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Comparison of simulators for assessing the ability to sustain wireless sensor networks using dynamic network reconfiguration

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ABSTRACT

Wireless sensor networks (WSNs) can be used for a variety of tasks. The goal is to sustain such networks for as long as possible while still maintaining acceptable performance on the task. Evaluating WSNs for such diverse tasks precludes actual deployment and thus requires simulation. In this work, we compare simulators that can model power consumption and allow dynamic reconfiguration of network parameters based on feedback from the end application. The simulation results demonstrate some fundamental differences in out-of-the-box performance in terms of the way the simulators behave and calculate power consumption. With modifications to parameters and behavior, however the simulators' outputs become more closely aligned. Overall, based on our selection criteria, ns-3 was the best WSN simulator of those evaluated for assessing the sustainability of a WSN in a variety of settings.

1. Introduction

Network simulation, a commonly used approach in the design, implementation, optimization, and evaluation of network algorithms and protocols, models the behavior of a real network operating under various configurations. This allows researchers the ability to run experiments in a controlled, reproducible manner without the time and expense of setting up an actual network test bed with real nodes, links, and devices to measure network parameter. Moreover, the intended environment may be prohibitive to recreate at any budget. For example, the ultimate working destination of a sensor network may be at the bottom of an ocean [1] or on the side of an active volcano [2].

A wireless sensor network (WSN) is a network of low-power sensing devices that communicate by means of wireless transmission and in which every node is potentially a router [3]. Sensor nodes detect and report detailed data about their surrounding physical environment. Different types of sensors may be attached to the node to sample temperature, pressure, seismic activity, vehicular movement, and so on. Typically, a WSN has many sensor nodes located inside or close to the monitored area.

This comparison study is motivated by our research into ways to reconfigure a network to maximize application performance, as depicted in Fig. 1, while simultaneously sustaining the network for as long as possible. Our assumptions are: static network nodes (the sensors do not move after initial deployment), adjustable data sending rates (at a minimum on/off capability), and the application must be capable of reporting its performance in a meaningful way, such as accuracy on a scale of 0–100% for an AI application that does classification. So, we want to find the best open-source WSN simulator that can model power consumption and has the ability to evaluate algorithms for dynamically reconfiguring network parameters based on feedback from the end application.

This paper details the key features, advantages and/or disadvantages, and limitations of available WSN simulators with respect to their feasibility as a research tool. The simulators are tested in various scenarios, matching as closely as possible the parameters and behavior of each.

The rest of this paper is structured as follows. Section 2 presents related work. Section 3 discusses currently available open-source sensor network simulators. Section 4 analyzes features of the various available simulators. Section 5 details the simulator setup, and Section 6 states the results. Section 7 discusses the lessons learned. Finally, Section 8 contains some concluding remarks.

2. Related work

Energy conservation (for longer network lifetime) in a WSN is typically dealt with in five main areas [4–6]:

1. Optimal sensor node scheduling between active and sleep states.
2. Balancing transmission power for high connectivity and low energy consumption.
3. Data compression to reduce unnecessary packet transmissions.

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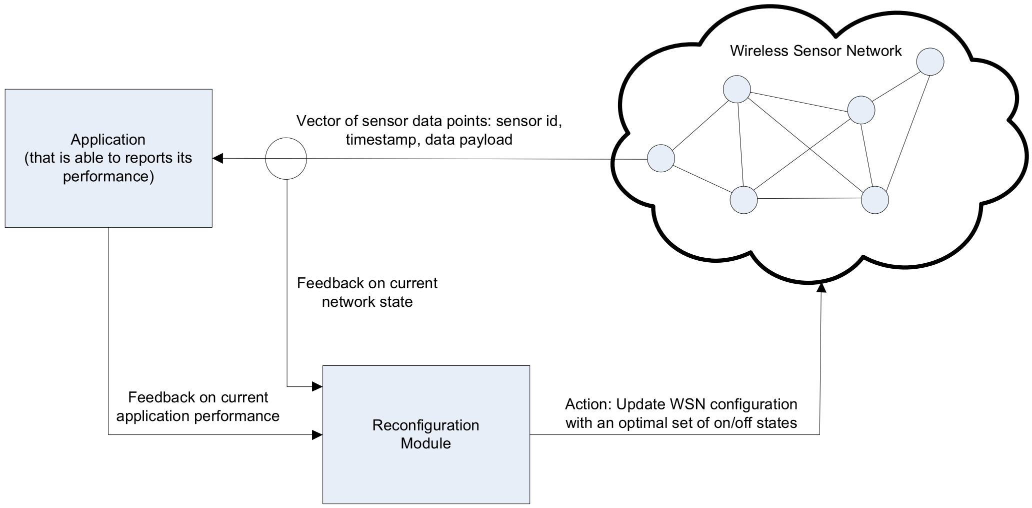

Fig. 1. Dynamic reconfiguration.

4. Data aggregation and clustering for energy efficient routing of packets.
5. Efficient packet re-transmission and channel access protocols.

In this paper, we focus on the area of sensor node scheduling.

Papers that have addressed these same or similar issues surrounding WSN simulator selection can be roughly divided into two groups: papers that review/compare various simulators without actually using them, and papers that include a comparison of simulator results. The papers that compare simulators all fundamentally agree that there is no one best, general-purpose simulator for all situations.

2.1. Comparison without simulator results

Many papers just present reviews and comparisons of various simulators based on apparent advantages and disadvantages gained through a search of the literature, without actually using them. In Imran et al.'s study [7], an evaluation criteria included popularity, support for WSNs, actively maintained codebase, and the technical support available. They noted that simulators cannot promise complete accuracy of results due to their use of simplifying assumptions.

The evaluation criteria in the work by Jevtić et al. [8] were level of detail, timing, software license, popularity, platform, graphical user interface support, models and protocols, and energy consumption. They provide guidance regarding which simulator to use in different situations.

Khan et al. [9] identified limitations of simulators and investigated their suitability for large-scale WSNs. They compared simulators based on interface, accessibility and user support, availability of WSN modules, extensiblity, and scalability.

Korkalainen et al. [10] tried to estimate the suitability of simulators for high-performance network planning and verification. They accomplished this by reviewing and summarizing the simulators' capabilities, especially considering popularity, support for WSN, and active maintenance.

Musznicki and Zwierzykowski [11] classified simulators according to their features and main applications. Singh et al. [12] sought to help researchers in selecting an appropriate simulator by presenting their best and worst features.

2.2. Comparison with simulator results

Regarding work that compares simulator results, Sundani et al. [13] performed a comparison based on scalability and level of abstraction. In addition, they reported a case study running ns-2 and TOSSIM with an increasing number of nodes and measured computation time. TOSSIM performed better than ns-2, as it appeared to follow a linear curve with large numbers of nodes.

In Feeney's study [14], results from five OMNet++ based simulators were compared with regard to backoff and contention. Her contribution was to introduce a scenario framework for comparing results from different simulators, with the idea that common testing will lead to better quality of and confidence in simulation results.

Weingartner et al. [15] compare simulator run-time performance and memory usage, showing large differences between the various simulators. However, they just presented these differences without identifying reasons the simulators might differ.

Bergamini et al. [16] found that using simulators in their default configurations would likely produce unreliable results. They compared simulator results with a real testbed in an effort to measure accuracy, determining that simple tuning can significantly increase accuracy.

The work closest to ours, Stetsko et al. [17] obtained calibration data using two MICAz sensor nodes and used two simulated nodes in comparing simulated energy consumption. They noted that even though the simulators were setup similarly, their results differed considerably. However, they only speculated on possible reasons for the differences and did not investigate further.

In contrast, our work simulates large numbers of nodes with forced routing due to large grid size and relatively short sensor transmission range. We experiment with the most commonly used simulators, including ns-3, a popular simulator primarily targeted for research use. In addition, we were able to identify the main reasons for differences in simulation results, and we share some important lessons learned from using the simulators.

3. WSN simulators

The WSN simulators included for consideration here are Castalia, TOSSIM, and ns-3. These are open-source simulators current research papers are found to use. OPNET is a famous network simulator A couple of older simulators, J-Sim [18] and SENSE