SIMULATION TOOLS FOR WIRELESS SENSOR NETWORKS IN MEDICINE
A comparative Study

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Abstract: This paper presents a study on three simulation tools for Wireless Sensor Nertworks (WSNs): Network Simulator 2 (ns-2), Java Simulator (J-Sim) and Sensor Network Emulator and Simulator (SENSE). We present the concept of WSNs, each simulator in terms of its features, a view on current applications of WSNs on medicine and a comparative study on the simulators studied. We conclude that SENSE presents the better approach for WSNs.

1 INTRODUCTION

Heart diseases are leading mortality in the United States, and aneurysm is the number one cause of death in Europe. The aging population of developed countries are posing significant weight in the budget of healthcare systems (Istepanian *et al*., 2004).

A Body Sensor Network (Aziz *et al*., 2006) can be used to monitor a patient in real world-life activities. Such network gathers data from several body parts for latter processing and detection of possible heart problems.

On-site patient monitoring leads to efforts in the concept of m-Health: "mobile computing, medical sensor, and communications technologies for health-care" (Istepanian *et al*., 2004).

Wireless Sensor Networks (WSNs) application began in military areas and are spanning into everyday life (Akyldiz *et al*., 2002). A WSN is composed of intelligent mobile sensors that comprise a processing part with memory, the sensing block, a wireless communication transceiver and a power module. The sensor nodes collaborate to gather data to another node, typically with more computational power and communication resources that receive the sensing data (Khemapech *et al.*, 2005). This node is commonly named sink, since it collects (sinks) data, or base station (since it can also send network parameters to the sensor network nodes).

Simulation has always been very popular among network-related research. However, WSNs presents additional challenges, since they are energy constrained, resource constrained and ideally, size constrained. Energy concerns bring communication challenges, since the majority of energy consumption in a node comes from wireless communication.

The rest of the paper is organized as follows. Section 2 shows the studied simulation tools and section 3 includes some applications of WSNs in medicine. Section 4 presents the comparative study and section 5 concludes the paper.

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2 SIMULATION TOOLS

This paper studies three of the main simulation tools freely available: the Network Simulation 2 (ns-2, January 2007), the Java Simulator (J-Sim, January 2007, Sobeih *et al*., 2005) and SENSE (SENSE, March 2007).

2.1 Network Simulator 2 (ns-2)

The Network Simulator version 2 (ns-2) was developed in the University of Berkeley, CA, USA, and it is actually the the-facto standard on network simulation in general. The simulator is object-oriented and based in two languages: C++ as the development language and Object Tool Command Language (oTcl) as the simulation description language.

Ns-2 is in constant evolution and worldwide use. Current version is 2.31 released in March 2007 and version 2.32 is still a pending release. Some extensions provide Sensor Network simulation, like the one provided by the Naval research Laboratory.

The two languages approach may step up the learning curve. However, Tool Command Language (Tcl) is very appropriate for writing simulation code, presenting a good learning curve, and C++ provides execution performance.

2.2 Java Simulator (J-Sim)

The Java Simulator (J-Sim), developed by the Ohio State University, USA and is construction is based on the Autonomous Component Architecture.

This simulator also uses two languages, Java and OTcl. J-Sim is component-oriented, so the basic entities are components that communicate with each other via send/receive data through ports. Ports are also components whose behavior is defined by another component named contract.

J-Sim also provides a script interface that allows integration with different script languages such as Perl, Tcl or Python. Furthermore, a friendly and appropriate graphical interface for simulation results, although the graphical interface leaves something to desire. J-Sim provides a model to simulate WSNs, as depicted in Figure 1. We clearly define the nodes that will stimulate de WSN (target nodes), the nodes that will constitute the sensor network itself (sensor nodes), and the sink nodes (also known as base stations). As with any simulation, we clearly need to know simulation parameters.

Target nodes have only one communication channel, the sensor channel, since they only send stimulus to the sensor network, the sensor nodes communicate in two ways, sensor and wireless channel, and finally the sink nodes only communicate in the wireless channel.

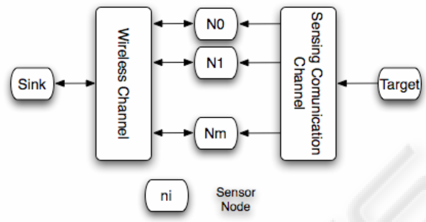

Figure 1: J-Sim simulation model for sensor networks.

2.3 Sensor Network Simulator and Emulator (SENSE)

Sensor Network Simulator and Emulator (SENSE) is the only simulator of the three that was specifically designed for sensor network simulation (SENSE, March 2007).

This simulator presents a component-based approach, created as a template class that allows the use of the component with different kinds of data. SENSE is still in an early stage of development. When trying to use the simulator we found some issues that were gladly solved by the developers. This simulator provides three user types: high level, network designers and component designers.

A component in SENSE communicates through ports: this model frees the simulator from interdependency. This also enables extensibility, reusability and scalability. Component extension in functionality is possible if the interface is compatible and no inheritance between components is used.

SENSE only uses C++ language and the interface only uses text, and the results are provided in a text file. This contributes to the efficient use of computational power, but greatly reduces the perceived user-friendliness.

SENSE requires that all nodes are identical. A common simulation engine stores the event queues of the system. SENSE compares the received signal strength with a threshold and decides if the packet has reached its destination.

3 MEDICAL APPLICATIONS OF WSNS

The use of intelligent medical monitoring can significantly decrease the number of hospitalizations and nursing visits (Heidenreich *et al*., 1999), by acting as an agent on human's behalf and launch of emergency alerts when appropriate. Human beings don't appreciate a visit to the hospital, even more when after a surgery (Naftalin and Habiba, 2000).

If a given health threat situation can be identified in advance, for instance the risk of an heart attack, measures can be taken to minimize or even suppress the risk. Some studies, namely on ECG (Zhou *et al.*, 2005) data retrieval, provide valuable insight on current health condition of a human being.

Body Sensor Networks usually consist of several implanted or wearable biosensors, such as ECG, EEG, glucose sensors, accelerometers, blood pressure and oxygen saturation sensors, temperature sensors, among others (Huaming and Jindong, 2006).

Medical applications span over different areas, such as heart-related, BSN applications, emergency response applications, asthma monitoring and even human error detection and correction. In (Lin *et al.*, 2006) authors present a solution for two important challenges: the first the discomfort of using a wired data-gathering system; and the achievement of the best path for data to flow in peer-to-peer wireless communication protocols.

A wearable ECG system, based on motes to create a WSN presented in (Taylor and Sharif, 2006), using the tMote Sky developed at Berkley University. In (Huaming and Jindong, 2006) authors used a WSN with BSN-MAC that they developed. A scheme collects context information through sensing and applies it to help detect QRS complex in an ECG. This information provides the means to build a personalized heart diary of a person. In (Lee *et al.*, 2007) authors present a WSN to collect ECG and body temperature. A server inside the hospital wirelessly receives data. Using this approach the patients are always being monitored and the server can process data in order to send alerts to medical staff. This presents great benefits when compared to the patient-initiated alarm.

(Lorincz *et al.*, 2004) present some challenges and opportunities for sensor networks in emergency response and a new architecture for wireless monitoring and tracking. In (Chu *et al.*, 2006), an experimental scenario is presented for patients with asthma or allergic situations, where a person is carrying a GPS-enabled system. A wireless system connects to a dedicated server in order to identify possible hazardous areas in the person's vicinity and issue an alert. In (Ohmura *et al.*, 2006), authors developed a sensor network in a real hospital environment that prevents medical accidents by monitoring nursing activities. The paper describes the design and implementation of the sensor network. Therefore, we can conclude that there is a broad range of applications for WSN in medicine, and that the development of novel sensors and novel ways to build sensors are of primordial importance, together with the wireless communication challenges and node deployment.

4 COMPARATIVE STUDY

Table 1 summarizes the main features of simulation tools ns-2, J-Sim and SENSE. J-Sim proves to be a good match for ns-2, no wonder that many researchers are using it instead of ns-2, mostly due to its ACA architecture. In (Sobeih *et al.*, 2005) a study is presented on the performance of ns-2 compared to J-Sim, so we target our efforts on J-Sim and SENSE.

Table 1: Summary of simulator tools features.

Event	***ns-2***	***J-Sim***	***SENSE***
Instalation	*Hard*	*Easy*	*Medium*
Version for Microsoft® Windows®	*No*	*Yes*	*No*
Popular in scientific and academic's	*Yes*	*Yes*	*No*
Object or component oriented	*Object*	*Comp*	*Comp*
Programming languages	*C++, oTcl*	*Java, oTcl*	*C++*
Learning curve	*Steep*	*Moderate*	*Moderate*
Easy to create only sample simulations	*No*	*No*	*Yes*
WSN simulation	*Extern*	*API*	*Dedicated*
Graphically-driven simulation build	*No*	*Yes*	*No*
Component diversity made to simulate	*Yes*	*Yes*	*No*
Supplies configuration network files	*Yes*	*Yes*	*Yes*
Easy to change a simulation model	*Yes*	*Yes*	*No*
Easy to define a simulation area	*No*	*Yes*	*No*
Easy to define number and position of nodes	*No*	*Yes*	*No*
Easy to create/change a protocol	*No*	*No*	*No*
Steps to run a simulation	*Few*	*Few*	*Some*
Display graphical mode to see simulation parameters	*Yes*	*Yes*	*No*

The first impression is that SENSE is more difficult to use than J-Sim: the "text-only" results, the C++ programming language for simulation creation and no graphical support.

We tried to simulate the sample WSN depicted in Figure 2 in J-Sim. On SENSE we managed to simulate a 11 nodes network, but not the same one.

It was not possible to simulate the same network in SENSE. In terms of battery the model Linear Battery was used, cpu base model for CPU, in the physical layer duplex transceiver was used, in the network layer a shr_ack and cbr in the application layer.

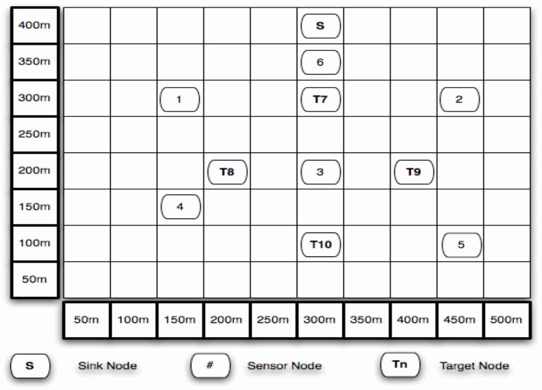

Figure 2: Simulated network node placement.

5 CONCLUSIONS

We provide some insight on three simulation tools used for simulating WSNs. The application on WSNs to medicine seems a very promising way to go, with clear benefits to users and medical staff.

Simulation rises as a good tool for early study of applications of WSNs in medicine, mainly if a given network is to be used and can be simulated.

In spite of a large user community and more experience on the J-Sim, we consider the SENSE simulator a better approach. Developed for WSN from scratch, the developing team answered very promptly to our requests and even released a new download to address the identified issues.

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