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Enhanced Sleep Mode MAC Control for EPON

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Enhanced Sleep Mode MAC Control for EPON

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Abstract This paper introduces sleep mode operations for EPON. New MAC control functions are proposed to schedule sleep periods. Traffic profiles are considered to optimize energy efficiency and network performances. Simulation results are analyzed in OPNET modeler.

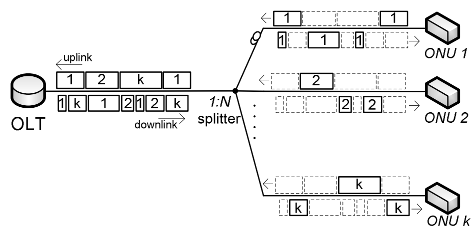

Fig. 1. EPON architecture with traffic transmission

1. Introduction

A new aspect in the design of future network is energy efficiency. Recent research has shown broadband access networks consume the high share of the total energy consumption by all telecommunication equipments. The Ethernet Passive Optical Networks (EPON) has been widely deployed in the access network. Although EPON consumes less power compared to other access technologies, it has raised attention to further power decrease, especially when the line rate is increased and the number of users is continuously grown.

A typical EPON system consists of one Optical Line Terminal (OLT) functionalized as a central office, one passive optical splitter, and multiple Optical Network Units (ONUs) residing at subscribers' locations (shown in Fig.1). In the upstream direction, multiple ONUs share a single link and the OLT distributes the upstream bandwidth using a bandwidth allocation mechanism. data are broadcasted to all ONUs in the downstream direction. Introducing a sleep mode operation is one of the ways to reduce the power consumption in network units [1-2]. In our proposed energy efficient EPON system, the main idea is to set ONUs into the sleep mode and assign a suitable sleep/wakeup time schedule at the OLT. To reduce power consumption, ONUs are designed to enter sleep mode when they do not need to either receive or send traffic. During a sleep period, an ONU turns off its transceiver to save energy. In case there is incoming data for a sleeping ONU, data is queued in buffers at the OLT. Obviously, energy is conserved if an ONU stays in sleep mode as much as possible. However, the sleep period should be carefully scheduled, so target ONUs can wake up and complete transmission without violating QoS requirements. The key design challenge is the energy management with efficient scheduling for sleep and wakeup periods among multiple ONUs. This paper proposes an improved sleep mode control scheme.

2. Design of Sleep Mode Control Operations

In this paper, an EPON system is shown as Fig.1. Each ONU sends upstream data to the OLT during assigned time slots. In the downstream, data are queued in the OLT when the arrival rate exceeds the output data rate. In our previous paper [3], we present a Downstream Centric Scheduling (DCS) policy to assign sleep periods according to both upstream and downstream traffic. As illustrated in Fig. 2, OLT allocates upstream transmission periods to the i^{th} ONUs by sending GATE messages (G_i). Upon receiving G_i, the polled ONU sends REPORT message (R_i) and uplink data (d_{ul}). G_i is defined as a signaling message in the Multipoint Control Protocol (MPCP) in EPON standard. An ONU is awake during the upstream transmission. The sleep period is assigned if the ONU need neither send data in upstream nor receive data in the upstream. As shown in Fig. 2, ONU_1 enters sleep mode during the period $t_3 - t_4$ and $t_6 - t_7$. In this scheme, downstream data (d_{dl}) is received along with a sleep mode GATE message (G_{DCi}), which indicates the time to sleep or wake up.

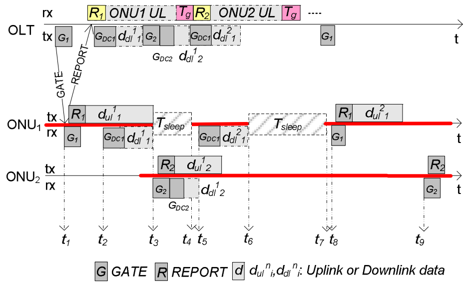

Fig. 2. EPON system with DCS energy management.

The OLT queues downstream traffic and schedules their transmission. The OLT acts as a central controller, because the OLT When the OLT detects an idle period existing between two successive busy processes (either upstream or downstream transmission), a sleep period is assigned. On the contrary, the ONU must keep awake if there is no queuing downstream traffic, because the OLT cannot calculate the next wakeup time.

A key improvement in this paper is that, the DCS scheme is enhanced by introducing a minimum sleep window, which is controlled based on the incoming traffic. It is perceived that the inefficiency of previous DCS scheme comes from lack of traffic profile analysis and estimation. For example, shown in Fig.2, ONU_2 keeps awake after receiving $d_{dl}{}^{1}{}_{2}$ until it starts next upstream transmission, even though there is neither upstream nor downstream traffic. When an ONU is lightly loaded, which in turn means a small amount of downstream incoming traffic, the OLT cannot always determine the wakeup time for next downstream packets based on the buffered data. Under this circumstance, the OLT assign the ONU a minimum value of sleep window (T_{min}) rather than keep the ONU awake. After the first sleep interval, the ONU transits into awake statues and listens to the traffic indication from the OLT. If there is no traffic, the ONU continues sleep mode, the next sleep window is double the preceding sleep interval. That is the duration of sleep interval in the nth sleep period is given $T_n = 2^{n-1}T_{min}$. As shown in Fig.3, the sleep period is increased if the ONU continues sleep mode (e.g. T_{min}, $2T_{min}$), until it starts the next transmission (at t_{poll2}).

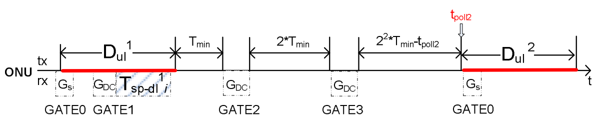

Fig. 3. Schematic of the sleep mode with minimum length.

3. Scenarios and Results Analysis

The EPON system and test scenarios are setup using the OPNET network simulator [4]. As shown in Fig.4, the energy aware control is embedded in the OLT and the sleep periods are assigned to the connected ONUs.

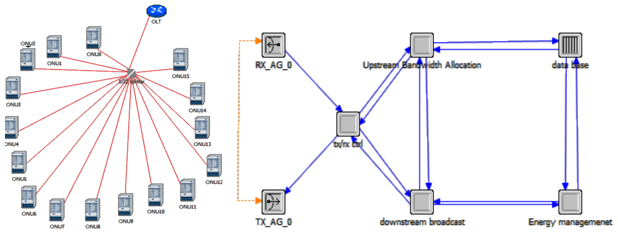

Fig. 4. Simulation setup and control functions in OLT.

The proposed Advanced DCS (ADC) is compared with the DCS, and the upstream centric (UC) scheduling scheme. The system performance is assessed using parameters, such as the power consumption and the average queuing delay. Various simulation scenarios are considered. The most significant improvements are listed in Fig.5. The advantage of ADC scheme is to reducing the awake time, which means power saving. When the incoming traffic load is low, the improved power saving is up to 10 to 15 percent. However, it increases the queuing delay in the OLT, because there is overhead time consumed by the ONU for wake up process. The tradeoff between energy saving and delay are illustrated.

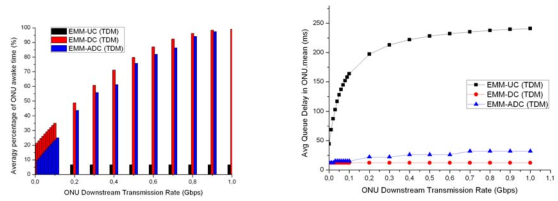

Fig. 5. Performance of a) power saving and b) queuing delay.

4. Conclusions

This paper focuses on the energy consumption in EPON. An enhanced sleep mode scheduling scheme is proposed, which is proven to improve the energy saving

5. References

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