A CupCarbon Tool for Simulating Destructive Insect Movements

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***Abstract*—This paper presents the first version of a Wireless Sensor Network design and simulation tool, called CupCarbon. It is a multi-agent and discrete event Wireless Sensor Network (WSN) simulator. Networks can be designed and prototyped in an ergonomic user-friendly interface using the OpenStreetMap (OSM) framework by deploying sensors directly on the map. It can be used to study the behaviour of a network and its costs. The main objectives of CupCarbon are both educational and scientific. It can help trainers to explain the basic concepts and how sensor networks work and it can help scientists to test their wireless topologies, protocols, etc. The current version can be used to study the power diagram of each sensor and the overall network and also to simulate "destructive" insect movements. The sensor programming is done individually in each sensor as it must have its own communication program. In this version, only sending or waiting commands, and mobility on the OSM map are implemented so far. The power diagrams can be calculated and displayed as a function of the simulated time. Prototyping networks is more realistic compared to existing simulators.**

I. INTRODUCTION

Development in the field of wireless communication and electronics in recent years has given rise to a new technology known as Wireless Sensor Networks (WSN). These are composed of a large number of sensors that can be deployed randomly and densely. A sensor is a small electronic device that can collect data from its environment and send it to a base station. The type of data collected varies depending on the application and the type of the sensors. Sensor networks have many applications in different fields such as health, environment, agriculture, geology, military, etc. Most applications of WSN are challenging for designers and this is due to the limited capacity of the nodes in terms of autonomy (battery), computing power and inaccessible areas. This makes the design of algorithms and programs for WSN too constrained. Therefore, performance evaluation tools become very essential in the process of designing a wireless sensor network. The simulation is one of the most used tools for this evaluation. There exists a large number of WSN simulation tools. Simulators are of four different types. The first type represents simulators that are based on *NS2* [3], which is a simulator developed in general for traditional networks. It uses discrete event simulation. The second family is based on the *OMNET++* simulator [6]. It is also a discrete event simulator. The third family of simulators is based on *Ptolemy II* [1], which is a framework for modeling, simulating and designing of parallel embedded real-time systems. The fourth family is specially developed for WSNs, such as *WSNet* [2] used to evaluate high-level designs, *Atarraya* [7] for teaching and research topology control algorithms and *J-Sim* [4] a framework for modeling and simulation.

In the context of this study, we present a simulator named *CupCarbon* which is based on multi-agent and discrete event simulation. It offers a simple and friendly graphical user interface for the modeling of the networks using the *OpenStreetMap* (OSM) framework. It integrates a framework that allows to simulate insect movements.

This paper is organised as follows. Section II will present the *CupCarbon* design and simulation tool. Some simulation results will be presented in Section III. The conclusion will be given in Section IV.

II. THE CUPCARBON SIMULATOR

CupCarbon is a multi-agent discrete event wireless sensor network simulator which is based on geolocation. It allows to model and simulate sensor networks on a digital geographic interface of *OpenStreetMap*. For this purpose, *CupCarbon* provides a set of easy-to-use and configurable objects. The use of multi-agent systems allows better optimisation of the simulation time by taking advantage of the parallelism of agents and events. *CupCarbon* is composed of two main components: a multi-agent simulation environment and the WSN simulator (*WiSeN*). These components will now be described.

A. Multi-agent Simulation Environment

CupCarbon provides an environment for a multi-agent simulation, which allows to run simulations and to monitor various events and changes over time. The use of a multi-agent system allows a reproduction of an environment similar to the real world system, wherein each object in the system operates autonomously while communicating with other objects in the same environment. The integration of *OpenStreetMap* in this environment provides an interface and a database of digitised data related to geolocation such as roads, the positions of buildings, etc. Among the main agents in the system, one can find sensors integrating the radio for sending and receiving packets and insects in order to study wireless sensor networks for destructive insects, for example.

CupCarbon allows to configure each agent of the simulated system without using low-level programming. Agents of the system can be linked to script files to program their communications. Such a file describes how an agent will communicate with its neighbours and its environment. It contains all the main actions to be performed by a sensor during the simulation.

B. The WSN simulator: WiSeN

WiSeN is the name of the module that represents the kernel of *CupCarbon* for simulating events related to the sensors (sending, receiving, waiting, etc.). It supports and manages the evolution of the state of each object in the system (energy, position, etc.) [5]. Its implementation in a multi-agent environment allows each agent to be executed independently and in parallel. Thus, it is possible to include mobility aspects and the detection of the target. Each agent generates events based on a previously saved script, already created by the user. The simulator organises events generated by agents (sensors, mobiles, etc.) according to their creation dates and executes them in the same order, and it updates their status (energy, position, etc.).

III. Case study

In this section we will show how to use *CupCarbon* to simulate the energy diagram of a sensor network.

A. Simulation Setup

Once the *CupCarbon* tool is started and a new project is created, it is possible to create a network of sensors directly on a geographical map which represents the main window of the software. It is possible to create routes to be assigned to mobiles. It is also possible to create and simulate mobiles, gas, fires and “destructive” insects. For the sake of simplicity, we have chosen as an example a simple network consisting of eight sensors.

Once the network is developed, the different communication scripts must be created and assigned to each sensor. One script can be assigned to multiple sensors. In our case, we create a single script that is assigned to all sensors. As soon as all communication scripts are associated with the sensors, the simulation can begin. The next section describes the results for the created network.

B. Simulation Results

Once the network is ready, the simulation parameters must be specified: the simulation time and the simulation step. Thus, the simulation can begin. In our case, we chose to simulate a period of 100 hours ($= 360K$ seconds) with a simulation step of one hour. Figure 1 shows the curves representing the energy diagrams obtained for each sensor.

If we take into account a `delay` of 100 milli-seconds for each outgoing 10 bytes, we can improve significantly the lifetime of the sensors. After 100 hours functioning, the battery of a sensor reaches 70% of its total capacity. In other words, this sensor consumes 30% of its battery each 100 hours functioning with an additional delay of 100 milli-seconds in its communication script and it dies after only 57 hours without this delay.

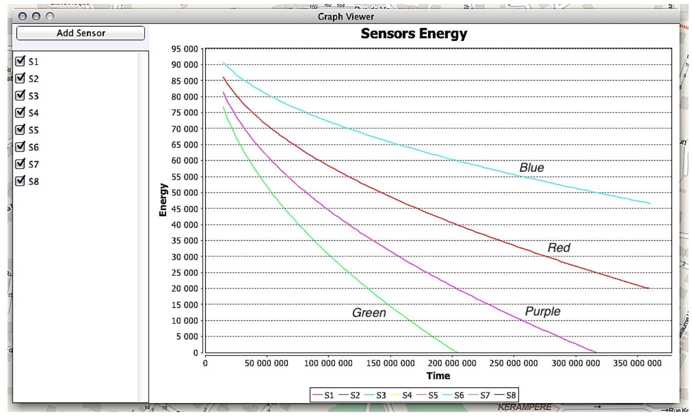

Fig. 1. Energy diagrams related to sensors (without the delay instruction).

IV. Conclusion

A simulator, *CupCarbon*, for the design and study of wireless sensor networks is presented. It allows to design networks using the *OpenStreetMap* framework. Networks can include sensors and other elements such as mobiles, gas, fires, etc. The presented tool can run two types of simulations. The Multi-agent simulation is used to parallelise the behaviour of each sensor to make it independent and also to simulate “destructive” insect movements. The discrete event simulation is used to simulate the communications between agents and especially between sensors. The main objective of this simulator is educational. It will demonstrate the use of wireless sensors under almost the same conditions as in the real world. The simulator can also be used to calculate the energy diagram of each sensor. A case study showing how to obtain this type of diagrams is also presented. The results are consistent with the structure of the network. We have shown that a simple delay of only 100 milli-seconds in the communication script of a sensor can improve significantly its lifetime.

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