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Limited Bandwidth Allocation with Sliced Credit in Gigabit Passive Optical Network

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Abstract: Limited bandwidth allocation with sliced credit (LBA-SC) is proposed and used in Gigabit passive optical network (GPON). Simulation results show that packet delay of high priority service can be dramatically reduced by using predictive SC grants.

Introduction

Most current dynamic bandwidth allocation (DBA) algorithms concentrate on Ethernet passive optical network (EPON), such as IPACT [1], BGP [2], HSSR [3], LSTP [4] and D-CRED [5]. As EPON works in asynchronous way, optical line terminal (OLT) can send bandwidth allocation grant in downstream at any time, and require optical network unit (ONU) to report bandwidth request in upstream during the allocated time slot. However, in Gigabit PON (GPON), fames are aligned periodically in 125μs-length in both downstream and upstream directions. The bandwidth allocation grants and bandwidth requests are transmitted as frame headers instead of specific control frames in EPON. As a result, OLT and ONU can exchange bandwidth information with each other more frequently. Additionally, the upstream bandwidth must be allocated based on the 125μs period. Since the typical cycle time of polling DBA is set as 1 or 2 ms, due to the limitation of hardware capability, new DBA algorithm for GPON is necessary because allocations based on the relatively long cycle time may be cut by the 125μs frame length, leading to bandwidth waste and low efficient.

In this paper, limited bandwidth allocation with sliced credit (LBA-SC) is proposed for GPON system. Services from ONU side are sorted as high priority (HP) and low priority (LP) service, which are served by OLT in different way. Continuous time slots below a length limitation are allocated to both services and additional sliced credit (SC) slots are allocated to only HP, so that the efficiency of LP service is maintained and the packet delay of HP service is dramatically reduced.

Bandwidth Map and DBRu in LBA-SC

In GPON, bandwidth allocations are enclosed in upstream bandwidth map (US BW map) [6]. As shown in Fig. 1, each allocation includes allocation identifier (Alloc-ID), start and stop time, where Alloc-ID indicates a communication flow, e.g. a subscriber or an ONU. Since the minimum processing time of ONU is 16.384 μs [7] and within one frame, the allocation in downstream frame (DSFrame) i is acquiescently used in upstream frame (USFrame) i+1.

The grants for each USFrame include two parts: sliced credits (SC) and limited allocations (LA). SC part carries short pieces of payload coming from all users, with dynamic bandwidth report upstream (DBRu), and LA part carries long pieces of payload from partial users. So in each USFrame, OLT receives bandwidth reports from all users, meanwhile, in each DSFrame, all users receive SC grants and some users receive LA grants. After received grants, users transmit data accordingly so that mentioned operations are repeated frame by frame.

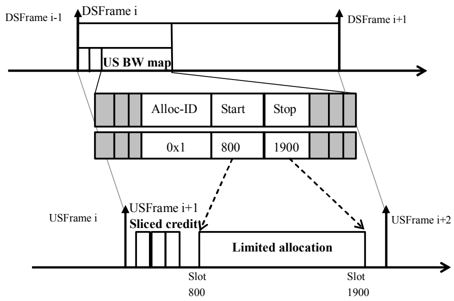


Fig.1. Bandwidth allocation by SC and LA grants

Fig.2 shows the HP and LP service in ONU, where time division multiplexing (TDM) and voice over IP (VoIP) are sorted as HP service, and other internet protocol (IP) based services are sorted as LP service. All IP packets including VoIP, IP1, IP2 and IP3 are managed by strict priority queuing. These packets are then encapsulated and multiplexed with TDM cells for transmitting.

As [6] defines, ONU can choose to report total queue length in 1 byte or report separate queue length in 2 or 4 bytes message enclosed in DBRu. Therefore, from the simple 1-byte DBRu OLT can get only total bandwidth request, and from the complicated DBRu OLT can get separate bandwidth requests about HP and LP service. In LBA-SC, these two kinds of DBRu are processed differently when OLT assigns SC grants.

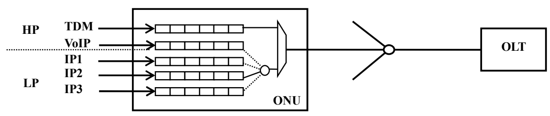


Fig.2. Services with different priority in ONU

Limited Bandwidth Allocation with Sliced Credit

LBA-SC assigns upstream bandwidth as two parts, SC and LA, as mentioned in the last section. SC grant is distributed to all users in every frame for the data coming after ONU transmitting the last DBRu. As shown in Fig.3, DBRu i-2 and DBRu i-1 are utilized to predict the data coming in Frame i-1.

The difference of HP bandwidth requests in these two DBRu is directly used as SC i in the case that DBRu includes separate HP/LP reports, or the difference of total bandwidth requests in these two DBRu is used as SC i after multiplying with a HR coefficient in the case that DBRu only includes the simplest report. In order to avoid sending too short SC, which will be omitted by ONU, or too long SC, which leads to possible bandwidth waste, the calculated SC grants are checked and limited in a range of 64~512 bytes, since 19440 bytes is the total length of a 125μs frame with 1.24Gbit/s bit-rate. After receiving SC i, ONU transmits HP data with DBRu in Frame i+1.

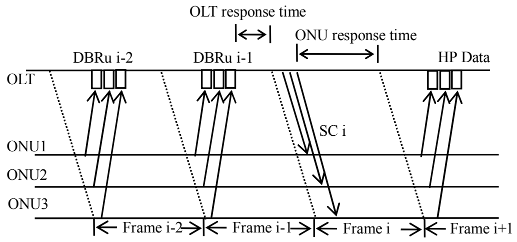


Fig.3. Calculation and transmitting of sliced credit

Unlike sending SC grant, OLT sends LA grants to users in flexible polling cycle. All ONUs send DBRu in each frame, however, some of them are omitted in LA assignment. The length of LA grant is set as total bandwidth request in the last DBRu, and is limited by the minimum value of 64. When the surplus bandwidth of current frame is less than 64, OLT ignores it. Moreover, when the surplus bandwidth of current frame is more than 64 and less than the bandwidth request of current ONU, OLT assigns the surplus bandwidth to this user and keeps serving this user in the next frame. As the result, one user can obtain consecutive LA grants, however, up to 4 frames. In the example shown in Fig. 4, OLT begins from ONU1 in Frame i-1 by using DBRu i-2, and goes on with ONU2 when there is bandwidth left. After serving ONU2, there is no enough surplus bandwidth so OLT waits and assigns LA to ONU3 in Frame i by using DBRu i-1.

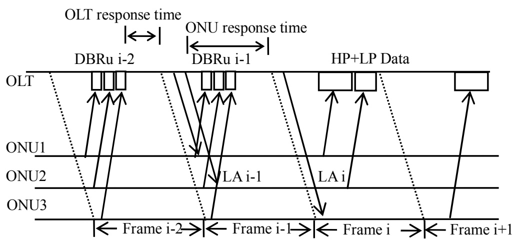
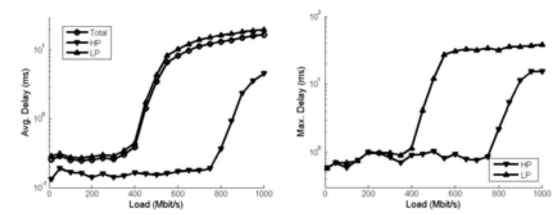


Fig.4. Calculation and transmitting of limited allocation

By using mentioned SC and LA together, the packet delay of HP service can be dramatically reduced because of predictive SC grants sending in 125μs period, and the efficiency of LP service is maintained by LA grants. Although in practical system grants may be decided based on the DBRu received several frames ago because of the response time of OLT, SC grant still takes effect, however, when the variation period of the traffic is more than the OLT response time,.

Simulation Result and Discussion



(a) (b)

Fig.5. Packet delay of high/ low priority services

(a) Average delay; (b) Maximum delay

In the simulation, there are 16 ONUs connected to 1 OLT and the total upstream bandwidth is set as 1.24Gbit/s. The traffic for each ONU includes 20% HP packets and 80% LP packets, both in length of 512 bytes, chosen from the popular packet length of 64 bytes, 256 bytes, 512 bytes, and 1518 bytes. The OLT response time is set as one frame, as well as the ONU response time.

Fig. 5 shows the average and maximum packet delay, where the delay of LP service increases with total load beyond 400Mbit/s, and that of HP service keeps low level before the load reaches 800Mbit/s. The average delay of HP service is less than 0.2 ms with load from 0 to 800Mbit/s, and the variation of its maximum delay is below 1ms in the same range, indicating low jitter for real-time services. So LBA-SC can provide HP services with good performance.

Conclusions

In this paper, LBA-SC is proposed for dynamic bandwidth allocation in GPON system. The upstream services are sorted as HP and LP service, and are served in different way, where continuous time slots below the limitation are allocated to both and additional sliced credit time slots are allocated to HP. Simulation results show that the packet delay of HP service can be dramatically reduced by using predictive SC grants. The average delay of HP service is less than 0.2 ms when the total load increases from 0 to 800Mbit/s, and the variation of the maximum delay is below 1ms in the same range. At the same time, packet delay of LP service increases with total load more than 400Mbit/s.

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