Demo Abstract: Castalia: Revealing Pitfalls in Designing Distributed Algorithms in WSN

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ABSTRACT

We present Castalia, a simulator for WSN that models many aspects of the WSN system and uses advanced models especially in terms of the channel and radio behaviour. We show the effects of these features in distributed algorithms that work fine with simpler simulators but fail under Castalia. The demo will present the differences, explain the failures and show how to redesign the algorithms to make them work under more realistic conditions.

Categories ad Subject Descriptors

D.2.2 Design Tools and Techniques, C.2.4 Distributed Systems

General Terms

Algorithms, Design.

Keywords: Simulation platform .

1. INTRODUCTION

Researchers in wireless sensor networks (WSN) have heavily relied in simulation to validate their ideas and methods. This is mainly due to the difficulty of deploying real systems (i.e., deploying tens or hundreds of sensor nodes in the physical environment, program them, excite them, and monitor their behaviour and state as the algorithm implementing the research idea unfolds). Due to the wide extent of the WSN research area, researchers usually focus on specific areas of system problems leaving the rest of the system's aspects to assumptions or sometimes to chance. Consequently their simulation needs are focused too. For example, they might only need to validate some high level properties of an algorithm or protocol, or they might want to test code running in the real platform by emulating the processor on the sensor nodes. These needs put very different demands on the simulator platforms used, abstracting away different parts of the real system.

There are two problems with this situation: 1) different simulators lead to incomparable results (even for similar tasks researchers usually choose slightly or grossly different simulators) and 2) the issues that are abstracted away are usually important and do affect the validity of the results. Most important among these issues are the various aspects of the communication abstraction. The work of Seada et al. [8] has showed how detrimental can be a simplistic channel/radio model to the design of a communication algorithm (specifically, a geographic forwarding algorithm was tested). Moreover, we should not forget that WSN are systems and many parts of the system affect the end result. For example the existence of a clock drift and a randomized start time for the nodes can make even simple protocols not work (if these issues were not taken into account).

The need for a simulator that takes into account various issues of the whole system and uses accurate models, (i.e., a simulator that has a chance to become a de facto standard), is present in the WSN field. We have developed Castalia [2], an open source simulator for WSN built on top of OMNeT++ [9]. Castalia features an accurate channel/radio model based on the work of Zuniga et al. [12], detailed radio behaviour, and forces the user to deal with many of the unpleasant -but yet important- aspects of communication. Castalia also features a flexible physical process model, takes into account usually neglected issues such as clock drift, sensor bias, sensor energy consumption, CPU energy consumption, and monitors resources such as memory usage and CPU time (apart form the obvious energy resource). In this demo we present these features, and more importantly, we show their effect on two distributed algorithms that were designed and tested with a less accurate simulator. We explain why the initial algorithms partially or totally fail and we show what design modifications are needed to make them operating.

2. RELATED WORK

Since many researchers in WSN come from a traditional networking background, ns-2 [8] is rather popular for the simulation of sensor networks. Ns-2 does not have the most advanced channel/radio models for systems such as WSN. More importantly, the models and structure favour traditional networks needs, where the users connect some protocols together (or slightly modify them) to assess some scenarios. When one tries to incorporate a distributed algorithm running in the nodes things get messy quickly. Researchers have identified early on the limitations of ns-2 so some tried to

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create or migrate to other platforms. Work such as [3] or [7] uses GlomoSim or OMNeT++ as their base but they are using rather simple channel/radio models. Simulators like TOSSIM [6] and Avrora [11] incorporate an emulator of the AVR processor found in several sensor platforms. This is very useful for real code debugging and other late development efforts, but because they are platform-specific and their accuracy is spent on the processor emulation they are not a good fit for initial algorithm/protocol design and testing. A more comprehensive survey of sensor network simulators can be found in [4].

3. DEMO

We start with a brief presentation of the main features of Castalia, such as 1) the channel/radio model, 2) the highly tunable MAC protocol, 3) the parametric physical process model, 4) sensing device bias and noise, 5) node clock drift.

To showcase the value of such features we test a popular tree formation and aggregation algorithm (finding periodically the maximum value sensed among nodes) and also a distributed estimation algorithm [1] designed to perform the same task. Both were initially designed and tested using a simulator simpler than Castalia (we will emulate the behaviour of this simulator using Castalia). The steps of the demo are:

1) Showing the tree formation and aggregation algorithm working with the simple simulator. Highlighting the assumptions of the simple simulator.
2) Showing the tree formation and aggregation algorithm failing with Castalia. Concentrating in a portion of the network and visualizing a few steps of the algorithm. Understanding a main reason for failure under more realistic channel/radio models: During the formation of the tree a node broadcasts its level (dashed line) reaching some nodes that become its children. Due to link asymmetry the children further away will usually have poor links back to the parent.

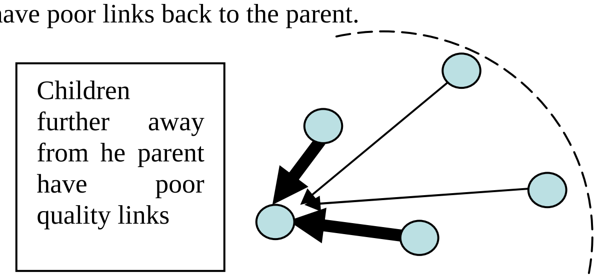

Figure 1: Asymmetry causing problems

3) Modifying the algorithm to address the problem, and test with Castalia again. Showing results that initially work but after some time begin to fail. Concentrate again in a portion of the network to reveal the problem comes from drifting clocks of the nodes.
4) Yet another modification to make it work stably. Finally having to decide on MAC parameter issues.
5) Test the distributed estimation algorithm in the simple simulator. Showing the benefits we get in energy compared to the simple tree aggregation approach.
6) Test the distributed algorithm in Castalia. The algorithm works but if we choose a naïve MAC we do not see any energy saving.
7) Choosing proper MAC parameters that allow the algorithm to work and experience energy savings. Realizing that the energy savings are not as great as in the simple simulator.

The visualization tool for Castalia helps us demonstrate these characteristics and issues in a dynamic and direct manner. We hope that the features of Castalia and its modular design, showcased in this demo, will attract a core of developers from the WSN community to help establish it as major WSN simulator for early-phase algorithm and protocol design.

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