Probabilistic Methods for Routing in Wireless Sensor Networks

Master degree subject

Karine Altisen Stéphane Devismes Pascal Lafourcade

Verimag Lab
Contacts: {Karine.Altisen, Stephane.Devismes, Pascal.Lafourcade}@imag.fr

Scientific Context. Recently, there was a growing interest in wireless sensor technologies. Such technologies have large-scale applications such as earthquake monitoring or military applications and small-scale services such as home automation.

Sensors are small devices that can generate data about the environment (for example, measure of temperature) and can used them for specific services (for example, emit an alarm when surrounding temperature is too high). They embed wireless communication capabilities for exchanging data between them, shaping thus an implicit network called a *Wireless Sensor Network (WSN)*.

A crucial problem for WSN is the one to transmit data from a given source sensor to a given destination. It is called *routing*. A routing protocol encapsulates the data into messages and then computes a path in the WSN to move them from sensor to sensor until reaching the target.

Routing protocols for WSN have two specifities. First, communications within a WSN are subject to faults such as link failures due to interferences and crash failures due to the low-power batteries of sensors. The structure of a WSN is *highly dynamics* and routing paths cannot be computed statically and once for all. Second, sensors can only communicate with other nearby sensors: routing paths can only be computed locally, piece by piece thanks to *distributed algorithms*.

Problem. We consider a network made of many sensors plus a server (so-called *sink node*). The sensors have to regularly route information to the server. Three approaches are typically used for routing.

- *Flooding* consists in routing the data without any infrastructure. The path is dynamically computed. It can be deterministic but the drawdack is that many control information have to be stored into the message. In contrast, it can use probabilistic methods but the message delivery is not guaranteed.
- *Overlay* consists in computing a routing table at each node and then routing the data using it. However, routing tables are difficult to maintain in a dynamic network.
- *Hybrid* mixes the two previous approaches. The idea is to use an overlay when the system is stable. When there are topological changes, the overlay can be temporaly perturbated. In this case, techniques derivated from flooding are used to find another path to the destination.

In a previous work [WSRABD07], Watteyne *et al* propose a hybrid routing protocol for WSN. The protocol mixes two strategies:

1. Computing a breath-first search tree rooted at the sink node (using the protocol in [HC92]) and then routing messages along the tree.
2. Collecting information into the message to deterministically update the route when some topological changes occur.

The main drawback of the method is its cost. Indeed, heavy control information (list of identifiers) are stored into the message during the routing to guarantee its delivery.

We propose to improve this routing protocol by introducing probabilistic methods into the protocol.

Subject. The subject consists in studying different alternatives for the second part of the previous protocol. Deterministic choices — based on heavy collection of information into the message — will be replaced by probabilistic choices by using classical optimization heuristics such as *simulating annealing* and *tabu search*. Both heuristics are designed to locate a good approximation of the global minimum of a given function in a large search space. Those methods have to be adapted to the context of distributed computing in WSN.

Precisely, the subject involves:

- a bibliographical study (WSN, routing protocols...),
- designing new routing protocols with non deterministic flooding,
- implementing and simulating those protocols (in a given simulation framework for testing and validating network algorithms)
- analysing the performances of the protocols (benchmarks from simulations and complexity analysis).

Working context The students will be integrated in the lab VERIMAG[1] in the "synchronous" team. The subject is part of the national project ARESA 2 (Embedded Systems and Wireless Sensor Networks) which involves academic as well as industrial cooperations.

Possible extensions into a PhD thesis.

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References

[HC92] Shing-Tsaan Huang and Nian-Shing Chen. A self-stabilizing algorithm for constructing breadth-first trees. *Inf. Process. Lett.*, 41(2):109–117, 1992.

[WSRABD07] Thomas Watteyne, David Simplot-Ryl, Isabelle Augé-Blum, and Mischa Dohler. On using virtual coordinates for routing in the context of wireless sensor networks. In *18th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (pimrc'07)*, Athens, Greece, September 3-7 2007. IEEE.

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