Université Nice SOPHIA ANTIPOLIS
LEAT
LABORATOIRE D'ELECTRONIQUE ANTENNES ET TELECOMMUNICATIONS
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UMR CNRS n° 7248

Proposition de sujet d'étude pour un contrat Postdoctoral
Laboratoire d'Excellence UCN@Sophia

Titre : Improving energy efficiency of communicating objects using multiple harvesters and reconfigurable antennas

Domaine applicatif du Labex UCN : Efficacité énergétique

Equipe d'accueil : LEAT (thématiques Modélisation, Conception Système d'Objets Communicants (MCSOC) et Conception et Modélisation d'Antennes (CMA))

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Thème de recherche proposé :

Context

Wireless Sensor Networks (WSN) provide a powerful combination of distributed sensing, computing and wireless communication that can be useful in various applications (monitoring, health and fitness, environment, automotive, smart building, etc.) [1]. However, energy consumption is a critical issue in the deployment of battery-powered wireless sensor networks (WSNs) for instance in monitoring applications which usually require long-term operations. Therefore, energy harvesting provides a potential solution to extend the system lifetime [2]. Moreover, for ensuring perpetual operations, a power manager is included to adapt the consumed power consumption according to the harvested energy over a long period. Most of current approaches consider solar-powered WSN since energy extracted from photovoltaic cells provides the most significant energy efficiency [4]. Nevertheless, other sources of harvested energy have also been considered such as thermal [2] or wind [3]. Another promising harvesting source is rectenna (antenna + rectifier) [5]. Rectennas, which receive RF power and converts it into DC power, have received important attention in the recent decades for the development of wireless power transmission.

Objectives and addressed issues (locks)

Most of the WSN systems have considered these different sources of energy independently. In this post-doc, we would like to address the problematic of using conjointly different harvesting source according to the environmental conditions. The related issues to this problematic concern the WSN hardware architecture as well as its software power management. The communicating object architecture has to provide an efficient harvesting system, especially adapted to different kinds of scavengers. Moreover, the renewable energy storage element (typically a battery or a super capacitor) needs to be properly sized in order to provide power to the object when no more energy can be harvested from the ambient environment. For that it is required to store a part of the energy from harvesters when it is available, and this is the role of a power manager.

Another research area that we would like to address concerns the use of reconfigurable antennas for WSN nodes [7]. Indeed, most of the current WSN systems use omni-directional antennas [6]. As the output RF signals are emitted in all directions in this case, this kind of antennas is definitively not efficient in terms of power consumption, range and interferences. Reconfigurable antennas, that are able to focus the output signal beam in different directions, provide a solution to the aforementioned issues. However, using reconfigurable antennas impacts the way WSN nodes will communicate. As a consequence, the physical,

medium access and network (routing) protocol layers [8][9] need to be reconsidered. Indeed, the node will have for instance to configure its antenna (and its RF chip) according to its position or its distance from the base station. In this project, we would like to address this problematic and more especially the case of mobile nodes and multi-hop communications. In that case, the node will have to dynamically control its antenna and its RF circuit according to its position as well as to the fluctuating channel conditions.

Expected results

Several outcomes can be expected from this research project. First, we would be able to propose a more energy efficient architecture for communicating objects, typically for a WSN context. As we expect to reduce the consumed energy (using reconfigurable antennas), and in the meantime to optimize the amount of harvested energy (using different harvesting sources), the lifetime as well as the quality of service of a WSN node will be improved. To achieve these objectives, a new protocol stack would have to be specified in order to take into account these new techniques. Finally, new power management strategies will be required to ensure an energy neutral operation of the node, i.e. balancing consumed and harvested energy over a long period (i.e. autonomous node). These different tasks need to be addressed by the post-doc candidate through a global approach, since local decisions may have an impact on the global behavior of the system. The objective is first to develop or extend existing models for communicating objects based on multiple harvesting systems and a reconfigurable antenna. Then the candidate will have to propose a way to validate these models as well as the power management policies using a simulation environment (such as [10] developed in LEAT), then a WSN hardware platform (e.g. PowWow platform [11]). A typical WSN monitoring application (e.g. environmental supervising) will be used for demonstrating the benefits of using reconfigurable antennas and multiple energy source for WSN autonomous communicating objects (but other applications could be considered).

This post-doc subject would take place in a collaboration between two different teams of the LEAT laboratory: MCSOC (System Level Modeling and Design of Communicating Objects) and CMA (Modeling and Design of Antennas).

Mots-clés : Wireless Sensor Networks, power manager, energy efficiency, energy harvesting, Rectenna, Reconfigurable antennas, network protocol layers.

Quelques références de travaux :

[1] D. Puccinelli and M. Haenggi, "Wireless sensor networks: applications and challenges of ubiquitous sensing," Circuits and Systems Magazine, IEEE, vol. 5, no. 3, pp. 19 – 31, 2005.

[2] L. Nhan, A. Pegatoquet, O. Sentieys, O. Berder, and C. Belleudy. Duty-Cycle power manager for Thermal-Powered wireless sensor networks. In International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), pages 1655–1659, 2013.

[3] D. Carli, D. Brunelli, D. Bertozzi et L. Benini, *A high-efficiency wind-flow energy harvester using micro turbine*, in Power Electronics Electrical Drives Automation and Motion (SPEEDAM), International Symposium, pp. 778–783, Jun 14-16, 2010.

[4] C. Moser, L. Thiele, D. Brunelli, and L. Benini, "Adaptive power management in energy harvesting systems," in Design, Automation Test in Europe (DATE), pp. 1–6, 2007.

[5] T.Q.V. Hoang, A. Douyere, J-L. Dubard, J-D. Lan Sun Luk, *TLM Design of a compact PIFA rectenna*, International Conference on Electromagnetics in Advanced Applications (ICEAA), pp. 508-511, 12-16 Sept. 2011.

[6] Terence Wu, Ronglin Li and Manos. M. Tentzeris, A Scalable Solar Antenna for Autonomous Integrated Wireless Sensor Nodes, IEEE Antennas and Wireless Propagation Letters, Vol. 10, 2011.

[7] G. Giorgetti, A. Cidronali, S. Gupta et al. "Exploiting Low-Cost Directional Antennas in 2.4 GHz IEEE 802.15.4 Wireless Sensor Networks, " in Proc. of ECWT, 2007.

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[8] R. Choudhury and N. Vaidya. "Impact of Directional Antennas on Ad Hoc Routing, " Personal Wireless Communications, vol 2775, pp 590-600, 2003.

[9] X. Huang, J. Wang and Y. Fang. "Achieving Maximum Flow in Interference-aware Wireless Sensor Networks with Smart Antennas". Ad Hoc Networks, vol 5:6, pp 885-896, 2007.

[10] Andrea Castagnetti, Alain Pegatoquet, Cécile Belleudy and Michel Auguin, *A Framework for Modeling and Simulating Energy Harvesting WSN nodes with Efficient Power Management Policies*, EURASIP Journal on Embedded Systems (JES), October 16th, 2012.

[11] PowWow, http://powwow.gforge.inria.fr [Online]

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