# Efficient Self-Stabilizing Algorithms for Pervasive Computing Systems

*PERSYVAL Master Research Internship*

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*We propose this internship in the context of Research Action "Pervasive Computing Systems" of* PERSYVAL-LAB.

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**Scientific Context.** Modern networks are very large-scale (about 100 000 nodes). Now, the more a network contains nodes, the greater the probability of failures is. Hence, today fault-tolerance is a main concern for distributed algorithm designers. In particular, since several decades, there is a growing interest for self-repairing methods. For example, (deterministic) *self-stabilization* [Dij74] is a versatile property, enabling a distributed algorithm to withstand transient faults in a network. Indeed, a self-stabilizing algorithm, after transient faults (*e.g.*, memory corruptions, message losses, topological changes, *etc.*) hit and place the network in some arbitrary state, enables the network to recover without external (*e.g.*, human) intervention in finite time.

A main advantage of self-stabilization is its cost both in terms of time complexity and resource consumption. Indeed, classical robust algorithms follow a *pessimistic approach*, suspecting all received information, and consequently precede all steps by sufficient checks to guarantee that their specification is never violated. In contrast, self-stabilization is considered as a *lightweight optimistic approach*, which assumes that processes operate correctly most of the time, but guarantees an eventual recovery after some of them fail. Self-stabilizing algorithms are also attractive for self-organizing systems, as they allow autonomous entities to converge to a distributed global structure such as a cluster or a spanning tree without requiring any initialization and only using local information exchanges. Finally, self-stabilizing algorithms do not require that the system in which they are deployed achieved strong properties, *e.g.*, usually self-stabilizing algorithm can be deployed in asynchronous systems equipped with a lossy MAC layer [DDT06]. For all these reasons, self-stabilization is desirable for fault-prone and resource-constrained systems, such as Wireless Sensor Networks (WSNs).

**Subject.** Many self-stabilizing algorithms work, assuming that every individual process holds a unique identifier. However, in large scale networks, especially the networks of simple fault-prone devices such as wireless sensors, such assumption may not be true. If identifier uniqueness cannot be ensured, the network may be considered anonymous. Anonymity could be also a useful property when facing security problems. However, anonymity causes several difficulties. In particular, many useful networking problems are known to be unsolvable in deterministic self-stabilizing settings. Two main approaches are usually considered to circumvent these impossibilities. The former consists in adding strong (even unrealistic) assumptions on the system, *e.g.*, making hypothesis on the execution scheduling. The latter consists in relaxing the specification of the problem with probabilistic guarantees only, for example, the liveness part of the specification is only almost surely ensured. Of course, this approach means the design of probabilistic solutions.

We recently proposed a variant of self-stabilization called *probabilistic snap-stabilization*. This property achieves stronger safety properties than self-stabilization, but weaker liveness properties. This subject consists in proposing new probabilistic fault-tolerant algorithms for anonymous networks using this variant. The proposed algorithms should achieved desirable properties to be suitable for WSNs. For example and as underline in the Research Action "Pervasive Computing Systems", performances of algorithms dedicated to resource-constrained systems, such as WSNs, should be predictable. So, the fault-tolerance properties of the proposed algorithms would have to be validated by theoretical proofs and their performances would have to be analyzed (either by analytical study or by simulations). Precisely, the subject requires:

- A bibliographical study: Understand the computational model, the problems to be solved, the expected properties, ...
- The design of a distributed algorithm. (The problem solved by the algorithm depends on the state of the art at the beginning of the internship; it will nevertheless be focused on solutions well suited for anonymous wireless sensor networks, *i.e.* solutions that handles the inherent constraint of such networks)
- The analysis of the proposed distributed algorithm:
  - Proof of its correctness.
  - Analysis of its complexity (*e.g.*, analytic upper bounds).
- Implementation in a simulation engine and analysis of the performances.

**Required Skills.** An important background about sequential algorithmic, in particular proof of algorithms, is mandatory. This subject also requires background about distributed systems and probabilistic tools (such as Markov Chains).

**Working context.** This internship is in the scope of the Research Action "Pervasive Computing Systems" of *PERSYVAL-LAB*. The students will be integrated in the lab Verimag[1] in the "synchronous" team.

Possible extensions into a PhD thesis.

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# References

[DDT06] Sylvie Delaët, Bertrand Ducourthial, and Sébastien Tixeuil. Self-stabilization with r-operators revisited. *Journal of Aerospace Computing, Information, and Communication (JACIC)*, 3(10):498–514, 2006.

[Dij74] Edsger W. Dijkstra. Self-stabilizing systems in spite of distributed control. *Commun. ACM*, 17(11):643–644, 1974.

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