Real-time Services in EPON

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Abstract: This paper proposes an improved scheduling algorithm that optimizes the allocation of the real-time services and elastic flows in EPON by spreading the real-time service periods lowering the delay and thus fulfilling the QoS requirements.

OCIS codes: (060.4510) Optical communication; (060.4250) Networks

1. Introduction

Among the different PON technologies the Ethernet-PON (EPON) is one of the most promising alternatives to satisfy operator and user needs, due to its cost, flexibility and interoperability with other technologies. The IEEE Std. 802.3ah introduces the concept of EPON with a nominal bit rate of 1 Gbps and the IEEE Std. 802.3av extends EPONs operation to 10 Gbps (10GEPON), the major difference compared to EPON is the physical layer.

One of the most interesting challenges in such technologies relates to the scheduling and allocation of bandwidth in the upstream (shared) channel. Key issues in this context are future end-user needs, integrated quality of service (QoS) support and optimized service provisioning for real-time and elastic flows. A survey of the most relevant algorithms is available at [1]. Among others the Interleaved Polling Adaptive Cycle Time (IPACT) is the most popular one [2]. IPACT does not support service level agreements (SLA) and cannot support QoS for services that are sensitive to time delay; therefore, IPACT is not a suitable algorithm for several services. To support QoS in EPONs there are various solutions proposed to date, available in [3], mostly based on the well-known service differentiation approach with strict or non-strict service disciplines. However in order to support the coexistence of new real-time emerging applications and the traditional applications in EPON, an appropriate mechanism to manage the bandwidth allocation in an efficient way is still an open issue.

In this paper, we merge two scheduler approaches. First, we will use the Distributed Resource Algorithm (DRA) [4] to manage the real-time flows to guarantee delay and delay jitter. And, then, we propose an algorithm based on our previous proposals, the Distributed Dynamic Scheduling (DDSPON)[5], which performs “slightly” better than the aforementioned IPACT, to allocate the bandwidth that non real-time traffic deserves in the intervals left free by the real-time flows. The proposals [6,7] address the problem of delay and delay jitter but concentrating the high priority flows at the beginning of each cycle unlike our proposal that spread optimally the real-time flows during the cycle fulfilling the real-time flow requirements minimizing delay jitter.

2. Real-time traffic allocation in EPON

An algorithm that distributes the real-time service periods as much as possible is better than a scheduler that concentrates them, because the concentrated service periods capture the channel for long time increasing the average delay and delay jitter of the non-real time flows. Although we defined the DRA in the context of wireless networks, it might be used in any context where scheduling of periodic flows is required. The DRA is devoted mainly to determine the service start time of each flow in order to distribute in time, as uniformly as possible, the allocation of resources for the different flows. The Figure 1 provides an example of allocation distribution according to the spread and concentrate distribution approaches.

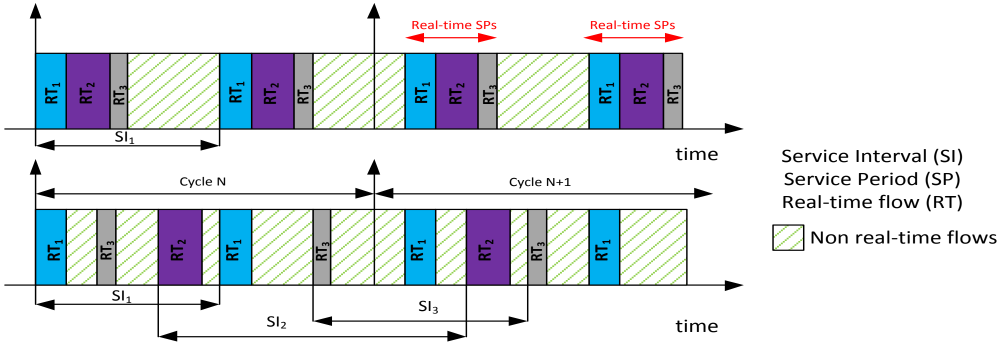

Fig. 1. Example of flows allocation with a concentrate and spread distribution approach.

If we defined the service period (SP) as the adjacent flow transmission time and the service start time (SST) as the beginning of the flow transmission, the flows are spread because the DRA algorithm allocates the SST of a new flow requested by any ONU by maximizing the minimum distance between the SPs of this new flow and the SPs of the already scheduled flows and thus minimizes the overlapping probability. The Figure 2 represents the occurrences in the channel of two periodic flows with service intervals, SI_1 and SI_2, which have service starting times SST_1 and SST_2. The figure also depicts the distance between consecutive allocations of the flows $d_{2,1}(k)$; to better understand of the distance concept between periodic flows and its distance in a channel.

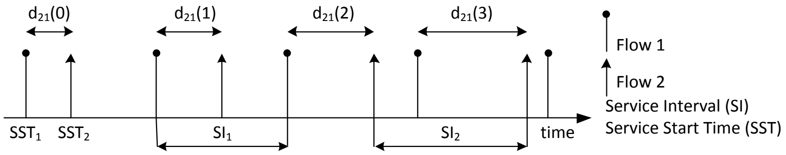

Fig.2. Distances between flows.

The distance between an occurrence of flow 2 and the previous occurrence of flow 1 can be express as:

$$d_{2,1}(k) = \left(d_{2,1}(0) + kSI_2\right) \, mod \, SI_1 \qquad (1)$$

The elements of the previous sequence, $d_{2,1}(0)$, can be expressed as:

$$d_{2,1}(j) = d_{min2,1} + j \cdot \mathrm{gcd}(\, SI_1, SI_2) \;\; j \geq 0 \qquad (2)$$

Where $d_{min2,1} = d_{2,1}(0) \, mod \, \mathrm{gcd}(SI_1, SI_2)$ and gcd stands for greatest common divisor. Thus an objective way of increasing the separation between the service times of flows 1 and 2 is to increase $d_{min2,1}$ and/or $\mathrm{gcd}(SI_1, SI_2)$.

The DRA algorithm requires checking all possible overlapping of scheduled flows along the time depending on the considered SST; unfortunately, this algorithm is NP-complete but when consider a EPON with a limited number of scheduled flows, an heuristic can be defined by the service start time and the service interval, because a repetition pattern occurs with a period corresponding to least common multiple (LCM) of the different service interval flows.

The lack of space in this paper does not allow including the complete explanation of the DRA algorithm. A simple algorithm that computes the new service start time of the N+1 flow (SST_{N+1}) and maximizes the distance to the rest of the N flows, can be implemented by performing the process in Algorithm 1.

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Algorithm 1 Distributed resource allocation algorithm (DRA)
  - Compute $\mathrm{gcd}(SI_i, SI_{N+1})$ for all the already $N$ already scheduled flows, $0 < i \leq N$.
  Compute the period of the absolute minimum distance, $T' = lcm\ (\mathrm{gcd}(SI_i, SI_{N+1}), \ldots, \mathrm{gcd}(SI_N, SI_{N+1}))$.
  For each scheduled flow generate all critical points, $\phi_{N+1,i} + k \cdot \mathrm{gcd}(SI_i, SI_{N+1})$, contained in $T'$.
  Define a sorted list L containing all critical points.
  Define a function F that operating on list L obtains the SST that maximizes the minimum effective distance.
  - The function F iterates over the list L containing the critical points of the absolute minimum distance function in order to find where the maximum of this function is.
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In addition to the DRA algorithm an admission control mechanism is applied to protect the real-time flows. The DRA algorithm is implemented in the OLT and is introduced as an extension of the DDSPON improving the allocation of real-time and elastic flows. The non-real time flows uses the DDSPON algorithm to optimize the upstream bandwidth. In DDSPON active ONUs are charged of managing the transmission times, while reporting to the OLT about such allocation. The computation of the bandwidth allocation is performed right through the ONU after having received from the OLT within the gate message the percentage of bandwidth (weight) allocated by the rest of ONUs, therefore the ONU computes its transmission window taking profit from the bandwidth left unused from low active ONUs. Furthermore the ONU compute its weight and send it to the OLT jointly with the bandwidth allocated by this ONU within the report control message. Notice that each ONU schedules the size of its transmission window dynamically and that the DDSPON is executed in an online framework because the scheduling process is executed without the need of waiting for the reports from the rest of the ONUs. The OLT continues having control of the channel because centralized the allocations and through the gate message complies with MPCP protocol.

3. Experiments and results

In this section, we present some relevant simulations carried out to evaluate the performance of the proposal by using the OPNET Modeler package. Our goal is to show that our scheme can guarantee the QoS requirements of the real-time services while reducing the delay of the rest of services as well.

In the testbed setting some assumptions are made: we consider a network offered load of 70%, the guard time and control messages are according to the standard. The initial values of the parameters of the simulation are: the number of ONUs is set up to 16; the channel data rate is set up to 1Gb/s; the maximum cycle length is set to 2ms. The input traffic that simulates non real-time services is of the self-similar type with a pareto parameter set to 0.7. The packet length is uniformly distributed between 64 bytes to 1500 bytes. We assume that each ONU has three different real-time flows with a service interval of 10, 20 and 30ms respectively and with a payload of 15000bytes.

We show the performance of our proposal compared with DDSPON but using a strict priority scheduling discipline (defined in P802.1D, clause 7.7.4), thus real-time and non-real time flows are placed in different queues according to their priority, and then packets in each queue are served from the head of a given queue only if all higher priority queues are empty. The Figure 3 shows the service start times of real-time flows in both scenarios (with and without DRA algorithm), as in figure 1 we can show the allocation according to the spread and concentrate distribution approaches, the last to the case of strict-priority. The DRA distribute the real-time flows so that the rest of the traffic could be placed between intervals left free by the real-time flows. The Figure 4 shows the advantage in average delay that our scheme provides to the non-real time services even when the real-time services already fulfilling with the QoS requirements.

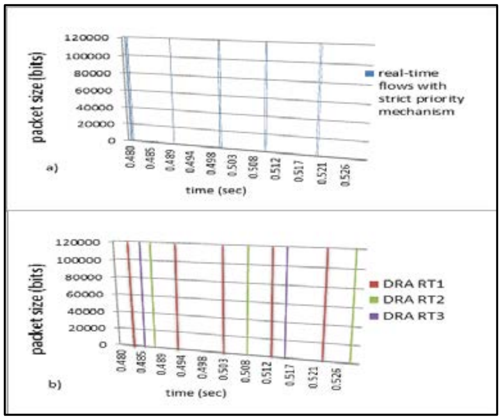

Fig.3 SST of real-time flows. a) Without DRA. b) With DRA

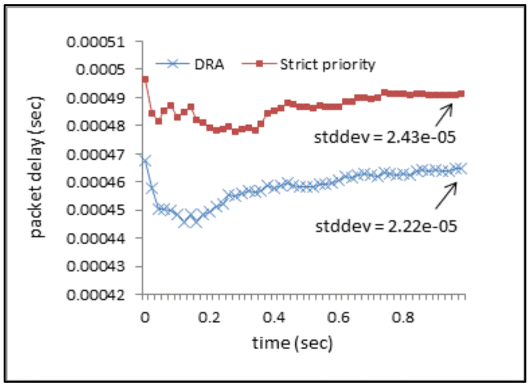

Fig.4 Packet delay of non-real time flows

4. Conclusions

Based on the previous arguments we have designed a new solution to resource allocation in EPON focused mainly in the guaranteed QoS requirements of real-time traffic, but also reduced the impact that the other kind of traffic can experiment. Unlike most of the proposals existent in the literature, our proposal is the one that distributes in the channel as much as possible the flow allocations of the different admitted real-time flows improving not only the overall performance of the real-time traffic but also of the non-real time yielding an overall better channel usage efficiency.

5. References

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