PhD Thesis Proposition

Laboratory: IRISA – GRANIT Team (Lannion)

Thesis Title: Learning to survive: Dynamic programming for autonomous and heterogeneous IoT networks

Key Words: Reinforcement learning, wireless sensor networks, energy harvesting, MAC protocols, power management

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Project Description

Internet of Things (IoT) networks consist of a large number of wireless nodes, which are densely deployed in remote places and cooperatively transmit collected data to base stations via wireless communications. To overcome battery-limited energy problems [akyildiz02jcn], nodes may rely on available environmental energy sources such as light, wind or heat. Due to the variety of IoT applications, these nodes form a very heterogeneous network, since they embed different sensors and radios, and therefore different computation abilities. To guarantee its sustainability, each node has to organize its different tasks (sense, process, transmit, receive, relay…) with respect to its environment, especially the energy that can be harvested. As a node has no prior knowledge of the energy cost of these controlled or event-based tasks, the latter has to be learned in real time. The role of the power manager is then to prioritize these tasks and allocate an energy budget to each of them, such that the consumed energy is equal to the harvested energy over a long period, which leads to Energy Neutral Operations (ENO).

In previous works, we designed generic power managers able to deal with the different energy sources [le13pimrc]. Our power manager adapts the duty cycle of the node according to the estimation of harvested energy and the consumed energy. To deal with the uncertainty linked to the energy sources, we recently proposed a new power manager based on fuzzy control [aitaoudia16icc], whose outstanding performances were evaluated through network simulations (Castalia/OMNeT++) and experiments on the PowWow WSN platform developed by the GRANIT team [granit13powwow].

Another way to design the power manager is to base on experience, especially thanks to reinforcement learning (artificial intelligence used in Alphago, for instance). Reinforcement learning differs from standard supervised learning in that correct input/output pairs are never presented, nor sub-optimal actions explicitly corrected. There is a focus on on-line performance, which involves finding a balance between exploration (of uncharted territory) and exploitation (of current knowledge), which particularly suits to energy harvesting mechanisms.

The node will thus be able to track the harvested energy but also the energy costs to execute its different tasks (that can also be time-varying).

General objectives and expected results

The first phase of this work will be dedicated to the bibliography study on Reinforcement Learning principles and its applicability to energy harvesting nodes [xiao15icc].

Then, the second phase will be the design of a RL-based power manager, that will adapt the energy budget to the residual energy in the battery. A particular attention will be given to the approximation functions that represent the value functions, exploring different forms from *weighted linear functions* to *outputs of neural networks*. These different possibilities will be evaluated by simulations, and compared to state-of-the art power managers.

Finally, the main contribution of this work will be to extend the proposed approach at a network level by learning the costs of the different tasks and by collaboratively deciding the best policies. The best strategy will be implemented on a real wireless sensor platform. A network composed of heterogeneous nodes will be deployed to confirm this superiority in terms of energy management and quality of service .

The PhD Candidate should have skills in computer science, artificial intelligence, as well as in wireless communications and microcontroller programming. He should be autonomous for the experimental part and have capacities for team work and easy integration.

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