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Cross-level model for power-aware Wireless Sensor Networks design

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Abstract

In many Wireless Sensor Network (WSN) applications, it is important to optimize the global energy efficiency to enhance both the node autonomy and the whole WSN lifetime. In this context, the achievement of a power-aware design is a complex task due to the impact over the WSN energy consumption of different parameters, which are inherent to application, network or node levels. Therefore, a cross-level energy model is a useful way to estimate this energy consumption, leading designers to take correct decisions at the earliest design stages. Thus, this paper describes the principles of a cross-level energy model, which tries to address some weakness of existing WSN simulators in terms of energy modelling.

1. Introduction

A Wireless Sensor Network (WSN) is a group of wirelessly interconnected nodes, which are in general simple, low-power and, very often, battery-supplied devices [1]. Due to their limited availability of energy resources, the power-aware design of WSNs is a major research issue whose relevance has increased in the last years. Consequently, engineers and researchers involved in the development of WSN applications must take the right decisions in terms of energy optimization at the very early stages of the design process. Usually, simulators and emulators have been employed to accomplish this task.

WSN simulators or emulators are in general dedicated to a specific level [2]. Some simulators deal with network or packet levels, such as NS2, OMNET++ or SENSE. Others are considered as code or Operating System (OS)-level simulators like EmSim and TOSSIM. Furthermore, simulators as ATEMU or AVROVA are defined as hardware emulators. As shown in Figure 1, a classification of WSN simulators can be also establish from their energy or not-energy oriented nature [3].

The analysis of the literature brings out that all these simulators have been developed to meet precise goals [4]: protocol evaluation, code or node emulation. Therefore, in the context of power-aware design, energy-oriented simulators suffer from some drawbacks. On one hand, OS emulators and network simulators forget in general lower levels concerns like the node energy consumption. On the other hand, hardware energy-oriented models, which are mostly limited to specific hardware or WSN platform such as MiCA2, are not often concerned by the high-level energy issues. This is the same for other cross-level approaches, such as IDEA1 [5], where the application level or some tasks, at the node level, like sensing are not necessarily considered.

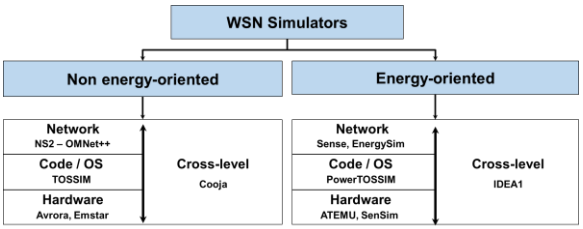

Figure 1. WSN simulator classification survey.

In conclusion, current simulator drawbacks must be overcome, with the goal of proposing an energy model that allows designers to realize how multi-level parameters interactions will impact not only the node energy consumption but also the network lifetime.

2. Proposed cross-level model description

The cross-level principles of the proposed energy model are illustrated by Figure 2.

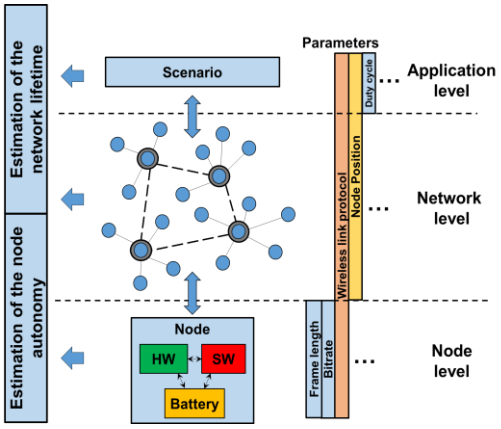

Figure 2. The cross-level model principles.

The first version of our proposed power-aware model is built on the assumption that energy consumption in

WSN takes place in a regular and periodic manner. Thus, each type of node has a specific and iterative pattern of energy consumption. A pattern consists of a set of phases, as illustrated in Figure 3 for the radiofrequency (RF) part of a node, which are repeated following a frequency F_p.

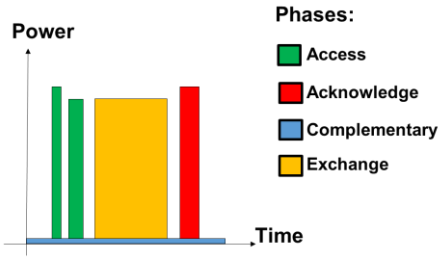

Figure 3. Pattern phases of the node RF part.

During each phase, the energy consumed by the node when performing a specific activity like sensing, data processing or message transmission, is modelized by means of several parameters which act at different levels [6]. For example, the energy consumed in the transmission phases is a function of the bitrate, the frame length, the node's power levels and the scheduling of each transmission phase. Indeed, the link protocol specifies the number, the structure and the order of different phases, while the employed RF chipset determines the consumed energy, that generally depends on the transmission output power.

3. Wireless link protocol comparison

To illustrate the usefulness of the proposed energy model, simulations have been conducted to compare two link protocols, IEEE 802.15.4 and IEEE 802.11a, in terms of energy consumption.

3.1. Simulation scenario description

The proposed simulation scenario is an open area measuring 25x25 m^2. Within this area, there are two nodes, node A and node B, that are 10 m apart. Periodically, the node A sends a message with a fixed-length payload to the node B through the wireless medium. As soon as the node B receives this message, it replies by sending the same message to the node A. The duration of each scenario is 100 s, and only the RF part consumption of each node is considered. The CC2420 and HDG204 transceivers have been respectively used for IEEE 802.15.4 and IEEE 802.11a link protocols.

3.2. Obtained results for the RF part

Different message payload sizes and pattern frequencies F_p have been applied to compare the two wireless link protocols. Considering these two parameters, Figure 4 shows the obtained results. In orange zone, the most energy-efficient protocol is IEEE 802.11a, whereas in the blue zone, IEEE 802.15.4 offers a lower energy consumption.

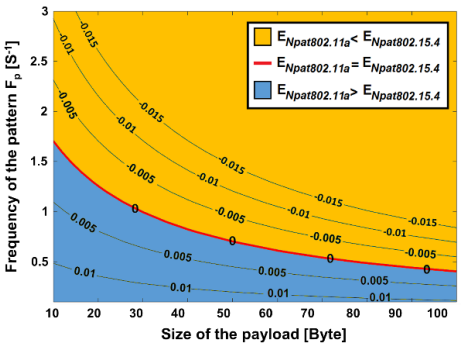

Figure 4. Wireless link protocol selection.

4. Conclusion

This paper has presented the principles of a cross-level energy model for power-aware WSN design, mainly oriented to application designers. The model usefulness has also been illustrated by comparing two wireless link protocol using a basic scenario. For future work, a simulation tool which implements the complete cross-level energy model must be provided, together with a validation of the tool by means of more complex simulation and experimental case studies.

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