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Simulation and sensitivity analysis of sensors network for cardiac monitoring

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Abstract
This study’s aim was to model and simulate a wireless sensor network and to propose a two-step sensitivity analysis for a targeted application related to home cardiac monitoring. After an initial phase of research to design the appropriate network simulator implemented in Omnet++, 13 simulation parameters have been selected to test their criticality. The sensitivity analysis relies on two consecutive steps carried out in Matlab: a screening phase (Plackett-Burman design) and a global sensitivity analysis (Space-filing design). Two output variables are considered: the number of packets received by the sink and the reception cache hit percentage. Four critical simulation parameters have been identified: the message length, bit rate, the background noise power and the energy detection of the radio receiver. In perspective, this sensitivity analysis will be included as a component of a Quality-by-Design approach of network development. This contribution is the early stage result obtained by Y. Kolasa during his MsC and PhD thesis (begun end of 2017) [2].

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1 Introduction
This study comes from a double context, the high-throughput analysis in preclinical cardiotoxicity tests 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 last 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, 4, 6]. 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 Holter ECG (24h). Those huge generated files beget transfer problems...
which was able to acknowledge received messages. The other
A Plackett-Burman design of experiments was used to im-
the sensitivity analysis was split into two phases. The first
or not) of acknowledge receipt of a packet, carrier frequency,
the three were retransmitters, used to forward the messages if
They were selected to have a wide range of action on

to which are added network connectivity constraints. Both
times, files’ size can sire too long transfer times, files’ poten-
tial corruption, and a poor users’ experience quality. In order
to ensure a faultless quality of service, we propose thereafter
an innovative approach combining network simulation and sensibility analysis.

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 straight through a
modeled flat with different materials and ensuing different

tion of their capacity to interact with their environment.

3 Sensitivity Analysis

The sensitivity analysis 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 im-
plement the preliminary selection of active parameters [3].

3.2 HDMR-ANOVA

Once the most active simulation factors have been identified,
a Sobol’ sequence was implemented to generate the simu-
lated data we need to estimate the sensitivity indices by an

3.3 Matlab Implementation

Matlab was used to generate a Sobol’ sequence of experiments and Omnet++ was launched via a batch file specifically
created to run each simulation of the experimental design.

4 Results

For the number of packets received, two critical param-
ters were identified: the message length and the bit rate. For the
reception cache hit percentage, the first two most critical

tors by simulations has been proposed. Preliminary results have

demonstrated its practical feasibility by combining two sim-
ulation environments: Omnet++ and Matlab. The proposed
technique allows to quickly identify the most critical param-
eters impacting the whole quality of service of the network.
This PhD thesis will be carried out in the context of the Hôpital virtuel de Lorraine to better account for the constraints of the medical context. The main objective is to develop a holis-
tic and safe engineering approach of medical sensors net-
works following the recent works on Quality-by-Design [2]
and by adapting it to remote cardiac monitoring.

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 sim-
ulation environments: Omnet++ and Matlab. The proposed
technique allows to quickly identify the most critical param-
eters impacting the whole quality of service of the network.
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