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Marc-Olivier Killijian, Matthieu Roy

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# Brief Announcement: A Platform for Experimenting with Mobile Algorithms in a Laboratory

Marc-Olivier Killijian  
CNRS ; LAAS ; 7 avenue du colonel Roche; F-31077 Toulouse, France  
Université de Toulouse ; UPS, INSA, INP, ISAE ; LAAS ; F-31077 Toulouse, France  
marco.killijian@laas.fr

Matthieu Roy  
roy@laas.fr

## ABSTRACT

In this work, we present a platform for testing algorithms on mobile systems. We advocate that the interest of the platform lies in many aspects: it shows that simulators are not accurate, especially with regards to wireless communication and delays assumptions. Such a platform can be used to *refine simulators assumptions*. Moreover, to the best of our knowledge, our platform is the first attempt to implement *mobility patterns*, that permit to test multiple distributed algorithms in the same movement configuration, allowing for reproducible experiments. Last, but not least, we want to open our platform to test other distributed and mobile algorithms, with the hope that it will open new problems and pose new challenges.

**Categories and Subject Descriptors:** C.2.4 [Computer Communication Network]: Distributed Systems - *distributed applications*; D.2.5 [Software Engineering]: Testing and Debugging - *distributed debugging*.

**General Terms:** Algorithms, Reliability, Experimentation.

## Motivation

Forthcoming distributed systems, such as networks of smartphone users, future Vehicular Area Networks as well as biological sciences experiments on animals, share three main features that are not taken into account in traditional distributed models:

- *Position-awareness*: processes have access to their physical position, using GPS-like technology.
- *Proximity networking*: processes are equipped with local-only wireless networking, and may have an intermittent access to an infrastructure.
- *Mobility*: processes are carried by users. Mobility of users, coupled with local communication capabilities, induces changes in the topology of the communication graph.

As a result, recent research works focus on the provision of new abstractions to formally reason on such systems, e.g., GeoQuorums [3], Collision Detectors [2], Geo-registers [5].

Due to the numerous different parameters of a mobile system and the lack of formal models, proofs of these algorithms are limited to simplistic cases. As a consequence, many results are validated using network simulators.

Yet, in [1], the authors show that the same protocol, run on different simulators, exhibits different behaviors. Network simulators are based on modeling of the different pa-

rameters that may be inaccurate, like the popular unit-disk wireless communication model. Henceforth, we believe that, in the case of evaluation of critical systems, simulation should be complemented by experimental evaluation.

## Design of the Platform

### Nodes.

We suppose that a typical node of the system is able to *i*) perform computation (it contains a *process*), *ii*) get its position in the physical space accurately and timely, and *iii*) communicate with nearby nodes. Nodes can be moved by users, changing the topology of the underlying communication network, yet nodes have no control on users' movements, that is mobility is *passive* only. Nodes can also fail at any instant.

### Scale ability.

Let us suppose that we want to evaluate a system whose characteristic surface is a few square kilometers, like a network of pedestrian users. To be able to test it within a laboratory, in which a reasonable sized room is in the order of dozens of square meters, the characteristic parameters of every hardware device have to be scaled down accordingly.

More precisely, let us consider a  $250000m^2$  experiment which has to fit within  $100m^2$ . The corresponding scale reduction is 50 in distance (2500 in surface). The following table shows, for each hardware device, the constraints implied by this reduction in scale.

Device	Real Accuracy	Scaled Accuracy
Wireless	range: 100m	range: 2m
GPS	5m	10cm
Node size	a few meters	a few decimeters
Node speed	a few $m.s^{-1}$	less than $1m.s^{-1}$

### Implementation details.

**WiFi Reduction** Limiting the range of wireless communication has been a technical challenge, since most hardware devices are optimized to increase transmission range. A satisfying solution consists in using, for this purpose, *signal attenuators* placed between the WiFi network interfaces and their antennas. An attenuator is an electronic device that reduces the amplitude or power of a signal without appreciably distorting its waveform. In our case, the attenuators are used to reduce the signal received and sent by the network interface. The necessary capacity of the attenuators depends on many parameters such as the power of the WiFi interfaces and the efficiency of the antennas, but also on the speed of the robot movements, the room environment, etc.

We characterized the relationship between all these parameters. From our results, and in our specific setting, a 2m range is attained using 26dB attenuators.

**Positioning Technology** To reach a centimetric accuracy for indoor positioning we used a dedicated motion capture technology, Cortex<sup>1</sup>, that tracks objects based on real-time analysis of images captured by infra-red cameras. The whole system is composed of 10 infrared cameras, connected to a dedicated server that locates dedicated tags in the environment. The Cortex system is able to localize objects at the millimeter scale, which is more than enough for the need of the platform

**Mobility** The next important feature is to be able to emulate mobility. A node in the system is implemented using a laptop computer, that includes all hardware devices and the software under testing, that is carried by a simple robotic platform, the Lynxmotion 4WD rover. A 4WD rover is able to carry a full node during a few hours, running at a maximum speed of  $1m.s^{-1}$ , which is consistent with our assumptions.

To have reproducible patterns of mobility, the rover embarks a dedicated software that moves the robot using two different schemes. Both designs allow for testing different algorithms using the same mobility pattern, and for testing the same algorithm with different mobility scenarios. In the simple scheme, a robot is following a black line on the floor. This solution is easy to implement but imposes that the operator “draws” the circuit for every different mobility pattern. The second scheme couples a predefined mobility pattern with the positioning service and ensures a given node moves according to the predefined pattern, programmed by the operator. This solution is more flexible: each node has its own mobility pattern specified for each experiment.

### The Resulting Platform.



Figure 1: The experimental platform

The current version of the platform for experimentation is shown in Figure 1. For testing purposes, we limited the number of nodes to four (recall that a node is a fully equipped mobile platform with a laptop, a wireless communication device and positioning-related hardware). The experimental room has dimensions 14m \* 7m. The photo shows the infrared cameras on top, the robots carrying laptops and modified wireless interfaces, and the black tape lines corresponding to an on-going experimentation.

## Results

For our first experiment, we used an application that we developed in the course of the HIDDENETS project<sup>2</sup>. The

<sup>1</sup><http://www.motionanalysis.com>

<sup>2</sup>HIDDENETS FP6 EU project: [hidenets.aau.dk](http://hidenets.aau.dk)

application is a distributed algorithm that stores critical information of all participants on nearby nodes, à la peer-to-peer, to be able to recover information in the case of a car accident [4].

Interestingly, the evaluation of the algorithms deployed showed different unexpected behaviors:

- The resulting system is *more asynchronous* than it was expected to be. More precisely, there exist many sources of delays, especially for the wireless network, that seem unpredictable. If testing is performed during a long interval, the system alternates between stable period, where delays can be bounded, and unstable periods, where the system is almost unpredictable.

- Network communication does not conform to the uniform disk assumption. For every run, and for every pair of nodes, those two nodes can sometimes communicate far beyond their supposed maximum communication radius. On the contrary, the same pair of nodes have, at an other instant, a very large delay for connection establishment, although they move very close during a few seconds.

For synchrony models, the results obtained indicate the need for refined models of synchrony, similar to stable partitions assumptions adapted to systems that are continuously evolving in their composition.

For wireless communication, the behavior is less predictable, due to the numerous physical factors that may impact the transmission; a randomized failure model for message transmissions would be more accurate.

## Concluding Remarks

We presented a platform for experimenting with mobile systems within a laboratory. To obtain a representative system, we introduced a scale reduction that is applied to every component of the system, namely size of nodes, speed of movements, wireless communication and positioning devices.

The aim of this platform is to be complementary with traditional simulators, since it allows for testing algorithms in more realistic scenarios than with simulators. Yet, the intrinsic limitations of testing with real hardware limits the number of nodes that compose the system: the time needed by an operator to develop the platform increases linearly with the number of nodes of the system.

We advocate that this platform is useful both for practical and theoretical reasons: it can be used to check the feasibility of algorithms in real life situations, and also opens problems with regards to the models used for all the components of the system.

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