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A Simulation Study of the IPACT protocol for Ethernet Passive Optical Networks*

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ABSTRACT

In this paper a particular Passive Optical Network based on the Ethernet framing is investigated considering a typical tree-based topology. User stations are managed for upstream data transmissions by means of a polling algorithm which has also to support a dynamic bandwidth management. Here the Interleaved Polling with Adaptive Cycle Time (IPACT) algorithm is investigated and evaluated through simulation, exploiting the ns simulation tool. Different scheduling disciplines which the IPACT may employ are evaluated in terms of bandwidth distribution, cycle times and queue lenghts.

INTRODUCTION

The explosion of the number of Internet users since the '90s has revealed the bandwidth bottleneck of the so called last mile. The ever increasing capacity of both processing of personal computers and transmission of core networks has made their interconnection section, the last mile, a serious problem to deal with. The xDSL solutions represent a very important approach that allows, basically, to connect users to the Internet at reasonably high speed over traditional and already installed copper twisted pairs. However, multimedia, interactive and high definition applications push for very high speed access networks, where each user is given a bandwidth greater than 100 Mbit/s. Passive Optical Network (PON) is a promising technology to solve the last mile problem. Ethernet over PON (EPON) has been regulated by IEEE and it is the subject of this work. In order to connect all users, not just business but also residential, point-to-point fibres from the central office should be installed. This approach comes to be too expensive since two transceivers per line should be employed. Thus, the point-to-multipoint (P2MP) topology is rather used where one single fibre is used both for down and upstream data communications. Following this, a concentrator is placed closed to a set of users with a passive coupler for connecting them. Several P2MP topologies are possible: tree, bus and ring. Here a bus topology will be considered. Fibre-to-the-curb (FTTC), fibre-to-the-building (FTTB) and fibre-to-the-home (FTTH) are possible ways to implement PON depending on where the fibre from the Optical Line Terminal (OLT), which is point-to-point connected to the network backbone, ends its run, at the curb, at the building or at home, respectively. Data transmissions are full-duplex over the PON and they are on separate channels. Downstream is the flow from the core to the OLT and then to the ONUs (Optical Network Unit), close to the users, while upstream is the data flow from users to the core network. Since there is one communication channel only from OLT to the core, a user access control for upstream transmissions has to be implemented to avoid collisions. The most common dimension in this scenario for contention resolution is the time, through Time Division Multiplexing. Downstream transmissions are broadcasted by OLT to all ONUs and data frames have a variable length up to 1500 bytes. These frames are broadcasted through a 1:N splitter, where N can be from 4 to 64 depending on the optical power available. Each frame has a label in the header which uniquely identifies the destination ONU. A ONU selectively reads incoming frames, forwarding the ones containing its identifier only. As mentioned above, upstream communications use TDM, where each ONU is assigned a time slot by OLT, in order to solve possible contentions, and two time slots are separated by a time guard interval. During each time slot more Ethernet frames may be transmitted. If N is the number of ONU, the set of N time slots is called cycle. When the ONU has the right to transmit, during its time slot, it is allowed to send all queued packets at top speed, for instance 1 Gbit/s.

THE IPACT ALGORITHM

The Interleaved Polling with Adaptive Cycle Time (IPACT) algorithm is widely known and in this work some further results are presented when different disciplines are adopted. This algorithm make use of polling with OLT as master which periodically sends queries to ONUs and this generates a polling cycle. Here we recall some possible scheduling disciplines which it can adopt. Let $u[i,j]$ be the transmission window assigned to ONU i in the j-th cycle and $r[i,j]$ be the requested window. Let also W_i^{max} be the maximum transmission window for the i-th ONU. For the static or fixed discipline, $u[i,j] = W_i^{max}$. For the discipline called Limited, $u[i,j]= min\{ r[i,j]; W_i^{max} \}$, which means that the requested transmission window is agreed if it does not exceed the maximum one. For the Constant Credit discipline, $u[i,j]= min\{ r[i,j]+const; W_i^{max} \}$. Here to the requested window a constant is added to take into account the estimated amount of data during the control exchanges between OLT and ONU.

NUMERICAL RESULTS

In this section, numerical results on the IPACT performance for three scheduling disciplines, regarding a tree topology with 4 ONUs, are reported. They have been obtained by means of simulations performed using the ns-2 simulator vers. 2.31. It is assumed a constant packet size equal to 1000 bytes and W_i^{max} = 50000 bytes. The optical link data rate between OLT and the core network is equal to 1 Gbit/s. Figure 1 reports the average bandwidth usage for single ONU for the three strategies as a function of the offered load. It is interesting to note that for low and medium loads the fixed discipline is highly inefficient since time slots are not fully used. On the other hand, the limited discipline exploits the bandwidth at the best since the slot is always completely filled in. Figure 2 shows the bandwidth usage for the four ONUs for the Limited discipline as a function of time for medium traffic load values. It is worthwhile noting the presence of peaks above and below the value of 250 Mbit/s (the average data rate per ONU) which reflect the dynamic nature of the Limited discipline: every time a ONU has few data to send a larger time slot is assigned to more demanding ONUs. Figure 3 reports the average queue length as a function of the average traffic load per cycle for the Limited discipline. This figure shows that for the current settings when the incoming data per cycle to a ONU exceed 49 Kbytes, the ONU can not transmit it completely so that some data are queued and this a potential cause of instability for the queueing system.

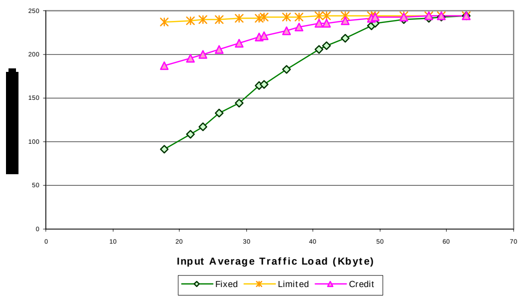

Figure 1

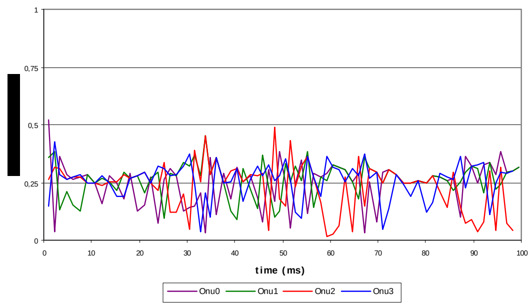

Figure 2

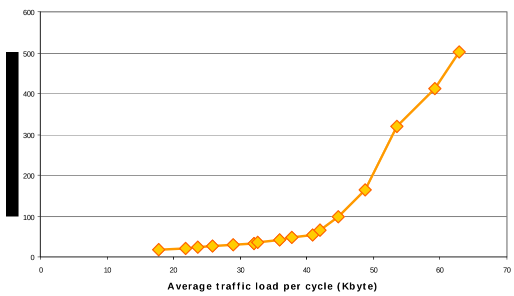

Figure 3

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