IEEE 802.11ah Restricted Access Window Energy Consumption Model for NS-3

Extended Abstract

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ABSTRACT

IEEE802.11ah is a new Wi-Fi standard aiming to provide long-range connectivity to densely deployed power-constrained station. In this abstract, we present an extension to the IEEE 802.11ah restricted access window (RAW) implementation in ns-3 to enable proper state transitions to and from sleep mode. This in turn enables accurate energy consumption modeling of this new technology. A comparison of RAW and CSMA/CA in terms of energy efficiency is provided, showing that RAW is considerably more energy efficient, due to shorter back-off periods.

1 INTRODUCTION

IEEE802.11ah, also known as Wi-Fi HaLow, is a standard for the communication of Internet of Things devices that works in the unlicensed sub-1GHz frequency bands. Its main characteristic is to be a technology that gives a good trade-off between range, throughput and energy efficiency. On the MAC layer, it offers different mechanisms to support power limited stations in dense networks, such as hierarchical organization, short MAC header, restricted access window (RAW), traffic indication map (TIM) and target wake up time (TWT).

The RAW mechanism was introduced in order to address the scalability of thousands of densely deployed devices. RAW aims to increase throughput and energy efficiency by dividing stations into different RAW groups, each having access to the channel during a non-overlapping interval. To support densely deployed energy constrained stations, also other mechanisms where added: delivery traffic indication map (DTIM) and target wake up time (TWT). TIM and DTIM are used from the AP to advise the station if there are buffered packets to be received. TWT allows further reduction of power consuming for stations transmitting data rarely. In fact, stations can stay in a power-saving state for very long periods of time without losing their association with the AP. This work focuses on the comparison of the energy consumed by devices, giving an overview of the results obtained using the implementation of the 802.11ah standard in our previously developed NS-3 802.11ah simulator [3]. Such a tool allows the simulation of many features of Wi-Fi HaLow such as fast authentication and association, short MAC header and RAW. In this abstract, we present an energy consumption model for the RAW feature of 802.11ah and its implementation in ns-3. This allows us to perform an in-depth comparison of the energy efficiency of RAW and DCF. This contrasts state of the art, which focuses on more simplistic analytical models [1, 2]. The remainder of this paper is organized as follows. Section 2 shows the background work done in the area of energy efficiency and the modeling of the states of the device. Section 3 describes the energy model and its implementation. Section 4 shows some preliminary results. The planned future extensions to this ns-3 implementation, considering at this moment only upstream traffic, are explained in the conclusions.

2 RELATED WORK

Bel et al. [1] present an analytical model for the energy consumption in an IEEE 802.11ah WLAN, considering TIM and page segmentation, considering the problems due to channel busy by reducing the transmitting consumption values in the simulation. As in our work, the transmission time is assumed to be negligible and it is assumed to consume no energy. Another analytical model to evaluate the performance of IEEE802.11ah was presented by Raeesi et al. [2], which models the energy efficiency of RAW under saturated throughput using DCF. These results are compared with the investigation of the RAW algorithm. This paper presents values for the energy close to real state-of-the-art circuitry. The aim of the paper by Wang et al. [4] is to optimize the energy efficiency considering the value of RAW parameters, not only taking into account parameters like throughput and less collisions. This is done using an optimization problem to maximize the uplink energy efficiency through RAW. In future works, the algorithm proposed in this paper can be used in order to dynamically find the optimal number of RAW groups. Zhao et al. [5] evaluate the new MAC features of 802.11ah with a system-level simulator using a model based on a finite-state machine, focused on uplink traffic. In comparison to the research outlined above, this work performance analysis is based on network simulation results, rather that on results of analytical models. It also takes into account also the timing a station finds the channel busy, considering also this energy consumption. Furthermore, it uses values for energy consumption taken from real state-of-the-art circuitry of IEEE802.11ah devices. Similar to [4, 5], our work assumes a scenario with upstream traffic.

3 RAW ENERGY CONSUMPTION MODEL

Using our previously developed simulator module [3], some modifications were applied in order to measure the energy consumed, and to allow devices to go into a sleep state outside their transmission or reception periods. Figure 1 depicts all potential state transitions in 802.11ah using RAW. It can be seen that before going into sleep mode, the device has to trigger the idle state.

Based on this state diagram, we properly implemented the state transition from idle to sleep into the 802.11ah ns-3 module. After receiving the beacon from the Access Point (AP) the station goes into sleep mode, until it arrives to its RAW slot or into a shared slot.

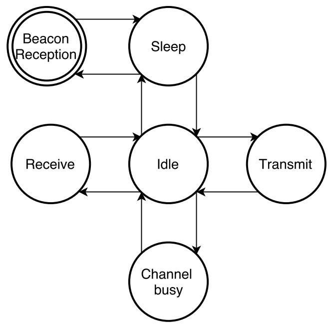

Figure 1: Station state diagram for 802.11ah RAW

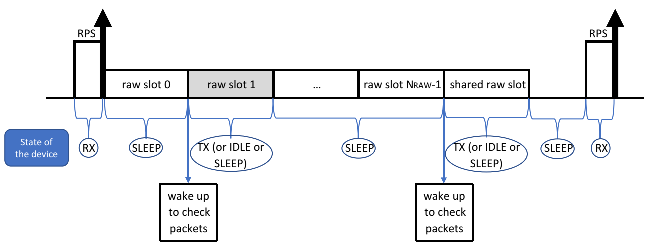

Figure 2: Example beacon interval of a station, consisting of different periods and the state of the station during each of them, the station is allowed to transmit during RAW slot 1 and the shared slot

Figure 2 depicts an example beacon interval for a station, as well as its state during each period. As we consider a sensor scenario with mainly upstream traffic, devices only wake up every time a packet has to be sent during their current transmission slot (either a RAW or shared slot).

4 PRELIMINARY RESULTS

In this section, we provide some preliminary results on RAW energy consumption as a function of total traffic load, as well as a comparison with DCF, using the proposed energy consumption model. The values used to calculate the energy consumption were taken from Raeesi et al. [2]. Specifically, four states are considered: TX (255 Mw), RX (135 mW), IDLE (135 mW), and SLEEP (1.5 mW). The energy consumed by an IEEE802.11ah station is obtained by multiplying the time the device is in a certain state by the corresponding power consumption of that state. The simulation was run with 512 stations, a fixed RAW configuration of 64 groups (each with 100 ms duration and consisting of 1 slot), and a fixed packet payload size of 256 bytes. Simulation were run with different traffic values of the stations in order to show the effects of traffic intensity on energy consumption, comparing RAW and traditional DCF. Fig. 3 shows the results of the simulation. The X-axis displays the total amount of traffic (Mbps), while the Y-axis depicts energy consumed (mW) and throughput (Mbps). It is clearly visible that energy consumption when using DCF is higher than when using RAW, if the traffic load is high. This is due to the grouping of stations, which allows a better management channel access and the station is able to enter sleep mode when it is not in its slot or has no packets to transmit.

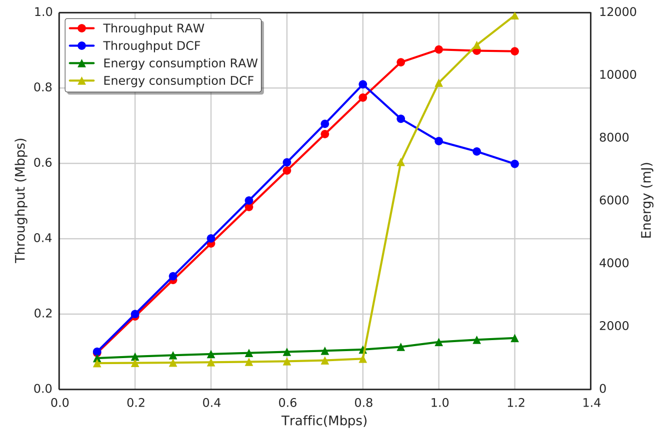

Figure 3: Comparison of throughput and energy efficiency of RAW and DCF, for varying total traffic load

When using DCF, stations spend a lot of time in the idle state during back-off, especially in denser and more traffic-heavy environments. This significantly increases energy consumed. As traffic increases, RAW also scales better than DCF in terms of throughput.

5 CONCLUSIONS

This abstract presents an update of the ns-3 802.11ah implementation of Tian et al. [3] in order to allow proper sleep state transition of stations when using RAW. This allows an in-depth and realistic analysis of the energy consumption of every station when using RAW in 802.11ah. Simulations using ns-3 were performed in order to validate the state transition implementation and compare energy efficiency of RAW and DCF. These preliminary results showed that RAW performed significantly better than DCF in terms of energy consumed, even when throughput is low. Planned future research on the 802.11ah ns-3 module consists of implementing DTIM and TWT, so that in addition to upstream, downstream traffic can also be supported.

ACKNOWLEDGMENTS

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