Multicast polling for 10G-EPON

W. Lim, Y. Yang and M. Milosavljevic

This paper proposes a multicast polling scheme for 10G Ethernet passive optical networks (10G-EPONs). In multicast polling scheme, the GATE message is broadcast to all ONUs with a new op-code of 0007. Comparing the proposed multicasting with traditional unicasting scheme, the downstream bandwidth consumption for control packet of the multicast is 0.011% compared with the unicast of 0.11% at the cycle time of 2ms. As a result of the upstream performance, the channel utilization improves 3% and the saturation offered load of the end-to-end delay for multicast and unicast is 0.8 and 0.7 respectively.

Introduction: The increasing demands of recent applications lately lead the research towards increased-capacity optical access solutions [1-2]. To support high bandwidth demands, the IEEE 802.3av 10G-EPON [3] has been standardized as one of the effective solutions for the realization of the next generation access network. The 10G-EPON supports the backward compatibility of EPON, low-power budge, compulsory forward error correction and dual-rate mode of downstream (10 Gbps and 1 Gbps) [3].

The OLT of the 10G-EPON transmits the GATE message for bandwidth granting using the unicasting scheme like 1G-EPON. The unicasting scheme implies that the OLT sends the GATE message to each ONU individually. Although this scheme is standardized [3], this can affect the network performance in terms of increased downstream bandwidth consumption, packet delay of upstream as well as reduced upstream utilization. To overcome these issues, this paper presents a multicast polling scheme based on OLT-centralized polling control message exchange. This approach is expected to improve the above performances in the presence of different class of services (CoS) and service level agreements (SLAs). By doing centralized polling, the OLT is aware of all ONUs bandwidth requirements therefore providing inter and intra dynamic bandwidth allocation (DBA).

Multicast polling for GATE message transmission: The multi-point control protocol (MPCP) protocol, standardized by IEEE p802.3av [3], provides services based on bandwidth requests and permission grant avoiding collisions in upstream. The protocol relies on two Ethernet control messages, named as GATE and REPORT. The multicasting scheme is proposed such that every ONU is polled periodically in a burst manner resulting in one GATE message for three different traffic classes to be sent to all ONUs. Compared to the previous control polling schemes [4], multicast polling requires a special control message to be added (op-code 0007 of Fig.1) on current fields in the GATE frame.

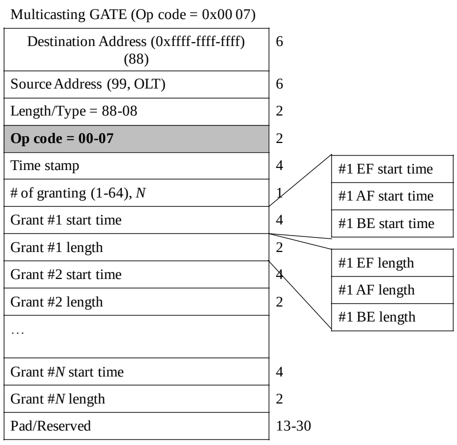

Fig. 1 *Proposed GATE message format for multicasting.*

Multicast polling is based on the concept of a group for gating. As a result, an arbitrary group of ONUs expresses an interest in receiving a GATE message from the OLT. The corresponding ONU must join the group, thus the OLT knows who the expected receiver is. The detailed operation is as follows:

1. Initially, the OLT send GATE message to all ONUs in a group using a single frame called multicast message. The payload of the packet contains each ONU's grant start time and length.

2. At specified cycle time, the OLT sends the single multicast message with the destination address '0x88'. Upon receiving GATE from the OLT, all ONUs reschedule their transmission start time and time slot. The ONU will then start sending its data based on the granted bandwidth from the OLT.

Dynamic Bandwidth Allocation: This section proposes two bandwidth allocation methods; the inter ONU scheduling among ONUs according to their SLA level and intra ONU scheduling according to three traffic classes.

1. Inter ONU scheduling: In the inter ONU scheduling, the OLT allocates surplus bandwidth according to three SLA levels with different weights, W_s, s = 0, 1, 2 from high to low priority. First the minimum guaranteed bandwidth, B_{MIN}, is defined as $B_{MIN} = (T_{cycle} - N \times T_g) \times R_{up} / N$ where T_{cycle} is the cycle time, N is the total number of ONUs, T_g is the guard time and R_{up} is the upstream capacity. The OLT calculates the surplus bandwidth, $B_i^{surplus}$, as follow

$$B_{h\,(h\in H)}^{surplus} = \frac{\left\{\sum_{l\in L}(B_{MIN} - B_l^{req})\right\} \times W_{\text{SLA of } h}}{\sum_{s=0}^{2} W_s N_s} \quad (1)$$

Note that B_i^{req} is the bandwidth requirement of the i^{th} ONU, H is the set of the heavily loaded ONUs ($B_i^{req} > B_{MIN}$), L is the set of the light loaded ONUs ($B_i^{req} < B_{MIN}$) and N_s is the number of ONUs subscribed to service level. Finally, the OLT allocates the granted bandwidth, B_i^g as follows

$$B_i^g = \begin{cases} B_i^{req} & , B_i^{req} < B_{MIN} \\ B_i^{req} + B_i^{surplus} & , B_i^{req} > B_{MIN.} \end{cases} \quad (2)$$

2. Intra ONU scheduling: The granted bandwidth, B_i^g, is the input parameter to the intra ONU scheduling for calculating each grant size for expedited forwarding (EF), assured forwarding (AF) and best effort (BE) classes. Two different sets of bandwidth profile, normal EF (sum of B_i^g < total capacity) and high EF (sum of B_i^g > total capacity), are applied to get the grant size of each traffic class. In normal bandwidth profile the grant size of each traffic class is obtained according to the following ratio: EF: AF: BE = 1.0: 1.0: 1.0. In case of high EF bandwidth profile, the ratio becomes: EF: AF: BE = 5.0: 3.0: 2.0. Finally, after finishing the inter ONU scheduling the GATE message includes three grant sizes to each ONU.

Performance evaluation: In this section, the performance evaluation of the proposed scheme is presented.

1. Simulation model description: In order to validate the proposed multicast polling scheme industrial standard OPNET network simulator is used. The simulation model consists of one OLT and 32 ONUs. The distance between the OLT and each ONU is 20 km. This paper is based on the symmetric 10G-EPON traffic model. Three SLAs, $SLA_{1\text{-}3}$ from high to low priority have been considered. The number of ONUs in each service level is set to 2, 10 and 20 respectively. The grant processing, propagation delays and guard time between ONUs are considered at 0.5 μs, 0.5 μs/km and 1 μs respectively. The traffic consists of three classes of packets: EF, AF and BE. The network traffic is implemented by a Pareto self-similar traffic model with a typical Hurst parameter of 0.8. By increasing the number of packets per second, the offered load is varied from 0.1 (10 Gbps × 0.1 = 1 Gbps) to 1.0 (10 Gbps). In terms of the traffic profile, 20 % of the total generated traffic is considered for EF and the remaining 80 % is equally distributed between AF and BE traffic. The packet size is uniformly generated between 64-1518 Bytes. The ONU offered load of 1.0 represents 312.5 Mbps (10 Gbps / 32 ONUs = 312.5 Mbps).

2. Simulation Results: Table 1 shows the improvement of the comparison of the downstream bandwidth consumption (DBC) for control packet. The DBC for the GATE message is calculated by

$$\text{DBC (\%)} = n \times \frac{(8+12+64+m)\text{byte} \times 8\text{bit/byte}}{T_{cycle}} \times \frac{1}{10\text{Gbps}} \times 100 \qquad (3)$$

where an 8-byte is for preamble, a 12-byte is for inter-frame gap (IPG) and a 64-byte is for traditional GATE message. Note that n is the number of polling times (for unicast, n=32 and for multicast, n=1) and m is the length and start time of the remaining ONUs (for unicast, m=0 and for multicast, m=31 ONUs×6 bytes for length and start time in Fig. 1).

Table 1: Comparison of downstream bandwidth consumption of control packet between Unicast and Multicast.

Cycle time (T_{cycle}, ms)	1	2
Unicast DBC (%)	0.22	0.11
Multicast DBC (%)	0.022	0.011

Fig. 2 displays the achieved upstream channel utilization of the multicasting scheme. It can be observed that for multicasting scheme the maximum data rate on the network is 8.1 Gbps however for unicast the saturation point is at 7.8 Gbps. Furthermore, Fig. 3 displays the upstream packet delay for all three SLAs versus ONU offered load. It can be observed that the threshold ONU loadings for the unicasting and multicasting scheme to achieve the saturation are 0.7 and 0.8 respectively. It means that the overall network offered load is less than 7.0 or 8.0 Gbps ([0.70 or 0.80] × 312.5 Mbps × 32 ONUs = 6.0 or 8.0 Gbps). The increase of 1.0 Gbps represents a 16.6 % improvement for the multicasting scheme. It also becomes evident from Fig. 3 that the ONU offered load, before packet delay reaches the 5 ms limitation for time-sensitive traffic, has been extended from 231.25 Mbps to 246.88 Mbps for SLA2 ONUs. The gained 55.63 Mbps bandwidth can then be utilized to support additional multimedia services for each ONU, such as online gaming, education-on-demand, and video conferencing.

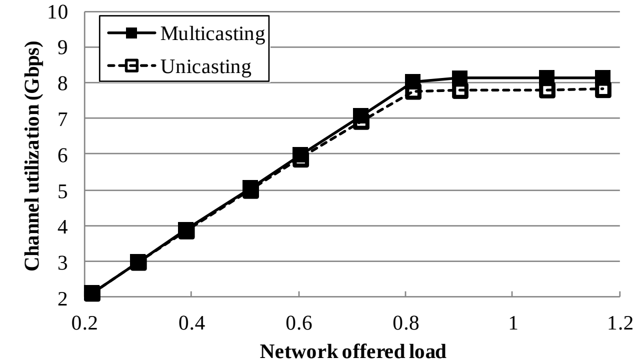

Fig.2 *Comparison of channel utilization.*

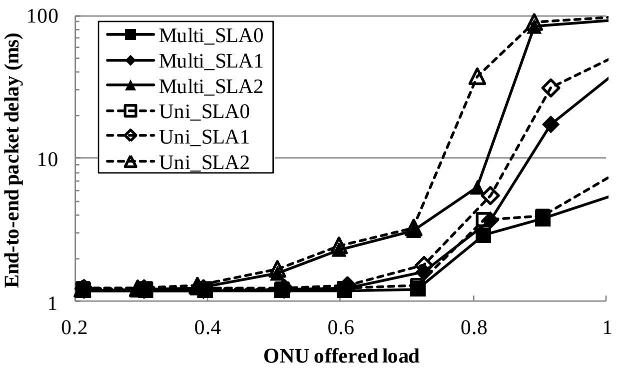

Fig. 3 *End-to-end packet delay according to three SLAs.*

Conclusion: In order to provide QoS aware MAC protocol for next generation access network, this paper demonstrated a multicast polling scheme for 10G-EPONs. The performance in the distinction of three SLA levels and CoS grades for a 20 km reach, 32-split has been evaluated. In particular, the OLT transmits the GATE message using the multicasting scheme with a new op-code of 0007 instead of the traditional unicasting resulting in reduced downstream bandwidth consumption and packet delay of upstream while improving the channel utilization of upstream.

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