The ONE-SAPERE Simulator: A prototyping tool for engineering self-organisation in pervasive environments

Jose Luis Fernandez-Marquez,
Francesco L. De Angelis,
Giovanna Di Marzo Serugendo [1]
ISS, University of Geneva, Geneva, Switzerland

Graeme Stevenson[2]
University of St Andrews,
St Andrews, UK

Gabriella Castelli [3]
Università di Modena e Reggio Emilia,
Italy

***Index Terms*—Bio-inspired, Self-organisation, Opportunistic Networking, Simulation**

I. Introduction

The widespread adoption of mobile devices with powerful sensing, computing, and communication capabilities creates an unprecedented opportunity towards harvesting and harnessing tremendously large volumes of sensed information so as to select and inform the most appropriate context aware services to support human users. We envision a point in the near future where such devices will opportunistically connect with each other to form dense infrastructures, with available resources exploited to offer spatially situated services that adapt to their context of use, and with the ability to enhance service delivery with myriad sensing modalities offered by the surrounding physical and virtual world.

Prototypical examples of such technology are gaining attention outside the laboratory: public displays in a shopping mall intelligently detecting the presence of people and personalising and adapting their content accordingly, vehicular control systems directing vehicles to avoid traffic, and social network based applications utilising information about the location and activities of friends to recommend activities.

Due to the complexity of such systems, simulators play a key role in understanding and validating emergent behaviours produced by the interactions between entities. Tools, such as, Netlogo and Repast provide a strong contribution and are widely used in the self-organising field. However, these simulators are limited when it comes to the engineering of self-organising systems: they do not directly provide support for implementing realistic scenarios through the import of real GPS traces, realistic networking, or maps. Additionally there is a significant gap between the code used in these simulators and the final code to be deployed and run on real system devices.

In order to mitigate this gap between simulation and real implementation, this paper presents The ONE-SAPERE simulator, the first simulator combining an opportunistic network environment simulator with a middleware for pervasive systems, which has already been released for Android devices and PCs. Each simulated node runs an instance of the actual middleware, supporting the prototyping, development, and validation of concepts using the self-same code that will later be deployed to devices in the wild. We give an overview about the capabilities of the simulator, providing references to publications containing further details describing aspects of our approach.

[1] {Joseluis.fernandez,francesco.deangelis,Giovanna.DiMarzo}@unige.ch
[2] graeme.stevenson@st-andrews.ac.uk
[3] gabriella.castelli@unimore.it

II. SAPERE: Middleware for Self-Organising Pervasive Ecosystems

SAPERE [1] proposes an innovative bio-chemically inspired framework in which the pervasive environment is architected as a spatial substrate where chemically inspired laws of nature, called eco-laws, regulate the overall system behaviour, grounding the framework on distributed, locally-scoped interactions to bring self-* properties to the system as a whole. Components of the pervasive service ecosystem interact and combine with each other according to their spatial relationships and the influence of the eco-laws acting upon them.

The SAPERE vision of a pervasive ecosystem is implemented as a lightweight middleware realised in Java SE and Android, embedding all the functionality of the SAPERE model. It consists of three main concepts: (1) *Live Semantic Annotations*, which are descriptive tuples that provide the singular means to represent information about entities in the pervasive ecosystem, (2) LSA Spaces, which run on each device in the ecosystem and serve as a container for hosting LSAs, and (3) *eco-laws*, which act in several ways to: create or destroy chemical-like bonds between LSAs, distribute LSAs across the network, fuse the content of LSAs together, or remove LSAs entirely. These primitives for basic interactions are key to developing self-organising behaviours and realising spontaneous interactions between devices. For more detail on SAPERE we refer the reader to [2].

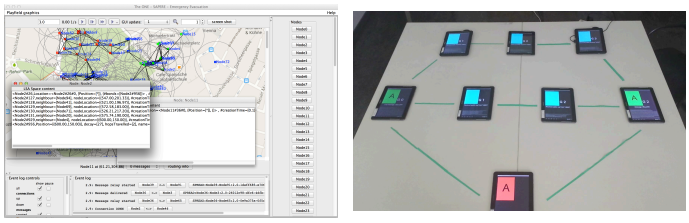

Fig. 1: The simulator and tablets, both running SAPERE code.

III. The ONE-SAPERE Simulator

The ONE-SAPERE simulator integrates the SAPERE middleware with The Opportunistic Network Environment (The One) simulator [3], allowing us to prototype and validate applications with realistic scenarios before deploying them.
The basic functionality of the simulation framework offers 4 standard self-organising primitives, realised as eco-laws: spreading, aggregation, gradient and decay [4]. These primitive offerings can be extended or composed to offer additional functionality. Examples include: *dynamic gradients* that update periodically depending on the perceived network topology; *chemotaxis*, that exploits the virtual multi-path infrastructure created by the gradient in order to route information; *self-organising data collection*, that draws data towards a common point in the network identified to be the most suitable for collecting or processing it, and *secure channels*, that combines an encryption service with chemotaxis and dynamic gradient for routing confidential data between devices running the SAPERE Middleware in a mobile ad-hoc network.
The corresponding video is available on-line [1].

IV. Sample Applications

We have developed several applications using The ONE-SAPERE simulator, a subset of them deployable on tablets.
Crowd Steering[2]: explores the use of gradient for crowd steering applications. Results prove that gradients can be used for steering people in cases such as emergency evacuations.
Self-organising data collection[3]: to gain awareness through reasoning over multiple sources information must be drawn towards a common point in the network, preferably in a self-organising way. The self-organising data collection library provides the required methods to implement in-network aggregation on top of high dynamic mobile networks [5].
Distributed Reasoning[2]: a combination of semantic technology, context-awareness and bio-inspired self-organisation techniques provides the groundwork for realising decentralised, self-organising situation recognition [6]. This library allows the development of situation recognition functions in a fully distributed fashion as the data flows from sources to consumers, allowing the resulting in-network consensus result to be consumed by the application, all while the self-organisation features of SAPERE support this execution over a fluid and evolving network topology [7].
Confidential Channel[4] [8]: combines an encryption service with chemotaxis and dynamic gradient for routing confidential data in a mobile ad-hoc network.

V. Future Work

This paper has introduced The-ONE SAPERE, a simulator that combines an opportunistic network environment simulator with a middleware for pervasive systems designed to support the prototyping, development, and validation of concepts using the same codebase that will later be deployed to devices in the wild. To extend the testing ground of this tool, we plan to extend the simulator to be executable on High Performance Computers, parallelising most of the code and increasing the number of nodes that can be simulated. We will also investigate enhancing the networking layers provided by The ONE simulator, supporting the realism of more established network simulators such as OMNET++ or NS3.

References

[1] F. Zambonelli et al., "Self-aware pervasive service ecosystems," *Procedia Computer Science*, vol. 7, pp. 197–199, Dec. 2011, proc. of the 2nd European Future Technologies Conference and Exhibition 2011 (FET 11).

[2] G. Castelli, M. Mamei, A. Rosi, and F. Zambonelli, "Engineering pervasive service ecosystems: the SAPERE Approach," *to appear in ACM TAAS*, 2014.

[3] A. Keränen, J. Ott, and T. Kärkkäinen, "The ONE Simulator for DTN Protocol Evaluation," in *SIMUTools '09: Proceedings of the 2nd International Conference on Simulation Tools and Techniques*. New York, NY, USA: ICST, 2009.

[4] J. L. Fernandez-Marquez, G. D. M. Serugendo, S. Montagna, M. Viroli, and J. L. Arcos, "Description and composition of bio-inspired design patterns: a complete overview," *Natural Computing*, pp. 1–25, 2012.

[5] J. Fernandez-Marquez, A. Tchao, G. Serugendo, G. Stevenson, J. Ye, and S. Dobson, "Analysis of new gradient based aggregation algorithms for data-propagation in mobile networks," in *Self-Adaptive and Self-Organizing Systems Workshops (SASOW), 2012 IEEE Sixth International Conference on*, Sept 2012, pp. 217–222.

[6] G. Stevenson, D. Pianini, S. Montagna, M. Viroli, J. Ye, and S. Dobson, "Combining self-organisation, context-awareness and semantic reasoning: the case of resource discovery in opportunistic networks," in *Proceedings of the 28th Annual ACM Symposium on Applied Computing*, Coimbra, Portugal, march 2013.

[7] G. Stevenson, G. Castelli, J. Ye, A. Rosi, S. Dobson, and F. Zambonelli, "A bio-chemically inspired approach to awareness in pervasive systems," in *First International Workshop on Sensing and Big Data Mining*, ser. SenseMine '13, November 2013.

[8] F. de Angelis, J. Fernandez-Marquez, and G. Di Marzo Serugendo, "Secure channel service for manets," in *Self-Adaptation and Self-Organizing Systems Workshops (SASOW), 2013 IEEE 7th International Conference on*, Sept 2013, pp. 9–10.

[1] http://youtu.be/EGbPq2rejmM
[2] https://bitbucket.org/JoseLuisFernandez/theone-sapere-crowdsteering
[3] https://bitbucket.org/aceyogi/saperemiddleware-wp3/wiki/Home
[4] https://bitbucket.org/fdeangelis/theone-sapere-securedchannel

This work has been supported by the EU-FP7-FET Proactive project SAPERE Self-aware Pervasive Service Ecosystems, under contract no.256873.