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멀티미디어 서비스 이용률 향상을 위한 진보된 MAC 프로토콜 성능분석

Performance Analysis of Enhanced MAC Protocol to Improve Utilization in Multimedia Service

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요 약 최근 이더넷 수동 광 네트워크는 산업에 있어서 뿐만 아니라 효율적인 광대역 서비스를 제공할수 있어 많은 연구가 진행되고 있는 분야이다. PON 네트워크에 있어서 MAC 프로토콜은 TDMA 방식을 기반으로 처리되고 있다. 본 논문에서는 기존의 채널의 시간 슬롯 분배 (대역폭 할당)방식에 있어서의 문제점을 공평성과 QoS 관점으로 살펴보고, 효율적인 자원 이용율을 제공하기 위한 진보된 대역폭 할당 기법을 제안한다. 이방식은 현재 휴지 상태의 ONU 들에게 할당된 사용하지 않는 대역폭을 최소화함으로서 모든 ONU 들에게 최대 대역폭 요구를 공평한 범위 내에서 충족 시킬수가 있다.

Abstract An Ethernet passive optical network (EPON) is an economical and efficient access network that received significant research attention in recent year. A MAC protocol of the PON, the next generation access network, is based primarily on TDMA (Time Division Multiple Access). In this paper, we addressed the problems of a dynamic bandwidth allocation (DBA) in Fairness and QoS Performance. We augmented the advanced bandwidth allocation algorithms to support efficient resource utilization by reducing the unused remaining bandwidth made by idle state ONUs. Our new proposed advanced bandwidth allocation algorithm can allocate effectively and fairly the bandwidths between end-users.

Key Words : EPON, MAC, Multimedia Service

Ⅰ. Introduction

The Ethernet passive optical network (EPON) is considered to be a very gorgeous solution for implementing fiber to the home (FTTH). It has a point-to-multipoint tree topology that carries 802.3 Ethernet frames between an optical line termination (OLT) and multiple optical network units (ONU) via a passive optical splitter. To share the upstream bandwidth among ONUs without collisions, robust and efficient medium access control is required [1][2].

Figure 1 shows the EPON system structure, as suggested by the IEEE 802.3 EFM SG. The OLT and the ONU are located at the End Point of a PSS (Passive Star Splitter), whereby they are connected by an optical fiber. For downstream transmission, OLT broadcasts a frame to all ONUs, and each ONU filters the received frame depending on its logical link ID (LLID).

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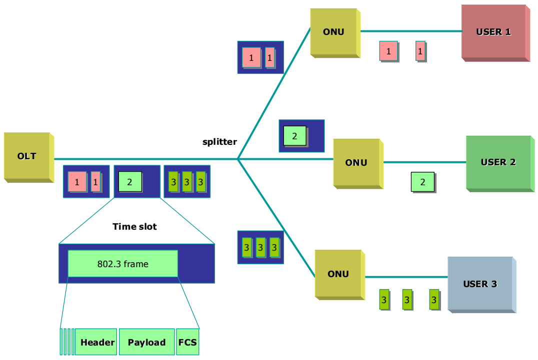

Fig. 1. Upstream and Downstream traffic flow in EPON

The contribution of this paper is as follows. We propose a new enhanced dynamic bandwidth allocation algorithm with fairness called ABGA, to improve bandwidth utilization efficiently.

Ⅱ. Related work and problems

Among various conventional DBA mechanisms, we explain interleaved polling with adaptive cycle time for DBA (IPACT) because itis the most popular due to efficiency and simplicity which shows high performance and low complexity. The IPACT uses an interleaved polling scheme where the next ONU is polled before the transmission from the previous ONU has arrived. This scheme provides statistical multiplexing for ONUs and results in efficient upstream channel utilization [2].

The Fixed scheme always ignores requested window size and grants the maximum window size W_{MAX} . Basically this scheme corresponds to fixed TDMA PON system [3][4]. This service is simple which does not needs modification of ONU/OLT. Howeverit does not consider the amount of traffic from each ONU.

The constant credit scheme uses a constant credit to the requested window size. The main idea in constant credit service is to add the credit in current window size. For example, if N bytes arrived between the times an ONU sent a Request and received the Grant message include window size. If the granted window size equals requested window + N, these N bytes do not need to wait for the next Grant to arrive, that is, they wouldbe transmitted with the current Grant, and the average packet delay will be shorter.

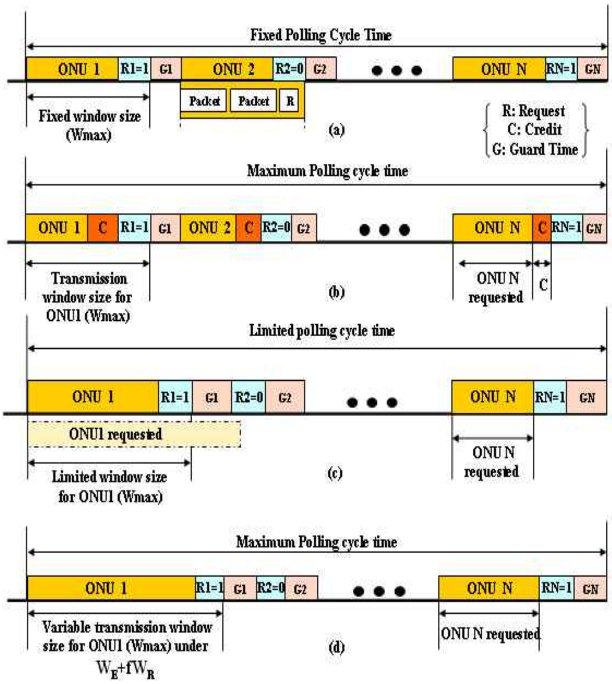

Fig. 2. Comparison of window size between IPACT(a)-(c) and proposed ABGA (d): (a) fixed (b) linear credit (c) limited case (d) ABGA scheme

The limited scheme grants as much as window requested but it could not exceed W_{MAX} . This scheme could achieve higher bandwidth utilization in uniform traffic case. Figure 2 shows the graphical explanation of the window size between IPACT and proposed ABGA scheme.

In this paper, we just compare limited service in IPACT with proposed ABGA because limited schemeis most conservation scheme and has the shortest cycle of all the schemes such as the fixed, constant credit, linear credit and limited schemes.

However, non-uniform traffic (burst traffic) roughly affects the degradation of upstream utilization [5]. In case that many ONUs are in idle state, that is., connected but transmitting only control message, increased ratio of guard time degrades bandwidth utilization and also limits maximum upstream bandwidth per ONU. In a corner case, given that 16 ONUs are connected to OLT, and just a single ONU is in active state, the utilization deteriorates below 0.6 in case of 5 usec guard time and 2 msec maximum cycle time. It becomes worse as a ratio of guard time over maximum cycle time (Cmax) increases or the number of ONU increases.

In IPACT, limited service scheme grants as much as window size requested but it cannot exceed W_{MAX}. Eq. 1 shows the k+1th window size for ONU_i in the limited scheme.

W_{MAX} : Maximum window size from ONUs

$W_i^{[k]}$: The K_{th} window size for ONU_i

$D_i^{[k]}$: The K_{th} request window size from ONUi

$$W_i^{k+1} = \begin{cases} D_i^k & if \quad D_i \le W_{\max} \\ \min(D_i^k, W_{\max}) & otherwise \end{cases} \quad (1)$$

This scheme can achieve higher utilization. However, it may fail to fully utilize the bandwidth under the non-uniform traffic.

For example, one OLT manage N numbers ONUs in the EPON network. Among N number of ONUs, just one ONU wish to sendthe data to OLT and others is idle state. In this case, the ONU can send data within the maximum window size W_{MAX} per every one cycle consisted of W_{MAX} and N number of guard time N·G and report time. That is, the utilization is limited to Eq. (2).

$$U = \frac{W_{\max}}{W_{\max} + N \cdot G} \quad (2)$$

This is because OLT could not grant more than W_{MAX} even if other ONUs do not use allocated guaranteed maximum size window. This means that if a lot of idle ONUs exists per cycle, the unused window size will be increased which cause degradation of the bandwidth utilization under up stream.

To resolve these problems, we propose a new enhanced DBA with fairness scheme, which achieves high bandwidth utilization, low delay, low packet loss and low queue occupancy.

Ⅲ. Advanced bandwidth Guarantee Allocation Algorithm (ABGA)

In this section, we present new enhanced dynamic bandwidth allocation scheme with fairness by using unused window size from idle ONUs. We assume that Cmax could be known when OLT start to initialize poll entry table using allocated maximum window size Wmax, N number of ONU connected to one OLT and guard time G. Wmax could be consisted of W_R and W_E where denote the total unused rest window size and the ensured maximum window size for ONUs respectively.

First, we could be determined the maximum cycle time Cmax using W_E, W_T and G where denote the ensured maximum window size to all ONUs, the tentative window size and guard time that provide protection for fluctuations of RTT and control message processing time of various ONUs. That is, we first could define the cycle time consisted of W_E, W_T and G. Figure 2 (d) shows the proposed ABGA maximum cycle time.

During per cycle proceeding, the total ensured window size for ONUs is determined as $W_E = \sum_{i=1}^{N} W_{E,i}$ where the $W_{E,i}$ is a reserved maximum window size for ONU_i. In our paper, we assume that all ONUs have the same ensured maximum window size. So, we can express the total ensured window size during per cycle as

$$W_E = N \bullet W_{E,i} \quad for \quad \forall i \tag{3}$$

The tentative window size also could be defined as

$$W_T = C_{\max} - N \bullet W_{E,i} - NG \tag{4}$$

Actually W_T is most important factor in our scheme to allocate bandwidth efficiently to ONUs without unused bandwidth. That is,all ONUs could share this tentative window size from OLT controller which manage tentative window. For example, when ONUs that exceeds ensured maximum window sizecompared with requested window size want to use extra tentative window size, at this time, OLT could allocate rest tentative window size proportion to fairness weighting factor (f). We can calculate rest tentative window size (W_{T-R}) using past N grants. The W_{T-R} could be calculates as

$$W_{T-R,i}^k = W_T - \sum_{j=(i-N+1)\bmod N}^{(i-1)\bmod N} \max(D_j - W_{E,j}, 0) \tag{5}$$

where the $D_j - W_{E,j}$ is an over-grant size for ONU_j.

The operation of proposed ABGA scheme in OLT isshown in Figure 3.

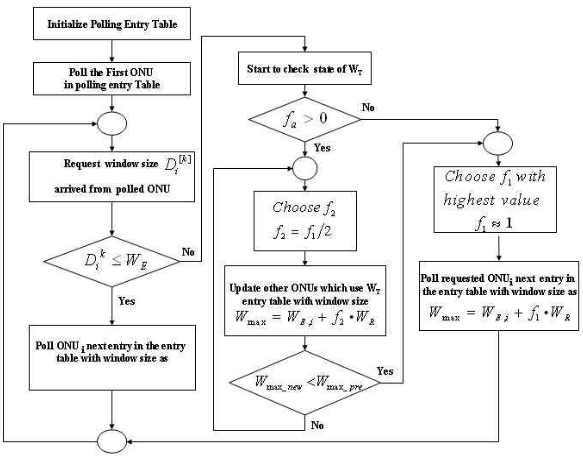

Fig. 3. Operation of proposed ABGA flowchart in OLT

In case of $D_i \le W_E$, the requested window size from ONU_i follows with predetermined W_{max} for service level agreement (SLA), and OLT grants the requested window size which does not exceed ensured window size W_E.

In case of $D_i > W_E$, the requested window size would be exceeded the ensured maximum window size. OLT controller starts to calculate suitable window size in advance without unused window size during maximum cycle time using fairness weighting factor. Therefore, if there are a lot of unused window size left by previous N-1 ONUs, OLT could allocate both tentative window and unused ensure window size which allocated to N-1 ONUs ($W_{E\_unused\_in(N-1)ONUs}$).

We can determinetotal unused rest window size for ONU_i during per cycle as

$$W_{R,i} = W_{T-R} + W_{E\_unused\_in(N-1)ONUs} \tag{6}$$

where $W_{E\_unused\_in(N-1)ONUs}$ is the unused ensure window size by N-1 ONUs.

The unused ensure window size which allocated to N-1 ONUs ($W_{E\_unused\_in(N-1)ONUs}$) could calculate as

$$W_{E\_unused\_in\,(N-1)ONUs} = N \square W_E - \sum_{j=(i-N+1)\bmod N}^{i-1} W_{E,j} \tag{7}$$

By using ABGA scheme, the k+1th maximum window sizethat can allocate for ONU_i is determined as follows.

$$W_{\max,i}^{k+1} = \begin{cases} D_i^k & if \quad D_i^k \le W_E \\ \min(W_{E,i}^k + f_{a,i}(W_{R,i}),\ D_i^k) & otherwise \end{cases} \tag{8}$$

where the 0< $f_{a,i}$ <1 is a fairness weighting factor to allocate fairly unused rest window size for ONU_i which wish to use W_R in short cycle period. The f_a is the most important factor to enhance the performance of DBA fairly to all ONUs. This f_a act as two ways such as f_1 and f_2 where f_1 denotes that currently no one uses tentative window size included unused ensured window size by N-1 ONUs and f_2 denotes that some ONUs are using tentative window size included unused ensured window size in the EPON networks. Specific explanations for f_1 and f_2 as follows.

In f_1 apply, whenN number of ONUs connected with OLT, among N ONUs, we assume that just one ONU have a lot of data, on the other hand, other N-1 ONUs is idle state which does not have data to send to OLT. In this case, first time OLT permit the f_1 factor to an ONU which wish to use tentative window size included unused window size by N-1 ONUs to send data efficiently without limited ensured window size. However, if there are some ONUs which want to use tentative address without limited ensured window size, first time OLT controller have to change all other ONUs which currently is using unused window size , W_R , that stored in the polling entry table proportioned with f_2 factor and then the OLT permit f_1 factor to required ONU. These procedures are shown in figure 3 in detail. That is, in the short cycle period, some ONUs wants to use rest window size. To reduce the a lot of cycle periods which could be caused unfairness between the ONU which already are using rest window size and new ONUs which require to use rest window size fairly, as soon as OLT receive the request message that exceed ensured window size from new ONUs it can permit f_1 factor just to new ONUs to update maximum window size (W_{max}) in polling table.

On the contrary, other ONU's W_R which already is using rest window size are decreased by proportioning to f_2 . After finish polling entry table changing, f_2 , OLT change f_2 to f_1 for next cycle.

This procedure recursively repeat until all ONU's W_R in OLT's polling table is converge to 1. This new efficient ABGA scheme with fairness factor could support proficientwindow size without unused rest window for ONUs. Therefore, the most advantage of ABGA compared with conventional DBA algorithms is to could be use W_R between ONUs fairly just after a few cycle. This means that a few cycle periodscould be increased overall utilization of bandwidth and allocated window size to ONUs fastly.

Ⅳ. Performance Analysis

In this section, we analyze the steady state fairness under fairness factor (f_a).

First we assume that N numbers of ONUs are connected with one OLT. Among N·ONUs, X out of N·ONUs want to use the rest window size with fairness weighting factor f_a . OLT check the rest window size to allocate rest window. If f_a =1, currently rest window (W_R) is using by some other ONUs.

On the other hand, if f_a =0, W_R does not consume by ONUs. To analyze the steady state fairness under exceed window size condition for ONUs, we use recursive formula of $W_{R,i}(k)$ where denote the rest window size included the ensure window size to ONUs at kth cycle for ONU_i. $W_{R,i}(k)$ is defined as

$$W_{R,i\neq 0}(k) = f_{a,i}W_{R,i}(k-1)+(1-f_{a,i-1})W_{R,i-1}(k) \quad f\, i\neq 0$$
$$W_{R,i=0}(k) = f_{a,i=o}W_{R,i}(k-1)+(1-f_{a,N-1})W_{R,N-1}(k) \quad if\, i=0 \tag{9}$$

So, the steady state value of $F(=f_{a,i}(W_{R,i}))$ converges to

$$F = W_{R,i} \Big/ \{(X-1)+1/f_{a,i}\} \quad for\ \forall i \tag{10}$$

The utilization of unused rest window could be calculated as

$$U_R = X \Big/ \{(X-1)+1/f_{a,i}\} \quad for\ \forall i \tag{11}$$

The convergence speed depends on f_a which effects on cycle period. This means that if we use f_a efficiently managed by OLT, the convergence speed become to rise. That is, we could allocate unused rest window to other ONUs which exceed request window size after a few cycle period. Consequently, some ONUs that wishes to use unused rest window can get the extra window fairly in the next cycle.

V. Simulation Results

In this section, we analyze the simulation results of the fairness in different bandwidth allocation algorithms. We consider a EPON structure with 16 ONUs connected to a tree topology.

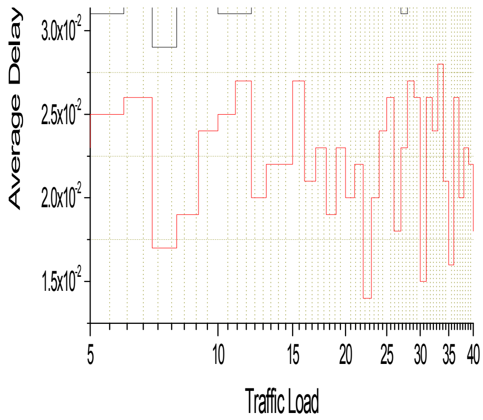

Fig. 4. The average delay of the high-priority class for ABGA, IPACT algorithms.

Figure 4 show the average delay which impact high-priority traffic on ABGA, IPACT algorithms. As shown in Figure 4, high-priority traffic has the end-to-end delay in the order of ABGA and IPACT. That is, ABGA is what better than IPACT, because IPACT method is based on interleaved polling scheme where the next ONU is polled before the transmission from the previous ONU. So, the total cycle time becomes longer than ABGA scheme.

VI. Conclusion

In this paper, we dealt with the dynamic bandwidth allocation problem in the Ethernet PON. Particularly, we proposed advanced dynamic allocation algorithm supporting fully resource utilization by reducing the unused remaining bandwidth.

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