Empirical Modelling of Wireless Sensor Networks

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1 Introduction

The focus of this paper is to study the techniques by which a Wireless Sensor Networks arrangement in a physical environment[1] can impact on the effectiveness of message propagation within the network. The model will be created in JS-Eden[4] and will also explore the effectiveness of this system for empirical modeling. The purpose of the EM model[3] created is twofold. Firstly, it is to explore the EM approach and the perceived benefits and drawbacks of it. Secondly, the model can be used as an educational tool to teach people the basics of a Wireless Sensor Network in an experiential way.

2 The Model

Wireless Sensor Networks, or WSNs for short, are a relatively new area of research and one which provides interesting and complex challenges[2]. A WSN consists of any number of small battery powered nodes which usually contain sensors that measure, among other things; temperature, humidity and light. The nodes are also built with wireless transmitters and receivers but because of their energy constraints transmission range is limited; therefore, the nodes in a WSN must work together to relay messages back to the base station of the network.

The goal of a WSN is to remain operational for as long as possible all the while completing the distributed task given to them, such as evaluating predicates or relaying values to the sink; this means factors such as node positioning can have a dramatic impact on the networks effectiveness.

2.1 Modeling a WSN

When modeling the Wireless Sensor Network model it was conceived to exist in two states, design and simulation. When in design mode the user can position the nodes of the network in any configuration they wish in relation to the base station which remains in a fixed position. The user can also adjust the radio range of the nodes to ensure that the nodes can communicate with each other. Finally, the user can adjust the predicate temperature to check.

In simulation mode the properties that were customizable before are now locked and instead the user can adjust other aspects of the system. For instance the user can step through the simulation using the step simulation button and can restart the simulation using the reset simulation button. The user can also adjust temperatures at each node in order to induce a response from the network, if for example the predicate to check was temp > 30 and the user increased the temperature of a node 3 hops away from the base station it would take 3 steps of the simulation for the message to reach the base station and for the simulation to end in predicate failure.

As just mentioned the simulation mode of the model can end in one of two ways: either with predicate failure if a nodes temperature is greater than the predicate temperature or with predicate success if the simulation runs to completion after 30 steps with no violations of the predicate detected by the base station.

2.2 Application of EM Concepts

Possibly the most important aspect of the Empirical modeling approach is experimenting with the model in order to intuitively establish beliefs as to the functions and abilities of a model. Therefore, an EM approach naturally lends it's self to experimenting with models based on the real world, such as a Wireless Sensor Network. EM models can be described in terms of 3 key concepts: observables, agents and dependencies.

The observables of a model are features of the domain or situation modeled, within this model some of these are: the position of the nodes, the temperature of the nodes, the predicate temperature to check, the message for a node to send and the message a node received last step.

The agents are entities within the model who are capable of initiating state change. Within the WSN model there are 9 agents, excluding the user, which are the 9 nodes of the network.

The dependencies are the relations between observables, within the Wireless Sensor Network model some examples would be: the relationship between the centre point of a node, it's position on screen and it's radio range on screen. Another would be the relationship between the predicate to check temperature and the temperature at each node. Finally, the relationship between a nodes position, it's radio range and whether it can send a message to another node.

2.3 LSD Specification

Although the model was not originally designed with an LSD specification, it is helpful to consider the model using the LSD language. The primary agents within the system are the Wireless Sensor Network nodes, the base station and nodes 1 through to 8. Next, to define the oracle, state and handle observables of these agents within the system.

The oracle observables of the agents include: the messages received by the node, the active state of the model and the radio range of the nodes. The state observables of the agents include: the temperature at the node, the message to be broadcast and the position of the node. Finally, the handle observables are: the message the node is to send and the list of other nodes in range of this node.

3 Evaluation

This section evaluates the EM model created in two ways. Firstly, an overall evaluation of the EM model with respect to how well it achieves the goal of modelling a Wireless Sensor Network. Secondly, future work that could be undertaken to the model is detailed.

3.1 Evaluation of Model

The EM model created is a solid realisation of some aspects of a Wireless Sensor Networks and is an excellent way to learn about and experiment with them. However, the model does require continued work before it can be considered a true modeling of a WSN, some of these improvements are detailed in the next section.

3.2 Future Work

As suggested the model still has several areas where it could be expanded to reach the goal of a true model of a Wireless Sensor Network. As future work on this project the next two agent of WSNs that would could be modeled are: battery power and radio interference.

Battery power could be modeled within the system to show the effects of network positioning on battery life on individual nodes and radio interference/message collisions could be modeled to show how multiple nodes sending at the same time can cause messages to be lost, modeling the unreliability of the communication method used between the nodes. Both of these extensions are fundamental aspect of any WSN design since they are some of the primarily limiting factors of a node.

4 Conclusion

In conclusion, it has been shown that Empirical Modeling can be used to create a model of a Wireless Sensor Network. Finally, it has also been shown that EM concepts such as dependency maintenance can make the rapid development of models easier than in traditional languages and modeling environments.

References

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