Simulation and Sensitivity Analysis of Sensors Network for Cardiac Monitoring

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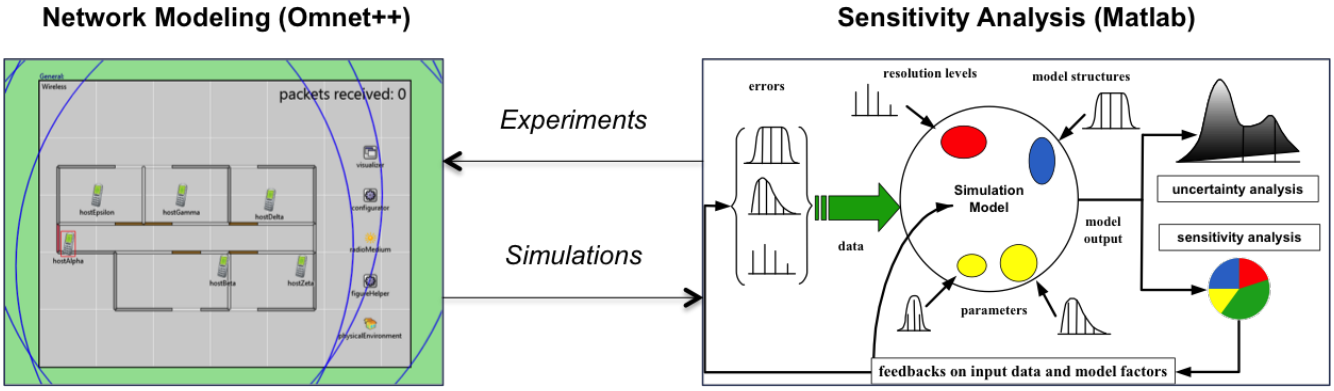

Figure 1. Design of numerical experiments for the robustness analysis of sensors networks

Abstract

This study's aim was to create a modelisation, and a simulation of a wireless sensor network in conjunction with the use of sensitivity analysis, robust analysis, and multicriteria optimization. The idea behind this is to use this technology in the medical scope of home cardiac monitoring. After an initial phase of research to find the right network simulator, the definition of the simulation parameters has started the robust analysis and sensitivity analysis using HDMR method. Next stage was to implement this method into Matlab, and to define a communication protocol between Matlab and the simulator, so they can exchange parameters and results. At last, gathered data analysis will help to define a product with optimized characteristics.

CCS Concepts • **Computer systems organization** → **Simulation**; *Sensors*; • **Networks** → Network reliability; Security; • **Statistics** → **Robustness Analysis**;

Keywords Internet of Things; Simulation; Sensitivity Analysis; Cardiac Monitoring

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1 Introduction

This study comes from a double context, the high throughput analysis in pharmaceuticals and the growing use of smart or connected objects to monitor patients' health. In both cases, the goal is to transmit cardiac signals for remote processing. These past few years, the improvement of measuring systems in pharmaceutical laboratories allowed to gather more accurate and numerous data during preclinical analysis. This increase in data size has two direct consequences : problem of storage, and sharing over internet [1, 3, 5]. Furthermore, some of those can contain sensitive data for which confidentiality must be ensured. In parallel, more and more smart objects are available and allow to monitor daily cardiorespiratory activity over long period of time, longer than traditional ECG (10s) or Hölter ECG (24h). Those huge generated files beget transfer problems to which are added network connectivity constraints. Both times, files' size can cause long transfer times, files' corruption, and a poor users' experience quality. In order to ensure a reliable, safe transfer of quality

(both in QoS and QoE meaning), it is necessary to estimate all parameters and their effect on the transfer. So we decided to combine network simulation, robust and sensitivity analysis, to help define products according to particular specifications.

2 Network Modeling

2.1 A Study Case

The study case was to simulate a network of five sensors. One of them was moving, and was the only emitter of messages. Another one was the sink of the network, the only target, which was able to acknowledge received messages. The other three were retransmitters, used to forward the messages if they received them. The emitter moves through a modeled flat with different materials, such as wood, cement, glass, etc and ensuing different perturbations.

2.2 Omnet++ Implementation

This case was implemented in Omnet++ with the library INET, which provides realistic elements to build a simulation with. It integrates widely used TCP and UDP protocols, sensor networks, energy management, interferences, etc.

2.3 Model & Simulation Parameters

The parameters chosen to vary in our different runs of simulation are the following, based on a relatively simple sensor network : the message length, the send interval, radio types and associated parameters, battery power, mac type, the use (or not) of acknowledge receipt of a packet, carrier frequency, energy detection and associated parameters, bit rate, max queue size, header bit length, path loss type and antenna type. They were selected to have a wide range of action on the sensors' capacity to interact with their environment.

3 Sensitivity Analysis

Sensitivity analysis is the study of how uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model input [4]. It was split into two phases. The first one aims at screening the most active parameters through a minimal number of simulations while in a second step a global sensitivity analysis was carried out to rank the total effects of the parameters selected after the screening study.

3.1 Screening of Parameters

A Plackett-Burman design of experiments was used to implement the preliminary selection of active parameters [2].

3.2 HDMR-ANOVA

Once the most active simulation factors have been identified, a Sobol' sequence was implemented to generate the simulated data we need to estimate the sensitivity indices by an Analysis of Variance approach based on a High Dimensional Model Representation (HDMR-ANOVA) [4].

3.3 Matlab Implementation

Matlab was used to generate a Sobol' sequence of experiments and Omnet++ was launched via a batch file created to run each simulation of the experimental design. Afterwards, the sensitivity indices were estimated according to the algorithm proposed in [4].

4 Results

Two outputs were studied during the simulations. The first one was the number of packets received by the sink at the end of each simulation. The second output is the reception cache hit percentage. For the first response variable, two critical parameters were identified: the message length and the bit rate. For the second output variable, the first two most critical factors were the background noise power and the energy detection of the radio receiver.

5 Conclusion

A prototype sensitivity analysis of a sensors network guided by simulations has been proposed. Preliminary results have demonstrated its practical feasibility by combining two simulation environments: Omnet++ and Matlab. A two-step statistical approach was proposed to speed up the analysis given the large number of simulation parameters to be tested. Such a technique allows to quickly identify the most critical parameters impacting the whole quality of service of the network. In short term perspective, parameters of the medical application, such as oxygen level monitoring, flow rate and remaining quantity during transfusion, will be added to assess the robustness of the remote cardiac monitoring.

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