Upstream Bandwidth Allocation Supporting Differentiated Services in OFDMA PONs

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Abstract--An efficient scheduling algorithm has been proposed for upstream bandwidth allocation in OFDMA PON systems to support differentiated services. Simulation result illustrates that the proposed algorithm obtains high throughput performance and channel utility.

I. Introduction

Orthogonal Frequency Multiplexing Access Passive Optical Networks (OFDMA PONs) [1-2] have numerous advantages such as high capacity access, flexible granularity of bandwidth allocation and compatible Optical Distribution Networks (ODNs). One of the major issues for OFMDA PONs is how to efficiently assign the upstream bandwidth to different ONUs based on their traffic information. There is a traditional two-layer bandwidth allocation (TLBA) scheduling algorithm introduced in [3]. Based on this traditional algorithm, a new scheduling algorithm has been proposed in [4] to improve the bandwidth utilization efficiency and throughput. However, the proposed algorithm in [4] does not consider the Quality of Service (QoS) and fairness of differentiated services.

In this paper, a novel scheduling algorithm for efficient upstream bandwidth allocation in the OFDMA PON systems to support differentiated services with different priorities has been proposed. The proposed scheduling algorithm is hierarchical two-steps scheduling, namely Inter-ONU scheduling and Inner-ONU scheduling. The bandwidth is allocated to ONUs by their total transmitted data weight value in the Inter-ONU scheduling to improve the bandwidth utilization efficiency and throughput, and in the Inner-ONU scheduling, the bandwidth is firstly distributed to the high-priority service to guarantee the QoS and then is proportionately distributed to the other services to keep the fairness. Throughout this paper, services are divided into three classes: Expedited Forwarding (EF), Assured Forwarding (AF) and Best Effort (BE). EF is a high-priority service for voice. AF is a middle-priority service for video applications and BE is a low-priority service for Internet access applications.

From the simulation result, compared with the TLBA algorithm, the proposed algorithm has higher throughput performance and channel utility efficiency by introducing the data weight value. Meanwhile, unlike the algorithm in [4], this novel proposed algorithm guarantees the QoS of the EF service and improves the fairness between AF and BE service.

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II. The Proposed Scheduling Algorithm

A. The sub-channel assignment scheme

The sub-channel assignment scheme for the proposed scheduling algorithm is shown in Fig.1.

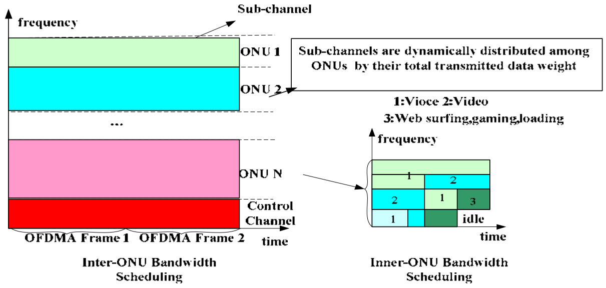

Fig.1 The proposed sub-channel assignment scheme

B. Explanation of symbols

T_{cycle} is the polling cycle of the OFDMA Frame. N is the number of the ONUs in the OFDMA PON systems. The amount of data collected by the Optical Line Terminal (OLT) from each ONU needing to be transmitted through the PON is stored in Matrix L, which can be written as (1)

$$L = \begin{bmatrix} L_{11} \dots\dots L_{1i} \dots\dots L_{1N} \\ L_{21} \dots\dots L_{2i} \dots\dots L_{2N} \\ L_{31} \dots\dots L_{3i} \dots\dots L_{3N} \end{bmatrix} \tag{1}$$

Where L_{1i}, L_{2i} and L_{3i} represents the amount of EF service, AF service and BE service data needing to be transmitted in ONU i (i=1,2…,N), respectively.

Suppose there are K sub-channels in OFDMA PON system and the size of each sub-channel is f_B .The bandwidth efficiency of each sub-channel is same, namely η. The weight value of EF service, AF service, and BE service is P_1, P_2, and P_3 respectively, where $P_1>P_2>P_3$. Average weight value is $AW=[A_1,A_2,\dots,A_N]$ and total weight value is $TW=[T_1,T_2,\dots,T_N]$,where $A_i=(L_{1i}\times P_1+ L_{2i}\times P_2+ L_{3i}\times P_3) / (L_{1i} + L_{2i} + L_{3i})$ represents the average weight value of ONU i and $T_i= L_{1i}\times P_1+ L_{2i}\times P_2+ L_{3i}\times P_3$ represents the total weight value of ONU i (i=1,2,…,N). Set S_i records the sub-channels occupied by ONU i. Obviously, $S_i \cap S_j = \emptyset (i \neq j)$. Suppose $X=(x_{ij})_{K\times N}$ is $K \times N$ dimension matrix, where x_{ij}=0 or 1. If x_{ij}=1, it represents sub-channel i is occupied by ONU j; if x_{ij}=0, it represents sub-channel i is not occupied by ONU j. D_{max} represents the largest number of the sub-channels that one ONU can occupy. $B=T_{cycle}\times f_B\times\eta$ is the amount of transmitted data of each sub-channel during each OFDMA frame duration cycle.

The assigned bandwidth size of different priority services in each ONU after the proposed algorithm will be recorded in matrix W, which can be written as (2)

$$W=\begin{bmatrix} W_{11}\cdots\cdots W_{1i}\cdots\cdots W_{1N} \\ W_{21}\cdots\cdots W_{2i}\cdots\cdots W_{2N} \\ W_{31}\cdots\cdots W_{3i}\cdots\cdots W_{3N} \end{bmatrix} \quad (2)$$

Where W_{1i}, W_{2i} and W_{3i} represents the number of EF service, AF service and BE service bandwidth size assigned in ONU i ($i=1,2...,N$), respectively.

C. The Proposed Scheduling Algorithm

Inter-ONU scheduling algorithm:

Step 1: Let $S_i=\varnothing$ (i=1,2…,N), $X_{K\times N}=0_{K\times N}$, calculate AW,TW, and B, k=1 and determine D_{max};

Step2: $i=\arg\max_{i\in\{1,2,\ldots,N\}} T_i$;

Step3: Let x_{ki}=1 and update matrix $X_{K\times N}$, put the sub-channel k into the set S_i and $T_i=T_i-B\times A_i$;

Step4: If $Num(S_i)\geq D_{max}$ or $T_i\leq 0$, let T_i=0, where the operation $Num(S_i)$ represents calculating the number of elements in the set S_i;

Step5: If $k=K$, then finish the algorithm and the distribution of sub-channels among ONUs can be seen in sets S_i (i=1,2,…,N). Otherwise, let k:=k+1,and go to step2.

Inner-ONU scheduling algorithm:

After Inter-ONU scheduling algorithm, we know ONU i gets $Num(S_i)$ sub-channels, let $W_{traffic}(i)=Num(S_i)\times B$ and $W_{rest}(i)=W_{traffic}(i)-W_{1i}$,where i=1,2…N.

Step1: Considering the high-priority of the EF service and guaranteeing the QoS, we should satisfy this service completely. Hence, $W_{1i}=L_{1i}$ (i=1,2,…,N);

Step2: Considering the fairness between AF and BE service, we assign the rest bandwidth according to the weight value proportion of the transmitted data, namely

$$W_{2i}=W_{rest}(i)\times\frac{L_{2i}\times P_2}{L_{2i}\times P_2+L_{3i}\times P_3};W_{3i}=W_{rest}(i)\times\frac{L_{3i}\times P_3}{L_{2i}\times P_2+L_{3i}\times P_3}\quad(i=1,2...,N) \quad (3)$$

III. Performance Evaluation

In this Section, we investigate the channel utilization (CU) and throughput performance of our proposed algorithm. CU is defined as $CU=M/D$, where D is the total amount of data needing to be transmitted and M is the total amount of data transmitted in OFDMA frame cycle. The simulation setup is as follows. Assume the OFDMA PON supports 32 ONUs and the upstream/downstream data rate is set as 10Gb/s. We consider 2048 OFDMA sub-channels, among which 32 sub-channel are shared by ONUs as message control channel. T_{cycle}=2ms, η=1$b/s/HZ$, D_{max}=256, P_1=9, P_2=5 and P_3=3. The proportion of different service is EF:AF:BE=2:3:4. We assume the traffic flows of each service are modeled by exponential sequence. To illustrate the performance of proposed scheduling algorithm, TLBA algorithm in [3] is also simulated based on the same condition.

In Fig.2, it's clearly that when traffic load<0.7, the throughput of the two scheduling are similar; when the traffic load>0.7, the throughput of TLBA is smaller than that of the proposed algorithm because of the failure of exploiting statistical multiplexing gain. Furthermore, the proposed scheduling algorithm not only guarantees the QoS of EF service, but improves the fairness between AF and BE service. In Fig.3, we can know that the channel utility of the two algorithms is similar when load<0.6. However, when load>0.6, the channel utility of the proposed algorithm is greater than that of TLBA.

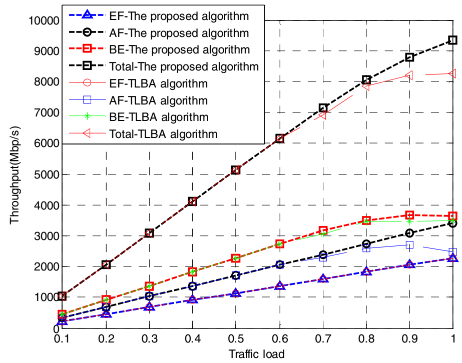

Fig.2 The throughput of different services of the two algorithms

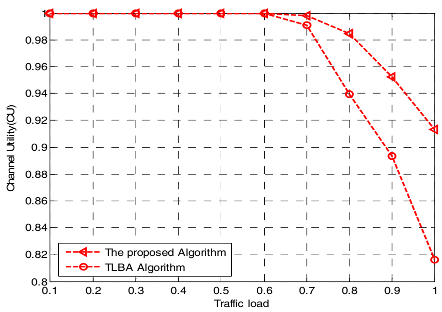

Fig.3 The channel utilization of the two algorithms

IV. Conclusions

This paper proposes a novel hierarchical two-steps scheduling algorithm for upstream bandwidth allocation in OFDMA PON systems. Simulation results illustrate the proposed algorithm has high throughput performance and channel utility. Meanwhile the proposed algorithm guarantees the QoS of the high-priority service and improves the fairness between AF and BE service.

References

[1]. D. Qian, J. Hu, and T. Wang, "10-Gb/s OFDMA-PON for Delivery of Heterogeneous Service," *OFC* 2008.

[2]. W. Wei, T. Wang, and C. Qiao," Resource Provisioning for Orthogonal Frequency Division Multiple Access (OFDMA)- based Virtual Passive Optical Networks (VPON)," *OFC* 2008.

[3]. J.Xie S.Jiang, and Y. Jiang, "A Dynamic Bandwidth Allocation Scheme for Differentiated Service in EPONS," *IEEE Communications Magazine,* vol. 43, pp.32-49, 2004.

[4]. Jingjing Zhang, Ting Wang, and NIrwan Ansari, "An Efficient MAC Protocol for Asynchronous ONUs in OFDMA PONs," *OFC* 2011.