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Dynamic Bandwidth Allocation Algorithm for XG-PON with Traffic Monitoring and Intra-Scheduling

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Abstract. This paper proposes a new scheme for dynamic bandwidth allocation for XG-PON (10-Gbps-capable passive optical network). In the propose scheme, an ONU (optical network unit) does not explicitly report its queue status to an OLT (optical line termination). The OLT monitors the bandwidth usage of each ONU to estimate the queue status of each ONU. The OLT allocates a bandwidth to an ONU when the previous allocated bandwidth was fully used. Also the OLT periodically allocates a probe bandwidth to an ONU to check the queue status of the ONU.

Keywords: XG-PON, DBA, traffic monitoring.

1 Introduction

XG-PON (10-Gbps-capable passive optical network) system consists of an OLT (optical line termination) and multiple ONUs (optical network units). To support QoS, an ONU maintains multiple queues for multiple service classes. In the XG-PON technology, a service class is known as T-CONT (transmission container) type. When the OLT sends packets to ONUs, a broadcasting mechanism is used. All ONUs receives a same packet from the OLT and accepts only if the destination of the packet is matched. Otherwise, the packet is discarded. When ONUs send packets to the OLT, only one ONU is allowed to transmit a packet to the OLT at the same time. If more than two ONUs transmit packets to the OLT at the same time, a collision occurs between the packets. To prevent the collision, the OLT performs a DBA (dynamic bandwidth allocation) to allocate the transmission time slot to each ONU [1][2].

For the DBA, the OLT has to know the request status of each queue of each ONU. Two methods can be used to know the queue status. The first method is a SR (status report) method that an ONU explicitly reports its queue status using a DBRu (dynamic bandwidth report upstream) field. The second method is a TM (traffic monitoring) method that an ONU does not report its queue status but the OLT estimates the queue status from the bandwidth usage of an ONU.

The SR method consumes the upstream bandwidth for the DBRu field. The OLT has to allocate upstream bandwidth not only for data packets but also for the DBRu field for an ONU. Also the OLT has to manage the report status of all ONUs for the DBA operation [3]-[6]. The TM method is relatively simple because the OLT does

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not need to manage the report status. To the best of our knowledge, the TM method has never been studied despite the simplicity of the TM method.

In this paper, we propose a new DBA scheme that uses the TM method. The OLT monitors the bandwidth usage of an ONU not a single queue of an ONU to decrease an estimation error. Also a grant is allocated to an ONU not a single queue of an ONU. The ONU performs an intra-scheduling to allocate the grant slot to its queues based on the T-CONT types.

2 Traffic Monitoring

An XG-PON system consists of a single OLT and N ONUs. To support multiple service classes, ONU has multiple queues. The service class is known as the T-CONT (traffic-container) type in the XG-PON technology. T-CONT types 2, 3 and 4 are considered in this paper. A packet arrived at an ONU from users is saved to a queue based on the T-CONT type of the packet. In upstream direction, only one ONU can transmit a packet to the OLT at a time. If two or more ONUs transmit packets to the OLT at the same time, a collision occurs. The OLT performs a DBA operation to avoid the collision. In this paper, each ONU does not report the requests of its queues to the OLT. Instead of receiving requests, the OLT monitors the bandwidth usage of each ONU to estimate the status of each ONU.

Every operation of an XG-PON system is synchronized with a frame duration (FD) of 125 μs. In each FD, the OLT produces the DBA result and then makes a bandwidth map (BWmap) to notify the DBA result to each ONU. During the DBA operation, the total size of the transmission slots is limited by the size of the FD.

It is obvious that an estimation error exists when we estimate the status of a queue of an ONU by monitoring the bandwidth usage of the queue. The estimation error will cause the inefficiency of DBA operation. To decrease the error and to minimize the effect of the error, we monitor the bandwidth usage of an ONU not a queue. The OLT estimates the total requests of all queues of an ONU and then produces a grant for the ONU. Then the ONU schedules the grant to its queues.

In the proposed method, ONU i has a service parameter A(i), and a timer T(i). The parameter A(i) is the allocation bytes that can be allocated to ONU i in each FD and the timer T(i) is the probe interval of ONU i in the unit of FD. Let G(i) be the grant for ONU i. Also suppose U(i) is the used portion of G(i) by ONU i. There is a time gap between G(i) and U(i). The OLT can check the used portion U(i) when the OLT receives the frames from ONU i after the grant G(i) is delivered to the ONU i. The time gap is 2 FDs if the distance between the OLT and an ONU is 20 km.

The proposed algorithm is based on the two facts: (i) if U(i) = G(i) then, the grant was not sufficient to serve all waiting frames and ONU i has remaining frames, (ii) if U(i) < G(i) then, the grant size was greater than the total size of all waiting frames and ONU i may or may not have newly arrived frames. In the fact (i), for simplicity, we ignore the case that the grant G(i) is the same as the size of the waiting frames. In this case, ONU i may not have remaining frames.

In the first stage of the proposed algorithm, we allocate a grant for each ONU based on the used portion U(i). For the case of the fact (i), we allocate A(i) for the grant of ONU i since ONU i has remaining frames. For the case of the fact (ii), we do not allocate any bandwidth for ONU i since it is not clear whether or not ONU i has a frame.

In the case of fact (i), if U(i) = G(i) = 0, that means no grant was allocated to ONU i. In this case, we do not allocate any new grant to ONU i since we do not have any information for ONU i. Once ONU i gets no grant, i.e., G(i) = 0, ONU i will never get a grant again. To prevent this starvation, we use the timer T(i) and a flag F(i). If F(i) = 1 and A(i) = 0, then we allocate P(i) for the grant of ONU i where P(i) is probe bytes that is used to probe the status of ONU i. In this paper, we assume that P(i) < A(i). Once P(i) is allocated to ONU i, we set F(i) = 0. The timer T(i) is decreased by 1 in every FD. When the timer T(i) has expired, the flag F(i) is set to 1 and T(i) is recharged to S(i) where S(i) is a probing interval of ONU i. The pseudo code of the first stage is given by

```
if (U(i) = G(i)  and U(i) > 0) {
    G(i) = A(i);
}
else if (F(i) = 1) {
    G(i) = P(i);
    F(i) = 0;
}
else {
    G(i) = 0;
}
U(i) = 0;
T(i) --;
if (T(i) == 0) {
    F(i) = 1;
    T(i) = S(i);
}
```

We now explain the second stage of the proposed algorithm. Let R be a remaining scheduling byte after the first stage. The initial value of R before the first stage is depends on the upstream bandwidth. For example, the initial value of R is 38,880 bytes if the upstream bandwidth is 2.5Gbps. In the second stage, the remaining scheduling byte R is fairly allocated to all ONUs. That is G(i) = G(i) + R/N for all ONU I where N is the number of ONUs.

For guaranteeing the service fairness among ONUs, the starting ONU number of scheduling operation is updated in each FD. For example, if the scheduling operation starts from ONU 1 in the current FD, then the starting ONU number will be 2 in the scheduling operation of the next FD.

When ONU i receives a grant G(i), the priority for the grant is in the order of T-CONT types 2, 3 and 4. First, the queue of T-CONT type 2 transmits its packets using the grant G(i) slot. Then the queue of T-CONT type 3 can send its packets using the remainder of the grant G(i). Finally, the queue of T-CONT type 4 can dispatch its packets using the remainder of the grant G(i).

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