A Novel Approach for Making Energy Efficient PON

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ABSTRACT

Nowadays Passive Optical Network (PON) requires that Optical Network Units (ONUs) wake up periodically to check if the Optical Line Terminal (OLT) has any message directed to them. This implies that ONUs change from sleeping mode in which they just consume 1 W to active mode in which the consumption goes up to 10 W. In many cases, the OLT does not have any packets for the ONU and it goes to sleep again, what supposes a waste of energy. In this paper, we propose a novel Hybrid ONU that relies on a low-cost and low-energy technology, IEEE 802.15.4, to wake up those ONUs that are going to receive a packet. Our first estimations demonstrates that our solution would save around 25000$ per year and OLT.

Categories and Subject Descriptors: C.2.1 [Computer Communication Networks]: Network Architecture and Design

General Terms: Algorithms, Design, Management

Keywords: Energy saving, PON, Sleep mode, converged.

1. INTRODUCTION

In a Passive Optical Network (PON), an Optical Line Terminal (OLT) is the centralized intelligence. It receives the packets from the core network and then delivers them to the destination Optical Network Unit (ONU) through optical fiber. On the other hand, the OLT assigns fixed time slots to the ONUs for the upstream transmission. In a typical PON architecture, in the downstream direction signal is broadcasted using a passive splitter, while in the uplink an ONU uses unicast transmissions. Under one OLT there can be 16, 32, or 64 ONUs.

According to the existing solutions [1, 2], an ONU goes to sleep mode when it does not have anything to send or receive. Then, the OLT sends a message to the ONU informing the next listening interval. ONU needs to wake up before that listening interval in order to receive the OLT's feedback. If there is any packet destined for that ONU, the OLT forwards it to the ONU. Otherwise, the OLT notifies the ONU when the next listening interval will take place and asks to switch into sleep state. Conversely, if an ONU receives any packets from the customer premises to the network, it stores the packet and transmits to the OLT during the assigned uplink transmission slot.

When the packet arrival rate is low, an ONU can take long sleep [1, 2] to save more energy. In such case, any arrived packet at the OLT might experience delay. As shown in Figure 1 the first packet destined to ONU 1 experiences delay $D = t_1-t_0$. Furthermore, in the existing approaches an ONU needs to wake up periodically and listen, even though it may not have any downstream packets to receive (see Figure 1). During these listening intervals an ONU approximately consumes 10 W of power, whereas the sleeping mode just requires 1 W consumption. Indeed, it is a waste of energy.

In this paper, we address those aforementioned issues. To mitigate such problems, we introduce a new ONU module, named as Hybrid OUN (HONU), and a novel protocol procedures. Using our approach, a significant amount of energy can be saved.
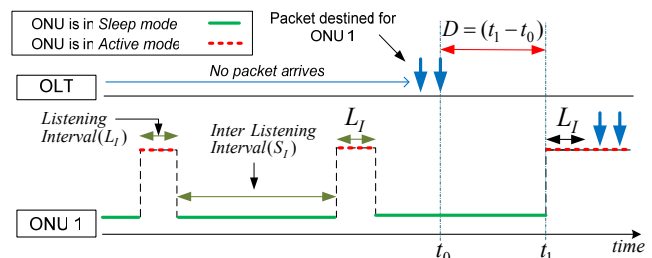

Figure 1. Listening procedure in the existing ONUs.

2. SOLUTION

The new ONU architecture (i.e., HONU) integrates the existing ONU module and an IEEE 802.15.4 module. In this approach, when the ONU module needs to go to sleep state the IEEE 802.15.4 module takes over the responsibility of periodic listening through its wireless interface, and after a packet arrival at the OLT, it is invoked to make the ONU module waking up. We design the protocol procedure in such a way that IEEE 802.15.4 module of a sleeping HONU can be invoked from the OLT through other active HONUs' IEEE 802.15.4 module using its wireless interface. It must be noted that IEEE 802.15.4 is a low-cost technology whose installation will just be a minor part of the budget required to deploy a PON network. Therefore, at a very low cost, we will be able to reduce a lot the energy consumption by extending the time in which an ONU uses the sleeping mode.

Basically, an ONU is composed of two parts: analog and digital as shown in Figure 2 (a). In absence of packet arrival, ONU goes to sleep mode by switching off most of the components (e.g., laser driver circuit, Tx, Rx [2]) of its Analog part. After switching off those components, the sleep coordinator notifies Interrupter

(i.e., IEEE 802.15.4) module to wake up periodically to check whether there is any downstream packet arrival notification arrives or not.


(a)

(b)
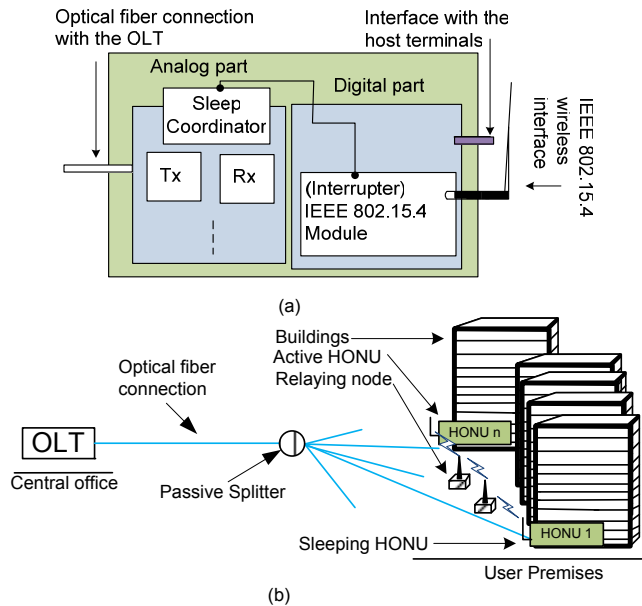
Figure 2. (a) Functional block diagram of a HOUN. (b) HONU deployment scenario in a customer premises.

We assume that at a given time at least one of the HOUNs is in active mode under the OLT. The OLT needs to notify a HONU on downstream packet arrival. Hence, even if there is no incoming downstream traffic, OLT invokes one of the HONUs to stay in active mode. As a result, the OLT can reach any Interrupter and make a HONU's analog part active on packet arrival. Furthermore, we assume that in the customer premises all the Interrupters can communicate among themselves through their wireless interfaces. Figure 2 (b) states a scenario where OLT requests the HONU 1 to be waked up through the HONU n, which is in active mode.

As the number of PON hosts is exponentially increasing, there would not be much distance between two HOUNs (e.g., the distance can be two consecutive buildings in an urban area). Then PON operators should deploy an IEEE 802.15.4 network that allows the interconnection of the different HONUs satisfying reliability and delay requirements. We consider that all these Interrupters and the intermediate relaying nodes sleep and wakeup synchronously. When a new packet arrives for a sleeping HONU, the OLT notifies the Interrupter of that HONU through any active HONU. After getting the notification from the OLT, the Interrupter of that HONU invokes the sleep coordinator. Sleep coordinator makes the analog part of the sleeping HONU active. Figure 3 states how HONU's ONU module switches to Active state. After being active, that ONU module synchronizes with the OLT's downstream clock and then start receiving the packets.

3. INITIAL RESULTS AND DISCUSSION

We perform some initial analysis in order to compute the energy saved when a PON network utilizes the proposed HONUs instead of the standard one. Figure 3 depicts that while an ONU of a 10 G Ethernet PON consumes 10 W, the Interrupters of our HONUs just need to use 30 mw [3] in the listening state. Then we roughly estimate that in a PON network with 32 ONUs our solution saves 450 kW/day. Then, assuming an average kW price of 0.15$, our solution would save 67.5$ per day. If we extend that saving to a complete year, the saving per OLT and year goes up to $25000. Then, in case an operator decides to widely deploy PON technology in a big and dense city (e.g. Seoul) thousands of OLTs would be required, and our solution would reduce electricity bill in millions of dollars. Besides, as all the HOUNs are reachable from the OLT, downstream packets experience reduced amount of delay. Future work will present this idea in more detailed.
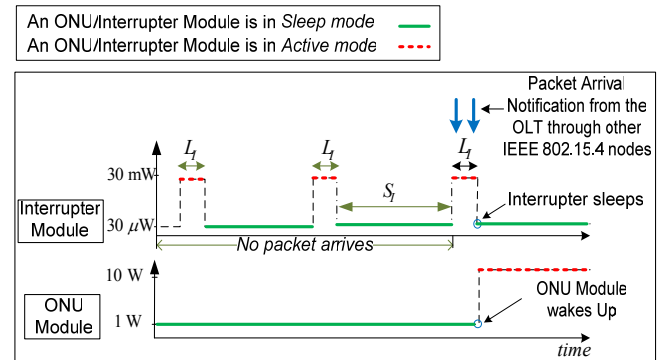
Figure 3. Proposed periodic listening procedure for an interrupter and on packet arrival wake up procedure for an ONU module.

4. REFERENCES

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