Experimental Evaluation of Ubiquitous Systems[*]

Why and how to reduce WiFi communication range

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1. INTRODUCTION

To the best of our knowledge, little research has been done on the evaluation of ubiquitous systems. In the ubiquitous and mobile computing area, evaluation of resilient mechanisms, such as [7] for example, remains an open problem. In most cases, the proposed algorithms are evaluated and validated using wireless network simulators. Since simulators use a model of physical components, such as network cards and location systems, this raises concerns as to the representativity of the assumptions that underlie the simulation [2]. Little work concerning the evaluation of algorithms in a realistic environment is available.

This calls for the development of a realistic platform, at a laboratory scale, to evaluate and validate fault-tolerance algorithms (e.g., group membership and replication protocols, backup mechanisms, etc.) targeting systems comprising a large number of communicating mobile devices equipped with various sensors and actuators. The goal is to have an experimentation platform allowing for reproducible experiments (including mobility aspects) that will complement validation through simulation. As we will see, an important issue within this platform is related to changes of scale so as to emulate as many various systems as possible.

We are developing an experimental evaluation platform composed of both fixed and mobile devices [6]. Technically speaking, each mobile device is composed of some programmable mobile hardware able to carry the device itself, a lightweight processing unit equipped with one or several wireless network interfaces and a positioning device. The fixed counterpart of the platform contains the corresponding fixed infrastructure: an indoor positioning system, wireless communication support, as well as some fixed servers. Our platform is set up in a room of approximately $100m^2$ where mobile devices can move around. By changing scale, we want to emulate systems of different sizes. Hardware modeling of this type of system requires a reduction or increase of scale to be able to conduct experiments within the laboratory. To obtain a realistic environment, all services must be modified according to the same scale factor. In the remainder of this paper, we discuss the technical issues that must be addressed to enable such changes in scale.

2. SCALE ISSUES

A first technical issue concerns indoor location. Indeed, most of the applications and ubiquitous systems we plan to experiment on this platform benefit from some kind of geopositioning, usually using a GPS device. As the platform is built indoors, within our laboratory, GPS devices are not able to receive the GPS satellite signals and thus cannot be used. An indoor location solution is thus necessary. The question of scaling can be translated into an accuracy problem: how accurate do we need the indoor location system to be? For example, if we consider a VANET experiment, a typical GPS in a moving car is accurate to within $5 - 20m$. So, for our $100m^2$ indoor environment to be a scaled down representation of (say) a $250000m^2$ outdoor environment (a scale reduction factor of 50), the indoor positioning accuracy needs to be $10 - 40cm$. Several technologies are currently available for indoor positioning [5], mostly based either on scene analysis (e.g., using motion capture systems) or on triangularization (of ultrasound and/or RF [8] [3]). For various reasons, mostly based on cost and performance issues, we chose the Crickets ultrasound solution.

Another important question is how to make the devices actually mobile. Obviously, when conducting experiments, a human operator cannot be behind each device, so mobility has to be automated. This is why we considered the use of simple small robot platforms in order to carry around the platform devices. The task of these robots is to “implement” the mobility of the nodes. If, for a given experiment, the emulated nodes are actively mobile, the devices need to have control over the mobility and thus need to communicate with the robot controller. Conversely, if the nodes are passively mobile, there is no need for any communication between the robots and the devices they carry and the robot controller can be correspondingly simpler.

2.1 Scaling Communication Range

The last and most important design issue for the platform concerns wireless communications. Indeed, the communication range of the participants (mobile nodes and infrastructure access-points) has to be scaled according to the experiment being conducted. For example, with a VANET experiment, a typical automobile has a wireless communication range of a few hundred meters, say 200m. With a scale reduction factor fixed at 50, the mobile devices communication range has to be limited to 4m. However, to cope with other experiments and other scale reduction factors,

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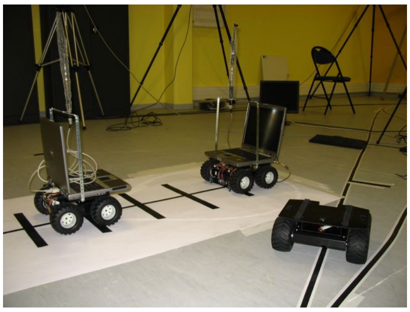

Figure 1: The current attenuation experiments

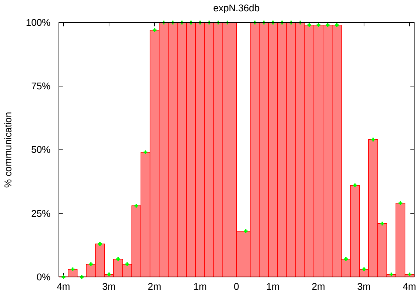

Figure 2: Example of the statistical results

this communication range should ideally be variable.

A solution would be to build a specific communication interface using a software-designed radio[4]. This would enable a software definition of most of the physical parameters influencing communication, henceforth enabling fine-grained control of the communication range. The drawback of this solution is that the communication drivers would be specific to this hardware, making it more difficult to use legacy protocols and services.

Some WiFi network interface drivers propose an API for reducing their transmission power. However, the implementation of this feature is often rather limited and many interface drivers only allow transmission power to be set to a few pre-selected values. Furthermore, many device drivers actually do not implement this feature, although they claim they do! Theoretically, a limited transmission power should accordingly reduce transmission range. This approach could also be applied using short range wireless technologies, such as ZigBee, Wibree[1] or Bluetooth.

Similarly, signal attenuators can be used 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. Attenuators are passive devices made from resistors. The degree of attenuation may be fixed, continuously adjustable, or incrementally adjustable. In our case, the attenuators are used to reduce the signal received by the network interface.

The objective of the experiment we are currently performing is to find the practical relationship between signal attenuation and communication range. More precisely, the ultimate goal is to be able to select the appropriate attenuation value according to some target range (corresponding to a given scaling factor). This experiment involves 2 laptops mounted on robot platforms and using an external WiFi interface to communicate with each other. One of the two nodes is static and the other one moves back and forth. Equivalent attenuators are attached between each external WiFi interface and its antenna. The mobile platform moves along a line, stops every $20cm$ for $5min$ and performs a measurement at every stop. For each measurement, the moving laptop joins the ad hoc network created by the fixed one, measures the communication throughput and then leaves the ad hoc network. The time for joining the network is logged, as is the measured throughput. A complete experiment is composed of 100 repetitions of a return trip along the 5m line. This data is logged and statistically analyzed offline, leading to figures such as the one presented on figure 2.

Future work includes to use the platform for the evaluation of several Vehicular Network applications, within the scope of the Hidenets project[1]. In particular, we are developing a distributed black-box application: each car possesses a virtual black-box implemented by cooperating neighbor nodes. The vehicles store recent events regarding themselves and their vicinity in this black-box. The evaluation platform will be used for verifying the resilience properties offered by the application, essentially tolerance to crash of the nodes.

3. REFERENCES

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