A MAC Scheme for Multimedia Services over ATM-based PON

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Abstract

This paper proposes a novel MAC scheme over APON based on the cell arrival timing information to provide residential and small business customers with multimedia services. The proposed scheme supports the frame format of ITU-T recommendation G.983 and also provides ATM service classes such as CBR, rtVBR, nrtVBR, ABR, and UBR traffics. Each service is allocated on the basis of priority and cell arrival timing information. Especially, the CBR and rtVBR services, which are sensitive to delay and CDV, are allocated with higher priority and more exact arrival timing resolution which is achieved with specific coding and ranging procedure. For the proposed MAC scheme, we present grant field format, minislot format, and bandwidth allocation algorithm. Computer simulation results show that the performance of the proposed scheme is significantly improved in terms of CDV and delay time in case of CBR and rtVBR services, comparing with the normal FIFO scheme.

I. Introduction

Optical fiber access networks are expected as the most future-safe solution to provide multimedia services for residential and small business customers. Especially, the PON(Passive Optical Network) has been proven to be a cost-effective way to introduce fiber into access networks. In addition, the ATM is considered as the basic transport technology of the B-ISDN which offers flexibility in terms of service transparency and bandwidth allocation. Therefore, the APON(ATM-based PON) combined with these two powerful techniques is expected to provide attractive low cost, robust, and flexible solutions for residential and small business customers [1]-[2].

The APON is basically shared-medium network and there needs, therefore, to be some form of access protocol that allows a terminal wishing to transmit data to do so without causing any interference to other terminals. For MAC of APON, the reservation based TDMA approach is known to be quite promising. There were several proposed MAC schemes over APON based on the reservation based TDMA [2]-[4]. However, these schemes do not follow the frame structure of ITU-T recommendation G.983.

In this paper, we propose a novel MAC scheme which follows the frame structure of ITU-T recommendation G.983 and also supports ATM service classes such as CBR, rtVBR, nrtVBR, ABR, and UBR traffics. The proposed scheme can offer an efficient bandwidth allocation method using service priority and cell arrival timing information achieved with specific coding and ranging procedure. Especially, in the case of CBR and rtVBR services, we can obtain the satisfactory CDV performance. We can also obtain the effective delay performance in accordance with service priority.

II. APON System and Frame Structure

In the APON environment, many terminals must share one optical fiber in the APON environment. The splitting ratio is 1:16 or 1:32, that is, one OLT(Optical Line Termination) can control 16 or 32 ONUs. One ONU is shared among several customers in the FTTC configuration which uses VDSL(Very-high-speed Digital Subscriber Line) technology from ONU to NT(Network Termination). In the FTTH, one ONU called ONT(Optical Network Termination) can support only one customer. In the downstream direction, the system can support 155.52Mb/s or 622.08Mb/s. On the other hand, in the upstream direction, the APON system can support only 155.52Mb/s.

From now, we describe briefly the frame structure of ITU-T recommendation G.983. The downstream frame structure for both 155.52Mb/s and 622.08Mb/s consists of a continuous stream of slots, each of which contains 53 bytes of an ATM cell or a

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PLOAM(Physical Layer OAM) cell. Every 28 slots a PLOAM cell is inserted. In the 155.52Mb/s case, a downstream frame contains 2 PLOAM cells and has 56 slots. It contains 8 PLOAM cells, and is 224 slots long in the 622.08Mb/s case. The OLT requests ONU to transmit ATM cell via grant conveyed in the downstream PLOAM cell. The length of a grant field in the downstream PLOAM cell is 8 bits. There are total 7 kinds of grants, that is, the data grant, the divided slot grant, the upstream PLOAM grant, the reserved grant, the ranging grant, the unassigned grant, and the idle grant. In the upstream direction, a frame contains 53 slots, each size of which is 56 bytes. Each slot consists of 3 overhead bytes and one ATM cell. The status of the ONU queues is transferred to the OLT by using minislot conveyed in the divided slot [5].

III. The Proposed Scheme Description

In this section, we describe the proposed scheme in terms of grant field format, minislot format, and slot allocation procedure. For describing and analyzing the proposed scheme, we select the system parameters as shown below.

- The maximum distance from OLT to ONU is 10 Km.
- The optical splitting ratio is 1:16 (The proposed scheme can serve maximum 96 customers with FTTC in which each ONU can support maximum 6 NTs).
- Downstream speed and Upstream speed are 155.52Mb/s (However, this scheme can also apply the same method in the downstream speed 622.08Mb/s).

A. Grant Field Format

We propose the data grant field format and the divided slot grant field format in the downstream PLOAM cell, as shown in Fig.1. In the data grant field, the first bit is set to zero for being recognized as the data grant by all ONUs. The address field of 4 bits which can distinguish 16 ONUs identifies each ONU sufficiently. In the proposed system, each ONU has 4 separate buffers, each for CBR and rtVBR traffic, nrtVBR traffic, ABR traffic, and UBR traffic. Therefore, the class field of 2 bits is used to direct one buffer among 4 buffers. In the divided slot grant field, the identification field is also used for being recognized as the divided slot grant by all ONUs. The first bit of 3 bits is set to one for distinguishing the

Identification	ONU address	Class	Spare
1 bit	4 bits	2 bits	1 bit

Identification field = 0
Class field : CBR and rtVBR data grant = 00, nrtVBR data grant = 01,
ABR data grant = 10, UBR data grant = 11

(a)

Identification	Sequence	Spare
3 bits	2 bits	3 bits

Identification field = 100
Sequence field : first divided slot = 00, second divided slot = 01,
third divided slot = 10, fourth divided slot = 11

(b)

Fig. 1. (a) Data grant field format of downstream PLOAM cell (b) Divided slot grant field format of downstream PLOAM cell.

data grant. We also use 2 bits to distinguish the divided slot grant, the upstream PLOAM grant, and the reserved grant. The ranging grant, the unassigned grant, and the idle grant of 7 kinds of grants are preassigned. The proposed scheme can take maximum 4 divided slot grants during a frame. Therefore, we make use of the sequence field to represent the sequence of the divided slot grants.

B. Minislot Format

In Fig.2, a divided slot consists of 4 minislots, per which maximum 6 NTs can be emitted. A minislot uses the 112 bits of a divided slot for announcing the number of the cell arrivals during a frame. We can utilize downstream slot as a global time base for all ONUs by using ranging procedure [3]. In the proposed system, the downstream 56 slots are divided into 8 segments. Then, each segment represents 7 time slot resolution of downstream slots, which means that the time of cell arrivals within 7 downstream slots is not differentiated. In the case of CBR and rtVBR, the 48 bits of 112 bits are used for indicating the number of cell arrivals of each segment during a frame. The maximum number of possible arrivals in each segment is 42 because an ONU has maximum 6 NTs. Therefore, the number of arrivals in each segment is indicated sufficiently by using 6 bits. The 48 bits of CBR and rtVBR cell arrival field can cover all 8 segments. We can also mark the number of each arrival in each cell arrival field of 9 bits for nrtVBR, ABR, and UBR during a frame.

C. Procedures of Slot Allocation

The proposed scheme based on the reservation TDMA consists of 4 procedure steps totally:

step 1: OLT periodically transmits to ONU the divided slot grant through downstream PLOAM cell, as shown in Fig.1(b), for investigating the

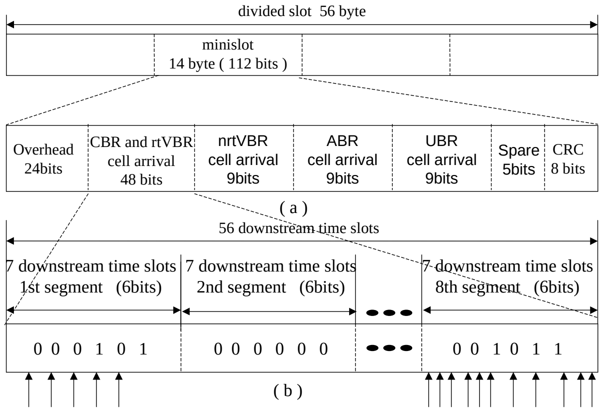

Fig. 2. (a) Upstream divided slot format and minislot format (b) Coding method for CBR and rtVBR cell arrival field.

buffer state of ONU.

step 2: Each ONU which takes the divided slot grant informs the OLT of the information of buffer state by using minislot as shown in Fig.2.

step 3: The scheduler of OLT using the information of minislots allocates the upstream slots to ONUs. Slot allocation algorithm is explained below.

1. Initially, upstream 53 slots of a frame are divided into 8 segments which consist of 7, 7, 7, 7, 7, 6, 6, and 6 slots, respectively. And the divided slots are allocated to the first slot, the second slot, the third slot, and the fourth slot in the first segment of the upstream 53 slots.

2. The requests of all minislots for CBR and rtVBR, nrtVBR, ABR, and UBR are written in the each request memory of the OLT. Especially, the request memory for CBR and rtVBR is divided into 8 segment memories. Each segment data of the CBR and rtVBR cell arrival field of minislot is written in its segment memory of the request memory for CBR and rtVBR.

3. for(segment=1; segment<=8; segment++)

{

1). When the requests of CBR and rtVBR exist in the segment memory, they are randomly selected and are allocated to the empty slots of this segment. If no empty slot of the segment, those requests are allocated to the empty slots of the next segment until all the requests of CBR and rtVBR are allocated.

2). When the requests of nrtVBR exist in the nrtVBR request memory, they are allocated to the empty slots of this segment in proportion to the number of requests from each ONU.

3). When the requests of ABR exist in the ABR request memory, they are allocated to the empty slots of this segment in proportion to the number of requests from each ONU.

4). When the requests of UBR exist in the UBR request memory, they are allocated to the empty slots of this segment in proportion to the number of requests from each ONU.

}

step :4 Finally, the ONU with the data grant as shown in Fig.1(a), transmits ATM cell in the slot allocated.

IV. Simulation Results and Discussions

A. Simulation Model

Basically, the proposed system follows the system parameters mentioned in Section 3. For simulation, we assume that the buffer size of OLT and ONU is infinite. We consider that the number of total terminals is 56(8 FTTHs and 8 FTTCs taking 6 NTs). The traffic source of CBR service is modeled by Bernoulli traffic. The traffic source of the other services is assumed to be ON/OFF traffic model: the PCR of rtVBR is 1.5Mb/s, nrtVBR 0.1Mb/s, ABR 2Mb/s, and UBR 0.1Mb/s. The average length of ON-duration and OFF-duration is assumed to be 10 and 14, respectively.

B. Results and Discussions

To evaluate the performance of the proposed scheme, we compare the proposed scheme with the normal FIFO scheme in which each ONU has one common buffer, and each service has no priority class and no timing information. As shown in Fig.3, in the normal FIFO scheme, each service has nearly same delay characteristics. On the other hand, in the proposed scheme, each service has different delay characteristic owing to different priority. The UBR service with the lowest priority quickly has higher delay in the proposed scheme than the normal FIFO scheme. However, we can understand in Fig.3 that as the load is increased, the proposed scheme has better delay performance than that of the normal FIFO scheme in the nrtVBR and ABR services. For the slot allocation of CBR and rtVBR traffics, the proposed scheme has to wait the time when the requests of all ONUs have been stored in the CBR and rtVBR request segment memory, and then be allocated in accordance with each segment which represents cell arrivals timing information. Therefore, we can find out that the CBR and rtVBR services

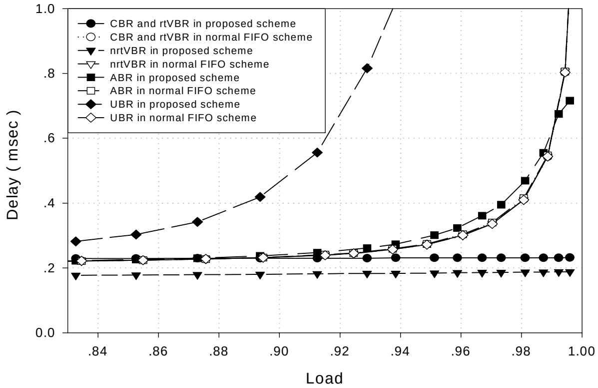

Fig. 3. Cell delay performance.

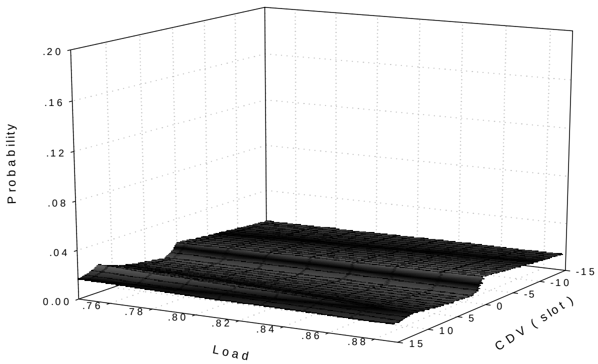

Fig. 4. CDV performance of normal FIFO scheme.

experience somewhat higher delay than those of the other services in the region of low load. However, the CBR and rtVBR services, which is highly sensitive to delay and CDV characteristics, have stable delay variance and the lowest delay in the region of even high load. Therefore, we find out that the proposed scheme provides efficient multimedia services based on delay characteristics.

In Fig.4 and Fig.5, the load axis represents the load experienced by only CBR and rtVBR services. Therefore, Fig.4 and Fig.5 show the probability distribution of CDV according to CBR and rtVBR load. When the load is about 0.8 in Fig.4 and Fig.5, the normal FIFO scheme approximately contains only 25% of CDV performance between -7 slots and 7 slots which are the time resolution of the proposed scheme, and 50% between -15 slots and 15 slots. However, the proposed scheme approximately contains 90% of CDV performance between -7 slots and 7 slots, and 99.9% between -15 slots and 15 slots. Also the normal FIFO scheme and the proposed scheme approximately have the standard deviation of 23.18 and 4.79, respectively. Consequently, we can find out that the proposed scheme with more exact time resolution for CBR and rtVBR services is much superior to the normal FIFO scheme in the CDV performance.

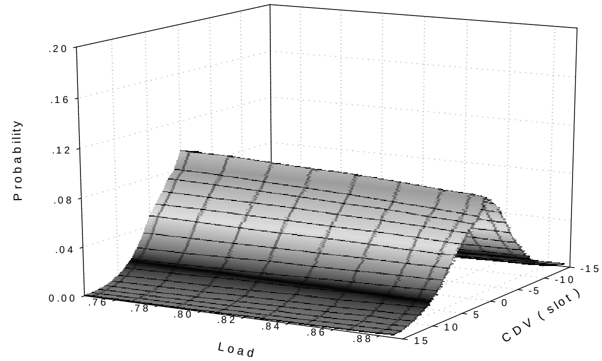

Fig. 5. CDV performance of proposed scheme.

V. Conclusions

In this paper, we proposed a novel MAC scheme based on the cell arrival timing information for multimedia services over APON. From simulation results, we verified that the proposed scheme had much better delay performance than the normal FIFO scheme, especially in the region of high load for CBR, rtVBR, nrtVBR, ABR services. In the CDV performance of CBR and rtVBR, the normal FIFO scheme without timing information had the standard deviation of 23.18 when the load was about 0.8. On the other hand, the proposed scheme with more exact time resolution had only 4.79. Therefore, we can conclude that the proposed scheme is much superior to the normal FIFO scheme in terms of CDV and delay.

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