Demo Abstract: Supporting Heterogeneous IoT Traffic using the IEEE 802.11ah Restricted Access Window

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ABSTRACT

IEEE 802.11ah is a new Wi-Fi standard operating on unlicensed sub-GHz frequencies. It aims to provide long-range connectivity to Internet of Things (IoT) devices. The IEEE 802.11ah restricted access window (RAW) mechanism promises to increase throughput and energy efficiency in dense deployments by dividing stations into different RAW groups and allowing only one group to access the channel at a time. In this demo, we demonstrate the ability of the RAW mechanism to support a large number of densely deployed IoT stations with heterogeneous traffic requirements. Differentiated Quality of Service (QoS) is offered to a small set of high-throughput wireless cameras that coexist with thousands of best-effort sensor monitoring stations. The results are visualized in near real-time using our own developed IEEE 802.11ah visualizer running on top of the ns-3 event-based network simulator.

1 INTRODUCTION

IEEE 802.11ah, also known as Wi-Fi HaLow, is a communication standard for heterogeneous Internet of Things (IoT) devices that operate in the unlicensed sub-1GHz frequency bands (e.g., the 868 MHz band in Europe) [1]. Its main goal is to provide a good trade-off between range, throughput and energy efficiency. On the MAC layer, several innovative features were introduced, such as fast association and authentication, restricted access window (RAW), traffic indication map (TIM) segmentation and target wake time (TWT). These features allow 802.11ah to support a large amount of energy constrained stations in dense networks and to achieve up to 1 km range in outdoor environments. The RAW mechanism was introduced in order to address the scalability of a large number of densely deployed devices (up to 8191 supported by one AP). It 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 [4].

Because of the high data rates that are supported (up to 7.8Mbps), 802.11ah is one of the first IoT technologies in which both high-throughput and low data-rate IoT devices can be supported in an energy efficient manner. In this demonstration we show the ability of IEEE 802.11ah's RAW to provide differentiated Quality of Service (QoS) to densely deployed heterogeneous IoT stations. Specifically, a small set of high-throughput wireless cameras are shown to successfully coexist with a large number of best-effort sensor monitoring stations. The demonstration is performed using an updated version of our ns-3 IEEE 802.11ah implementation [3], adding support for bidirectional traffic and QoS differentiation. Moreover, simulation results are presented in near real-time to the audience using a newly developed visualizer [2].

2 DEMONSTRATION SCENARIO

In this demo, we consider a scenario with different devices that have heterogeneous traffic requirements, specifically cameras and sensors. For cameras a consistent reliable throughput is necessary, while the sensors send measurements over specific intervals and have low throughput demands. We show how a proper RAW configuration offers the required differentiated QoS for both types of devices. The main goal of the demo is to show how IEEE 802.11ah is able to manage differentiated devices by way of the RAW mechanism, grouping stations based on their traffic demand in order to satisfy heterogeneous throughput, packet loss and delay requirements. It compares RAW to a baseline result using the traditional 802.11 CSMA-CA channel access method.

The QoS differentiation feature is implemented using an intelligent RAW optimization algorithm, based on TAROA [5]. The algorithm splits the stations into two RAW groups, one for high-throughput cameras and one for best-effort sensors. The number of slots per group is dynamically optimized for maximum scalability based on the estimated number of stations in each group. The duration of the two groups is also optimized in real-time in order to minimize latency and packet loss for camera stations, while maintaining a predefined boundary on packet loss for sensor stations.

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Table 1: List of parameters used in the simulation

Parameter	Value
Beacon interval	102.4 ms
Number of cameras	8
Camera data rate	150 kbps
Camera MCS	MCS8, 2 MHz
Camera RAW group duration	51.2 ms
Number of sensors	200–1000
Sensor MCS	MCS0, 2 MHz
Sensor transmission interval	10 s
Sensor RAW group duration	51.2 ms
Sensor RAW slot number per group	4
Sensor packet size	64 bytes

To illustrate the strength of RAW to provide differentiated QoS to heterogeneous sensors and devices, an example result is shown in Figure 1. This illustrative result is based on a static RAW configuration, as depicted in Table 1. We consider 8 cameras and a varying number of sensors (i.e., from 200 to 1000) that send traffic to a server via the AP. Each camera has a date rate of 150 kbps and each sensor sends one packet of size 64 bytes every 10 seconds. Two RAW groups are used, the 8 cameras are in one RAW group, all the sensors are in another RAW group which is further split into 4 RAW slots. As shown in Figure 1, CSMA and RAW both almost have no packet loss with 200 sensors. However, as the number of sensors increases to 1000, sensors get 21% packet loss for CSMA while only around 5% packet loss for RAW. With CSMA, the increase of sensors also results in packet loss for cameras, from 600 sensors on, cameras start to suffer packet loss, around 30% packets are lost with 1000 sensors, while only 0.4% packet loss occurs when using RAW. With 0.05% and 5% packet loss as the upper boundary for cameras and sensors respectively, up to 600 sensors can be supported with CSMA, while 1000 can be supported with RAW. The result clearly reveals that RAW is able to guarantee high performance for a large number of densely deployed IoT stations with heterogeneous traffic requirements.

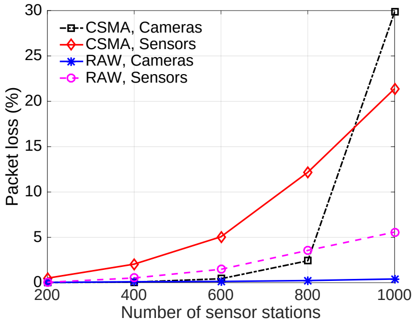
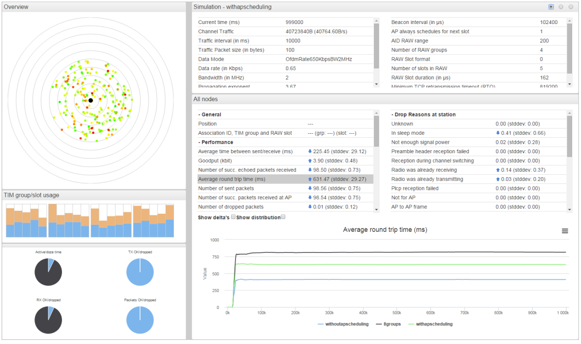


Figure 1: Packet loss comparison for CSMA and RAW, with 8 cameras and a varying number of sensors



Simulation - withapscheduling

Current time (ms)	999000
Channel Traffic	40723840B (40764.60B/s)
Traffic interval (in ms)	10000
Traffic Packet size (in bytes)	100
Data Mode	OfdmRate650KbpsBW2MHz
Data rate (in Kbps)	0.65
Bandwidth (in MHz)	2
Propagation exponent	3.67

Beacon interval (in µs)	102400
AP always schedules for next slot	1
AID RAW range	200
Number of RAW groups	4
RAW Slot format	0
Number of slots in RAW	5
RAW Slot duration (in µs)	162
Minimum TCP retransmission timeout (RTO)	819200

All nodes

- General	
Position	---
Association ID, TIM group and RAW slot	--- (grp: ---) (slot: ---)
- Performance	
Average time between sent/receive (ms)	↓ 225.45 (stddev: 29.12)
Goodput (kbit)	↑ 3.90 (stddev: 0.48)
Number of succ. echoed packets received	↓ 98.50 (stddev: 0.73)
Average round trip time (ms)	↑ 631.47 (stddev: 29.27)
Number of sent packets	↓ 98.56 (stddev: 0.75)
Number of succ. packets received at AP	↓ 98.54 (stddev: 0.75)
Number of dropped packets	↓ 0.01 (stddev: 0.12)

- Drop Reasons at station	
Unknown	0.00 (stddev: 0.00)
In sleep mode	↓ 0.41 (stddev: 0.66)
Not enough signal power	0.02 (stddev: 0.28)
Preamble header reception failed	0.00 (stddev: 0.00)
Reception during channel switching	0.00 (stddev: 0.00)
Radio was already receiving	↑ 0.14 (stddev: 0.37)
Radio was already transmitting	↑ 0.03 (stddev: 0.20)
Plcp reception failed	0.00 (stddev: 0.00)
Not for AP	0.00 (stddev: 0.00)
AP to AP frame	0.00 (stddev: 0.00)

Show delta's ☐ **Show distribution** ☐

Figure 2: 802.11ah simulation visualizer

3 802.11AH SIMULATION VISUALIZER

While the ns-3 simulator has several visualization tools and can export *.pcap files that can be analyzed with traffic analyzer tools, most of these tools only report the final result once the simulation is finished. To analyze the evolution of parameters of interest in near real-time, we have created snapshots of a number of metrics relevant for evaluation of the test network. These metrics are then sent to a visualizer which allows easy inspection of the evolution of each metric per station and which reports the overall distribution of the metrics for all stations while the simulation is running. This greatly speeds up the detection of problems in simulations and we can quickly determine if the parameters of the simulation are relevant. It is implemented as a NodeJS web-server which (i) hosts the simulation data sent by ns-3 through TCP connections each second of the simulation time and (ii) forwards the data to the web-browser clients through a web-socket in case of live data. It also writes the simulation data to a file which can be retrieved to compare simulations against each other. The visualizer is shown in Figure 2 and depicts the network topology, RAW slot usage, as well as multiple other metrics for near real-time tracking shown in the tables. Green (good) and red (bad) color gradations in the network topology map depict the behavior of the node in the context of the selected metric.

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