Distributed Approach for Cross-Layer Resource Allocation in Wireless Sensor Networks
Master Internship

Olivier Alphand   Karine Altisen   Stéphane Devismes   Franck Rousseau

LIG — Verimag
Contacts: {`Olivier.Alphand, Karine.Altisen, Stephane.Devismes, Franck.Rousseau`}`@imag.fr`

Scientific Context.   The Internet of Things (IoT) as it is defined today aims at interconnecting physical objects using Internet technologies. This brings two complementary scenarios in the picture: Machine to Machine interaction, where connected smart objects can interact autonomously with each other, and physical world interaction, where sensors quantify their surroundings and actuators may act upon their immediate environment. These networks are envisioned as a major source of data, stored remotely in the cloud for later analysis, hence contributing to the rise of Big Data.

Wireless Sensor Networks   (WSNs) constitute one of the major enabling technologies for the development of the IoT. It is well accepted that the design of smart objects requires small autonomous embedded systems that will be scattered all around the environment, either as autonomous sensing and/or actuating nodes, or as part of larger components, like devices, buildings or even cities. Support for communications is a core requirement and the wireless technology is of primary interest as it allows seamless, easy, cheap, and most of all, untethered deployment. WSNs are multi-hop wireless networks made of many small nodes that have to run on scarce resources: (i) scarce energy coming from batteries or harvested from the environment, (ii) little processing power and small memory of low power micro-controllers, (iii) short range and unreliable communications due to ultra low power radios. Resulting networks are highly dynamic: wireless communication links are unstable and prone to external perturbations, nodes are fault-prone, since they might crash at any moment because of their limited energy and easy accessibility on the field, and there is no stable communication infrastructure due to the two previous items. To sum up, WSNs are **large-scale distributed systems** that must be **fault-tolerant**.

Standardization   is undergoing a fast pace at all the layers of the protocol stack. In particular, the IEEE 802.15.4 standards are dedicated to the physical and link layers, where Medium Access Control (MAC) is of primary interest. On top of them, 6LowPAN/IPv6 and RPL, standardized at the IETF, are dealing with the network layer and routing. IEEE 802.15.4e defines TSCH (IEEE Std 802.15.4e-2012, `http://www.ieee802.org/15/pub/TG4.html`), a new MAC which focuses on ultra low-power and high reliability, targeting industrial applications. TSCH is named upon its two key principles: Time Slotted operations and Channel Hopping. The former reduces the radio activity to the minimum, providing ultra low-power operation, while both together guarantee time and frequency diversity, hence providing high reliability. More precisely, TSCH organizes communications using *cell* reservations, where each cell is defined as a pair made of a time slot and a channel.

Now, TSCH defines only how to execute a communication schedule. For this reason, the IETF is currently working on the standardization of 6TSCH, an intermediate layer that will provide the missing parts. In this scope, support for resource allocation is being defined and will be compatible with both centralized and distributed approaches, but will not specify any algorithm. However, up to now, the resource management

support relies on external centralized entities. For example, a *centralized path computation engine* is used to pre-compute static schedules and paths. Such approaches clearly do not scale up. Our position is to go beyond this limitation by proposing efficient distributed algorithms and implementations for resource allocation.

Subject. The objective of this work is to provide the means to operate a WSN with TSCH in a fully distributed manner, namely without using any centralized entities. To reach this goal, the subject focuses on MAC in order to compute and allocate, in a distributed manner, global schedules of cells that will guarantee required properties. Precisely, the subject requires:

- A **bibliographical** study: TSCH and existing implementations, candidate distributed algorithms to compute schedules of cells.

- **Implementation**: implementation of a solution, first carried out on a simulator (6TiSCH Simulator, `https://bitbucket.org/6tisch/simulator/overview`) and, depending on the state of advancement, an implementation on real platforms will be possible thanks to IoT-LAB (`https://www.iot-lab.info/`), an open testbed held in INRIA Grenoble.

- **Comparison**: solutions will have to be compared with existing, centralized, one in order to validate the approach.

Required Skills. An important background about sequential algorithmic is mandatory. This subject also requires background about distributed systems and networks protocols. Ability in the following required: Python, C/C++, networking (some knowledge about micro-controller programming would be a plus but not essential)

Working context. The internship is part of the ANR Persyval project IOIT. The student will be integrated in the Drakkar team[1] in LIG lab with regular meetings with the Verimag[2] team.

Possible extensions into a PhD thesis.

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[1]http://drakkar.imag.fr/
[2]http://www-verimag.imag.fr/