Comparison of Propagation Loss Models for an Ad-hoc Wi-Fi Simulation in ns-3

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***Abstract*—This paper investigates the impact of five propagation loss models on Wi-Fi communication in ad-hoc scenarios with two nodes using the ns-3 simulation framework. With the availability of various models and the possibility of using multiple simultaneously, selecting the most suitable model for a given scenario poses a challenge. The analyzed models include Friis free space, Fixed RSS, Three Log Distance, Two Ray Ground, and Nakagami. Simulations were executed under identical conditions, measuring throughput for varying runtimes and signal strength for increasing distances between nodes. Results highlight two distinct classes of models: Fixed RSS and Nakagami exhibit constant signal strength, while Friis, Two Ray Ground, and Three Log Distance models show distance-dependent degradation. The study provides valuable insights for researchers configuring propagation loss models in ns-3 simulations for wireless communication networks.**

I. Introduction

A variety of propagation loss models for wireless communication networks are available in the ns-3 simulation framework. It is not always clear which model is the most appropriate choice for a given scenario. The complexity is augmented by the ability to use multiple models in conjunction. This paper analyzes the differences between five different propagation loss models in a Wi-Fi simulation and their impact on the simulation results. The simulations are conducted in an ad-hoc scenario with two nodes. The paper aims to provide a guideline for future researchers to configure propagation loss.

II. Methodology

All simulations are conducted in the ns-3 simulation framework[1], version 3.39, using an identical scenario. Two nodes communicate with each other in an ad-hoc 5 GHz Wi-Fi network via UDP. The first node continually sends packets of 1450 bytes to the other node with a rate of 75 Mbit/s. The sending node uses a transmitter with a transmission power of 10 dBm. The receiving node has a sensitivity of -101 dBm, which is the default value used by ns-3. Both nodes are equipped with omnidirectional antennas with a gain of 1 dBi. The simulations are executed on a Ubuntu system with an Intel Xeon E5-4650 CPU and 50 GB of memory. A constant position mobility model is used, as the nodes are not moving during the simulation.[2] The physical layer is implemented using the Yet Another Network Simulator based on [3]. All configuration that is not explicitly mentioned is left at the default value. That includes the default Auto Rate Feedback WiFi Manager that adapts the transmission rate based on the received signal strength (RSS). [5]

The following propagation models are examined with the corresponding parameters listed in TABLE:

- **Fixed RSS model**: This model takes a constant RSS as input and does not change it based on the distance between the nodes.
- **Friis free space propagation model**: The model described Harald T. Friis in [2] is proportional on the inverse squared distance and applies to free space transmission.
- **Three log distance model**: A modification of [1] which is conceptualized for suburban environments using different factors.
- **Two ray ground model**: As described in [6], there are two paths for the signal to reach the receiver: a direct path and a reflected path.
- **Nakagami model**: A stochastic model based on the measurements done in [4].

We conduct two different simulations. First, to determine the necessary runtime of the simulation, the throughput is measured for increasing runtimes. The distance between the nodes is constant at 10 m. Afterwards, the signal strength and throughput is measured for increasing the distance in steps of 1 m between the nodes. A fresh simulation environment is set up for every distance step in order to ensure identical starting conditions.

III. Results

First, we need to determine the simulation runtime for the comparison of the propagation models. Figure 1 shows the throughput results of running the same simulation at increasing runtimes. The throughput asymptotically approaches a value of over 73 Mbit/s, which is very near the datarate of 75 Mbit/s. After the initial rapid increase in throughput, the throughput only slightly increases with increasing runtime. The simulation is therefore run for 50 s as this can be considered a sufficient runtime to reach a stable state.

Analyzing the measured RSS shown in Figure 2, there are two main types of propagation models. The models Fixed RSS and Nakagami do not result in a decrease of RSS relative to

[1]See https://www.nsnam.org/

[2]The source code of the simulation is available at https://github.com/KingOfDog/ns3-wifi-propagation

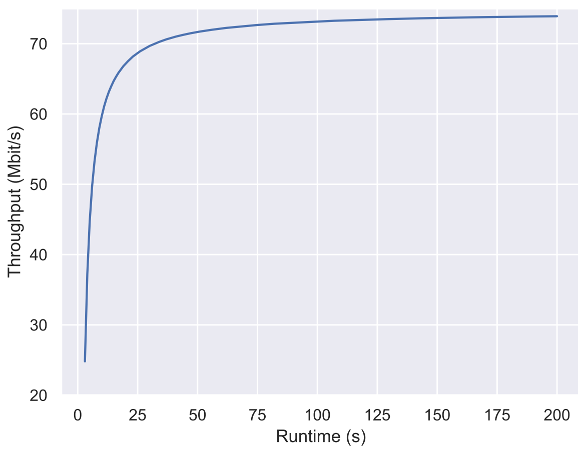

Fig. 1. Throughput measurements of a Wi-Fi simulation using the Friis propagation model with varying runtime.

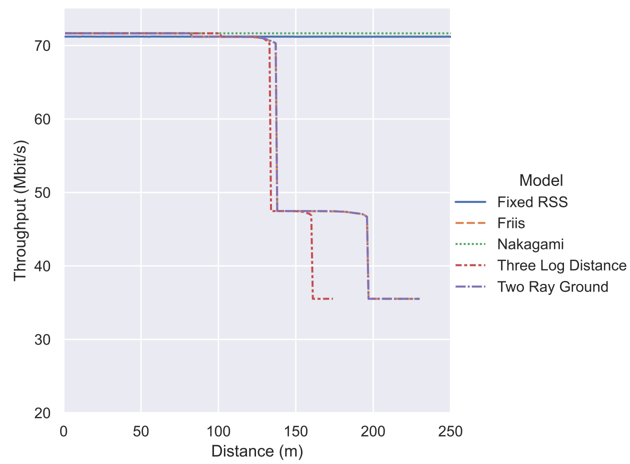

Fig. 3. The two classes found in the RSS measurements are also observed in the throughput measurements.

the distance between transmitter and receiver. The three other models, in turn, lose signal strength with increasing distance, resulting in a loss of signal at around -82 dB. With the Three Log Distance model, this threshold is reached at 175 m. The Friis and Two Ray Ground models, on the other hand, reach the threshold after 230 m. Overall, the Friis and Two Ray Ground models behave almost identically, leading to the lines overlapping in the graph.

Similar trends can be observed in the throughput measurements shown in Figure 3. Given the non-decreasing RSS of the Fixed RSS and Nakagami models, the throughput remains virtually constant at 71.1 Mbit/s and 71.6 Mbit/s, respectively. The other three models initially result in similar throughputs which decreases in two steps, first to around 47 Mbit/s, then 35 Mbit/s before being cut off because of signal loss. Both the Friis and Two Ray Ground models follow the same curve, whereas the Three Log Distance model is slightly below. The drops in throughput are explained by the Auto Rate Feedback WiFi Manager which switches to a different modulation when multiple consecutive transmissions fail.

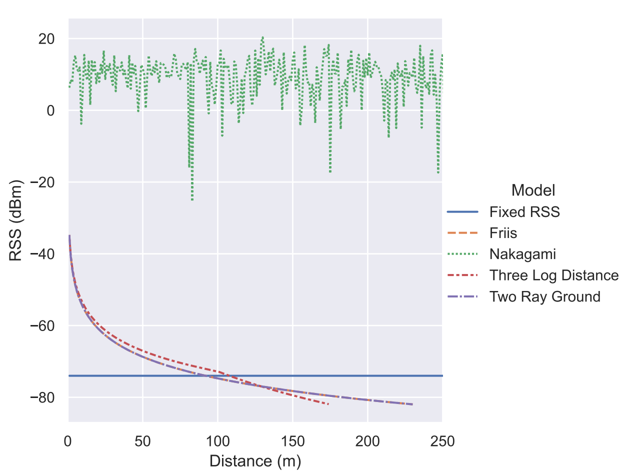

Fig. 2. The RSS in relation to the distance between nodes clearly shows two distinct classes of propagation models.

IV. Summary

In this study, we investigated the impact of five different propagation loss models on Wi-Fi communication in an ad-hoc scenario with two nodes. The propagation models analyzed were the Friis free space model, Fixed RSS model, Three Log Distance model, Two Ray Ground model, and Nakagami model. The aim was to provide guidance for researchers in selecting appropriate propagation loss models for their simulations.

The results revealed distinct behavior among the propagation models. The Fixed RSS and Nakagami models exhibited constant signal strength regardless of distance, resulting in stable throughputs close to the maximum achievable data rate. In contrast, the Friis, Two Ray Ground, and Three Log Distance models demonstrated signal degradation with increasing distance, leading to throughput decreases and eventual signal loss.

The simulation runtime analysis indicated that a 50-second duration was sufficient to achieve a stable state in our experiments. The measured throughput asymptotically approached the data rate of 75 Mbit/s, supporting the adequacy of the chosen runtime.

In summary, the selection of a propagation loss model significantly influences simulation outcomes in Wi-Fi ad-hoc scenarios. The Fixed RSS and Nakagami models may be suitable for scenarios where signal strength remains constant, while the Friis and Two Ray Ground models are appropriate for scenarios with distance-dependent signal degradation. The Three Log Distance model showed a unique behavior, positioned between the constant and distance-dependent models. Researchers should consider these findings when configuring propagation loss models in ns-3 simulations for wireless communication networks.

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