Demo: Interactive Web Visualizer for IEEE 802.11ah ns-3 Module

Extended Abstract

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ABSTRACT

In order to meet the rising demands for Internet of Things technologies, Wi-Fi community has developed Wi-Fi HaLow (IEEE 802.11ah). The new standard extends Wi-Fi supporting dense deployments of autonomous devices with various power capabilities and traffic patterns over a wide area. As there is no hardware supporting Wi-Fi HaLow available at the market yet, ns-3 opted to be an appropriate starting point for research on Wi-Fi Halow. However, extracting and parsing the data from ns-3 is in most cases time consuming and prone to mistakes. Post-processing is even harder when a large number of simulations need to be analyzed and even the Tracing System cannot simplify this task much. To automate data extraction and analysis, we developed a user-friendly interactive visualization and post-processing tool for Wi-Fi HaLow called ahVisualizer. In this demo, we present the ahVisualizer and demonstrate its operation with ns-3 on several examples of Wi-Fi HaLow networks. The ahVisualizer enables live monitoring of a set of measurements for each individual node, as well as insight in live measurements for a network as whole. It enables offline comparison of saved simulations and plotting series of metrics over a set of simulations. This tool provides an immediate insight in a simulation results while the simulation is running, and it makes both data extraction and analysis significantly faster and easier.

CCS CONCEPTS

• **Networks** → **Network performance evaluation**; • **Human-centered computing** → *Visualization*;

KEYWORDS

ns-3, visualization, analysis, post-processing, distributed simulations, IEEE 802.11ah, Wi-Fi HaLow

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1 INTRODUCTION

Having become a key driver for networking technology evolution, the Internet of Things paradigm raised a number of challenges to developers of wireless networks. The main two challenges are (1) providing connectivity for an extremely high number of energy-constrained devices, and (2) heterogeneity challenge where a single network should be efficient for devices with different capabilities, traffic patterns and quality of service requirements. LoRa, Sigfox, ZigBee and Bluetooth Low Energy can respond to the first challenge only in some niche scenarios specific for each technology. An attempt to address both challenges has been done by 3GPP and IEEE 802 LAN/MAN Standard Committee who amended a new Wi-Fi standard, IEEE 802.11ah or Wi-Fi HaLow. This standard is useful for various scenarios typical to the Internet of Things. It extends the transmission range of Wi-Fi devices up to 1 km, allows an Access Point (AP) to support up to 8192 associated stations, and is suitable for rare and energy efficient packet transmission of battery powered sensors and actuators, as well as for heavy flow transmission of much more powerful devices like video cameras [1], since the maximal available data rate exceeds 350 Mbps.

As IEEE 802.11ah standard was published recently (in May 2017), the hardware supporting Wi-Fi HaLow is not available at the market yet. However, a number of experimental evaluations of the standard are performed through simulation either using Matlab or ns-3. Given that ns-3 closely reflects actual protocol behavior and can easily be set up to evaluate a broad range of network and traffic conditions, we opted to use the IEEE 802.11ah ns-3 module [2] in our research. However, extracting and analyzing useful data from a large set of ns-3 simulations is not a straightforward task. The output from ns-3 can be obtained by simple printout, using NS_LOG or the Tracing System. Unlike the Tracing system, the other output methods typically provide both necessary and unnecessary information available once the simulation is finished. The bulks of raw data then need to be parsed in order to extract useful information. The Tracing system provides mechanisms for more selective output and it can immediately be formated into a form acceptable by gnuplot, but only for a single simulation. Analysis of a large set of simulations still requires extensive parsing after the simulations. Parsing of such output requires writing of additional scripts, which is time consuming, error-prone and a repetitive task.

We avoided the difficulty of post-processing and the limited visualization options by developing a tool that covers both, the ahVisualizer. ahVisualizer provides an easy interface for both live monitoring and analysis of data obtained from thousands of simulations, it shows the evolution of interesting parameters over time while simulating very dense networks with thousands of nodes. The ahVisualizer is based on the Tracing system and currently only supports IEEE 802.11ah module [2]. However, its design does not prevent the visualizer to be applied in a broader context than IEEE 802.11ah. In the future, we therefore plan to extend it for general use with ns-3.

In this demonstration we show the capabilities of the ahVisualizer through several simulations of IEEE 802.11ah networks. Specifically, we demonstrate the live ns-3 simulation monitoring, the offline comparison of several simulation results and plotting the series of values from a set of simulations.

2 DEMONSTRATION SCENARIO

In this demonstration, we simulate an arbitrary IEEE 802.11ah network with different devices that have heterogeneous traffic requirements, namely IP-cameras and sensors. The main goal of the demonstration is to present simulation results using ahVisualizer. The ahVisualizer enables the (1) live simulation monitoring, i.e. an insight in live evolution of desired measurements, either for any individual node or the average value for entire network; (2) offline comparison of measurements previously obtained from several simulations and (3) offline data analysis, i.e. extracting data from a large set of ns-3 simulations and ploting data series from that set of simulations.

We run and optionally monitor several simulations with different density and/or network configuration. Measurements from each simulation are automatically stored in an NSS file . To illustrate the differences in network performance over several simulation scenarios, we load obtained NSS files to the ahVisualizer to overlap diagrams of respective measurements from the respective set of simulations, as in Figure 1. We show the differences in performance of individual nodes, as well as the overall network performance, e.g. throughput, average latency, power consumption etc. Additionally, we demonstrate data analysis from a set of almost 20 000 previously run ns-3 simulations using the ahVisualizer. We show how different parameters influence overall network performance parameters for different network configurations, e.g. how configuration of minimum TCP retransmission timeout influences the number of TCP retransmissions for different TCP segment sizes and different Modulation and Coding Schemes (MCSs) in IEEE 802.11ah network serving IP cameras. The demonstration aims to show how meaningful information can be extracted from a large set of ns-3 simulations in only a few clicks.

3 AHVISUALIZER

The ahVisualizer currently supports ns-3 version 3.25 with 802.11ah Wi-Fi. It is custom designed to animate the Traffic Indication Map (TIM) Segmentation and Restricted Access Window (RAW) mechanisms on the MAC layer of 802.11ah. Besides, it also shows the network topology, network configuration and plots the time changes of many metrics for each node, but also the mean values and standard deviations of all the metrics for the whole network.

The ahVisualizer program consists of three components, namely the ns-3 component, the NodeJS web server and the website. In the ns-3 component, we implemented several new classes in order to handle the traced data in a structured manner, to serialize it and to send it to NodeJS server via TCP. The NodeJS web server acts as a host for the simulation data received from ns-3. The server

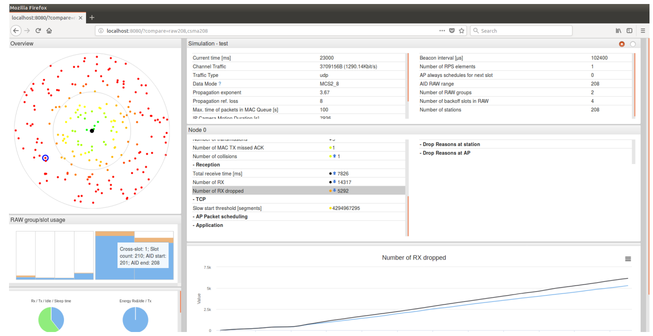

Figure 1: Offline comparison of measurements from a couple (generally, a set) of different ns-3 simulations.

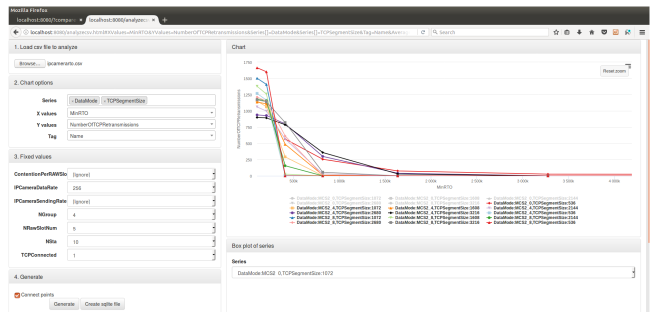

Figure 2: Web interface for quick and easy analysis of large ns-3 simulation sets.

forwards the data to the web-browser clients via WebSocket in case of live data. It also writes simulation data to an NSS file which can later be retrieved by the clients to compare simulations against each other. When a web-browser client subscribes to multiple streams, i.e. simulations, the server will send each stream in series either by reading out the stored NSS files or forwarding the live data in case of live simulation monitoring. A web-client receives the simulation data and visualizes it. In live simulations, the simulation data is updated every second. A web-client for data analysis analyzes the data from a CSV that is previously constructed from a set of NSS files. It reads the loaded CSV file, provides all its attributes in drop-down lists to choose axes and series variables and plots the configured series as illustrated in Figure 2.

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