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# A novel early DBA mechanism with prediction-based fair excessive bandwidth allocation scheme in EPON ☆

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**Abstract**

In this paper, we propose a novel *Early dynamic bandwidth allocation* (E-DBA) mechanism incorporated with a prediction-based fair excessive bandwidth allocation (PFEBA) scheme in Ethernet passive optical networks (EPONs). The E-DBA mechanism can reduce the *idle period* in the traditional DBA mechanism. On the other hand, the PFEBA scheme can provide more accurate prediction to ensure the fairness of each ONU and improve the overall system performance. The proposed model makes prediction for different traffic classes according to the variation in traffic for each ONU in the EPON. The PFEBA scheme includes the *unstable degree list*, predictions made using *linear estimation credit* and the fair excessive bandwidth allocation scheme. The simulation results show that the proposed E-DBA mechanism with PFEBA scheme can improve the system performance of well-known DBA algorithms in terms of wasted bandwidth, wasted bandwidth improved percentage, downlink data available bandwidth, throughput, average end-to-end delay and average queue length, especially under high traffic load.


*Keywords:* E-DBA; PFEBA; EPON; Fairness; System performance

## 1. Introduction

The high-capacity feature of multi-access optical fiber networks compared with other access network technologies is the main motivation behind advances in optical technology. The passive optical network (PON) is regarded as a promising solution for the next-generation broadband access network because it is simple, cost-effective and scalable. The PON architecture, shown in Fig. 1, comprises a centralized optical line terminal (OLT), splitters, and connects a group of associated optical network units (ONUs) over point-to-multipoint topologies to deliver broadband packet and reduce cost relative to maintenance and power.

Two standard organizations, International Telecommunications Union Standardization Sector (ITU-T) and Institute of Electrical and Electronics Engineers (IEEE), have led the discussion of PON specifications. In ITU-T, a series of ATM-based Broadband PON (i.e., ATM-PON, BPON and GPON), have been recommended [1]. On the other hand, Ethernet PON (EPON) has been discussed in IEEE 802.3ah as one of the extensions of Gigabit-Ethernet [2]. The main difference between EPON and ATM-based Broadband PON is that EPON carries all data encapsulated according to the IEEE 802.3 Ethernet frame format between the OLT and ONUs. Low maintenance cost, compatibility compared with existing networks, and minimal protocol overhead make EPON a promising solution for the next-generation broadband access networks. Moreover, the EPON is the primary type of PON technology that reduces fiber deployment dramatically while preserving the merits of Ethernet networks.

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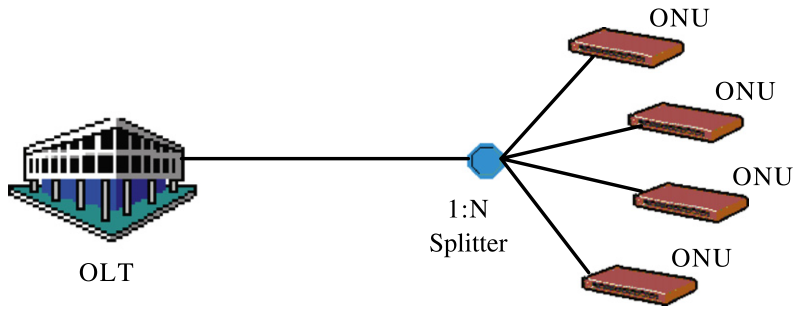


Fig. 1. Tree-based PON topology.

The EPON provides bi-directional transmissions, one is downstream transmission from OLT to ONUs; the other is upstream transmission from ONUs to OLT in sequence. In the downstream transmission of the EPON, all the control messages and the data packets are carried and broadcasted from the OLT to each ONU through the entire bandwidth of one wavelength as a downstream channel. Each ONU discards or accepts the incoming Ethernet frames depending on the packet header addressing. In the upstream direction, all ONUs share the common transmission channel towards the OLT, only a single ONU may transmit data in its time slots to avoid data collision. Hence, a robust mechanism is needed for allocating time slots and upstream bandwidth for each ONU to transmit data. In EPONs, the mechanism is called *multi-point control protocol* (MPCP) involving both GATE messages and REPORT messages. The OLT allocates upstream bandwidth to each ONU by sending GATE messages with the form of a 64-byte MAC control frames. GATE messages contain a timestamp and granted time slots which represent the periods that ONU can transmit data. ONUs may send REPORT messages about the queue state of each ONU to the OLT, so that the OLT can allocate the upstream bandwidth and time slots to each ONU accordingly.

In other words, the EPON can be regarded as a multi-point-to-point network in the upstream direction where multiple ONUs share the same transmission channel and transmit data to the OLT. Hence, an important issue for emerging research is how to access the shared bandwidth allocation by medium access control (MAC) protocols to prevent collision and share the channel capacity fairly among ONUs to provide better system performance. The bandwidth allocation schemes can be divided into two categories: *fixed bandwidth allocation* (FBA) and *dynamic bandwidth allocation* (DBA). In the FBA scheme, each ONU is pre-assigned a fixed time slot (TDMA scheme) to send its backlogged packets at the full capacity of the link. This will lead to inefficient bandwidth utilization when the traffic of ONUs is light. Contrast to the FBA, the DBA assigns the bandwidth according to the bandwidth requested by each ONU. Therefore, the DBA scheme can provide more efficient bandwidth allocation for each ONU to share the network resources and offer better Quality-of-Service (QoS) for end-users than the FBA scheme.

First, this paper proposes an *Early DBA*(E-DBA) *mechanism* for reducing the idle period in the traditional DBA mechanism. Second, the E-DBA sorts the sequence of each ONU according to the variance in historical traffic required and arranges some REPORT messages of ONUs with the violent variance in traffic required to precise DBA time. Therefore, the OLT can get the fresh queue information to make more accurate prediction for the next cycle. Furthermore, the efficient and robust prediction-based fair excessive bandwidth allocation (PFEBA) scheme is incorporated to consider the fairness of excessive bandwidth allocation among ONUs in the EPON to improve system performance. For the concept of fairness, not only the heavily-loaded ONUs, but also the lightly-loaded ONUs are considered in the proposed scheme.

The proposed model makes prediction for different traffic classes according to the variation in traffic for each ONU in the EPON. In this paper, we discuss an EPON architecture that supports differentiated services and classify services into three priorities as defined in [3], namely the best effort (BE), the assured forwarding (AF), and expedited forwarding (EF). While EF services require bounded end-to-end delay and jitter specifications, AF is intended for services that are not delay-sensitive but require bandwidth guarantees. Finally, BE applications are not delay-sensitive and do not require any jitter specifications. Simulation results show that the proposed E-DBA mechanism with PFEBA scheme outperforms other existing well-known DBA algorithms in high traffic load.

The rest of this paper is organized as follows. Section 2 describes the related work. Section 3 proposes an E-DBA mechanism which incorporates the PFEBA scheme for dealing with fairness involving prediction. Section 4 shows the simulation results in terms of average packet delay, average queue length, wasted bandwidth, downlink available data bandwidth and throughput. Finally, Section 5 draws conclusions and offers suggestions.

## 2. Related work

Dynamic bandwidth allocation without prediction mechanism, such as limited bandwidth allocation (LBA),