Ph.D. thesis

Safe, efficient and low-energy self-adaptation for Cyber Physical Systems - Application to a scientific observatory in the Arctic tundra

Hélène Coullon
IMT Atlantique, Inria, UiT

Issam Raïs
UiT

Otto Anshus
UiT

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1 Context - the DAO project

In the DAO project (`https://en.uit.no/project/dao`), led by Otto Anshus, a scientific observatory, consisting of a set of autonomous distributed observation units (OUs), is deployed on the arctic tundra during the polar winter to study the impact of climate change on ecosystems.

A Cyber-Physical System (CPS) is being built in the DAO project. It is composed of OUs with sensors (e.g. temperature, pressure, CO2 sensors), actuators (e.g flash lights), computing, and storage resources (e.g., Raspberry Pi) on which are available a set of small services (i.e., micro-services) for observations, storage, computations, network, etc. Each OU is deployed during the summer and can be inaccessible for more than 6 months due to weather conditions and the dangers of the Arctic Tundra during the winter. Hence, once deployed those OUs have to be autonomous and have to collaborate to make and coordinate scientific observations for scientists. This requires that OUs are able to self-manage, in other words to self-adapt to dynamic changes in their environment (faults, dynamic requirements from scientists, new point of interest in the environment, etc.).

Furthermore, each OU is subject to strong uncertainties and constraints. First, energetic constraints, because OUs are only equipped with batteries [5]. Second, computing and storage constraints, because resources in CPS are limited and possibly heterogeneous. Third, autonomous constraints, because most of the time OUs are disconnected from a network (for energy savings and unavailability of the network) [4].

2 Previous work and objectives

In previous work, Hélène Coullon (and her collaborators) has published contributions on the execution part of an adaptation. Two metrics were of interest in this work compared to the academic literature and to the DevOps configuration and orchestration tools: the safety of the adaptation process; the efficiency of the adaptation process. To this purpose, the formal model Concerto, and its implementation, have been designed [1, 2, 3]. Evaluations have been conducted for the adaptation of distributed software systems in the Cloud. However, to tackle the above CPS specificities, additionnal properties are of interest. In particular, we aim at tackling: (i) a decentralized adaptation, so that if facing disconnections each OU are still able to adapt; (ii) an adaptation that handles uncertainties and rollbacks in case of failure, to guarantee fault-tolerance and unexpected changes; (iii) an adaptation able to model its fine grain energy consumption and resource consumption in addition of its efficiency.

In this Ph.D. thesis, we will study a way to tackle safe, efficient, and low-energy self-adaptation for CPS under strong constraints and high uncertainties.

3 Organization and expected skills

The selected candidate will have the great opportunity to be co-supervised between the Artic university of Norway (Otto Anshus and Issam Raïs) and IMT Atlantique France (Hélène Coullon). Half of the Ph.D. will be spent in Tromso, Norway, and half of it in Nantes, France.

The candidate will be required with the following elements:

- a Master 2 degree (or equivalent) in computer science,
- knowledge and interest on distributed systems and cyber-physical systems,
- knowledge and interest on distributed architectures (e.g., micro-services) and DevOps practices,
- knowledge and interest on concurrency, parallelism,
- a good level of english,
- be curious and eager to learn.

If you are interested, and you wish to get more details, please contact the following persons:

- Helene Coullon : helene.coullon@imt-atlantique.fr
- Issam Raïs : issam.rais@uit.no
- Otto Anshus : otto.anshus@uit.no

References

[1] Maverick Chardet, Hélène Coullon, and Christian Pérez. Predictable Efficiency for Reconfiguration of Service-Oriented Systems with Concerto. In *CCGrid 2020 : 20th IEEE/ACM International Symposium on Cluster, Cloud and Internet Computing*, Melbourne, Australia, May 2020. IEEE. doi:10.1109/CCGrid49817.2020.00-59. URL `https://hal.inria.fr/hal-02535077`.

[2] Maverick Chardet, Hélène Coullon, and Simon Robillard. Toward Safe and Efficient Reconfiguration with Concerto. *Science of Computer Programming*, 203:1–31, March 2021. doi:10.1016/j.scico.2020.102582. URL `https://hal.inria.fr/hal-03103714`.

[3] Hélène Coullon, Claude Jard, and Didier Lime. Integrated Model-checking for the Design of Safe and Efficient Distributed Software Commissioning. In *IFM 2019 : 15th International Conference on integrated Formal Methods*, Integrated Formal Methods, pages 120–137, Bergen, Norway, December 2019. doi:10.1007/978-3-030-34968-4_7. URL `https://hal.archives-ouvertes.fr/hal-02323641`.

[4] I. Raïs, J. M. Bjørndalen, P. Hoai Ha, K. Jensen, L. S. Michalik, H. Mjøen, Ø. Tveito, and O. Anshus. Uavs as a leverage to provide energy and network for cyber-physical observation units on the arctic tundra. In *2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS)*, 2019. doi:10.1109/DCOSS.2019.00114.

[5] I. Raïs, O. Anshus, J. M. Bjørndalen, D. Balouek-Thomert, and M. Parashar. Trading data size and cnn confidence score for energy efficient cps node communications. In *2020 20th IEEE/ACM International Symposium on Cluster, Cloud and Internet Computing (CCGRID)*, 2020. doi:10.1109/CCGrid49817.2020.00-46.