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Performance analysis of Energy Efficient Ethernet on video streaming servers

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ABSTRACT

Current trends on traffic growth oversee a steady increase of video streaming services, and the subsequent development of the associated infrastructure to allocate and distribute such contents. One of the operational costs associated to this infrastructure is the power bill. Therefore any mechanism used to decrease it, reducing also the carbon footprint associated to it, is welcome. In this work we investigate the suitability of the recently standardized IEEE 802.3az Energy Efficient Ethernet (EEE) for video traffic generated by video-streaming servers. The conclusion of the analysis is positive about the achievable energy savings, due to the inherent features of traffic patterns of video-streaming servers which help reducing the number of transitions between active and low-power modes in EEE.

1. Introduction

The Internet growth has also raised several concerns about its power consumption and the need to improve its energy efficiency [1]. It is estimated that the Internet accounts for tens of TWh, an amount that could be significantly reduced if energy efficiency policies were applied. One of the first efforts toward energy savings is the IEEE 802.3az (Energy Efficient Ethernet) standard [2] which reduces the energy consumption of Ethernet devices by introducing a low-power (or sleep) mode. As Ethernet is the dominant technology for wire-line LANs, with more than one billion devices already deployed, Energy Efficient Ethernet (EEE) is expected to enable large energy savings [3]. However, previous studies in simulation [4] and with actual power measurements [5] have shown that the performance of Energy Efficient Ethernet greatly depends on the traffic pattern, and may not be as efficient as originally expected. This is due to the large power-mode transition times; that is, most of the power required for the transmission of an isolated Ethernet frame is spent in activating the link and putting it back to the low-power mode, rather than on actual data transmission. On the contrary, when several Ethernet frames are transmitted back-to-back, such a burst of data shares the sleep-to-active mode transition overhead resulting in larger energy savings [6].

Such bursty traffic pattern has been observed in video-streaming traces, which suggests that the adoption of EEE in video-streaming servers may achieve large power savings. Hence, this article attempts to analyze and quantify the suitability of the Energy Efficient Ethernet standard for the service of real time video streaming in IPTV networks, using the H.264 codec which is becoming the most popular video codec [7]. Indeed, given the high popularity of video streaming services such as YouTube, Hulu or Netflix, Internet video is expected to comprise about half of the total traffic share in the Internet by 2016, according to latest estimates [8].

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2. Background

2.1. Overview of Energy Efficient Ethernet

Concerning power consumption of legacy Ethernet equipment, two important facts have been observed:

1. Consumption increases with the link speed [5]. This is due to the increased hardware complexity that is required to achieve higher speeds.
2. Consumption is always maximum and does not depend on the traffic load because of the continuous transmission of physical layer signaling in the absence of user data [5]. This signaling is mandatory to keep the receivers aligned to the channel conditions.

The latter behavior is very effective in ensuring high-speed communication, but it results in poor energy efficiency, especially when the link is lightly loaded. This is usually the case for links that interconnect end-user computers to a LAN, where there is more room for power savings [9].

To improve energy efficiency, the Energy Efficient Ethernet (IEEE 802.3az) standard [2] defines a low-power (also known as, low-power idle or sleep) mode that can be used when there is no data to transmit. The power consumption while in the low-power mode is expected to be much lower (typically 10%) of that in the active mode [4]. The operation of Energy Efficient Ethernet is illustrated in Fig. 1. In the figure, the following times are defined:

T_w denotes the wake-up time, that is, the time required to exit the low-power mode, and bring the link ready for transmission.
T_s refers to the sleep time, that is, the time needed to enter the sleep (low-power) mode, for instance, after the transmission of the last frame.
T_q denotes the maximum values for periods with no transmission. After a T_q with no activity, a refresh period T_r is needed.
T_r refers to the short refresh periods, that is, the signaling periods necessary to keep the receivers aligned.

However, EEE is not as efficient as it was originally expected because the wake-up and sleep-down times are too large with respect to the frame transition time. Table 1 summarizes the minimum values (that is, best cases) for T_s and T_w as proposed in the 802.3az standard, along with their transmission efficiencies η_{Frame} computed for long and short Ethernet frames as:

$$\eta_{\text{Frame}} = \frac{T_{\text{Frame}}}{T_w + T_{\text{Frame}} + T_s} \quad (1)$$

where T_{Frame} refers to the Ethernet frame transmission time (frame size divided by link rate). Thus, η gives the percentage of time spent on actual data transmission per wake–transmission–sleep cycle.

As noted from Table 1, the wake and sleep times are considerably high with respect to the frame transmission time T_{Frame}, especially for small frames. Hence, the energy consumed for the transmission of a single frame, assuming the Network Interface Card (NIC) is in the low-power mode, requires a total time of $T_w + T_{\text{Frame}} + T_s$, whereas only T_{Frame} is used for actual data transmission. The T_s and T_w clearly impose an energy overhead which, for the case of 1000BASE-T reaches up to 99.4% for small frames (150-byte long). Such an excessive energy overhead makes EEE very inefficient in scenarios where the traffic load is low and the average frame size is small, as shown in [4,5].

However, large power savings may be achieved if a group of frames are transmitted together (i.e. back-to-back), as proposed in [6]. This way, the link is only awaken for the transmission of a large portion of data, hence the cost of waking up and sleeping down a link is shared between several frames, greatly improving its efficiency:

$$\eta_{\text{Burst}} = \frac{T_{\text{Burst}}}{T_w + T_{\text{Burst}} + T_s} \quad (2)$$

Here, $T_{\text{Burst}} = N \times T_{\text{Frame}}$, typically $N \geqslant 10$.

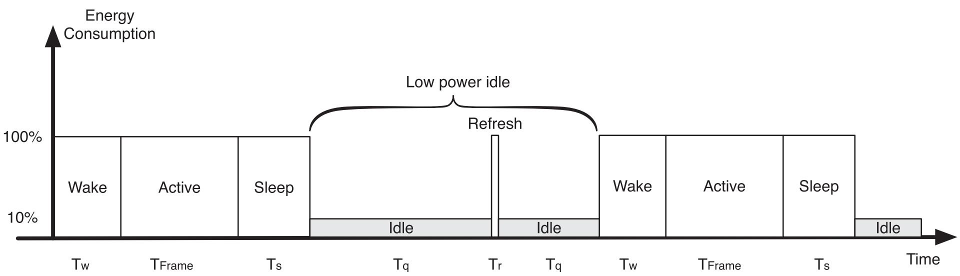

Fig. 1. Transitions between active and low-power modes in Energy Efficient Ethernet.

Table 1
Wake up, sleep and frame transmission times for different speeds, as proposed in IEEE 802.3az.

Protocol	Min T_w (μs)	Min T_s (μs)	T_{Frame} (1500B) (μs)	η_{Frame} (%)	T_{Frame} (150B) (μs)	η_{Frame} (%)
100BASE-TX	30	200	120	34.3	12	4.9
1000BASE-T	16	182	12	5.7	1.2	0.6
10GBASE-T	4.48	2.88	1.2	14.0	0.12	1.6