We designed the model that can accommodate IEEE 802.1 AVB traffic in those 10G EPONs and suggested Intra-ONU scheduling model to allocate bandwidth more effectively. Our Intra-ONU scheduling model showed lower end-to-end delay for class 5 traffic. Also we suggested AGBA to to accommodate for QoS of multimedia traffic in 10G EPON. The suggested 10G EPON is not just the issue of bandwidth expansion but will be able to a solution which can accommodate multimedia service with high capacity in the future.

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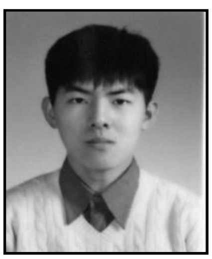

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