

STSM Grant Report

COST STSM Reference Number:

COST-STSM-CA15140-35872

COST Action: CA15140

STSM type: Regular (from Italy to Romania)

Grant Period (exact dates): 23/01/2017 to 08/02/2017

Applicant Name: Dr Christiancarmine Esposito

Topic: Distributed Nature-Inspired Optimization for Resource Scheduling and Migration in the Internet of Things

Working Groups related: WG2

Home Institution:

University of Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano SA, Italy

Host Institution:

University Politehnica of Bucharest, Faculty of Automatic Control and Computers, Computer Science and Engineering Department, 313 Splaiul Independentei, Bucharest 060042, Romania

Description of the activities performed

Workplan (Tasks and Activities)

The topics on which the WG2 of the CA15140 (Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice - ImAppNIO)) focuses include the development of novel practice-driven theoretical frameworks and paradigms. Specifically, the overall idea is to determine needs and issues of novel and unforeseen applications of nature-inspired optimization (NIO) to concrete problems, so as to create innovative theoretical approaches able to go beyond the current state-of-the-art and advance the NIO theory. A fundamental part of this WG is to look for links with industry partners and companies so as to engage their eventual interest in industrial research on NIO as a solution for their needs in specific applications.

The scope of the STSM is to investigate the challenging problem of resource management and scheduling within the context of the Internet of Things and its upcoming evolutions due to the application of the Edge Computing and/or Fog Computing vision. Task and Resource scheduling are characterised by an extended literature in the field of applying optimization techniques in order to find the best scheduling by optimizing certain objective functions by using analytical, heuristics or meta-heuristics resolvers. However, this problem within the context of the Internet of Things introduces novel challenges such as constraints on the device capabilities, the need of a distributed and continuous resolution of the optimization problem and the selfishness of the node behaviours. The final goal of this work is to apply the latest solutions from the game theory in order to approach such a problem in the most effective and efficient manner by integrating it with an evolutionary natural-inspired scheme.

The workplan has been organized into 3 main activities, here articulated in tasks in the following:

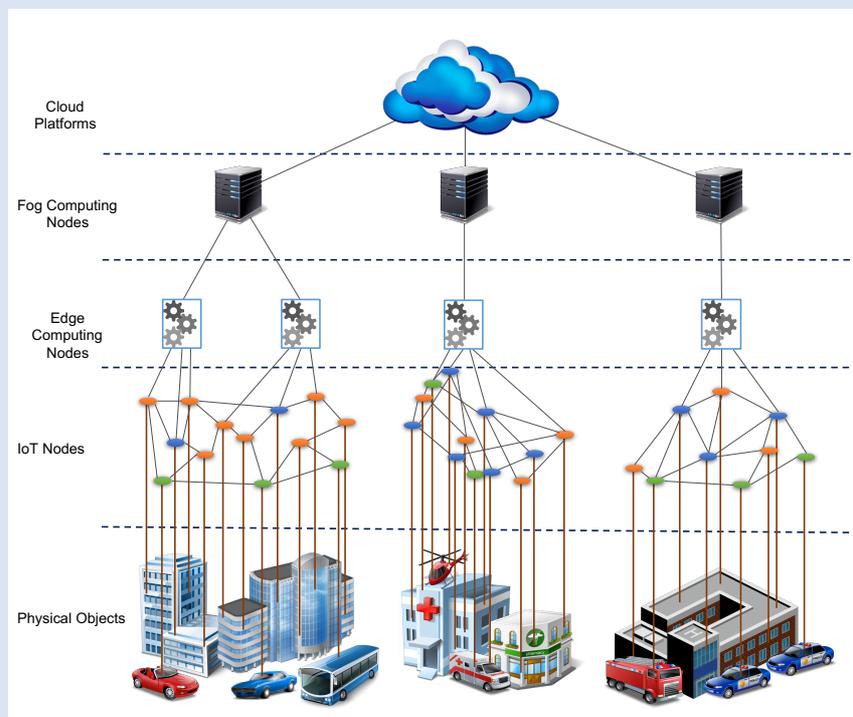
1. Formalization of resource scheduling within the Internet of Things
 1. Collection and analysis of the papers and report on the state-of-the-art on resource scheduling in the IoT
 2. Definition of a micro-service architecture for applications running within an IoT
 3. Formulation of the Optimization problem underlying the resource scheduling in the IoT

2. Game Theoretic Nature-inspired Optimization for IoT resource scheduling
 1. Collection of similar solutions that applies game theory for the resource scheduling in the IoT and analysis of their limits
 2. Definition of a solution based on the Evolutionary Game Theory
3. Implementation of a simulation-based prototype to validate the solution
 1. Implementation of a simulator of a generic IoT
 2. Implementation of the solution in the simulator
 3. Validation of the solution and assessment of its quality

Realisation of the workplan

The activities have been organized on a weekly basis, where the STSM involved 15 full days, excluding the arrival and departure days to/from Bucharest. The second and third activities have been conducted within these days, where the second activity lasted for the first week, while the third action took the remaining days. While, the first action has been considered as a preparation for the work to do during the STSM and has been realized during the days before the visit.

The first week has been devoted to the definition of the tentative solution to the resource management in IoT by means of evolutionary game theory, after a reciprocal presentation and critical analysis of the relevant activities of the two groups. Specifically, in the first day a presentation has been given to the research group of Prof. Pop on the key recent activities conducted by Dr. Esposito and the outcome of the first action on the formalization of resource scheduling within the IoT. During such a presentation, the above architectural picture of the IoT (and the upcoming evolutions of Edge and Fog Computing) as an ecosystem of disparate ICT systems has been discussed, and the software has been proposed to be modelled by the so-called microservice approach, where software artefacts running on each node of the mentioned architecture are composed of multiple units of computations with specific interfaces and reciprocal dependencies among themselves.



Upon such a view, the set of resource management needs has been formalized and detailed in terms of performance, resource consumptions, availability and security. In additional, the typical resource scheduling policies as been expressed as a combination of the simple operations of

resizing, duplication and migration, each by precise pros and cons depending on the nodes hosting the specific target of these operations. The overall objectives and operations have been composed and formalized in a multi-objective optimization problem modelled as a resource allocation issue. The next step has been to approach such a problem in a dynamic manner by means of game theory by defining the set of strategies for each player of the game, and the determination of their payoff and costs so as to drive the strategy selection and fitness estimation. Moreover, the Replicator Dynamics Process has been defined so as to have a evolution of the population, i.e., the player, when varying the environmental conditions and the application needs so as to commence resource re-scheduling operations and converge to a Evolutionary Stable State.

The remaining of the visit has been devoted to a study of the means to simulate the envisioned architecture and the proposed approach. All the available simulators for IoT has been analysed based on the easiness and analysis support. We have concluded that an ad-hoc Java application able to model the architecture was the most suitable solution; therefore, we have designed and implemented such an application able to generate a set of nodes belonging to the different layers of the mentioned architecture and to run our formalized evolutionary game. Furthermore, we have defined a representative workload and measures of interest in order to have a explicative use case for our approach and a proper quality characterization of the obtainable resource management. A first set of experiments has been conducted with encouraging preliminary results, which presented some limits of our approach and after the visit we have further improved our game formulation. Currently, the final experiments are undergoing so as to have a precise characterization of the quality of our approach and a paper is under preparation. By the beginning of May such a paper will be completed and submitted to the identified journal (as described in the following).

Finally, the basis has been set, in terms of possible publications, contributions to the Action and more strategical activities, to setup a permanent long-term collaboration between the two groups (by means of a joint signed agreement on mutual collaboration).

Results/Achievements (incl. list of publications)

The results of the visit can be summarized into a joint special issue proposal at J-SAC and a joint publication at a flagship international journal, which is under preparation. Moreover, the collaboration among Dr. Esposito and Prof. Pop during the visit has produced the following accepted joint publication:

- G.V. Iordache, F. Pop, C. Esposito, e A. Castiglione, “Selection-based Scheduling Algorithms under Service Level Agreement Constraints”, Proceedings of the International Workshop on Smart Services for Edge and Cloud Computing (SSECC-2017), 29-31 May 2017.

Moreover, the days after the visiting a joint proposal for a special issue on the application of the NIO techniques within the context of disaster resilient network has been submitted at the editorial board of the IEEE Journal on Selected Areas in Communications (J-SAC) for their consideration (According to the Journal Citation Reports, this journal has a 2013 impact factor of 4.138). In addition, during the visit a joint publication on the security issues and micro-service architecture in the IoT has been submitted at the IEEE Communication Magazine (which has a 2013 impact factor of 5.125), and a paper is being written for submission to the Special Issue on Advances in Big Data Analytics for Management at the IEEE Transactions on Network and Service Management (IEEE TNSM, which has a 2013 impact factor of 1.296) in order to present the results of the mission.

List of attached documents

- Boarding passes from Napoli to Bucharest via Rome, and from Bucharest to Napoli via Rome both with Alitalia;

- Signed long-term collaboration agreement among Dr. Esposito and Prof. Pop;
- Submitted joint special issue proposal;
- Submitted ComMag paper and Accepted SSECC-2017 paper with acknowledgement to the Cost Action.

Signed by: Christian Esposito
Napoli, 20 February 2017

Christian Esposito

Confirmation signed by the host institution of the successful execution of the STSM is attached to this report:

Host responsible: Prof. Florin Pop

Signed by: Prof. Florin Pop
Bucharest, 25 February 2017

Florin Pop