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Novel dynamic flow allocation scheme over ethernet passive optical networks

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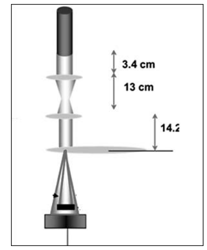

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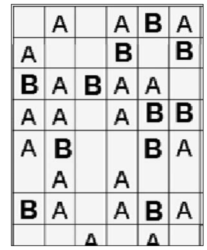

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Novel dynamic flow allocation scheme over ethernet passive optical networks

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Abstract. A new dynamic flow allocation scheme to guarantee quality of service and more stabilized performance is proposed, replacing an Ethernet passive optical network. This new scheme improves a priority-based access network, converting it to a flow-based access network with a new access mechanism and scheduling algorithm. With this new scheme, a network service provider can provide upper limits of transmission delays by the flow. The modeling and simulation results with mathematical analyses obtained by this scheme are also provided. [DOI: 10.1117/1.2802100]

Subject terms: access network; DBA; flow; EPON.

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1 Introduction

Significant growth in Internet traffic and emerging new services has created an incentive for service providers to upgrade their access network architecture. Certain distinguished services, such as classified services and session-based services, would come out of next generation network (NGN).[1] Most of these services are based on a flow-based network, which guarantees quality of service (QoS). A core network would have enough capability to support flow-based services by employing the Multiprotocol Label Switching (MPLS) technique. However, access networks need an additional scheme.

An Ethernet passive optical network (EPON) is a very efficient architecture for access networks. However, it cannot support flow-based services. Although it can offer priority-based services with the combination of dynamic bandwidth allocation (DBA) algorithm and multipoint control protocol (MPCP),[2] a previously proposed scheme is not sufficient to support flow-based services for the NGN. Until now, most of the priorities of traffic flows from optical network units (ONUs) have been determined when users subscribed for a specific service. Consequently, user data frames have been approximated by constant flows. There will be other forms of traffic flows that have different priorities and sessions in NGN. Whenever sending data through a core network, customers may choose flow characteristics instantly.

The conventional DBA algorithm over EPON concerns with bandwidth assignment between an optical line terminal (OLT) and an ONU for efficient uplink transmission. When OLT assigns bulk bandwidth to ONUs on demand using priority-based scheduling algorithm,[3] ONUs cannot guarantee the service quality of each flow in an access network, because they cannot distinguish traffic by flow and type of service. Since ONUs themselves only consider the service order of the queued packets inside, some packets that are fragmented previously from the same flow would have different opportunities to be served. That makes the flow delayed. Therefore, one needs to find the way to transmit those divided packets as a flow at the same time.

2 Proposed Scheme

The proposed dynamic flow allocation (DFA) scheme is the mechanism that an OLT allocates not only bandwidth to ONUs but also flow tags to individual flows of the customer premises equipment (CPE). In order to utilize the DFA scheme, a new scheduling algorithm, known as constraint-based weighted fair queuing (C-WFQ), is proposed.

A flow tag is a key item of this novel scheme. By using this proposed flow tag, we can improve network intelligence additionally that informs many things, such as identification of fragmented packets, reserved network resource information, and a switched path, which cannot be supported without the flow tag in a legacy access network. The detailed usage of flow tags is shown below.

The flow tag assigned by an OLT is determined by the policy and service level agreement (SLA) after reserving core network resources. Here, it is assumed that a future core network will be a flow-based network to support end-to-end QoS-guaranteed services. This flow tag is requested and assigned dynamically through the option field of the MPCP.

Figure 1 illustrates the DFA mechanism. First, by choosing a flow type of data, a customer tries to send data through an access network unless the data type is fixed or predetermined as short messages. The CPE then transmits the customer's data packets with flow type information to an ONU. After receiving the data packets, the ONU sends a

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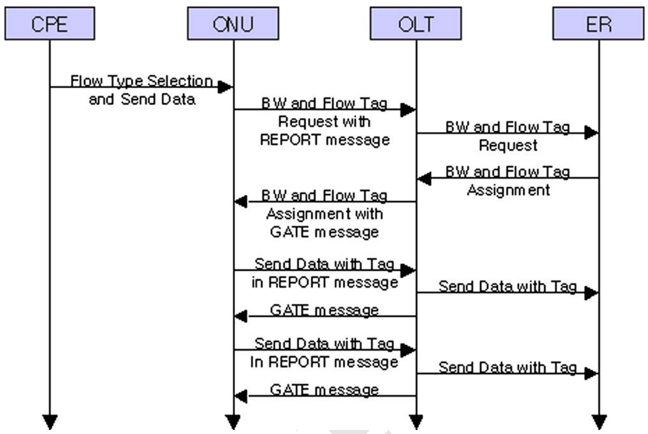

Fig. 1 Flow-based access mechanism over EPON.

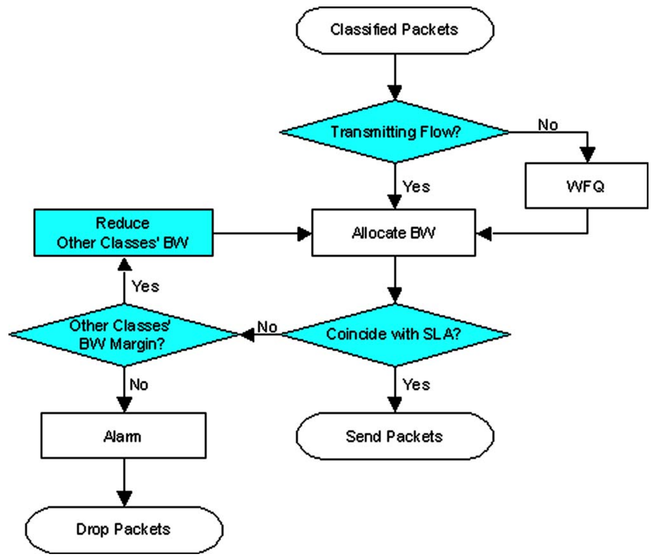

Fig. 2 Scheduling Algorithm of a constrain-based WFQ.

request of flow allocation and bandwidth assignment to an OLT by a REPORT message. The OLT transfers a request to an Edge router (ER) to reserve bandwidth and receive a corresponding flow tag. The ER belongs to core a network, which runs on the flow-based protocol. Therefore, the ER itself has to have the transfer resource control function (TRCF) to support bandwidth reservation and other resource controls; otherwise, the OLT should transfer the request to other control equipment that has the TRCF.[4] The ER contacts an authentication server to obtain the customer information, and reserves available bandwidth through the networks, if possible. The ER then assigns a tag to the corresponding flow and sends bandwidth information and the flow tag back to the OLT. The OLT passes the bandwidth and tag information through a GATE message to the ONU. Following the gate message, the ONU transfers customer's data packets by a REPORT message with the tag. Consequently, the OLT passes the customer's data packets to the ER and sends the information back again through a GATE message to the ONU. Once the path is set up, there is no need to request bandwidth again for the same flow until the path is shut down. This path is linked to the label switched path of a core MPLS network.

In addition, the OLT can guarantee the bandwidth through an end-to-end network as well as an access network, because the OLT gets the flow tag information from the ER, which has already reserved core network resources. Therefore, the connection admission control (CAC) should be required to block incoming traffic for the worst case of network congestion, if needed. The CAC will give customers the alarm immediately when CPE chooses the unavailable traffic type or tries without permission at the same time.

Additionally, an OLT and an ER can transfer the tagged packets faster by checking the tag information only, without looking up destination addresses and a route table as in the case of MPLS networks.

To employ the flow-based access mechanism, the general weighed fair queuing (WFQ) is not a proper solution, since high priority packets have to yield precedence to the low priority packets when the low priority packets belong to the flow that is being transmitted through a flow-based EPON. High priority packets may have to yield to guarantee minimum bandwidth of the low priority packets when needed. To meet the above requirements, the WFQ should be modified to a C-WFQ.

Figure 2 illustrates the C-WFQ algorithm. When the classified packets come into an ONU from the CPE, the ONU distinguishes the packets. If the packets belong to the flow being transmitted, the ONU will attach the same label and allocate the same bandwidth. Otherwise, the ONU allocates bandwidth by the WFQ algorithm. After that, the ONU has to compare the allocated bandwidth with corresponding SLA. If the assigned bandwidth is enough to satisfy the SLA, the packets are sent to an OLT. If, however, it does not have sufficient resources to assign, the ONU should reduce the other bandwidth that is already being used for other flows. Mostly, the ONU would retrench bandwidth of lower priority classes. If all the reducible resources belong to higher priority classes, the ONU will cut those resources off and allocate the bandwidth again. In the worst case, if there is no marginal resource, the ONU should raise an alarm and drop incoming packets.

3 Discussion

To evaluate the performance of the proposed scheme, a DiffServ router model[5] is used. The main difference between the DFA model of this paper and the DiffServ router

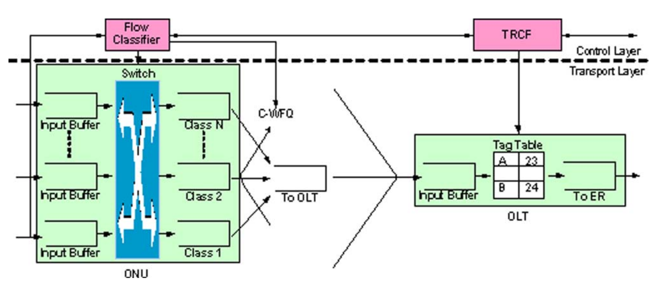

Fig. 3 Flow-based up-link architecture over EPON.

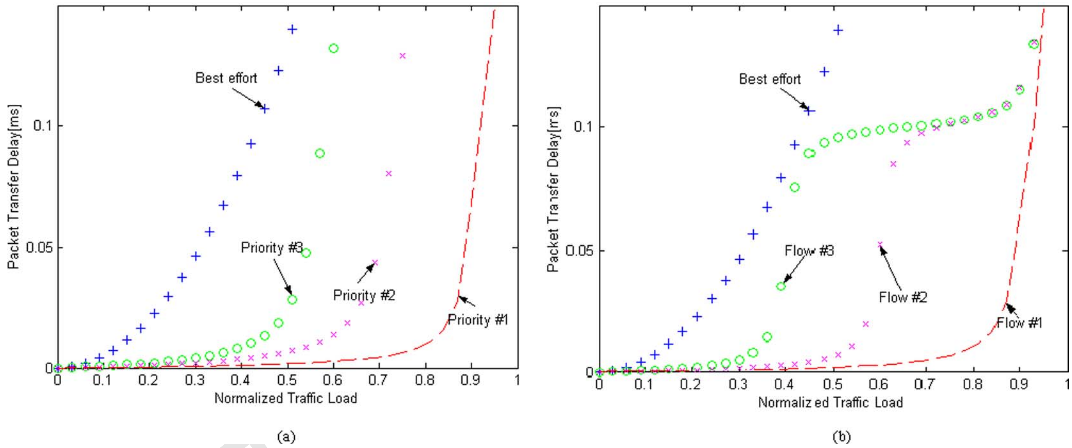

Fig. 4 Delay characteristics comparison between (a) existing algorithm vs (b) proposed algorithm. (a) Existing priority-based scheduling method. (b) Novel flow-based scheduling method.

model is concerned with whether an access passive optical network or a core router network is being used.

Figure 3 shows a DFA architecture model. The DiffServ router model is modified into a flow-based EPON model. The Flow Classifier, a control function of an ONU, arranges incoming packets according to their associated priorities and class identities. The roles of the Flow Classifier are reserving resources, requesting flow tags, classifying incoming packets, and so on. The classified packets are sent to an OLT in accordance with a C-WFQ algorithm. After arriving at the OLT, the packets are forwarded to the ER by looking up the tag table, which is written by the TRCF.

From the DiffServ router model,[5] the formula for drop probability p is

$$\dot{p} = 1 + \frac{R_i^2 C_i^2}{4N_i^2} - \sqrt{\frac{R_i^2 C_i^2}{2N_i^2} + \frac{R_i^4 C_i^4}{16N_i^4}}, \tag{1}$$

where R_i, C_i, and N_i are round-trip time, allocated bandwidth for class i, and number of flows in class i, respectively. Using the above dropping probability [Eq. (1)], the delay of class i, i.e., D_i, can be derived approximately as

$$D_i = \frac{T_i}{C_i} = \frac{0.4B_i}{w_i C}, \tag{2}$$

where T_i, C_i, B_i, w_i, and C are target queue length, allocated bandwidth, the buffer size of class i, the WFQ weight of class i, and total capacity, respectively. From Eq. (2),[5] the delay of class i in the flow-based scheme can be calculated. To evaluate the performance of our algorithm, a MATLAB® tool is used and we assumed the NGN environment, which has incremental queue length for each class, 1 MB as the maximum buffer size, 2 as the bandwidth differentiation parameter, and 32×10^9 bits/s as the total transmission rate.

Figure 4 shows the packet delay performance of class 4 curves. Upon increasing the traffic load intensity, the delay curves are also raised depending on the priority. Figure 4(a) is a simulation result according to the existing priority-based scheduling algorithm, and Fig. 4(b) is the output of new proposed algorithm. Flow #3 in the Fig. 4(b) shows that the delay time is saturated around 0.1 ms, because it is assumed that a customer signed an "at least 0.1 ms delay" contract with a service provider. Another customer who has Flow #2 made a similar contract, which includes a different priority and the same maximum delay time of 0.1 ms. Here, we can see Flow #2 has a higher priority than Flow #3, because Flow #2 has better performance until the Normalized Traffic Load is less than 0.55. After 0.55, higher priority Flow #2 has to sacrifice to guarantee minimum performance of Flow #3 up to the congestion, and Flow #1, which has the highest priority, also has to yield some capacity to low priority flows to meet the SLA.

4 Conclusion

The newly proposed DFA scheme is the NGN version of DBA algorithm. The main advantage of this scheme is that we can allocate bandwidth to specific customer's flows and also guarantee minimum bandwidth in the access area with respect to corresponding SLAs. With this proposed algorithm, the service provider can offer a guaranteed-QoS service before network congestion.

As shown in Fig. 4(b), this DFA scheme helps any flow sustain minimum throughput independent of priority classes except the "Best Effort class" at the network congestion. However, the priority-based scheme in Fig. 4(a) has a fairness problem. In case the high priority packets are rushing at the network, low priority packets are hardly transmitted.

Moreover, the flow-based scheme makes it possible to use the advantages of MPLS by the flow tag, such as explicit routing. Due to the complexity and delay time to wait for resource reservation for C-WFQ algorithm calculation, the total performance degradation is observed as a tradeoff.

Acknowledgments

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