APPEL À PROJETS DE RECHERCHE

FICHE d'IDENTITÉ

Caractéristique générale : Plate forme / Testbed
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Titre du projet
Very Large Scale Open Wireless Sensor Network Testbed

Acronyme ou titre court : SensLAB

Thème de l'appel
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Durée du projet : 36 mois

SensLAB

Very Large Scale Open Wireless Sensor Network Testbed

Abstract

The purpose of the SensLAB project is to deploy a very large scale open wireless sensor network platform. SensLAB's main and most important goal is to offer **an accurate and efficient scientific tool** to help in the design, development, tuning, and experimentation of real large-scale sensor network applications. Ambient and sensor networks have recently emerged as a premier research topic. Sensor networks are a promising approach and a multi-disciplinary venture that combines computer networks, signal processing, software engineering, embedded systems, and statistics on the technology side. On the scientific applications side, it covers a large spectrum: safety and security of buildings or spaces, measuring traffic flows, environmental engineering, and ecology, to cite a few. Sensor networks will also play an essential role in the upcoming age of pervasive computing as our personal mobile devices will interact with sensor networks dispatched in the environment.

The SensLAB platform will be distributed among 4 sites and will be composed of 1,024 nodes. Each location will host 256 sensor nodes with specific characteristics in order to offer a wide spectrum of possibilities and heterogeneity. The four test beds will however be part of a **common global test bed** as several nodes will have global connectivity such that it will be possible to experiment a given application on all 1K sensors at the same time.

If deployed, SensLAB would be a unique scientific tool for the research on wireless sensor networks.

Keywords

Testbed, wireless sensor network, energy, resource allocation, self-organized networks, hybrid networks

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Part I

Project Description

1 Introduction

The purpose of the SensLAB project is to deploy a large scale open sensor network platform. SensLAB main and most important goal is to offer **an accurate and efficient scientific tool** to help and foster the design, development, tuning, and experimentation of real large scale sensor network applications. Ambient and sensor networks have recently emerged as a premier research topic. However, due to their massively distributed nature, the design, implementation, and evaluation of sensor network applications, middleware, and communication protocols are difficult and time-consuming tasks. Several national (e.g., ANR SVP, ANR ARESA, and ANR SENSOR), European (e.g., IP WASP and IP MOSAR), and US projects (e.g., NSF CENS, UCB NEST) have emerged in the domain of sensor networks, autonomic, and ambient networking. It appears strategic and crucial to offer to researchers and developers accurate software tools, physical large scale testbeds to benchmark, tune, and optimize their applications and services.

Simulation is an important phase during the design and the provisioning step. However, although simulation tools are useful to provide further understanding of a system, they suffer from several imperfections as simulation makes artificial assumptions on radio propagation, traffic, failure patterns, and topologies. In order to design robust applications that have to be deployed under real-world conditions, the developer needs **appropriate tools** and methods for testing and managing its large scale wireless sensor network applications.

The abovementioned statement implies that, in order for the final application to be deployed, run, and tested under real conditions, it must be implemented on real hardware. Unfortunately, the development and testing of real experiments engaging distributed systems like sensor networks quickly become a nightmare if the number of nodes exceeds a few dozens. The daunting logistical challenge of experimenting with thousands of small battery-powered nodes is the key factor that has greatly limited the development of this field. The main reasons for this very high complexity come from a variety of factors:

- Sensors are small devices with very limited interface capacities, mainly in terms of debugging and friendly programming interface.
- Software deployment, node re-programming, and debugging are traditionally done through dedicated interfaces (e.g., JTAG) which require the connection of the device to a dedicated PC and thus the individual manipulation of sensor nodes.
- Sensors are generally powered by a battery which also implies human interventions. Each intervention is time consuming, error prone and not really gratifying.
- There is a crucial lack of development tools and software environments that may help the development of applications and their configuration.

We propose to eliminate several of the problems listed above by building SensLAB, a large-scale open wireless sensor testbed of 1000+ nodes, and then operating it as an open research facility for academic and industrial groups who want to experiment with novel distributed sensing architectures. An overview of the SensLAB testbed is depicted in Fig. 1. In addition to theory, simulators, and emulators, there is a strong need for **large scale testbeds** where real life experimental conditions hold. Facing this huge complexity, the SensLAB project proposes to set up a distributed large-scale open wireless sensor network testbed. The objective is to provide a research infrastructure for networking sensors and to offer a large scale instrument for the exploration of sensor network issues in reproducible experimental conditions. The platforms will be generic and open. This means that a user will be able to deploy its home made applications without any kind of restrictions on the programming language, on the programming model or on the OS that he/she must use as opposed to already in place sensor testbed trials (see Section 2).

The accomplishment of the SensLAB project will require efforts both on the *hardware* and *software* sides, toward the following objectives:

O1. (Hardware) To offer real time, robust, and reliable access to the distributed platform.

O2. (Hardware) To provide wired feedback channel for management/logging.

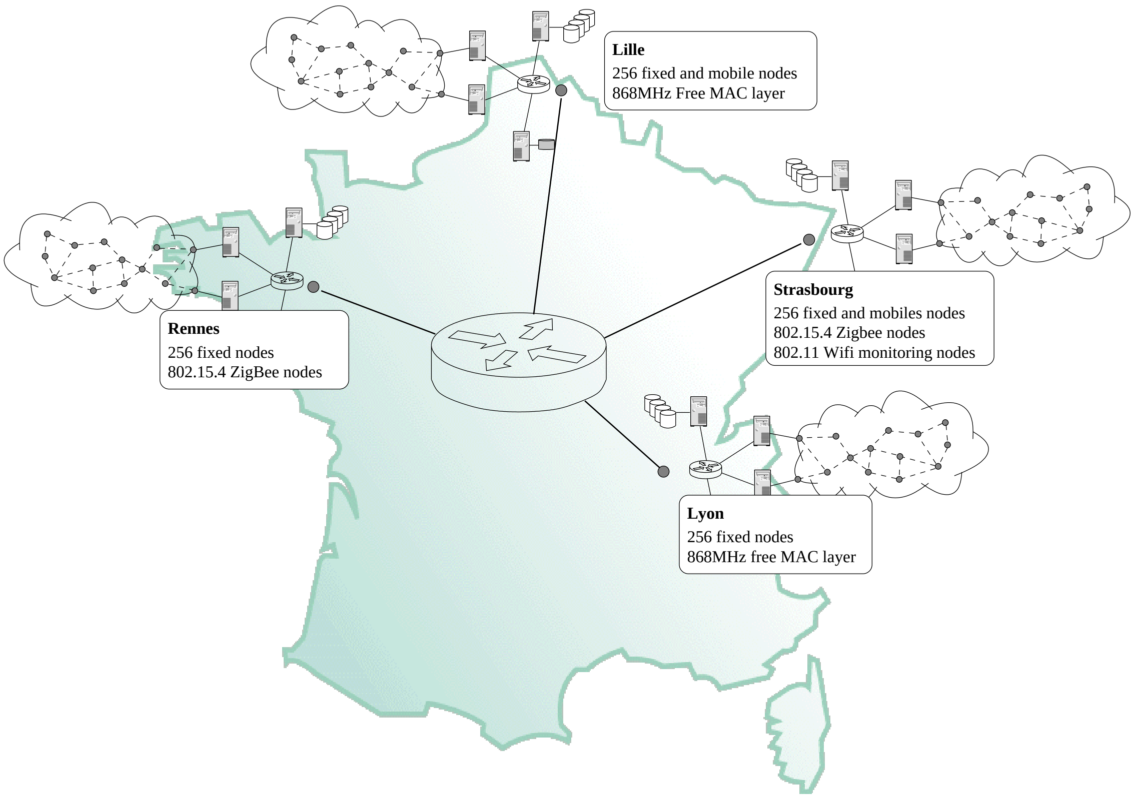

Figure 1: SensLAB national wireless grid testbed.

O3. (Software) To support multiple simultaneous applications and guarantee the security and the integrity of the data generated during an experiment.

O4. (Software) To assure public data retrieval in a real time fashion.

Hardware related efforts. These efforts will mainly be dedicated to the design of a controller card that will guarantee the achievement of objectives O1 and O2. The design of this specific card, in charge of the control of the sensor nodes will be done in work-package 1 (see Section 4.1). The main role of this controller is to guarantee *(1)* **reliable access** to the nodes in order to perform operations such as a reset, a reboot, or the loading of code whatever the current state of the sensor node or the software it is running. Users must have a full control in terms of OS, software deployment on each sensor node (which implies also tons of erroneous codes); *(2)* **real time monitoring** of the sensor nodes. The external monitoring (*i.e.*, totally independent from the deployed user application code) will include precise and real-time access to fundamental parameters such as energy consumption and radio activity on a per node basis; *(3)* **security and data integrity** between consecutive experiments on the same nodes. Indeed, the controller will erase all memories of a sensor node (mainly internal and external flash memories) before loading any new code in order to assert that an application can not gather the data generated by a previous application; *(4)* **real time control** of the experiments by providing a set of commands that may influence an application environment (e.g., turn sensor nodes on/off to mimic crashes, emit radio noise by sending fake data in order to perturb transmissions, modify the monitoring frequency parameters).

Software related efforts. These efforts are going to be focused on the design and implementation of the management tools and infrastructures required for such an ambitious test bed. A global management software is needed to achieve objectives O3 and O4. SensLAB testbed should accept multiple applications simultaneously and provide ways to experiment an application in an isolated fashion. A large set of tools will be developed, adapted and deployed to manage batch and reservation services. Application deployment should be done via XML like configuration files containing all node specific parameters (name, location, port, program, etc.), logging and monitoring specifications (samples frequencies, samples types) and external stimuli/events (reboot time, radio noise generation, mobility, etc.). The user will access to SensLAB via a unique web interface that will offer several services to reserve, configure and deploy experiments. Of course the user will also be able to upload his/her home made configuration files.

By combining complementary ambitious efforts, SensLAB offers a support to a broad range of research projects in large-scale sensor networks. The main goal of SensLAB is to open up the testbed to a broad spectrum of research groups to enable many as yet unforeseen projects. The testbed will be envisaged and designed to insure an exploitation strategy beyond the project duration with a strong commitment of the universities, research institutes like CNRS and INRIA, as well as a European strategy for its support and maintenance.

2 Context and State-of-the-Art

Ambient networking and wireless sensor networking are the focus of a significant amount of attention and effort of the research community. The main motivation has been to address the challenges posed by the wireless sensor network paradigm, which include limited node power, processing, and communication capabilities, dense network deployment, multi-hop communications, as well as heterogeneous application-specific requirements. As stated above, ambient networks are becoming a strategic domain of research and raise a large amount of new challenges, attracting the worldwide community in several domains of computer sciences but also requiring interdisciplinary researches. However, a gap still remains in terms of experimental results in large scale dynamic ambient networks.

One barrier to the widespread use of ambient networks or sensor networks is the difficulty of coaxing reliable information from nodes whose batteries are low, whose micro-controller may contain bugs and errors, or whose connectivity is intermittent. Nodes tend to be widely scattered and often malfunction; but an ambient network that represents the world inaccurately or incompletely is of limited use. It is thus very important to conduct *in situ* experiments and researches to better understand the characteristics and compensate for some of these flaws.

The main and most important goal of the SensLAB testbed is to offer **an accurate and efficient scientific tool** to help in the design, development, tuning, and experimentation of real large-scale sensor network applications. The SensLAB project proposes to address several strategic points in the domain of ambient networking: prototyping environment, open fully instrumented test beds, in situ experiments, data analysis/visualization. Addressing all this research points in the context of ambient network and wireless sensor network is a real challenge. SensLAB is designed to support a broad range of research projects in large-scale sensor networks and within SensLAB we will propose and test existing protocols, services and applications like routing, localization, DTN strategies in order to test them in terms of robustness, scalability, and performance. In addition to the projects that we will undertake ourselves, it is undoubtedly the main goal of SensLAB to open up the testbed to other research groups to enable many as yet unforeseen projects.

2.1 Project position

We review here some well know projects and works in the domain of sensor/ambient networks and we try to summarize the state of the art related to large scale ambient networks and describe some initiatives that are related to the work proposed in SensLAB.

As stated above, a key topic is to gather precise, accurate, long-term data. Efforts to acquire mobility data for DTN scenarios have expanded rapidly in the past couple of years but their number remains still low. The Reality Mining [6] experiment conducted at MIT has captured proximity, location, and activity information from 100 subjects over an academic year. Each participant had an application running on its mobile phone to record proximity with others through periodic Bluetooth scans and location using information provided by the phone on the cellular network. The UMass DieselNet project [5] also aims at studying DTN routing in challenging contexts such as power outages or natural disasters. A testbed to gather interactions between 40 buses in western Massachusetts was deployed in 2005. Other experiments with iMotes have been conducted by the IST Haggle [14] project, which explores networking possibilities for mobile users using peer-to-peer connectivity between them in addition to existing infrastructures. Note that all these mobility traces are now available from a common portal [2]. The drawback of all these researches is either that the number of nodes is small and/or that the testbeds are not open to the community. It gives a first experimental data set suitable for simulation purposes but it does not allow the deployment of real code on real nodes.

From a more test bed point of view, we describe some initiatives that are related to the work proposed in SensLAB:

CitySense [12] is an urban scale sensor network testbed that is being developed by researchers at Harvard University and BBN Technologies. CitySense will consist of 100 wireless sensors deployed on light poles around the city of Cambridge, MA. Each node consists of an embedded PC, IEEE 802.11a/b/g interface, and various sensors for monitoring weather conditions and air pollutants. CitySense is intended to be also an open testbed. As we can see, CitySense and SensLAB share similar objectives, but SensLAB's objectives are much more ambitious. Citysens is more a mesh like testbed with high power radios and PCs. It does not allow testing application on small devices constrained by energy, memory, CPU, etc. Note that the SensorScope [7] project, that aims to study the energy exchanges and balances at the earth/atmosphere boundary only provides data collection and it's not open to code deployment.

ORBIT [18] is a collaborative NSF project that focuses on the creation of a large-scale wireless network testbed to facilitate a broad range of experimental research on next-generation protocols and application concepts. The ORBIT (Open Access Research Testbed for Next-Generation Wireless Networks) system is a two-tier laboratory emulator/field trial network testbed designed to achieve reproducibility of experimentation, while also supporting evaluation of protocols and applications in real-world settings. In particular, the laboratory-based wireless network emulator relies on a large two-dimensional grid of static and mobile IEEE 802.11x radio nodes which can be dynamically interconnected into specified topologies with reproducible wireless channel models. Once the basic protocol or application concepts have been validated on the lab emulator platform, users can transpose their experiments to the field trial network, which provides a configurable mix of both high-speed cellular (3G) and IEEE 802.11x wireless access in a real-world setting. The ORBIT's philosophy is similar to SensLAB but it's dedicated to IEEE 802.11 like networks and not to constraint and embedded sensor networks.

ARMER is a platform that focuses on the study of human behaviours. It aims at developing a new theoretical platform and associated computing tools necessary to model and to understand dynamic wireless networks. The ARMER's philosophy differs from the one of SensLAB since it does not aim to study the sensor intrinsic behaviour and uses a fixed MAC layer.

Wireless Sensor Network testbeds. There exist WSN testbeds like MoteLab [4], Kansei [13], WASAL [10], TWIST [22] but all are less ambitious and do not target the same objectives. Generally, those testbeds are not really open to the broad community. Despite having dedicated wired back-channels, none of the testbeds listed above offers any accurate and real time power control functions. Testbeds do not offer radio instrumentation and/or noise injection. Nodes are not running on batteries, so it's quite hard to determine the real application life time. Moreover, networks are quite small (dozen of nodes) and dedicated to internal use most of the time. The testbeds neither offer mobility nor the possibility to study hierarchical protocols in order to interconnect sensor network clouds through the Internet. Such testbeds do not offer a complete and accurate development framework for prototyping, debugging, tuning and profiling. A last important drawback is that they all use IEEE 802.15.4 MAC layer and impose TinyOS [17]. Two problems arise. First, fixing the MAC layer to only IEEE 802.15.4 nips in the bud any research that targets at the optimization/improvement of MAC layers. Second, imposing TinyOS constrains applications to use a well know OS that is neither really optimized nor efficient in terms of energy consumption and clock frequency optimization.

Never before has there been a large scale testbed (1,024 nodes) explicitly designed for sensor network experimentation. SensLAB offers many advantages over the alternatives: simulation, small testbeds, and customized infrastructure. As the testbeds are close to the real world deployment environment, experiments performed using SensLAB will reflect the natural complexities that are frequently lost in a simulated model. SensLAB opens the door to experiments and applications that were previously only available via simulation.

Several projects (national and European) working on sensor networks may benefit from the SensLAB infrastructure. Indeed, several projects are targeting the design and deployment of sensor network applications or the design of autonomic and ambient networking infrastructure but they do not have the opportunity to use large scale wireless sensor grid testbeds to prototype and benchmark the performances of their proposals. Usually, only simulations or very small prototypes (dozen of nodes) are used, introducing weaknesses and flaws in the robustness of the proposed solutions and approaches. Projects also suffer from a lack of dedicated tools for sensor network embedded application development.

We will not give an exhaustive list of projects dealing with sensor and ambient networking. We will restrict ourselves to close projects where we are directly involved, offering a complementary approach and that may benefit from SensLAB.

ANR/TLCOM SVP [8] and ARESA [11] are two projects that target the use of large scale sensor networks. The availability of SensLAB appears as a real opportunity for both projects.

European IST WASP [15] is a project that aims at narrowing the mismatch between theory and practice by covering the whole range from basic hardware, sensors, processor, communication, over the packaging of the nodes, the organization of the nodes, towards the information distribution and a selection of applications. The emphasis in the project lays in the self-organization and the services, which link the application to the sensor network. The general goal of the project is the provision of a complete system view for building large populations of collaborating objects.

European IST MOSAR [16] is a project aimint at gaining breakthrough knowledge in the dynamics of transmission of AMRB, and address highly controversial issues by testing strategies to combat the emergence and spread of antimicrobial resistance, focusing on the major and emerging multi-drug antimicrobial resistant micro-organisms in hospitals, now spreading into the community. In order to better understand the spreading of Infections caused by antimicrobial-resistant bacteria (AMRB), large scale sensor network will be deployed in order to gather the dynamic of the interactions between patients/patients, patients/medical staff and medical/medical staff.

2.2 Economic Context and a Market Analysis

Microprocessors are finding their way into all kinds of applications and devices. The number of microprocessors is growing at a rate of more than 7,000 million per year. In addition, new, short-range, low-power, wireless technologies, like ZigBee (www.zigbee.com) or UWB (Ultra Wide Band), make highly cost-effective connectivity possible. Unit costs for devices with wireless communication capabilities are now below 3 euros and further dropping. This justifies hooking up objects and devices to the network far beyond what has been previously technically or economically feasible. It paves the way for a new and rapidly growing domain which includes all kinds of sensor network elements. In addition, the new technology will open up vast new areas of application in the business sector as well as in the public sphere.

The emergence of short-range, low-power, and wireless technologies opens up a brand new perspective on the number of devices with connectivity in the future. From a telco point of view, these connected objects represent a huge potential for extension of the existing networks and businesses. Given sound business models, telcos should benefit from their strong positions in the market and generate substantial value from the fast growing sensor network domain. For the industrial domain, wireless sensor network are use in a M2M (Machine to Machine) approach. We can classify applications in two main branches : control and monitoring. Monitoring concerns merchandise localization, stock inventory, stock management, automation of the supply chain. In such context, industrial may use short range technologies like RFIDs, and information exchange will be unidirectional. Control applications are much more complex since they do require a decision process based on multiple information and data feedback. We give below a short non exhaustive list of control applications:

- industrial process control
- environmental monitoring
- severe environmental process
- preventive maintenance
- real time monitoring
- electricity consumption optimization
- staff security

Such applications can be deployed by using traditional wired networking technologies but wireless networks offer an easiest deployment and self configuration. Actually, a lot of actors in the domain of sensor are positioning themselves on the wireless connection market in order to provide self configuring deployment products.

	2004	2005	2006	2007	2008	2009	2010
Industrial process	1.93	5.84	10.00	17.80	35.20	76.20	165.00
Control and monitoring of buildings	1.40	2.84	4.80	10.70	21.46	46.10	95.44

The sensor network market is in expansion, especially in the US and in the EC. Based on the study of the World Semiconductor Trade Statistics organization, the sensor market will be part of the segment that will encounter a dazzling success in the next period. Even if the researches in US are very active and exist since roughly 10 years now, they consider that we only see the tip of the iceberg. The New York Times (May 10, 2005) declares that "*the field is young*" and that in the past few years, officials and experts say, the science foundation has spent more than $100 million to foster planning and research on the new sensor networks, and it foresees more than $1 billion in large ecological projects, mainly observatories.

	2004	2005	2006	2007	2008	2009	2010
US $ Million	72.4	160	227	321	517	934	1834

From the study conducted by OnWorld, the RF module market for sensors will reach 465 million of units in 2010. 35% will be dedicated to industrial application and 28% for the automation and control of buildings and homes. This market represents $72 million in 2004 and $2 billion en 2010. This evaluation corresponds to RF OEM and not to a sensor node suitable for the final application. The cost of an assembled node could be 4 to 10 times greater. Other studies, even more optimistic forecast a real explosion of the market. WTRS (West Technology Research Solutions LLC, Mountain View, CA) announces a market of 600 million of units in 2008. As costs of producing wireless sensor networks drop, sales are rising – a trend the industry expects to continue as the new technology matures and applications expand.

In this way, we emphasize that mastering the design, the development, and the management of large scale wireless embedded applications represents a strategic objective for a broad community. *SensLAB offers a scientific tool through a large scale wireless grid testbed, open to any research groups to enable many as yet unforeseen projects.*

3 Partnership

The SensLAB consortium gathers the main actors with a high expertise in distributed sensor nets – academic and industrial – and we are in close collaboration proximity. All partners will collaborate very closely in this project, and plan for many visits between our organizations.

3.1 INRIA (Projects ARES, ASAP and POPS)

INRIA, the national institute for research in computer science and control, operating under the dual authority of the Ministry of Research and the Ministry of Industry, is dedicated to fundamental and applied research in information and communication science and technology (ICST). The Institute also plays a major role in technology transfer by fostering training through research, diffusion of scientific and technical information, development, as well as providing expert advice and participating in international programs. By playing a leading role in the scientific community in the field and being in close contact with industry, INRIA is a major participant in the development of ICST in France.

Throughout its six research units in Rocquencourt, Rennes, Sophia Antipolis, Grenoble, Nancy and Bordeaux-Lille-Saclay, INRIA has a workforce of 3,500, 2,700 of whom are scientists from INRIA's partner organizations such as CNRS (the French National Centre for Scientific Research), universities and leading engineering schools. They work in 120 joint research projects. Many INRIA researchers are also professors whose approximately 950 doctoral students work on theses as part of INRIA research projects.

Research groups involved in SensLAB are ARES in Lyon (INRIA Rhônes-Alpes), ASAP in Rennes (INRIA Rennes) and POPS in Lille (INRIA Futurs). All these research groups are common projects with CNRS (ASAP and POPS), Universities (Université de Haute-Bretagne for ASAP and Université des Sciences et Technologies de Lille for POPS) and INSA Lyon (ARES).

INRIA ARES project. The ARES (Architectures of Networks of Services) team deals with problems related to deployment of services on radio networks architectures, in ad hoc or wireless LAN mode, organized around fixed infrastructure, or using both combinations. The different issues to address concern the interoperability of different systems and protocols, as well as the optimization of radio, networks and systems resources while deploying and using any service. The goal of the ARES project is to model and to develop architectures and software support for hybrid wireless networks. Such networks rely on heterogeneous technologies including Personal Area Networks (PAN) and Wireless Area Networks (WAN) in infrastructure mode and/or in ad hoc mode (i.e. an infrastructure less mode); they connect people, but also an increasing number of devices. The main relevant issues concern the interoperability of different systems and protocols, and the optimization of radio, network and system resources for services deployment and provision. Considering the diversity and variability of the technical and environmental constraints, adaptation is a key to the success of hybrid networks. ARES is focused on four main challenges: integrating different types of mobility, controlling cross-layer interaction, providing self-configurability, and supporting quality of service (QoS). ARES contains 30 members including 16 permanent members (Professors, Associate Professors, Full researchers).

The INRIA ARES project is also involved in several related and complimentary national and European projects, like in the RECAP platform Project. ARES is involved in the IST IP Project "**W**irelessly **A**ccessible **S**ensor **P**opulations" (WASP), in the HEALTHCARE IP MOSAR project and in several related national projects: RNRT SVP (SuperVise and Prevent) and Malisse (MALIcious Sensors). All these projects have several complementarities and will benefit from SensLAB. All the protocols designed and studied in SVP for example will be stressed on a real large scale sensor testbed.

INRIA ASAP project. The ASAP (As Scalable As Possible) team is newly created is located both in IRISA and INRIA Futurs (Orsay), lead by Anne-Marie Kermarrec. Its research activities range from theoretical bounds to practical protocols and implementations for large-scale distributed dynamic systems to cope with the recent and tremendous evolution of distributed systems. Effectively we observed huge evolutions:

- Scale shift in terms of system size, geographical spread, volume of data.
- Dynamic behaviour due to versatility, mobility, connectivity patterns.

These characteristics lead to a large amount of uncertainty. Mastering such uncertainty is actually our goal. We aim at providing a wide range of applications (from content delivery networks to sensors networks, from backup systems to voice over IP, from publish-subscribe systems to genomic databases). We focus our research on two main areas: information management and dissemination. We believe such services are basic building blocks of many distributed applications in two networking contexts: Internet and wireless sensors. These two classes of applications, although exhibiting very different behaviours and constraints, clearly require scalable solutions. ASAP team regroups 14 researchers (including 1 professor, 1 senior researcher, 2 associate professors and 2 researchers). The ASAP team is involved in several related national projects: RNRT SVP (SuperVise and Prevent) and Malisse (MALIcious Sensors). Our objective in the SVP project is to design solution to aggregate data in a dynamic network. The Malisse project aims to investigate algorithm to aggregate data in a sensor network despite of the presence of Malicious (or Byzantine) sensors. These two projects will significantly improve by the use of the large scale platform provided by SensLab. The feedbacks from experiments over a real platform will allow us to evaluate our solution and to improve our sensor and network model by taking into account their characteristics and so to design more realistic and optimized algorithms. These algorithms can also be evaluated in a real environment which is an improvement regarding simulation.

INRIA POPS project. The POPS research group investigates solutions to enhance programmability, adaptability and reachability of small objects designated by POPS (Portable Objects Proved to be Safe). The POPS set contains small devices like smart cards, RFID tags or personal digital assistant which are characterized by limited resources, high mobility and high security level in spite of untrusted environment. The development of applications integrating POPS suffers from lack of “reachability” of such platform. Indeed, most of POPS are not easy to program and high level of expertise is needed to produce software in such limited operating systems and devices. Moreover, POPS mobility induces sudden and frequent disconnection, long round trip times, high bit error rates and small bandwidth. Hence, POPS system has to adapt itself to application requirements or modification of its environment. In that context, we are conducting research in the connected areas of embedded systems and mobile networking. POPS research team regroups 20 researchers (including 1 Professor, 4 Associate Professors and 1 full researcher).

The POPS research group is a common research project between CNRS, INRIA and University of Lille 1. Inside the IRCICA[1] Research Federation, the POPS research group contributes to the “Sensor Network Hard-Soft Project” in partnership with CSAM research group from IEMN. The main topics in this project are to study hard-soft interface and optimizations for large-scale networks. High-speed communication in indoor environment is also studied in the context of smart home.

The POPS project is also involved in several related and complimentary national and European projects, like in the RECAP platform Project. First, POPS is involved in the IST IP Project “**W**irelessly **A**ccessible **S**ensor **P**opulations” (WASP). The general goal of the WASP project is the provision of a complete system view for building large populations of collaborating objects. Thus, WASP project would be able to provide SensLAB with advices adaptive to applications and platform and, the other way round, SensLAB would give an experiment feedback to WASP. POPS is also involved in the RNRT SVP (SuperVise and Prevent) Project which proposes the study, the realization and the experiment of an integrated ubiquitous architecture to make easier the conception, deployment and optimal exploitation of supervising and preventing services over several kinds of dynamic networks. The SVP project aims to implement large scale *in vivo* applications. It might need feedbacks from experiments over SensLAB platforms to decide such technological choice.

3.2 Thales Communications S.A.

The Thales Group totalled revenues of over 11 billion Euros in 2005, half from the Civilian businesses and half in the Governmental and Defence domains. Within the 60.000 employees worldwide (50.000 in Europe), one third is involved in R&D that totals 1.9 billion Euro (18% of revenues),

Thales Communication France (TCF) revenues reached 1 billion Euros with 4.600 employees. TCF addresses every activity related to telecommunications: wireless communications, IP networks, satellite communication, network administration and security. TCF has a long experience in very large Information Systems and secure infrastructures for systems and networks, including Internet and Intranets. TCF also

[1]IRCICA=Institut de Recherche en Composants logiciels et matériel pour l’Information et la Communication Avancée. `http://www.ircica.univ-lille1.fr`

develops a full range of telecommunication platforms and components, a range of high performance security products and has a deep skill in secure telecommunications for public and governmental organisations, emergency services and armies.

The laboratory of TCF involved in SensLAB is the Advanced Information Technologies Lab (TAI) whose mission is to envision the future approach, architecture and technology for Thales systems within the Architecture Framework Centre. The TAI team is involved in leading edge IT projects aiming in specification, design and integration of security and telecommunication infrastructures.

TAI personnel belongs to the following set of expert profiles:

- Network experts, especially for fixed and mobile IP network design.
- Security architects for networks and information systems.
- Information system experts on architecture and modelling aiming to increase adaptability and dependability.

The IST project MORE (started in mid 2006 for three years) aims at developing an innovative middleware platform, that will produce a definitive incorporation of embedded systems and networks to enable pioneering applications in civil and commercial settings. As well as enhancing person-to-person interaction via embedded middleware between the major wireless standards, MORE is implementing new technology to facilitate communication and distributed intelligence across groups of sensors. Central to the project will be the design of a middleware that hides the complexity of the underlying heterogeneity of embedded systems through providing simplified APIs and management mechanisms for the future operators of these systems.

The MORE middleware follows a Service Oriented Architecture approach: the applications are thus intrinsically distributed across different, distant nodes of various capacities. As the number of software components and target hardware nodes grow, debugging, testing and validating such applications becomes increasingly complex. Testbeds that allow the deployment of applications for validation purposes such as the one proposed by the SensLAB project become absolutely necessary for the success of distributed middleware such as envisaged by MORE.

3.3 Université Pierre et Marie Curie – Paris 6, LIP6

The LIP6 laboratory of the Université Pierre et Marie Curie – Paris 6 (http://www.lip6.fr) is one of the largest computer science laboratories in France (>350 researchers) covering a wide spectrum of topics ranging from theoretical computer science to VLSI, among them, the The Network and Performance Analysis group covers issues related to networking and aims at developing a vision for the future Internet as well as design solutions to shape and manage it. The target of the group is the control of ubiquitous, mobile and versatile networks that expand everywhere in our private and professional environments. Part of the core of our work concerns problems related to mobile networks, resource management, scalability, ambient networks, self-organization, and peer-to-peer communications. The group develops a modern approach of research in networking, through basic research and transfer activities, in strong cooperation with worldwide academic partners and industrial leaders. It is also the core of Euronetlab, a joint laboratory between industrial and academic partners. Transfer is measurable though our contributions to standardization bodies (e.g. IETF: MLDv2 or RTP XR), the creation of start-ups (like Qosmos) as well as numerous research contracts (Thales, Alcatel, France Telecom, Nortel, Cegetel, EADS, and Sprint). The group activity is supported by permanent researchers, Post-Doc, international visitors, engineers and about 40 PhD students. Therefore, the group has established a critical mass of about 60 faculties/engineers/PhDs. Besides recurrent financial support, a large part of the budget comes from contracts at the national, European, and International levels. The LIP6 Network and Performance group is an international centre of excellence in networking and one leader in this area in France. In the area related to this proposal, the LIP6 is currently leading the European IST WIP project on the self-organization of spontaneous community networks, and participating in two National projects: RNRT SVP, whose objective is to investigate and deploy an integrated ambient architecture for the conception of dynamic networks; and RNRT Airnet, whose objective is to conceive an interconnection infrastructure for mobile networks relying on local wireless networks operating in public frequency band.

3.4 Université de Strasbourg, LSIIT

The Image Sciences, Computer Sciences and Remote Sensing Laboratory (LSIIT) is a mixed research unit (UMR 7005) of the CNRS and of the Louis Pasteur University (>150 researchers).The major research topics are Computer Sciences, Signal Processing, Automatics and Remote Sensing. It depends on the Department of Science and Technology of Information and Engineering (ST2I).The Networks and Protocols Research team (i.e. RP) of the LSIIT works mainly on the design and analysis of protocols and networking architectures, particularly in using the new IPv6 internet protocol. We are interested in problems with multipoint communications, such as multicast routing, reliable multicast. We are also interested by various aspects of mobility (terminal mobility, communication mobility, service location, sensors networks). We also work on network topology generation and simulation. The LSIIT-RP team regroups 14 researchers (including 2 Professors and 3 Associate Professors).

The LSIIT-RP team is involved in the RNRT AIRNET project where we are working on a new framework for wireless mesh networks. This work is complementary with the Senslab testbed where we plan to deploy new algorithms to optimize routing information based on geolocation information.

3.5 Expertise / complementarities and synergies in project.

The INRIA research groups involved in SensLAB LSIIT, and LIP6 have been key players and have developed a strong expertise in the field of wireless sensor networks in the scope of the French CNRS platform project “Sensor and Self-Organizing Networks” (aka RECAP) where they are very active.

Success in this collaboration is expected also due to ongoing collaboration in the context of the ANR SVP project, which proposes the conception of an ambient integrated architecture to help conceiving, deploying, and exploiting multiple services on dynamic wireless sensor networks. The applications investigated in the SVP project are typical examples that would benefit from a testbed such as SensLAB.

4 Project organization and resources

As stated in the previous sections, there is a crucial need for further research into the modelling and analysis of large-scale ambient dynamic networks. Research in wireless networks is rich and very active, but it has reached a stage at which theoretical propositions and results need to be confronted with reality in order to be confirmed in practice. Current simulation techniques do not sufficiently capture the dynamic conditions of the wireless environment to be able to give good and reliable directions for continued protocol and application development. The aim of the SensLAB project is to deploy, manage and make available **a controllable and able to be monitored experimental large scale testbed** in order to offer a great service to the research community. The goal is to structure a large research community by offering a scientific tool.

The test bed will be useful to a large spectrum of research activities: radio resource optimization, MAC protocol design, routing protocols, capacity and provisioning, naming/addressing capabilities, energy awareness and optimization, scaling, self organizing structures but also embedded OS design, application benchmarking and dimensioning. Embedded systems such as small secure communicating objects require design methodologies where software and hardware design are tightly coupled to meet real-time, cost and energy consumption constraints. Here again being able to deploy and test solutions/applications on a large scale execution platform like SensLAB is essential to cope with both spatial concurrency and temporal scheduling issues. The research conducted should embrace all kind of innovations at any level and should not be restricted or confined to a specific layer. In addition, the SensLAB testbed will allow addressing disruptive approaches, as opposed to simply evolutionist ones. **Through this high collaborative research effort, the goal is to promote shared methodological research and the emergence of a new architecture, alternative protocols or original services.**

By offering an enhanced experimental large scale sensor network test bed composed of several radio technologies, a set of developing tools to help the user in the design and the deployment of its distributed embedded application and a complete management and monitoring infrastructure to collect, treat and analyze the experimental data obtained, the SensLAB project will foster innovative researches in networking, embedded systems, operating systems and applications.

Our first plan is to assemble a physical platform featuring 4 local platforms each with 256 wireless sensor nodes. All local testbeds will be connected by the RENATER Education and Research Network through a virtual private network. The managing and monitoring software developed inside the SensLAB consortium as well as all specifications and requirements will be distributed in open source such that, in a second phase, other research centres will have the opportunity to join the SensLAB when it will be mature and operational (after the second year). During the first phase, the deployment of 4 testbeds will allow to test interoperability, to test hierarchical protocols and applications running on large scale networks and to set up specific characteristics in order to offer a broad set of complementary features.

SensLAB is clearly a set of resources composed of both hardware and software aspects and we will detail below the two aspects that are at the heart of the test bed. In order to reach the ambitious goal fixed and address the challenges while minimizing the risks we structure the SensLAB project around four complementary work packages:

WP1. This work package is dedicated to the hardware architecture of the wireless nodes and to the test bed deployment. Thanks to a high collaborative research effort funded by the CNRS (RECAP project), INSA the Lyon (CAPNET project) and INRIA, we have a strong asset in the design of wireless sensor nodes that makes such a project possible. From our experience in the design of sensor node[2], we will not redevelop here new wireless node but only a small monitoring connector in order to fulfil the goals in terms of controllability and monitoring features. This work package will also supervise the deployment of the physical test bed: nodes, wired monitoring infrastructure, gateways, servers, etc. INRIA/ARES will lead the workpackage.

WP2. This work package gathers all software development related to the management, access, gathering and experimental code loading on the plate form. The software tools must provide to the final user a way to get an account, log on SensLAB in order to develop its application on its own internal SensLAB private area, reserve time slots and nodes, parameter the monitoring feedback, load the code and launch his/her experiment. During a running experiment, the user can be logged-on and change the monitoring parameters, view monitoring data on-line, perform data analysis and have access to the database storing all results, change the noise generators. Once the experiment is done, the user can view, analyze monitored data stored in his/her specific database. University of Strasbourg will lead the work package.

WP3. This work package will develop specific applications in order to illustrate and emphasis the need of using SensLAB. The main goal is not to develop new protocols but to use the facilities of the trial network testbed in order to test and evaluate existing protocols and applications in real-world settings and to stress them in terms of radio activity, scalability. . . The several applications proposed will also take advantage of the specific features of the 4 local testbeds. These applications will also serve as input tutorials to promote the use of SensLAB. THALES will lead the work package.

WP4. The last work package is dedicated to the management of the testbed and also to the Dissemination and Use Plan, for which all investigators will participate, in furtherance of the project goal of providing a set of services to the scientific community at large. Within the DUP task, we also propose to setup tutorial materials and advanced practice lab on SensLAB in order to introduce topics like introduction to the SensLAB environment and tools. We also want to take benefits of SensLAB to propose advanced tutorial and go into the major concepts required to program sensor network applications. University Pierre et Marie Curie will lead the work package. A specific task dedicated to the management will be included.

The work packages WP1 and WP2 will clearly be the phase 1, dedicated to the design, the setup and deployment of the testbed. The work package WP3 will be a first use of the platform within several kinds of research activities. WP3 will initiate the phase 2 of the testbed. We will discuss later in section 5 how other projects will also use it. Finally, WP4 will present how the platform will stay operational. The section 5 will also emphasis on possible evolutions and on how the SensLAB testbed will stay up to date and operational.

[2] WSN430 nodes: `http://www.worldsens.net`

4.1 WP1: Hardware Architecture / testbed deployment

Leader	**INRIA/ARES**						
Efforts	INRIA/ARES	INRIA/ASAP	INRIA/POPS	THALES	LIP6	LSIIT	Total
	30	12	12	0	0	12	66

The general SensLAB architecture will feature 4 local platforms each with 256 wireless sensor nodes. All local testbeds will be connected to the RENATER Education and Research Network by a virtual private network in order to offer a global laboratory sensor network testbed designed to achieve reproducibility of experimentations and to support evaluation of protocols and applications in real-world settings. Operation on 4 different sites allows more flexibility in terms of experimental services as it allows for example to run experiences in parallel without any physical interaction. It also allows to instantiate different services/characteristics on each platform: RF, MAC, GPS, WiFi, Mobility. . . and thus to offer an heterogeneous wireless sensor network. This will allow to test hierarchical protocols and complex applications deployed on several local testbed that may interact.

As noticed in the previous sections, the architecture must fulfill a given set of criteria in order to become a scientific tool and a community resource used for the evaluation of emerging wireless network protocols and applications. We also want the SensLAB testbed to be used as a proof-of-concept prototyping platform for wireless aspects of the future Internet research infrastructure. Let us recall briefly the main mandatory features that must offer the testbed:

1. offer a real-time, robust and reliable access to the distributed platform. The testbed must offer to the user a high-level of control over protocols and software used on the radio nodes. No assumption should be done at this point on the OS running on the wireless nodes, on the programming model. . . The remote access to the testbed should deal with software and hardware failures.

2. provide wired feedback channels for management/logging and extensive measurements capability at radio level, on an energy consumption level and provide also the ability to correlate data across layers in both time and space.

3. support multiple applications simultaneously and guarantee security and integrity of the data generated during an experiment.

4. be generic in terms of applications and researches

5. scalability in terms of the total number of wireless nodes

6. reproducibility of experiments which can be repeated with similar environments to get similar results.

In order to be generic and thus be a tool used by several domains and research activities (PHY, MAC, Routing, naming, application and services) the user must be able to load any application on a wireless node. This imply that he/she could load and run any OS, any kind of codes with bugs... and thus we must provide a secure mode and access to reboot and load any node. We do have the same constraint for the management and the monitoring of nodes. It appears mandatory to offer a secure and out of band network to control all nodes. In order to be operational very quickly we plan to take benefits of our past experience in developing wireless sensor node. Thanks to a high collaborative research effort funded by the the CNRS (RECAP project), INSA the Lyon (CAPNET project) and INRIA we have a strong asset in the design of wireless sensor nodes. We plan to reuse the basic node called WSN430 that was successfully designed in the ARES group and the CEGELY laboratory. WSN430 (see figure 2) is an ideal fit for low ultra low power wireless module for sensor network applications. This module is simple enough to offer a great robustness. Basically it is composed of a 8Mhz TI MSP430 ultra low power 16 bit RISC mixed-signal micro-controller with 10KB RAM, 48KB flash memory; 1MB flash memory for data storage, Ultra low power TI CC1100 multi channel RF transceiver with an on board antenna, unique ID. Extension of the WSN430 concerning a GPS module, additional sensors cards, WiFi capabilities is currently ongoing and supported by Lyon science transfer. The WSN430 is thus a mature technology and is available and ready to be deployed in a large scale ambitious testbed.

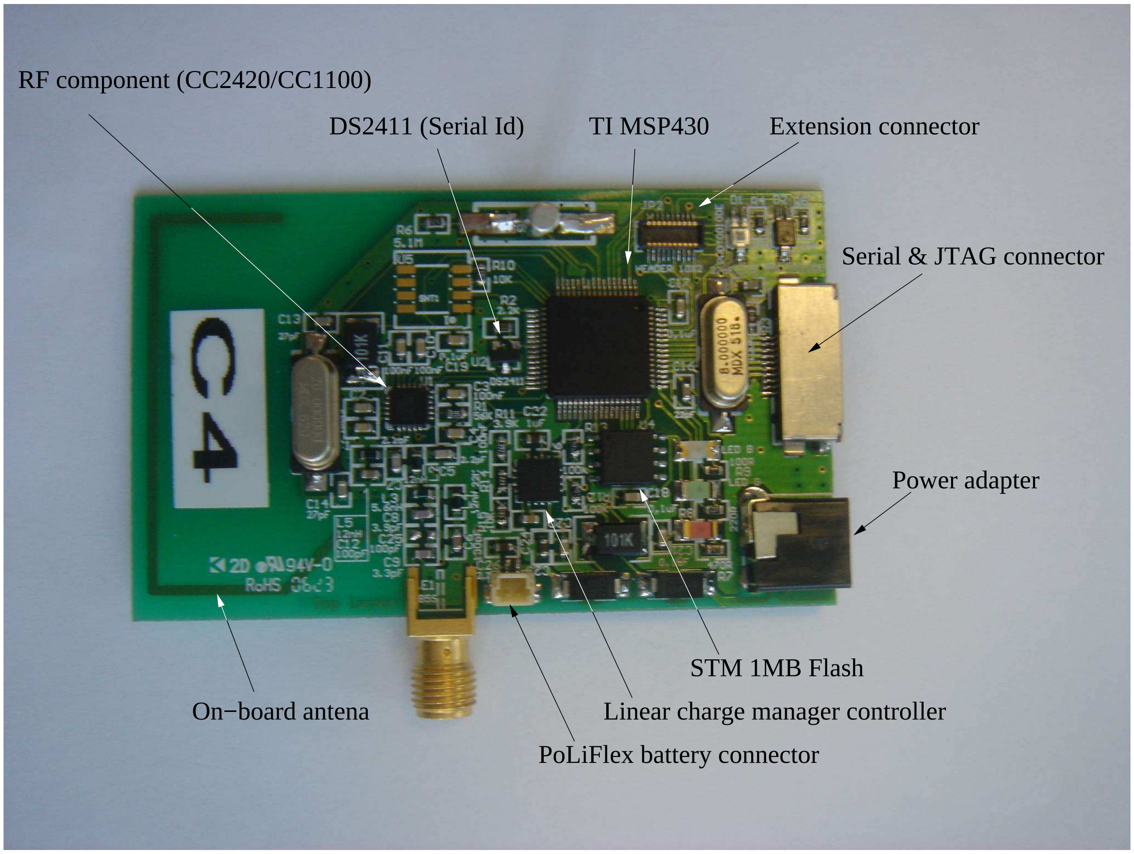

Figure 2: WSN430: ultra low power wireless module.

Task 1.1 The first task of the WP1 will be to develop a way to offer a real-time, robust and reliable access to a wireless node and also to provide wired feedback channel for management/logging. In order to control the wireless node we need to set up a control on each wireless node. The platform will be composed of two WSN430 modules. One of these module will be totally open and another one will monitor the first node and control it. In order to connect both node and also and monitoring features and capabilities we need to develop a connector that will made the junction between the open wireless nodes and the controller. The figure 3 depicts the final node architecture. This task will be conducted by the INRIA/ARES project. Basically, the controller modules will allow to control the open wireless node from the controller node: reset the wireless node, erase all data on it (internal and external flash), upload new code, control the electrical power of the node (switch the power from the battery or from the DC power of the infrastructure). The connector module will also embed a power consumption gauger that will enable to monitor the power used by the wireless node. The connector module will be link to the monitoring infrastructure by a serial link connected to a serial port access server. The connector module will also be plugged to a continuous power source. Note that the monitored node will still have a battery and can either run on battery or on continuous power. This will allow to test the scalability in terms of energy and life time of applications deployed and benchmarked.

Based on the SensLAB node (composed of 1 open wireless node, 1 controller node and 1 connector module) the next step will be to deploy all local testbed and interconnect them. We will start by setting up one platform and then deploy the 3 others.

Architecture of a local platform. Each platform will have a common architecture in terms of monitoring infrastructure and inter networking. The figure 4 depicts a generic local testbed architecture. Each SensLAB node is connected via a serial link to one serial access server. The access server will be able to

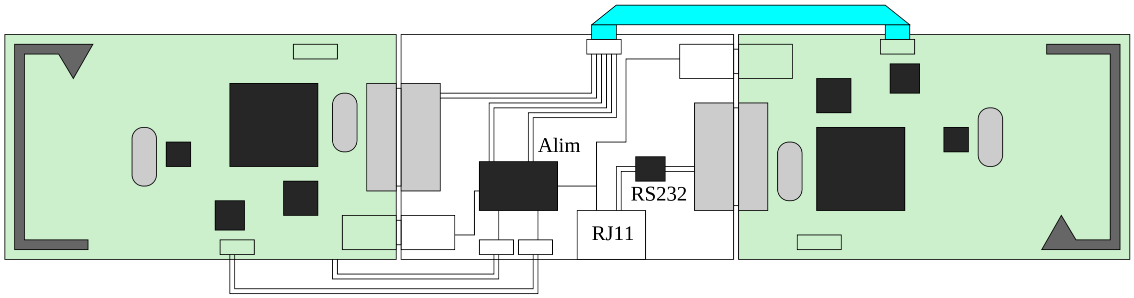

Figure 3: SensLAB node module

control each SensLAB node individually (sending commands to reset, configure, shut down the node). The access server will also be in charge of collecting all monitoring data generated by the SensLAB node (radio activity, power consumption). The other common part in all platform will be the SensLAB gateway nodes directly connected to the backbone network of the global testbed. Gateway/sink nodes are thus composed of a classical SensLAB node connected to a PC where the user is allowed to deployed specific running codes/OS/applications in order to control its application. We plan to deploy 4 to 8 SensLAB sink nodes by local testbed. It will allow to run in parallel up to 8 experiments. Of course we will not deployed 8 PCs but we will use virtual, Linux based, machines hosted on a server and assign to each virtual machine a given serial port in order to connect the user virtual PC to its SensLAB sink node. From the virtual machine node, the user will be able to open TCP/IP connections to any other sink nodes and thus test and benchmark heterogeneous and hierarchical protocols and applications. Finally, all local testbeds will have a unique Internet gateway that will be the "*entry point*" into the global SensLAB trial testbed.

Task 1.2: Lyon platform. The first testbed that we will set up will be in Lyon inside the INRIA/ARES project since this partner have the strongest experience in developing and in the technology used. The platform will be composed of 256 WSN430 nodes and will use the TI CC1100 RF component. This means that the MAC layer of the radio will not be fixed in the hardware. It's very important to offer one open RF platform in order to allow experimental tests and development around MAC protocols for sensor network. Since energy is a key issue is the context of sensor network domain, the MAC layer is one of the first layer that should be optimized and tune. Such open platform will allow to test cross layer design of MAC/routing/applications.

The second main characteristic of the Lyon platform is that we will provide a complete developing environment for developing and prototyping sensor network applications. This environment based on two softwares WSNET and WSIM developed by the INRIA/ARES partner allows to simulate an application on the complete platform and to debug, profile the application code without any change in the application code. We will describe more precisely the simulation software specifications in section 4.2.

The Lyon testbed will also be the reference in terms of infrastructure deployment (cables / network connexion / serial access server), in terms of monitoring and gateway access, in terms of storage and Data Base configuration. In order to supervise this first fundamental phase of the project, we plan to hire a full time research engineer in order to follow and manage all physical and development aspects and help the research engineer in this task. The engineer in charge will also play a key role in the valuation and the transfer of the experience learned during the first setup to other partners. The first phase should provide recommendations and clear manuals in order to facilitate the setup of upcoming platforms.

Task 1.3: Lille platform. The second testbed will be set up in Lille inside the INRIA/POPS project. The platform will also be composed of 256 WSN430 nodes and will also use the TI CC1100 RF component. But, contrarily to every other platforms, some nodes will be mobile. Among the 256 sensors, we plan

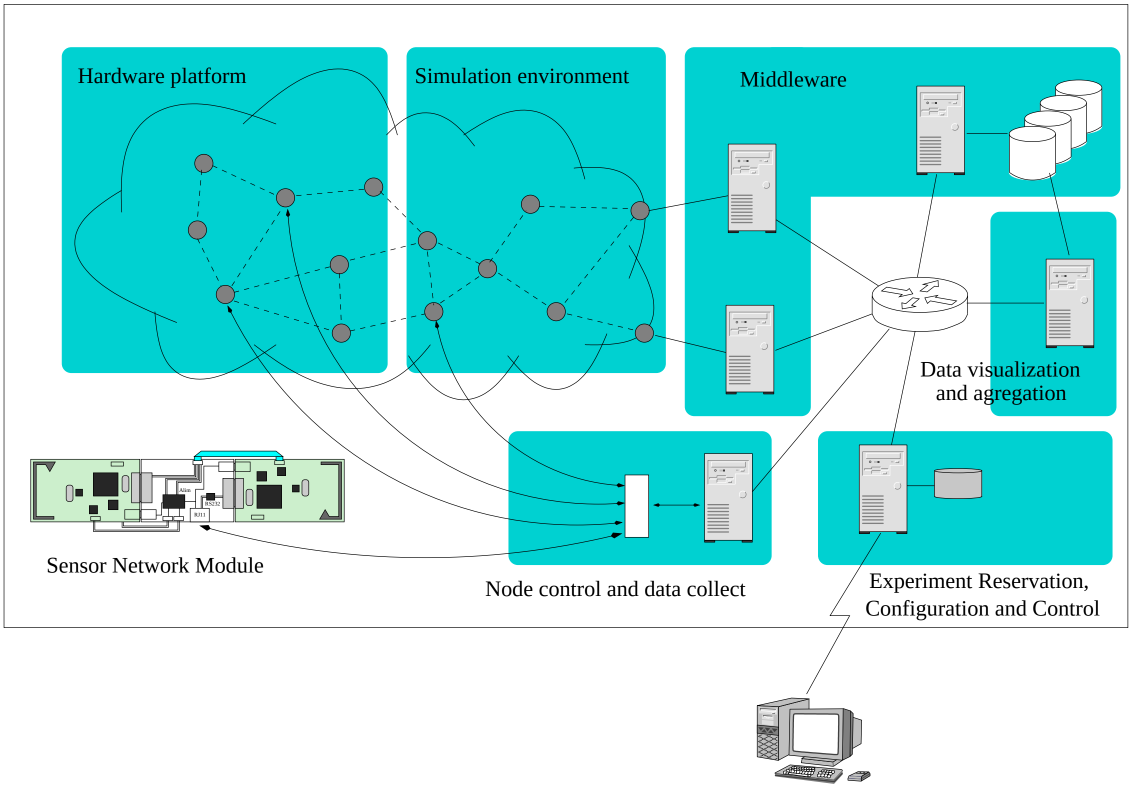

Figure 4: SensLAB local testbed architecture.

to have 32 mobile ones and the 8 sinks will also be mobile. The mobility scheme is still to be defined but it will be deterministic. Generally, mobility has strong effects on wireless network protocols but is very difficult to simulate properly. This platform will such provide a complete developing environment for developing sensor network applications for mobile environments.

Since nodes will be mobile, linking them via a serial interface would not be convenient. Therefore, mobile sensors will communicate and be monitored via a wireless WiFi interface. Thus, for these mobile nodes, the RJ11 slot on Figure 3 will be replaced by a wireless WiFi card. The 224 fixed remaining nodes will be similar to the ones of the first testbed deployed in Lyon, *i.e.* where the MAC layer is not fixed in the hardware and totally open.

The platform will embed 16 sink nodes, 8 of them will be mobile nodes. This platform will thus offer the opportunity :

- to analyze the intrinsic behavior of sensors nodes when they are mobile. Is it similar to the behavior in static environment ? Is energy consumption the same in both cases ?
- to analyze a completely mobile sensor network (in considering only mobile nodes) regarding data sensing, routing and recovery performances.
- to analyze interactions between fixed and mobile sensor networks regarding data sensing, routing and recovery. How do mobile sensors send data to fixed sensors and vice et versa ? How do mobile and fixed sinks gather data coming from both mobile and fixed sensors?
- to analyze the impact of the mobility on both the sensor behavior and the quality of data sensed.

All these aspects are important for designing efficient protocols for sensor networks and are still too misunderstood.

Task 1.4: Rennes platform. The third testbed will be deployed in the IRISA laboratory and manage by the ASAP team. This platform will be composed of 256 WSN430 with the radio component CC2420, at the contrary to the first platform in Lyon, this platform is turns towards application evaluation and in particular aggregation algorithms. Aggregation is a classical application in a sensor networks, its aim is to collect and manage information produced by sensor and communicate this data to the sink node. To do that, sensors will board a vibration sensor which provides information about staff movements in the laboratory building. This platform thus offers the opportunity to evaluate the correlation between data and localization, which is one of the most basic hypothesis uses by the majority of aggregation mechanisms but in the best of our knowledge this assumption was never validated by real experiments. This testbed provides a platform to experiment algorithm in a real environment with also real data. The second particularity of this testbed is the use of the ZigBee network protocol which is well known to be energy efficient, required only few resources but with also a limited bandwidth. This platform can be a comparison point for the other platforms which use Wifi.

Task 1.5: Strasbourg platform. The fourth testbed will be setup in Strasbourg on the LSIIT area. The platform will be composed of 256 WSN430 nodes. They will be broken down between inside and outside. The platform will thus be divided in two adjacent sub-platform: the one indoor, the other outdoor.

All of the indoor nodes will use 802.15.4 and WIFI chipset, fit in the open module of the WSN430, to communicate with the others on the experimental network. They will all be connected to the wired network, by way of the connector module, for control and monitoring.

The outdoor nodes will mainly use 802.15.4 and WIFI chipset to communicate with the experimental network. Some of them will be fit out with 802.15.4 chipset for communication, and a GPS chipset in place of WIFI to provide geolocation capability. All of the outdoor nodes will be monitored using a WIFI chipset fit in the controller module of the WS430 node.

This platform will thus offer the opportunity to test routing algorithms in a mixed environment : especially algorithms based on geolocation mechanisms, indoor and outdoor, and the transition from one to the other.

Tasks description

Task	Start month	End month	Partners	Descriptions
T1.1	T0	T6	**INRIA ARES**	SensLAB node building. This task will give the specification of all types of nodes required and provide the wireless node, the controller node and the connector.
T1.2	T4	T12	**INRIA ARES**	First SensLAB local testbed setup in Lyon. This task will deploy the physical infrastructure to setup a first local testbed. It implies all the serial and power connections to all controller nodes, to set up a Multipurpose Network Serial/Access Server for controlling the 256 controllers and the networking infrastructure.
T1.3	T12	T18.	**INRIA POPS**, INRIA ARES	SensLAB local testbed setup in Lille. (256 nodes, 32 will be mobile and "link" to the monitoring infrastructure by wifi)
T1.4	T12	T18	**INRIA ASAP**, INRIA ARES	SensLAB local testbed setup in Rennes. (256 nodes with 802.15.4 RF capabilities)
T1.5	T12	T18	**LSIIT**, INRIA ARES	SensLAB local testbed setup in Strasbourg. (256 nodes with 802.15.4 RF capabilities and WiFi capabilities, some nodes will also be GPS enable)

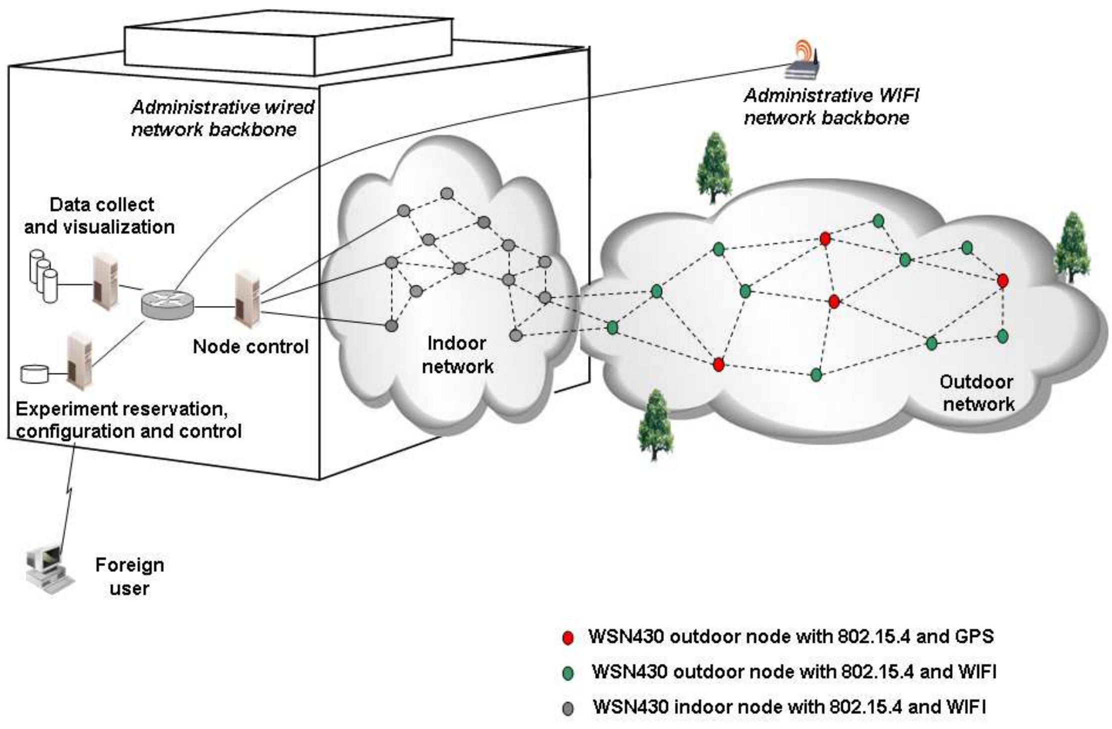

Figure 5: SensLAB Strasbourg platform.

Milestones

Milestone	Date	Descriptions
M1.1	T0+4	node hardware prototype delivery / testing
M1.2	T0+8	physical testbed setup (32 nodes)
M1.3	T0+16	global SensLAB interconnection

Deliverables

Deliverable no.	Deliverable title	Deliverable date[1]	Nature[2]	Dissemination level[3]	Participants
D1.1	**SensLAB node**: each node is composed of 2 WSN430 and one connector	T0+6	P	PU	**INRIA ARES**

Deliverable no.	Deliverable title	Deliverable date[1]	Nature[2]	Dissemination level[3]	Participants
D1.2	**Testbed set up documentation**: This document will describe technical configuration / set up / serial link connexion / power and detailed specifications for the networking and connecting devices used for building a local SensLAB testbed. This document, delivered in a first version after the set up of the first local testbed in Lyon will be amended in order to fulfill the specific requirements of other testbeds.	T0+12	R	PU	**INRIA ARES**, all
D1.3	**SensLAB Plateform**: The 4 distriuted testbeds will be depoyed and configured.	T0+18	D	PU	**INRIA ARES**, all

[1] Month in which the deliverables will be available. Month 1 marking the start of the project, and all delivery dates being relative to this start date. [2] The nature of the deliverable uses the following codes: R = Report, P = Prototype, D = Demonstrator, O = Other [3] The dissemination level uses the following codes: PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services).

4.2 WP2: Software Architecture

Leader	**LSIIT**						
Efforts	INRIA/ARES	INRIA/ASAP	INRIA/POPS	THALES	LIP6	LSIIT	Total
	30	16	22	6	4	22	100

This work package will develop software modules and programs needed for running the global trial testbed. Figure 6 illustrates an overview of SensLAB services. As noticed in previous sections, several services must be offered by SensLAB:

- supporting multi site experiments while providing unique interface for the user that wants to run experiments.
- supporting multiple applications simultaneously and guaranteeing the security and the integrity of the data generated during an experiment.
- assuring data retrieval in real-time.
- offering development suite for testing and debugging sensor network applications without code modification.

The software will be developed by all partners hosting local testbeds. LIP6 and THALES ares included in the WP2 since “final users” are primarily concerned by the functionnalities. LIP6 and THALES will contribute to the specifications of the software suite. THALES will also bring its very higth expertise in software specification and will lead the delivrable D2.1.

Figure 4 illustrates in blue/grey the 5 main software components and functionalities offered by SensLAB:

1. The **experiment handler** is one of the most important functionalities in the SensLAB framework as the user will mainly interact with the platform through this key component. It allows to configure all experimental parameters via several configuration sections. The first section deals with the node parameters, reservation and configuration. The second section deals with experimental setups, sampling frequencies, error injection, radio noise configuration.

2. The second important component is the **node handler** that is in charge of controlling/configuring each SensLAB node and collecting monitoring data. The node handler interacts with the physical node controller.

3. A **software suite** offering a complete programming, debugging and tuning environment suitable for the provisioning and the design of wireless sensor network application will be available from the SensLAB portal. This software suite will be based on WSim and WSnet that have been developed by INRIA/ARES.

4. **Data Analysis and Visualization** modules will be developed to allow on line and post-mortem analysis of monitoring and experimental data gathered by the measurement framework during the whole experiment life and stored in databases.

5. Finally, a set of software modules will be developed to set up the underlying **software framework** needed by all the modules described above. Linux virtual machines will be used and configured for each SensLAB user. Database will also be created for each user and tables will be created for each experiment launched by an user. For each experiment, SensLAB allows to save results to a database for later analysis.

All these services represent the heart of SensLAB. From a given point of view, one may compare SensLAB to a wireless sensor grid testbed since it is operated as a shared service to allow a number of projects to conduct wireless network experiments on-site or remotely. We choose to dedicate one specific work package to each software component listed above. The interaction between each module is important and must be treated with an extreme care.

Since SensLAB will be spread over 4 sites with specific features, the modules developed should also be generic and extensible in order to gather such particularities. Moreover, in future expansions of the SensLAB testbed, one may plan to connect additional sites with other requirements/characteristics (*e.g.*, in terms of sensors/actuators connected to SensLAB nodes).

Task 2.1: Node Handler. As it is described in WP1 and illustrated on Figure 3, a SensLAB node is composed of two identical PCB (WSN430) linked by a connector module. One WSN430 is totally open to the experimenter and the other one is used to control the open node. The node controller could stop, start, reset the open node, control the radio /noise activity through its own RF component, receive code to upload, monitor and send back sample informations on the serial link. Services offered by a node handler are to reboot each of the node, then load an application, then set the relevant parameters for the experiment in each controller node to add controlled interference or monitor traffic and interference. The node handler also specifies the filtering and collection rules of the experimental data and generates a database schema to support subsequent analysis of that data.

The aim of this task is to design and implement the software needed on each node controller and on the node handler. The node handler will be linked to a serial access server gathering all serial links. The task 2.1 will propose the protocol between the two entities. The protocol should define the way commands are sent to the node controller and how monitoring and collected data are sent back to the node handler. The node handler must also offer a well defined API to the experiment handler since the node handler module will export its connectors as a management entry points. The software framework used should be flexible and extensible in order to support several configurations since we will also use WiFi connexion instead of serial link to connect some node handler to SensLAB nodes in some local platforms. Moreover, the software should use a component based approach since it could be interested to add pre-treatment modules (*e.g.*, one may want to add a module that exports the average energy consumed over the last 10 min.) The modules deployed should also be configured dynamically since during an experiment the user may want to tune the sampling frequency according to the behavior or the application phases.

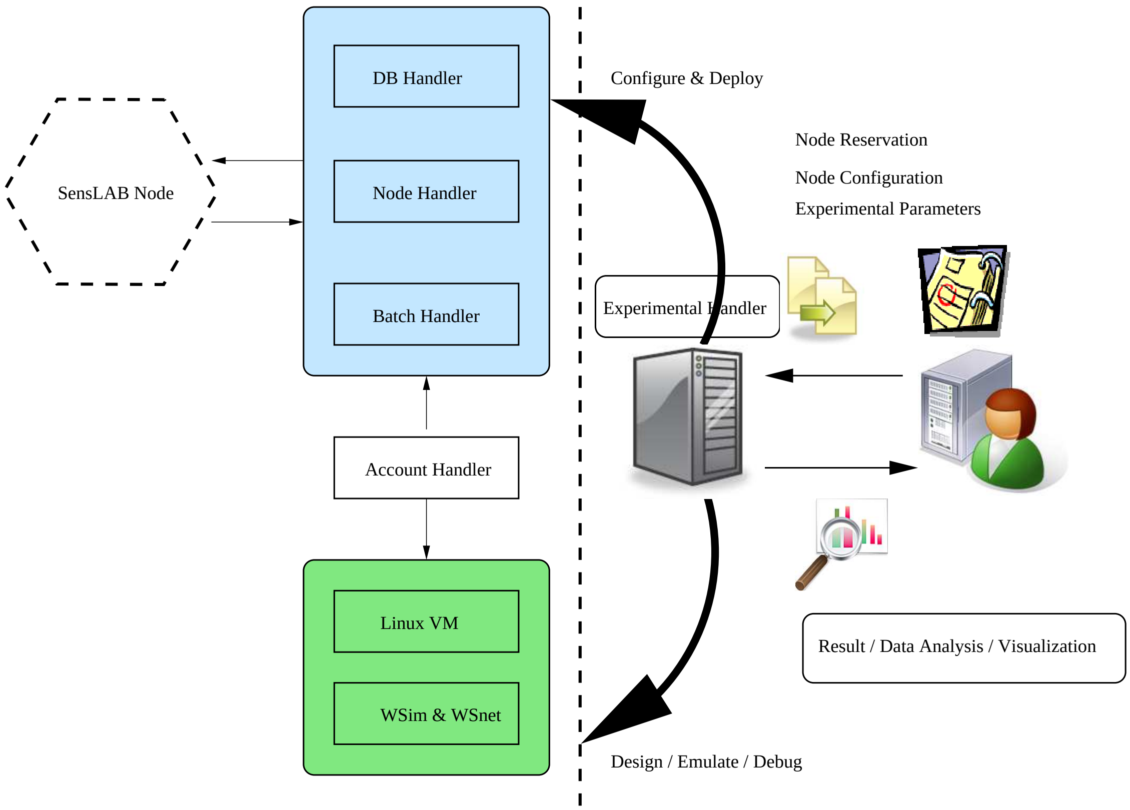

Figure 6: Experiment software support framework.

Task 2.2: Experiment Handler. The experiment handler is the central point used by users to reserve, control, configure and set up experimental parameters. The distributed aspect of the SensLAB wireless grid testbed increase the complexity of the reservation and control interface that SensLAB should provide to the experimenter. It should be possible for example to reserve for a given period a subset of nodes in Lyon and another subset in Lille. Through the main experiment handler, the user will configure all nodes by groups or individually, assign one or several applications code and launch the experiment. He/she will also get back all results (see figure 6).

Despite services directly available and configurable from the experimenter, experiment handler should also manage a large set of hidden services so that we insure that the global wireless grid testbed will run in a flexible and easy access fashion. The services that must be handled are :

- Configure and bootstrap the software framework attached to each user when an account is create and/or when he/she enters SensLAB. For example, a Linux Virtual Machine will be dedicated to each user so he/she will be root and able to install, compile, add any additional software he/she needs. When a new user account is created, a Linux VM will be created on each site and a name / IP address will be inserted in the SensLAB internal DNS.

- Guarantee a "physical" interconnection of the Linux VM when the user is running an experiment. More precisely, one or more sink nodes present in the testbed could be reserved and connected to the Linux VM of the user via serial line connexions. Through these serial ports, the user could run his/her applications to collect application specific data from the sensor network. Collected data could be treated on the Linux VM and send to other applications running on the same Linux VM and/or on remote location since all Linux VM will be connected by a private network enabling a deployment of a global and hierarchical sensor network application.

- Reserve time slots and physical nodes needed by an experiment. A batch process will be set up and configured. Several configuration files will be provided by the user. A configuration GUI could be used to select nodes, assign application to nodes, configure noise parameters, sampling frequencies of monitored data through generated XML configuration files.

- Launch experiments and gather monitoring data. For each experiments, a table will be created in the user database. More precisely, each user will have its own database associated to his/her account. Monitoring data will be stores in tables to support subsequent analysis of that data.

Task 2.3: Software Framework. This task will gather all software deployments and networking configurations dedicated to the internal management of SensLAB. As opposed to the experiment handler, the software framework task is internal but still crucial. The internal services will be use by other software components. Internal services are mainly be composed of:

- a global account management via a distributed LDAP infrastructure. An account creation must provide access to all local testbed via their gateways, the instantiation of a Linux VM, the set up of a storage (home for the user files and data base for the experiments). The LDAP/DNS service deserves our undivided attention since if one site is down, the rest of the SensLAB testbed should be accessible.
- a VPN infrastructure between all local sites. An IP address policy set up for all Linux VMs. It may be also useful to setup and configure a private dynamic DNS in order to get a transparent access to all Linux VM dedicated to each user on each site.
- Storage configuration. As stated above, a data base must be created for each user to support subsequent analysis. The DB infrastructure, configuration and security is part of the Software Framework. The file system is also an important part. Each user should have his/her own home account, accessible from his/her Linux VM and possibly from all sites.

Task 2.4: Data Analysis & Visualization. This task will be in charge of the data Analysis & Visualization tools offered by SensLAB. All monitoring data collected during an experiment are stored in tables to support subsequent analysis of that data. The data analysis tools will be based on a generic web interface suitable for several table formats. The goal here is to deliver data to external systems after the experiment or during the experiment. The web interface provides an interactive way to visualize and filter quickly in a user friendly approach data stored in database tables. Of course, the experimenter will always be able to perform direct SQL requests on his/her tables by using a SQL browser provided on the web or by building its own programs / scripts.

To perform this tasks, data warehouse techniques may be used [27]. The underlying idea of data warehouse technologies is to identify among a data base, a set of facts (monitoring measure of the SensLAB node in our case) and dimensions (time, node number, position...). From these set extraction, one can plot the variations of the fact studied versus on dimension. from a more general point of view, it defines an hypercube. The Data Analysis & Visualization toolkit will apply several OLAP[3] operations (aggregation/detail over one dimension, selection of a sub-hypercube, projection, rotation...). We propose to set up and configure an OLAP server and offer an access from it to the data of experimenters. All development will be done to run on the Linux environment and will probably use decisional database techniques like Mondrian [3] or Bee [1] that are based on the Tomcat [9] technologies.

This task will also benefit from applications deployed and benchmarked with the project since filters, views commonly used by developers will be proposed by the Data Analysis & Visualization toolkit. It will thus be possible to propose a set of analysis functions and tools to get an easy access to most commonly used performance evaluation criteria such as power consumption, signal noise ratios, number of packet including packet error rates diagrams. These diagrams will be generated as reports and can be viewed on faked color maps.

More complex estimators based on dynamic graphs that are currently under studies in several laboratories can also be included. These estimators can be proposed by research groups for third party evaluation

[3]On-Line analytical Processing

for experimenters. Each experimenter will be proposed to save its experimental data on a SensLAB repository so that a public set of reference traces will be made available to researchers and institute working on sensor network analysis tools.

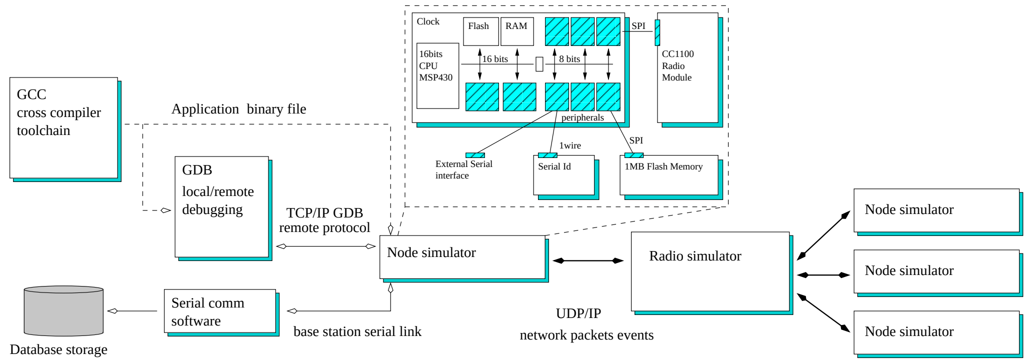

Figure 7: Distributed simulation environment for Wireless Sensor Networks.

Task 2.5: Simulation & Debugging Software Suite. Despite the relative simplicity of its basic components - a sensor node is composed of an integrated sensor, a processor, a radio and an energy battery - and compared for example to a PC, sensor networking offers a great diversity: diversity in the hardware, in the radio and physical layers, in the operating systems, in the constraints and in the application. Almost all kind of data traffic patterns, mobility patterns or communication patterns can be encountered. Facing this variety of problems, there is no "one-fits-all" solution but rather one "better" solution for each specific case.

As a result of this diversity, the design, implementation and deployment of a sensor network application is a really complex task. Choices have to be made at each level of the design process and these choices generally have an impact on the application efficiency. Moreover, debug and profiling of micro-controllers and more generally distributed embedded systems is clearly a hard task. As a consequence, there is a real need for a development framework that gives developers the opportunity to test and simulate all solutions at the different layers; from the high level design to the implementation through the hardware choices. Moreover, the development framework should not induce too much extra load to developers such as the writing of the application or the constraints in various descriptive languages. The process should be as intuitive as possible.

In this context, the ARES team has developed WORLDSENS that offers an integrated platform for the design, development, prototyping and deployment of applications for wireless sensor networks. Moreover, WORLDSENS offers a set of tools for debugging and profiling code. This integrated platform consists in two simulators, WSIM and WSNET, that are used at the different level of the application development and that offer very accurate results on the application performance. It basically performs distributed simulations of the hardware platforms and radio medium with an instruction and radio byte accuracy.

WSNET is s modular event-driven wireless network simulator which offers a precise simulation of a radio medium. WSIM is a hardware platform emulator executing the target binary code normally executed in the node. Its hardware model granularity is derived from the sensor node printed circuit board. The simulator is composed of hardware block descriptions that match the chip level description of the system. Each block description is available as a software library within the simulation framework and a sensor node platform can be built by selecting the components description and by writing a single file that describes the physical interconnection between these blocks. WSNET and WSIM can be used together to form the WORLDSENS simulation platform which offers the opportunity to simulate with high accuracy a whole sensor network. Each node of the sensor network is simulated by a WSIM program while the radio medium simulation is performed by WSNET. The simulation platform is depicted in Figure 7.

The simulation framework includes several features such as a logger library to report selected system events and messages (*e.g.* missed peripherals interrupts that occur while interrupts are disabled in the micro controller) or to catch some frequent programming errors that the block developer would like to report (*e.g.* sending a byte to an UART without proper initialization). WSIM also supports a fast event tracer mechanism that saves to a file a selected signal activity. These traces can be used offline to study the runtime behavior of the sensor node with regards to timed events. Among the reported traces, the simulator can report events such as current clocks changes, interrupt reporting or serial port activity. This file can be used for offline performance analysis and timing validation among the platform peripherals. Finally, WSIM has the ability to act as a GDB remote debugger that can be used for target binary code debugging using step-by-step mode with breakpoints and watchpoint as a conventional debugger. While simulating of a complete sensor network, it is possible to use several serial connections or gdb connections to different WSIM programs. In this case all the nodes are stopped and the complete simulation is put in step-by-step mode according to the nodes that are debugged. This allows to use the WORLDSENS environment to debug distributed protocols at the source level using only simulation tools.

The goal of this task is to integrate the WORLDSENS framework as a development, debugging and prototyping toolkit for SensLAB. We plan to propose a development environment offering the simulators in configurations matching the real testbeds so that the developers can test and debug before deployment their application code in an environment corresponding to the experimental testbeds.

Milestones

Milestone	Date	Descriptions
M2.1	T0+4	Simulation & Debugging tool suite. It is important to release a first version of WSIM and WSNET inside the consortium early since it may be used by the internal training activities.
M2.2	T0+6	Connexion betwenn Node Handler v0.1 and a SensLAB node througth the controler node.
M2.3	T0+12	Experiment Handler and Software framework v1.0 implemented in the SensLAB trial test bed set up
M2.4	T0+18	Support external research experiments

Deliverables

Deliverable no.	Deliverable title	Deliverable date[1]	Nature[2]	Dissemination level[3]	Participants
D2.1	**Management software specifications**: This important document will describe all specifications and choices made for the 5 tasks of WP2. It will describe the basic, advanced, optional, mandatory functionalities of each local testbed in term of software services. The document will also detail all choices made in terms of batch control, Linux VM, Data Base, OS, VPN...	T0+3	R	PU	**THALES**, all
D2.2	**Node Handler code, release V1.0**:	T0+9	O (code)	PU	**INRIA ARES**, ASAP, POPS, LSIIT, THALES
D2.3	**Experiment Handler code release V1.0**:	T0+12	O (code)	PU	**INRIA POPS**, ARES, ASAP, LSIIT, THALES
D2.4	**Software framework package release V1.0**:	T0+12	O (code)	PU	**LSIIT**, INRIA ARES, ASAP, POPS, THALES
D2.5	**Data Visualization code release V1.0**:	T0+18	O (code)	PU	**INRIA ASAP**, ARES, POPS, LSIIT, THALES
D2.6	**Node Handler, Experiment Handler and Software Framework code release V2.0**:	T0+24	O (code)	PU	**INRIA ARES**, ASAP, POPS, LSIIT, THALES

Deliverable no.	Deliverable title	Deliverable date[1]	Nature[2]	Dissemination level[3]	Participants
D2.7	**Data Visualization code relase V2.0**:	T0+30	O (code)	PU	**INRIA ASAP**, ARES, POPS, LSIIT, THALES
[1] Month in which the deliverables will be available. Month 1 marking the start of the project, and all delivery dates being relative to this start date. [3] The nature of the deliverable uses the following codes: R = Report, P = Prototype, D = Demonstrator, O = Other [4] The dissemination level uses the following codes: PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services).					

4.3 WP3: Applications

Leader	**THALES**						
Efforts	INRIA/ARES	INRIA/ASAP	INRIA/POPS	THALES	LIP6	LSIIT	Total
	6	10	12	14	16	12	70

WP1 WP2 WP3 Training Mgt total CDD LABO LIP6 20 0 4 16 5 3 28 12 16

The fact that SensLAB offers global interconnection among the all platforms is a very important point. It will allow testing applications at different configuration conditions: homogeneous (four possible conditions in the current status of the proposal), within each of the platforms, and hierarchical/hybrid when the global infrastructure is used. Concerning this lattest point, using a hybrid infrastructure allows investigating several crucial research problems:

Resource management. Accessing the platforms through cellular or satellite network might impose some problems of resource management in terms of power consumption, memory, and bandwidth.

Intermittent connectivity. This is a parameter that needs to be taken into account. The ability for nodes in the network to communicate varies with time, creating an overall intermittent connectivity (sometimes preventing end-to-end routes to be set up at any time). This can result from nodes shutting off (for energy conservation), or some of the nodes moving (if mounted on vehicles or carried by mobile users) or also related to the availability of some links (e.g. for satellite).

Benchmarking. SensLAB will allow benchmarking the behavior of large scale protocols and application under several configurations (GPS nodes, WiFi nodes, mobile nodes, mobile sinks). It appears mandatory to use such scientific tool to test the fundamental limits of hybrid networks, to test the impact of the mobility in terms of capacity, energy, and latency.

Self-organization. SensLAB will allow to investigate how self-organizing networks can be used to publish dynamical services, how to manage te localization of users, how to implement semantic service localization, profiles? Such strategic research will not be conducted directly within the SensLAB project but are clearly a topic that can benefits from an open large scale wireless sensor network testbed.

Security. SensLAB will also contribute by offering an ideal environment to test and benchmark architecture for medium and large scale wireless sensor networks with the full level of security that will make them trusted and secure for all applications. The IST STREP UbiSec&Sen project may benefits from such testbed. Projects like ACI security SPLASH (Securing mobile ad hoc networks) or the INRIA ARC MALISSE (MALIciouS SEnsors) and PRIAM (Privacy Issues and AMbient intelligence) may benefit form in situ testbeds.

The applications that will be developed to explore these features are detailed in the following, and represent tasks of Work Package 3.

Task 3.1: Resistance against Aggregator Compromises in a Very Large-Scale Environment

(Application conducted by LIP6.)

In many applications of WSN, data may be sensitive to external events that are not expected to happen under normal operation of the network. In particular, data confidentiality and availability are important characteristics the network should be able to assure. Guaranteeing such characteristics is a tough task, especially when the sensor nodes are composed of inexpensive devices with limited hardware capabilities. In this case, where providing tamper resistance is almost impractical, compromising a node is an easy and attractive option for attackers.

The limited nature of sensor nodes opens up possibilities for multiple vectors of attack. Provided that radio communication is expensive in terms of energy consumption, it is very important to reduce the communication overhead.[4] An interesting approach to achieve such an objective is to perform *data aggregation*, where relaying nodes exploit the distributed nature of the network and perform in-network processing. Guaranteeing security in aggregation schemes is particularly challenging because node compromises in such a scenario are doubly problematic, both in terms data confidentiality (eavesdropping) and availability (denial of service). Indeed, by compromising an aggregator node[5] the attacker would endanger all of the readings that are part of the aggregate the node is in charge of.

Several researchers have already studied the problem of securing data aggregation. Mykletun *et al.* [24] suggest using ciphers for which some arithmetical operations over ciphertexts have some arithmetical signification on the cleartext. While this technique allows for some security, a compromised node may still stop aggregating and forwarding data. Even worse, tampering and replay attacks cannot be detected with such a solution. Przydatek *et al.* [26] propose a number of techniques to ensure the integrity of the aggregated data for some aggregation functions. Although integrity can be satisfactorily assured, the proposed schemes are difficult to implement and provide neither confidentiality nor protection against denial of service (DoS) attacks. Hu and Evans [23] propose a scheme that provides authentication and integrity which is secure even when some nodes are compromised, however it fails in the case where two consecutive aggregators are compromised. Furthermore, this scheme neither addresses confidentiality nor availability. Wagner [28] studies the inherent security of some aggregation functions. But he only considers the level of impact a compromised sensor may have on the final result. His work concerns the security of aggregation functions, not the aggregation security itself.

We are currently investigating confidentiality and availability for data aggregation in WSN. In particular, we have proposed three new schemes whose main idea is to exploit using multiple paths toward the sink. In fact, a sensor may split a handful of its readings into n separate messages such that t messages are needed to reconstruct the readings. By sending messages along disjoint paths, a sensor ensures that intermediate nodes do not have complete knowledge of the sensed data. The techniques used rely on the concept of secret sharing and information dispersal. Although they have been recognized in many research areas (*e.g.*, parallel computing, distributed storage, databases, and ad hoc networking), surprisingly neither secret sharing nor information dispersal have been applied to the context of wireless sensor networks nor to the specific problem of data aggregation.

We performed preliminary both real experiments and simulations using the implementation described above. Experiments were done at *small scale* (six nodes and three-path topologies) to test the practicality of the schemes. In order to stress the implementation, we performed simulations using Tossim. Tossim is a sensor network simulator that compiles directly from TinyOS code and simulates the TinyOS network stack at the bit level. This has the advantage of perfectly modeling the behavior of the implementation.

The problem with the experimental approach we adopted is clearly *scale*. So far, as stated above, results have been obtained either through simulations or on a test bed composed of only six nodes. With SensLAB, the following non-exhaustive list of objectives will be possible to achieve:

High number of participants. Contrary to the preliminary experiments we could perform, in which the number of nodes was extremely reduced, with SensLAB it will be possible to evaluate the behavior

[4] Transmitting 1Kb at a distance of 100 meters costs as much as executing 3 million instructions with a general purpose processor [25].

[5] That is, capturing an aggregator node and having access to its internal state and cryptographic material. The attacker may therefore turn an authorized node into a malicious one.

of the proposed algorithms in a situation that would be closer to the reality. Indeed, with the number of nodes available in SensLAB, realistic situations will be better captured.

Real multi-path routing. Recall that multi-path routing is a basic requirement of our proposed algorithms. For the first time, we will be able to evaluate our algorithms with realistic multi-path communication. This will certainly allow us obtaining results we could not get with our preliminary six-node network.

High Diameter. The diameter of the network is also an important parameter in the types of protocols we are evaluating. This aspect does bring the "multi-hop aspect" so important in wireless self-organizing networks.

Energy consumption. What is the energy consumption in real wireless sensor networks? Answers to these questions have only been obtained either through simulations or small-scale tests. With SensLAB, it will be possible to evaluate such a parameter with a multitude of network configurations.

Different attacks. At the scale provided by SensLAB, it will be possible to realistically implement different types of attack: uniformly random, concentrated, simultaneous, sporadic, organized, passive, active, and many others.

Task 3.2: Analysis and modeling of fundamental properties of the network

(Application conducted by LIP6 and INRIA/ARES.)

It appeared recently that most real-world networks have nontrivial properties which make them very different from the models used until then (mainly random, regular, or complete graphs and ad hoc models). It has also been observed that these properties have a key impact on various phenomena of interest like robustness, spreading of information or viruses, and protocol performance. This makes the field of the analysis of such networks a key issue in these contexts. The goal in this field is to identify more such properties, as well as identify their causes and consequences.

Complementary to this, the question of the modeling of these networks is also a key issue: generating networks having the same properties than the observed networks is essential for simulation purposes. Indeed, running simulations (for observing the behavior of a protocol for instance) on generating networks having different properties allows a good understanding of the impact of each property.

The data obtained from the SensLAB project will allow us to make progress in the fields of analysis and modeling of contact networks. Moreover, some of the observed networks will be created by mobile nodes. Very few data on such networks is currently available, therefore this data should lead to key advances in the analysis of *dynamic* networks, on which very little is currently known.

In this project, we will bring the following contributions:

- Study the fundamental properties of the SensLAB underlying connectivity graph.
- Study the dynamic of this network.
- Define theoretical models accurately representing the observed properties.

Task 3.3: Disruption-Tolerant Applications

(Application conducted by THALES.)

Few experiments have already been conducted to collect connectivity data in DTN scenarios. Bluetooth based experiments have been conducted within the framework of the IST-HAGGLE project. They deployed on different sets of people (conference attendees, corporate employees, group of friends) these iMotes (sensors from Intel) to measure and characterize interactions (i.e. timing of contacts) between people. The biggest experimentation had 40 participants. The Reality Mining experiment, conducted at MIT, has captured proximity, location, and activity information from 100 subjects over an academic year. Each participant had an application running on their mobile phone to record proximity with others through periodic Bluetooth scans. UMass DieselNet project has deployed hardware in buses of the city of Amherst

(MA, USA) in the perspective to provide services to users and the bus company. They are currently studying data transfer opportunities using Wi-Fi that could take place between any two buses and between buses and public Access Points (APs). 60 days of traces are available to the community. All these data set are available through the community portal CRAWDAD (Community Resource for Archiving Wireless Data At Dartmouth).

All these research efforts have aimed at: (1) better understanding the interactions between nodes in DTN scenario, (2) evaluating early-stage networking protocols in simulation. Statement 2 is strongly connected to statement 1, as it has been shown that considering the way nodes interact with each other's is crucial in the design of networking protocols in DTN. However, when one looks at where the research community stands, we clearly see that connectivity patterns of nodes are still not very well characterized. No accurate mobility model has been proposed and confronted with real connectivity data, and processes that drive interactions between nodes have still not been characterized. As a consequence, more data collection efforts have to be conducted to offer the research community the possibility to study large-scale DTN scenarios. SensLAB will strongly contribute to this by performing experiments at a scale never achieved before (involving up to 1000 participants).

Despite the fact that SensLAB will help collecting traces relevant for the research community, It will also allow to deploy and evaluate DTN protocols and applications in a real testbed. Deploying DTN applications represent a step further studies in simulation, as one has to deal with limitations inherent to the communicated devices used. Indeed, these devices have limited buffers, batteries, computation power and memory. These limitations are somehow additive in DTN as the size of the network and application demand increase, making the design of networking solutions even more challenging. Dealing with all these factors is crucial with regards to services provided to users. As a consequence, they have to be considered in every design choices. Most of the DTN networking functionalities have to be challenged being deploy in real scenario to see if they handle these limitations. For instance, SensLAB will propose and evaluate in real scenarios protocols for routing, transport, and neighbouring discovery. These protocols will be evaluated with regards to their adaptivity to resources limitations and performance from a user perspective. The large-scale considered in this project is a worldwide premiere and will offer our community to be at the head of DTN research efforts.

The interest of the research community and industry for real deployments of DTN technologies and application is growing. The UMass DieselNet project will soon offer disruptive tolerant web applications (e.g. email, web search) to customers in the buses. Deployments of rural kiosks using the DTN reference architecture is being experimented in India to provided services to remote population at low costs. Kiosks provide a variety of services such as birth, marriage, and death certificates, land records, and consulting on medical and agricultural problems. 50 seismic stations have been deployed and connected with long range Wi-Fi links within the Middle America Subduction Experiment (MASE) in the USA. Delay tolerant operations are being tested for node administration and data collection. BUZZeeBee is a commercial messaging service for wireless handheld devices. When someone else using BUZZeeBee is encountered, a spontaneous wireless connection is automatically created. Messages can be addressed to a specific user or target a group of users.

Task 3.4: Localization Application

(Application conducted by LSIIT.)

One of the first experimentation using the specificity of the Strasbourg platform (providing indoor and outdoor environment), will be to try out new mechanism based on geolocation information.

It will specially allow to test and improve:

- routing algorithms driven by contextual information (ie : geolocation)
- travel prediction
- the using of mobility model to optimize radio resources
- power consumption saving

A classical scenario will be to use stand-alone mobile nodes, communicating by the way of WIFI and/or 802.15.4 interface with the experimental network. These nodes will go accros both parts of the test bed (inside and outside). The location information will be gathered on one hand by the way of autonomus mecanism like GPS ouside, on the other hand inside or outside using WIFI geolocation based on algorithms.

Task 3.5: Stock Management with physical database

(Application conducted by INRIA/ASAP.)

Database management systems represent today one of the most important software market. Currently, classical software databases are a representation of the real world, so they require daily update and periodical and costly synchronization in order to reflect accurately the reality they represent. Instead, the main idea of physical databases is that merchandises of the stock interact together to replace the software database. For this purpose, each merchandise is equipped with a sensor containing the information related to that merchandises. The aim of this application is to be able to manage at least the following requests:

- Have we still some merchandises of that type?
- Have we sufficient merchandises of that type?
- How many merchandises of that type we have?

To manage these requests, we have to design two services: (1)diffusion of the query to localize the merchandises and (2)aggregation to process it. In this context the SensLab architecture will allows use to evaluate our algorithm with different application scenarios. In this kind of application at any time some merchandises can be sold or delivered and so leave or join the network. The association of a control node to each application node allows us to start or turn off any sensor as desired and so apply different scenarios.

Milestones

Milestone	Date	Descriptions
M3.1	T0+10	Specification of the applications
M3.2	T0+16	First feedbacks on the deployment & test on the local testbeds
M3.3	T0+20	First feedbacks on the deployment & test on the global testbed
M3.4	T0+22	Implementation requirements
M3.5	T0+24	First version of the implementation of the applications

Delivrables

Deliverable no.	Deliverable title	Deliverable date[2]	Nature[3]	Dissemination level[4]	Participants
D3.1	**Detailed description of the applications**	T0+12	R	PU	**THALES**, all
D3.2	**Results of Application T3.1**	T0+34	R	PU	**LIP6**
D3.3	**Results of Application T3.2**	T0+34	R	PU	**LIP6**, INRIA ARES
D3.4	**Results of Application T3.3**	T0+34	R	PU	**THALES**
D3.5	**Results of Application T3.4**	T0+34	R	PU	**LSIIT**

Deliverable no.	Deliverable title	Deliverable date[2]	Nature[3]	Dissemination level[4]	Participants
D3.6	**Results of Application T3.5**	T0+34	R	PU	**INRIA ASAP**

[1] Month in which the deliverables will be available. Month 1 marking the start of the project, and all delivery dates being relative to this start date. [3] The nature of the deliverable uses the following codes: R = Report, P = Prototype, D = Demonstrator, O = Other [4] The dissemination level uses the following codes: PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services).

4.4 WP4: Management, Training acitivities and Dissemination

Leader	**LIP6**						
Efforts	INRIA/ARES	INRIA/ASAP	INRIA/POPS	THALES	LIP6	LSIIT	Total
	9	6	6	3	8	7	39

The special training work-package underscores the importance that SensLAB accords to training activities and disseminations. These WP indicates how the SensLAB partners, as a consortium or as individual organizations, intend to exploit the results of the work and all other information relevant to exploitation and follow-up work. Especially, a good explanation of the insertion of the SensLAB results and services into several research domains and also the industry is important. WP4 also incorporates the management of the project. Furthermore, to successfully reach the ultimate goals of this challenging project, as described above, a strong management structure is required. To fulfil this aspect, a reasonable part of the resources, 16 Man Months (less than 6%) will be dedicated to management, which are claimed separately from the RTD activities.

This SensLAB project proposes to create a universally accessible virtual laboratory that allows researchers worldwide to perform more accurate performance evaluations of both current and new protocols for large scale wireless sensor networks through remote access to the testbed. SensLAB takes a transversal view of many complementary and multidisciplinary domains. The outputs provided by SensLAB will find great applicability in technological areas: networking, systems, and services. We think that the concepts and services developed and offered in the SensLAB project are also very amenable for a take-up by SMEs.

The process of publishing and exploiting SensLAB's results will follow several parallel directions.

Scientific publications: Publications of the main results of SensLAB in internationally recognized journals and conferences will be a permanent objective of the project. We expect that, with the original experimental part of SensLAB we will have useful results that should be disseminated within the scientific community.

Extensive use of the Internet: A web site will be deployed with two goals in mind. A first, secured part of the site that aims at helping the partners of the project to cooperate in a more efficient way. The second, and most important one, will serve as an interface to the public domain. from this site, users can manage his account and once log, review his/her experimental results (see section 4.2) but also get FAQs, documentations, tutorials, code samples...

Multidisciplinary meetings: The success of SensLAB will be dependent on its impact on the research developed in the domains related to the target applications described in this proposal. It will then be fundamental that regular meetings be organized between SensLABś consortium and experts of other disciplines.

Popularization: A particular focus of SensLAB will be the popularization of its services. We intend then to popularize SensLAB's achievements through publications and demonstrations of wider interest. SensLAB will demonstrate its results with prototypes during specific events, for example those organized by the ANR program.

SensLAB organizes training workshops to disseminate SensLAB results and promote SensLAB services. The strategy of the SensLAB training activities to concentrate on the teaching and training of future executives (e.g. in university courses and courses provided by research institutes) to broaden the amount of users and co-operators of the future. We also want to address.

The SensLAB consortium is in a very good position to fulfil this strategy. The SensLAB consortium consists of industrial partners that are in a leading position in Europe (Thales), universities with very high reputation and leadership within the field of Wireless Sensor Networks (LIP6, LSIIT) and an institute of applied research that is acting as a mediator between science and industry (INRIA).

INRIA, LIP6 and LSSIT, as academic partner, already contributes significantly to workshops and summer schools. For instance, involved members recently gave tutorials in ResCom 2004 and 2006 (summer school), IEEE SCVT (conference), EcoTel 2004 (winter school), IrisaTech workshop on ambient computing (workshop), AlgoTel 2005 (conference), CFIP 2006 (conference), Mexican Workshop on Wireless Networks and Mobile Computing (workshop), ETR 2005 (summer school), and RFID 2005 and 2006 (conference). Our goal is to advertise SensLAB results in such events by the conception of tutorials dedicated to these results. We will also focus our effort on demonstrating the use of SensLAB during demo sessions in conferences like IEEE Infocom, ACM Sensys, ACM SPOTS...

SensLAB will also organize training workshops dedicated to the use of SensLAB and to the domain of wireless sensor networks. Such tutorial may comprise an introduction to Wireless Sensor Networks covering the current state-of-the-art in wireless sensor networks and its significance and future applications to sensing and monitoring devices. It then goes into the major concepts required to program embedded applications followed by an introduction to the basic architecture and concept of SensLAB. It will detail the physical testbed and the use of the software suite. The software suite is already used in a graduate courses at INSA de Lyon on "Embedded Systems and Real Time". There will be a session on programming which will illustrate how to build, debug, and run applications on SensLAB how to send/receive data wirelessly, how to use the sinks.

Tasks description

Task	Start month	End month	Partners	Descriptions
T4.0	T0	T36	**INRIA ARES**, ALL	**Management**, one GA (General Assembly) every 6 months; one PMT (Project Manegement Team) meeting every 3 months
T4.1	T0	T36	**INRIA ASAP**	**SensLAB web site**.
T4.2	T6	T36	**LSIIT**, ALL	**Preparation of training materials for students.** In addition to serving as a research platform, SensLAB targets could also being used by courses that give students first-hand experience with large scale wireless sensor services. Students, especially student from technical branches, are interested and have to be interested in technical details. This task will prepare training materials that consist of SensLAB scenarios, applications and the underlying technologies that can be used for a complete lecture and will prepare applications that can be used for the training in practices and for the preparation of graduate/master courses.

Task	Start month	End month	Partners	Descriptions
T4.3	T18	T36	**LIP6**, ALL	**Preparation of materials for tutorials and summer schools.** In contrast to student lectures, Tutorials and Summer schools address another target group of SensLAB: Academics and young professionals, that means also current or future executives. Here the intense training takes place, either a one-day-training in conjunction with a scientific conference or a one-week-training at an external seminar. This situation makes great demands on the quality of the training material that should comprise from the applicability of Wireless Sensor Networks to the most detailed technical issues.
T4.4	T0	T24	**POPS**, ALL	**Internal training activities.** To guarantee an effective cooperation of all project members it is essential that all involved engineers, and other project members are starting at a comparable level. But not only at the beginning of the project also during the research and development phase the communication of important project results and milestone between the project members is essential for the success of the project. The main issue of this task is the selection of appropriate training material for internal purposes from the already generated training materials of the other tasks and the organization of the internal workshop.

Milestones

Milestone	Date	Descriptions
M4.1	T0+3	SensLAB Web Site specification
M4.2	T0+6	First SensLAB internal training workshop.
M4.3	T0+12	First lectures and practical courses with students with respect to Wireless Sensor Networks.
M4.4	T0+18	SensLAB platform access through the SensLAB Portal
M4.5	T0+24	First SensLAB workshop

Deliverables

Deliverable no.	Deliverable title	Deliverable date[2]	Nature[3]	Dissemination level[4]	Participants
D4.1	**Web portal**	T0+6	O	PU	**INRIA** **ASAP**
D4.2	**Training material for students**	T0+12	R	PU	**LSIIT**, all
D4.3	**Workshop / school**	T0+18	R	PU	**LIP6**, all

[1] Month in which the deliverables will be available. Month 1 marking the start of the project, and all delivery dates being relative to this start date. [3] The nature of the deliverable uses the following codes: R = Report, P = Prototype, D = Demonstrator, O = Other [4] The dissemination level uses the following codes: PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services).

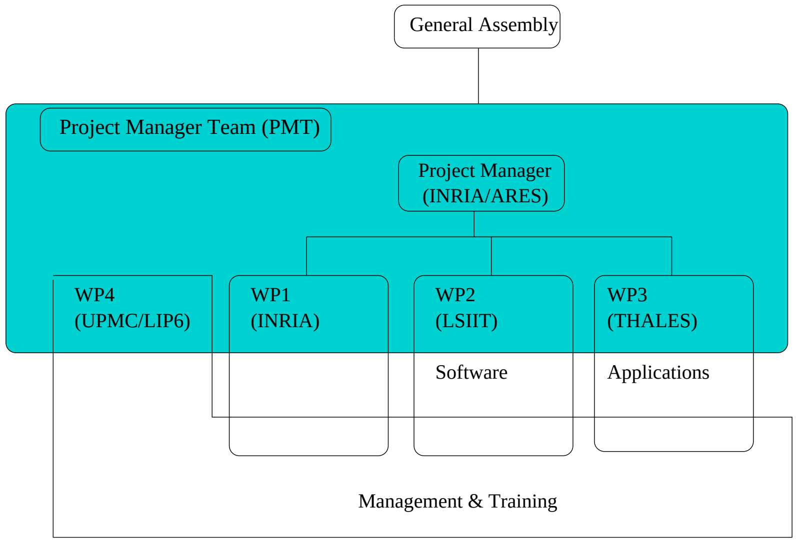

Figure 8: Project organization diagram.

4.5 Project Management structure

The project management structure given below was defined to successfully accommodate the complexity of an ANR/TLCOM project. It was defined to clearly identify the responsible members of the various organisms of the consortium as well as to optimize communications between the various partners, boards and committees. Excessive complexity was explicitly not used in order to avoid unnecessary additional steps in the communication structure. The management structure will be based on rules and regulations as agreed in the Project Consortium Agreement, PCA.

The project's consortium agreement (PCA) will include between others, preventive measures for arrangement of IPR, exploitation rights, confidentiality, decision-making and change-procedures, cooperation after the project's end as well as negotiation with third parties and addition of participants.

The General Assembly (GA) is the body consisting of representatives of all participants, with the task to supervise the project and will be chaired by the coordinator. The GA will meet every six-month or, if necessary, more often to ensure the project progress. The GA will provide a forum for the discussion of management and major technical issues. In addition, the GA will decide on the work plan, budget issues, addition of new partners and calls for new partners and will prepare proposals to the ANR. Voting procedure is described in the Project Consortium Agreement (PCA).

The Coordinator is responsible for the management of the entire project. The coordinator is also the link between the project and the ANR. The Project Manager, Eric FLEURY, deals with the scientific/technological management of the project.

Work Package Leaders (WPL) will coordinate the work carried out in a Work Package and are responsible for the planning, monitoring and technical reporting of the relevant WP. The WPL has to organize technical discussions for that specific WP, facilitate the communication in and between work-packages and will report to the PMT and GA.

The Project Management Team (PMT) consists of the Project Coordinator and the Work Package Leaders. The PMT is responsible for monitoring the progress of the project, quality assurance, and the day-to-day management of scientific and technological activities. The PMT will meet every three months or more frequently if special issues need to be handled. The PMT is the interface between Work Package Leaders and the GA.

4.6 Decision-making mechanisms

At the highest level, the SensLAB General assembly (GA) will provide a forum for the discussion of management issues and major technical issues. Decisions of the GA are binding for the project. The GA will decide on:

- The entering into the consortium of new contractors.
- The exchange of work affecting the project as a whole or re allocation of SensLABś budget.

The Project Management Team (PMT) is responsible for the day-to-day project management of the project, the progress monitoring, quality assurance, the strategic direction of SensLAB and setting the agenda for the full project. The PMT will make proposals to the General Assembly for:

- Entering into the contract of new contractors.

The PMT will decide on:

- Press releases and joint publications.
- Technical road maps.
- Control of technical audit procedures to ensure the effective day-to-day coordination and the monitoring of the progress of the technical work affecting the project as a whole.

Part of the control framework will be that all technical reports, like the Interim and Periodic Activity Reports and the deliverables will be discussed and approved by the PMT before sending to the ANR. Day-to-day decisions on technical level affecting the individual work-packages will be taken by the WP leader, where needed after consultation with the Project Manager.

4.7 Corrective actions

The problem handling and corrective actions philosophy of the consortium is in the first place based on prevention. In case a problem arises, it will be tackled as soon as possible and at the lowest possible level, meanwhile bringing it to the immediate attention of the Project Manager.

Each partner of the consortium is responsible (liable) for the performance of any part of its share of the project or other ANR contract obligation. In case, however, that a partner fails or under performs, this will be promptly documented in project meeting minutes. The project manager will try to solve the problem immediately by all possible means and, if necessary, an official letter will be sent by the project manager to this partner (with notification to GA and ANR project officer).

Meanwhile, if necessary, an extra meeting with the PMT will be organized in order to solve such problem and limit the impact for the Project. In case the problem cannot be solved by the PMT, it will be escalated to the next level, the GA. A meeting of the GA will then be organized at short notice. All actions will be properly documented. The GA will either solve the problem or decide on the final corrective actions, which may be banning the partner from the project. More details on the procedure are described in the project consortium agreement (PCA).

4.8 Quality assurance

As most partners can rely on best practices from previous ANR collaboration projects; the dealing with quality assurance is therefore not unfamiliar for this project. In the PMT meetings quality control and monitoring the progress against results will be an explicit agenda item. If needed, corrective actions will be set. Corrective actions will be undertaken in case the progress deviates from the project program.

Quality assurance of the technical reports and deliverables will be done via peer review. An internal review team, possibly consisting of experts out of the project, will review and give its recommendations on the quality and content towards the GA. The GA will then decide and approve these documents before sending them to the ANR.

Risk	Risk	Contingency plan	Milestone
SensLAB node too expensive	low	Define a new set of nodes	T0+3
Loss of a partner	very low	Dependent on partner's responsibilities, remove task or redistribute work	permanently
Work-package results are not delivered or do not arrive in time	medium	Try to work out and reschedule other tasks	T0+3, T0+6, T0+9, T0+12, T0+18, T0+24, T0+30, T0+34
Exterior unexpected constraints (on the testbed deployment board which enforces law on building security)	low	Find a new place to deploy the platfporm.	T0+6, T0+12

Table 7: List of major risks and contingency plans.

4.9 Risk management and contingency plans

The clear responsibility structure of SensLAB reduces the risk of unnecessary waiting and delayed decisions. The work-package leaders initiate, coordinate, and execute (part of) the work needed to produce a deliverable. The project coordinator takes responsibility for the timely delivery of the deliverables. The following risks are identified for SensLAB and their contingency plans are presented in Table 7.

5 Expected results and perspectives

Through SensLAB we expect to develop a large scale open wireless sensor network testbed. SensLAB is **open** since it is design as a shared testbed that will enable many novel research activities that can leverage the existence of a permanent, large scale sensor network. We will detail below how we imagine the future exploitation of SensLAB but we plan to draw on the experience of the PlanetLab [21] and OneLab [20]. We will similarly open up SensLAB and encourage external research groups, both academic institutions and industrial labs, to undertake studies using this environment. SensLAB will be labeled by MINEALOGIC (*pole de compétitivité*) and this will also increase the interest of a large spectrum of additional partners in the project. SensLAB will reinforce the competitiveness of both French and European IST enterprises and academic labs by shortening the cycle of evaluation for their new protocols, applications and services.

SensLAB is designed to be extensible in many directions. The initial node platform and sensor suite requested in this proposal are by no means set in stone and we expect that new devices and sensors will be introduced over time. Adding sensing devices is always possible since WSN430 nodes offer a 2×10 extension connector. We can also expect that additional universities and labs will ask to join the consortium and will connect their local testbed. To be more precise, the infrastructure build by SensLAB is mostly independent of the choice of the nodes and their technology. All the efforts invested in the infrastructure (hardware of the backbones and softwares of the global managing platform) will remain if a node upgrade is done. The only hardware part that depends on the node technology is the controller card that links two nodes. Its cost is negligible compare to the cost of sensor nodes. Thus if one site wants to upgrade a local test bed, or if one center wants to build a new local testbed with another technology then a new controller should be design but its architecture stays very simple and thus easy to build and produce.

SensLAB will be persisting for several years. (from 4 to 6 years beyond the project duration). Indeed, the technology used in the nodes is based on the ultra low power TI MSP430 which is one of the most up to date and efficient micro controller. On one hand, advances and miniaturization of micro-electronic will produce smaller micro controllers but with a strong impact on the energy consumption. On the other hand, by keeping the actual ratio power over energy, 32bits micro controllers will be proposed on the market, but roughly not before 4 years. The main and major problem remains: how to design efficient large scale distributed wireless sensor/ambient applications. The key issues are not at the hardware level but mainly in the design of services and tools offering efficient ways of taking benefits of the underlying hardware. Just changing the node technology will not answer the key questions which insures SensLAB to become obsolete just because of an hardware evolution.

SensLAB will evolve smoothly. The use of a Web-based interface for scheduling, programming, monitoring SensLAB and visualize data will in many ways mask users from a platform evolution. Using Linux as the host operating system, which is relatively stable and well-supported by the research community, will facilitate application portability.

SensLAB will offer a scientific tool for a large spectrum of research. Within the consortium, we propose several applications and uses of SensLAB to test the behavior and the scalability of protocols and applications proposed by our research teams. We aim to validate/invalidate assumptions made by sensor network protocol designers about the hardware and environment. Then, we expect SensLAB to allow us to turn us away from the theory in order to design protocols more suitable to realistic environments as for routing, synchronizing, data propagating, data gathering, data aggregating, etc. SensLAB will allow us to better understand the impacts of technical choices (like the choice of the MAC layer), and of the environment (mobility, wave propagations, etc). As SensLAB is an open platform it will also be used by a large variety of research labs in order to foster their development, applications and services.

Resource allocation and sharing. We do not want to allow any user to "lock down" the entire testbed for significant periods of time. However, we want that multiple applications to share SensLAB. In order to seed interest in the SensLAB testbed, we plan to initially impose no resource constraints on applications. That is, users will be given accounts on SensLAB and expected to use the testbed in a cooperative manner. This approach was taken by the initial deployment of PlanetLab and was very effective at getting users involved with the system before any sharing policies were introduced. As the popularity of the testbed increases, we expect the resource management problem will become more severe and we will turn on a mechanisms for limiting resource use in the batch process (limitation on the number of nodes, on the experiment duration). Specific requirements (large number of nodes on a very long period) will be treated separately by the PMT (Project Managment Team).

SensLAB will be open up to external and third parties research projects. As is is highlight in all our commitments, SensLAB is an open platform and our ultimate goal with SensLAB is to build an infrastructure to support a broad range of research projects by a very large variety of research groups. Running experiments is the basic service that SensLAB offers to thirds parties. As it is mentioned above, we also plan to connect SensLAB to OneLab in order to open to platform to a larger audience and guarantee a long duration. Adding third parties in the SensLAB consortium, that is, adding a new platform local site is also take into account in our management structure and will be detailed in the PCA (Project Consortium Agreement).

Educational Activities and Broader Impact. As stated in the WP4, the development of a large-scale sensor network testbed will also benefit educational activities at the graduate and undergraduate level as well as continuous training. We intend to integrate SensLAB into labs for graduate courses on sensor networks, operating systems, and hardware architecture. The undergraduate Operating Systems curriculum will be extended to cover distributed systems and will use SensLAB as an environment for experimentation. Finally, to promote SensLAB as a experimental and pedagogical testbed, we intend to work with the CNFM [19] network. The CNFM goal is to be the link between partners within the framework of agreements with French public authorities, and mainly the Ministry of Education. CNFM also helps innovation. Research laboratories use the facilities of the CNFM for the achievement of their national or European programs. It also provides specific training and services including consultancy, appraisal and technical assistance.

Exploitation strategies. As stated above, we definitively envision SensLAB as a Research community support that will last on a long term period since the platform is extensible, open and offers ambitious services to a entire research community.

We have already contact Bernard ESPIAU who is Deputy scientific director to the Technological Development Department at INRIA. He is also responsible for monitoring ANRDs (National Activities and Action for Research and Development) and for coordinating experimental actions in all these areas – in this capacity he reports to the Technological Development Department. The interest and commitment of INRIA is real and INRIA will foster and help SensLAB by providing human resources to maintain the platform beyond the project duration.

We also take benefit of the support given by the CNRS RECAP project. The CNRS is also a prime actor in SensLAB and will play a major role in the future exploitation of the testbed and in its maintenance. The universities and laboratories, member of RECAP will also engage efforts in the exploitation of SensLAB (through regional cluster funding, BQR). It is the case during the project with a non negligible number of scientist/engineers involved in the RTD activities that represents a minimum critical mass to carry out this ambitious plan but it will be also the case beyond the project duration by offering engineers man month to insure a maintenance.

To exploit and insure a broader use of the platform, we envision to link SensLAB to OneLab. We will similarly open up SensLAB and encourage external research groups, both academic and industrial, to undertake studies using this environment.

Finally, we envision to get financial incomes by offering additional services. In order to seed interest in the SensLAB testbed, we plan to initially impose no resource constraints on applications. That is, users will be given accounts on SensLAB and expected to use the testbed in a cooperative manner, especially for the storage part of experimental data. This approach was taken by the initial deployment of PlanetLab and was very effective at getting users involved with the system before any sharing policies were introduced. As the popularity of the testbed increases, we expect the resource storage management problem will become more severe and will require mechanisms for limiting resource use in space and time. We plan to propose additional services like: storage capabilities greater than the normal one (in time and space), data exploitation, expertise and special courses for application tuning. Such "*optional*" services can be proposed by universities and laboratories hosting the local platforms.

5.1 Relevance to the objectives of the ANR/TLCOM priority

A testbed should be a shared resource targeting a challenging technological point. It should be generic, open to other potential partners and not restricted to a too limited set of actors.

SensLAB is designed to support a broad range of research projects in large-scale sensor networks. SensLAB will be open to researchers, allowing them to collect data, experiment with networking protocols, test applications and services and reprogram nodes over a web-based interface. The research domain does not concern only the large networking community, but will offer also a scientific tool to other domains like system, application benchmarking, service provisioning. We plan to use SensLAB as an essential component of projects involving MAC layer protocols design, energy OS design, efficient localization, multi path routing protocols. In addition to the projects that we will undertake ourselves, **the main goal of SensLAB is to open up the testbed to other research groups to enable many as yet unforeseen projects.**

A platform should structure a community by gathering knowledges and know how in order to foster the development of new technologies, interoperability tests, services, usage, applications

Our ultimate goal with SensLAB is to build an infrastructure to support a broad range of research projects by a large spectrum of research groups, both from academic institutions and the industry. Building and supporting SensLAB as a shared testbed we will enable many novel research activities that can leverage the existence of a permanent, large scale wireless sensor network. From the strong experience gathered from the National CNRS project RECPAP we will foster the structure of the networking community. We envision SensLAB not just as a singular testbed for the entire sensor networking research community but as a resource for an even broader community interested by ambient applications/services. Issues that were previously only open to simulation studies can be experimentally validated using SensLAB. Research areas include, wireless ad hoc networking, wireless sensor networking, ambient applications and distributed systems.

Our ability to dynamically allocate sensor nodes to individual experiments, as well as provide remote (Web-based) programming, debugging, and instrumentation, makes it possible to open up the SensLAB testbed to users at other academic institutions and industrial labs. As mentioned previously, several on going ANR or European projects will benefit from SensLAB: ANR ARESA, ANR SVP, ANR SENSOR, IP-IST WASP, IP-HEALTHCARE MOSAR... Moreover, we plan to connect SensLAB to OneLab, offering a great added value.

Platforms should be open to third parties.

SensLAB is design and dedicated to be an open platform. It will be open to both academy and industrial labs and to a large set of ANR and European projects. The decision of adding new partners inside the consortium (*i.e.*, new physical platforms, will be manage inside the consortium board and decide by a GA (General Assembly) upon proposition of the PMT (Project Management Team). Our management structure is defined to clearly identify the responsible members of the various organisms of the consortium as well as to optimize communications between the various partners, boards and committees. Excessive complexity was explicitly not used in order to avoid unnecessary additional steps in the communication structure.

SensLAB is structured in 3 main phases as proposed by the ANR TLCOM call:

Phase 1: Design and building of the platform. This first phase will be handle by WP 1 and 2.

Phase 2: Exploitation of the platform will be initialized by WP3 where we plan to run our own experiments to test their behavior and also to test all functionalities of SensLAB. Then, as mentioned above, we will open up SensLAB and encourage external research groups, both academic institutions and industrial labs, to undertake studies using this environment.

Phase 3: Insure and maintain operational condition and insure its evolution. SensLAB proposes an exploitation strategies in order to insure a fruitfully exploitation beyond the project duration. The main axes of this long term vision are: *(i)* strong commitment of INRIA, CNRS RECAP and universities hosting the local testbed in terms of resources and human efforts; *(ii)* open up SensLAB to OneLab to insure a broad access and utilization; *(iii)* additional and optional services.

Delivrables list

Deliverable no[1].	Deliverable title	Deliverable date[2]	Nature[3]	Dissemination level[4]	Participants

Deliverable no[1].	Deliverable title	Deliverable date[2]	Nature[3]	Dissemination level[4]	Participants
D2.1	**Management software specifications**: This important document will describe all specifications and choices made for the 5 tasks of WP2. It will describe the basic, advanced, optional, mandatory functionalities of each local testbed in term of software services. The document will also detail all choices made in terms of batch control, Linux VM, Data Base, OS, VPN...	T0+3	R	PU	**THALES**, all
D1.1	**SensLAB node**: each node is composed of 2 WSN430 and one connector	T0+6	P	PU	**INRIA ARES**
D4.1	**Web portal**	T0+6	O	PU	**INRIA ASAP**
D2.2	**Node Handler code, release V1.0**:	T0+9	O (code)	PU	**INRIA ARES**, ASAP, POPS, LSIIT, THALES
D1.2	**Testbed set up documentation**: This document will describe technical configuration / set up / serial link connexion / power and detailed specifications for the networking and connecting devices used for building a local SensLAB testbed. This document, delivered in a first version after the set up of the first local testbed in Lyon will be amended in order to fulfill the specific requirements of other testbeds.	T0+12	R	PU	**INRIA ARES**, all
D2.3	**Experiment Handler code release V1.0**:	T0+12	O (code)	PU	**INRIA POPS**, ARES, ASAP, LSIIT, THALES

Deliverable no[1].	Deliverable title	Deliverable date[2]	Nature[3]	Dissemination level[4]	Participants
D2.4	**Software framework package release V1.0**:	T0+12	O (code)	PU	**LSIIT**, INRIA ARES, ASAP, POPS, THALES
D3.1	**Detailed description of the applications**	T0+12	R	PU	**THALES**, all
D4.2	**Training material for students**	T0+12	R	PU	**LSIIT**, all
D1.3	**SensLAB Plateform**: The 4 distributed testbeds will be depoyed and configured.	T0+18	D	PU	**INRIA ARES**, all
D2.5	**Data Visualization code release V1.0**:	T0+18	O (code)	PU	**INRIA ASAP**, ARES, POPS, LSIIT, THALES
D4.3	**Workshop / school**	T0+18	R	PU	**LIP6**, all
D2.6	**Node Handler, Experiment Handler and Software Framework code release V2.0**:	T0+24	O (code)	PU	**INRIA ARES**, ASAP, POPS, LSIIT, THALES
D2.7	**Data Visualization code relase V2.0**:	T0+30	O (code)	PU	**INRIA ASAP**, ARES, POPS, LSIIT, THALES
D3.2	**Results of Application T3.1**	T0+34	R	PU	**LIP6**
D3.3	**Results of Application T3.2**	T0+34	R	PU	**LIP6**, INRIA ARES
D3.4	**Results of Application T3.3**	T0+34	R	PU	**THALES**
D3.5	**Results of Application T3.4**	T0+34	R	PU	**LSIIT**
D3.6	**Results of Application T3.5**	T0+34	R	PU	**INRIA ASAP**

[1]: Delivrable numbers in order of delivery dates. [2] Month in which the deliverables will be available. Month 1 marking the start of the project, and all delivery dates being relative to this start date. [3] The nature of the deliverable uses the following codes: R = Report, P = Prototype, D = Demonstrator, O = Other [4] The dissemination level uses the following codes: PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services).

6 Intellectual property / free or open source software

(1-5 pages) Give an analysis of intellectual and industrial property questions in terms of existing patents and licenses to obtain. Outline the principles for the IP agreement that would be developed within the consortium once the project is launched. In case of free or open source software, give indications on the type of software license to be used.

The terms and conditions for creation, protection, sharing and ownership of Knowledge, generated by the partners in the SensLAB project, will be agreed upon in the SensLAB Projects Consortium Agreement (SPCA). The SPCA will be based on the EICTA (European Information & Communications Technology Industry Association) model and will be signed by all partners before the start of the project. By establishing this legal framework the SPCA consortium will be able to pursue an active patent and licensing policy. In general the essence of the EICTA SPCA is that Knowledge, which may arise from the work in this consortium, will be accessible on a royalty free basis to all members of the consortium. In addition, Pre-existing know how will be accessible on a royalty free basis to all members of the consortium to the extent the Pre-existing know how is needed to perform work in the consortium. Partners may request until two years after the end of SensLAB to receive a license for Pre-existing know how of a Party under favorable conditions if such license is needed to Use Partners' Knowledge. The protection of the Knowledge, generated by the partners is especially designated to WP3 where partners will test, deployed and stress their own applications that potentially are Pre-existing know.

In order to seed interest in the SensLAB testbed and foster other testbed depoyments, we will have a specific release policy concerning the hardware releases and the software developped in WP1 and WP2 that targets the managment of the infrastructure.

Public software and hardware releases: All of the software developed under WP1 and WP2 of this project (delivrables) will be released with an open source license, and the hardware designs will be published with no restrictions on use. We we will setup and use a forge to facilitate the scientific collaborations of people. A forge offers easy access to the best in CVS (as well as subversion), mailing lists, bug tracking, message boards/forums, task management, site hosting, permanent file archival, full backups, and total web-based administration.

Note that the open source licence does not concern Pre-existing know and previous software development done by partners. This will permit external groups to replicate the SensLAB environment for themselves, seeding an active community effort to continue developing the platform. We will endeavor to collaborate closely with external groups deploying SensLAB networks. Tying all of these systems into a single, coherent Webbased interface will allow external users to program all of the SensLAB deployments using a single set of credentials.

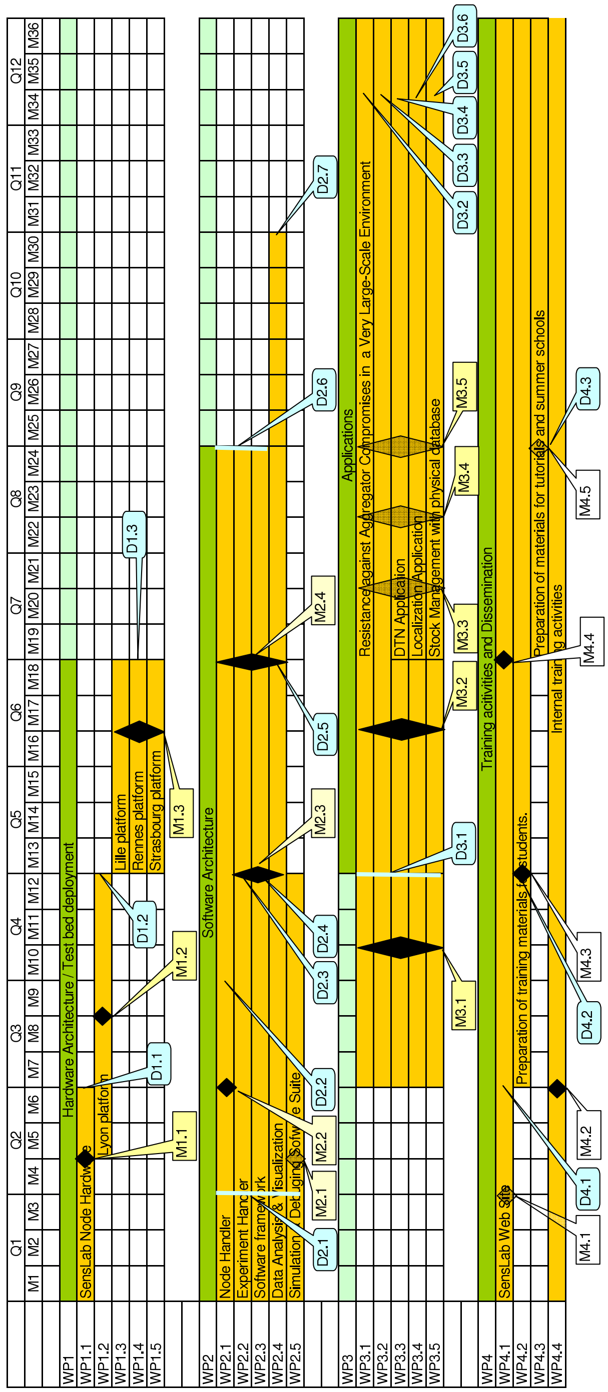

Figure 9: Gantt chart of the SensLAB project. We plot the schedule of all tasks and milestones.

Part II

Financial Resources

7 Partner resources

7.1 Project effort

The project has a full duration of 36 months. It is a research oriented / platform driven project. One Industrial partner participates in the project. The project effort form for the full duration of the project (in man-months) is given in table 9. The WP1 represents 24% of the total efforts, WP2 represents 36%, WP3 represents 25%, the WP4 represents 15% (with a distribution of less than 6% for the management and 9% for the training and DUP). Thus 60% of the project is dedicated to WP1 and WP2, which are at the heart of our project. 25% is dedicated to WP3 which will stress protocols and applications by using all functionalities of SensLAB.

Concerning the partners, INRIA represents 62% but gather 3 research teams. Note that ASAP is an INRIA team of IRISA which is a mixed research unit (INRIA, CNRS, University of Rennes 1 and INSA Rennes). POPS is also an INRIA team which is a common project of University of Lille, CNRS and INRIA. Finally, ARES is an INRIA team which is a common project of INRIA and INSA de Lyon. The effort of each INRIA team (ARES, ASAP and POPS) are: 27%, 16% and 19%. LSIIT, which is a mixed research (University of Strasbourg and CNRS) represents 19% of the man month efforts. LIP6 which is a mixed unit (University Pierre et Marie Curie and CNRS) represents 10% and finaly THALES represents 9%. The project is definitively a testbed project that will reinforce the competitiveness of both French and European IST enterprises and academic labs by shortening the cycle of evaluation for their new protocols, applications and services. The project is not a pure fundamental project since its main goal is to set up and exploit a large scale wireless sensor network testbed. The consortium is taking advantage of THALES that will give its expertise in software specification.

Partner	RTD & Innovation	Training	Management	Total
INRIA	150	13	8	171
THALES	20	1	2	23
LIP6/CNRS	20	5	3	28
LSIIT/CNRS	46	4	3	53
Total	236	23	16	275

Table 9: Project effort (man months) for the 36 months of the SensLAB project.

7.2 Financial plan and project resources

In order to reach the goals set for SensLAB the partners have prepared a detailed work and resources plan for the full duration of the project that is 36 months. The SensLAB project requires for its full duration a budget of 1.8 MEuro and the funding being requested from the ANR 1MEuro. All budgets listed in the forms (Table 10) reflect the estimated costs expected to be incurred in carrying out the project and were calculated according to the accounting systems of the partners.

Partner	Costs	Requested grant to the budget
INRIA	1 060 317 Euros HT	661 768 Euros HT
THALES	301 985 Euros HT	124 780 Euros HT
LIP6/CNRS	157 581 Euros HT	60 083 Euros HT
LSIIT/CNRS	351 248 Euros HT	228 687 Euros HT
Total	1 871 131 Euros HT	1 075 318 Euros HT

Table 10: Total cost for the full duration of the SensLAB project.

Required personnel In order to carry out the RTD and innovation related activities highly qualified scientists and technologists from industry and academia are needed. The number of scientist/engineers involved in the RTD activities represents a minimum critical mass to carry out this ambitious plan.

Furthermore, to successfully reach the ultimate goals of this challenging project, as described above, a strong management structure is required. To fulfill this aspect, a reasonable part of the resources will be dedicated to management, which are claimed separately from the RTD activities and included in the training and management WP4. The daily management of the project will consist of a dedicated project leader and work-package leader. The resources allocated to the management are less than 6% of the total effort (see table 9).

The main part of the required personnel is dedicated to sites hosting a testbed. The scientist/engineers involved will develop the platform, design the software, deploy the platform on each site, tune the management software in order to accommodate each local test bed specificity. For each site we ask for a engineer in charge of the platform for a 2 year long period. For the Lyon site, in charge of the whole project it seems mandatory to guarantee a engineer on the whole duration of the project (3 years). Other partners effort are mainly dedicated to the WP3 and the deployment of applications on the test bed.

Resources for training activities An adequate personnel budget is foreseen to execute the tasks described in work-package 4. The training activities represents 8% of the total efforts. We believe that fostering the dimension of training/courses/workshops is a good way to seed and promote SensLAB in the research communities.

Required equipment and material The most important part of the budget (300Keuros) is foreseen to acquire the nodes, node controllers, networking backbone infrastructure, computational and storage servers and serial access server.

Part III

Annexes

8 Recommendation letters

We list here persons interested by the SensLAB project. We have solicited them to send recommendation letters:

1. Mischa DOHLER, Senior Expert, France Telecom R&D, mischa.dohler@orange-ftgroup.com
2. Bernard ESPIAU, Deputy scientific director to the Technological Development Department of INRIA. Bernard.Espiau@inria.fr.
3. Timur FRIEDMAN, in charge of the European OneLab project. timur.friedman@upmc.fr
4. Pierre GENTIL, president of the Organization of Public Interest (GIP) CNFM, Pierre.Gentil@inpg.fr

9 Partner CV

9.1 INRIA ARES

Dr. Guillaume Chelius received the Graduate and Master degrees in Computer Sciences from the Ecole Normale Superieure de Lyon (Lyon, France) in 1999 and 2001 respectively. Guillaume Chelius was visiting scholar at the Uppsala University in Sweden during the year 2000. He received its PhD Thesis on "architectures and communications in spontaneous wireless networks" from the INSA de Lyon (Lyon, France) in 2004. By November 2004, he joined the INRIA ARES team as an INRIA Research Scientist. Guillaume Chelius was a visiting scientist at the INFRES department of the ENST (Paris, France, November 2004), at the LIP6 laboratory (Paris, France, Jan. to Jun. 2005), at the LNCC laboratory (Petropolis, Brazil, Sept. to Dec. 2005) and at the CTTC (Barcelona, Spain, January 2007).

Guillaume Chelius' main research interests include several aspects of spontaneous multi-hop wireless networks. In the fields of ad hoc and sensor networks, he is particularly interested in architecture aspects, communication & MAC protocols as well as energy-constrained protocols. He also works on auto-configuration mechanisms in IPv6 networks. Guillaume Chelius is involved in several national (RNRT SVP) and European (FP6 IST WASP and FP6 HealthCare MOSAR) projects on sensor networks. During these last years, he has participated to the animation of the scientific community through the participation to Program Committees (InterSense, AlgoTel), the organization of workshops and conferences (RECAP, FAWN, AlgoTel).

1. G. Chelius, A. Fraboulet, and E. Fleury. *Worldsens: Development and Prototyping tools for Application Specific Wireless Sensors Networks*. In ACM SPOT 2007, April, 2007, Cambridge (MIT Campus), Massachusetts, USA. ACM (< 16%)
2. G. Chelius, A. Fraboulet, and E. Fleury. *Worldsens: a fast and accurate development framework for sensor network applications*. In The 22nd Annual ACM Symposium on Applied Computing (SAC 2007), Seoul, Korea, March 2007. ACM.
3. E. Ben Hamida, G. Chelius, and E. Fleury. *Revisiting Neighbor Discovery with Interferences Consideration*. In the Third International Workshop on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks (PE-WASUN), Torremolinos, Spain, October 2006. ACM.
4. G. Chelius, E. Fleury, and T. Mignon. *Lower and upper bounds for minimum energy broadcast and sensing problems in sensor networks*. In International Journal of Parallel, Emergent and Distributed Systems, Volume 21, Issue 6, 2006.
5. C. Chaudet, G. Chelius, H. Meunier, and D. Simplot-Ryl *Adaptive probabilistic nav to increase fairness in ad hoc 802.11 mac*. In Ad Hoc & Sensor Wireless Networks : an International Journal (AHSWN), vol. 2, n°2, 2006.

Stéphane d'Alu is a research engineer at INSA de Lyon in the CITI laboratory since 2006. He received his engineer degree in computer science in 1998 from ESIAL.

He was an expert engineer for several research projects at INRIA Lorraine and ENS Lyon, such as the grid computing or the active networks. He worked for the NIC France (AFNIC), where he realized the tool used for the domain name validation.

He was in charge for the site of Lyon, in the Grid5000 context, of a computer grid aimed at the experimentation. Grid500 was a multisite project gathering 9 sites distributed geographically in France, with for goal to reach 500 nodes in Lyon at the end of 2006. His collaboration on a technical ground with the persons in charge of the other sites allowed the realization of a complex software configuration (DNS, DHCP, LDAP, apache, OAR, ...). He also managed the installation and administration of network core equipment such as Extreme/BlackDiamond, Foundry/EdgeIron, Cisco/Catalyst. He set up a documentation system for the project, and provided support to the team for the realization of experimentations and demonstrations.

Pr. Eric Fleury is Professor at the INSA-Lyon since 2003. Eric Fleury is co-head of the CITI Lab and vice-head of the INRIA ARES project. He is the leader of the CNRS TAROT action and is the co chair of the Networking domain of the CNRS GDR ARP. He was also a member of the RTP Networking and communication of the CNRS and is an expert for the CNRS Expert Committee on Networking and communication. Eric Fleury is an expert for the OFTA (Observatoire Français des Technologies Avancées) for the ambient computing group. He is the representative for the French part of the European project COST 295 and the secretary of the management committee of the COST Action 295. Eric Fleury was an expert for the NSF panel on networking and he is an expert for the COST program. Eric Fleury was the chair of the ACM DIALM (Sixth International Workshop on Discrete Algorithms and Methods for Mobile Computing and Communications) conference in 2003 and is the general chair of the workshop FAWN 2006 (Foundation and Algorithms for Wireless Networks). He is General chair of IEEE International Workshop on Theory meets practice in Wireless Sensor Networks 2007 (T2PWSN 2007) and local Chair for the topic Mobile and ubiquitous computing at EuroPar 2007. Eric Fleury is the leader for the INRIA Rhône-Alpes of the project FRAGILE of the ACI Sécurité and he is on the board of the CNRS project RECAP on sensor networks. He is in charge for INRIA of the IP project WASP and MOSAR.

1. G. Chelius, A. Fraboulet, and E. Fleury. *Worldsens: Development and Prototyping tools for Application Specific Wireless Sensors Networks.* In ACM SPOT 2007, April, 2007, Cambridge (MIT Campus), Massachusetts, USA. ACM (< 16%)

2. G. Chelius, A. Fraboulet, and E. Fleury. *Worldsens: a fast and accurate development framework for sensor network applications.* In The 22nd Annual ACM Symposium on Applied Computing (SAC 2007), Seoul, Korea, March 2007. ACM.

3. Yu Chen and Eric Fleury. *A distributed policy scheduling for wireless sensor networks*. In IEEE INFOCOM, 2007. (< 18%)

4. Yu Chen and E. Fleury. *Topology-Transparent Duty Cycling for Wireless Sensor Networks*. In IEEE International Parallel & Distributed Processing Symposium (IPDPS 07), Long Beach, California, USA, 2007. IEEE. (< 27%)

5. Nathalie Mitton, Anthony Busson, and Eric Fleury. *Efficient Broadcasting in Self-Organizing Sensor Networks.* International Journal of Distributed Sensor Networks (IJDSN)., 1(2-3), January 2006.

Dr. Antoine Fraboulet is associate professor at INSA Lyon and a member of the CITI Lab. He is a member of the INRIA Ares group. Antoine Fraboulet obtained his PhD from INSA Lyon in 2001. His main research interests are on operating systems, compilers and code generators for embedded systems with a focus on hardware/software interface and optimisations. He is a member of the technical committee of the IEEE International Workshop on Theory meets practice in Wireless Sensor Networks 2007 (T2PWSN 2007). He is one of the author of the Worldsens tool suite and the main author of the WSim hardware simulator.

1. A. Fraboulet and T. Risset. *Master interface for on-chip hardware accelerator burst communications*. Journal of VLSI Signal Processing, to appear, 2007.

2. G. Chelius, A. Fraboulet, and E. Fleury. *Worldsens: Development and Prototyping tools for Application Specific Wireless Sensors Networks*. In ACM SPOT 2007, April, 2007, Cambridge (MIT Campus), Massachusetts, USA. ACM (< 16%)

3. G. Chelius, A. Fraboulet, and E. Fleury. *Worldsens: a fast and accurate development framework for sensor network applications.* In The 22nd Annual ACM Symposium on Applied Computing (SAC 2007), Seoul, Korea, March 2007. ACM.

4. A. Scherrer, A. Fraboulet and T. Risset. *Automatic phase detection for stochastic on-chip traffic generation*. In International Conference on Hardware Software Codesign, Proceedings of the 4th international conference on Hardware/software codesign and system synthesis (CODES-ISSS), Korea, pages 88 - 93, October 2006. ACM Press.

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9.2 INRIA ASAP

Dr. Marin Bertier received my PhD from University of Paris 6 in 2004. During his PhD, he was member of the INRIA project REGAL (REpartition et Gestion d'Applications à Large échelle) on Resources management in large scale distributed systems. After that, he was professor assistant at University Paris X and he was member of the INRIA project Grand Large during one year. He became, in 2005, associate professor at the INSA of Rennes. He works in the IRISA laboratory as member of ASAP project.

1. B. Maniymaran, M. Bertier, A.-M. Kermarrec. *Build One, Get One Free: Leveraging the Coexistence of Multiple P2P Overlay Networks* In Proceedings of the 25th IEEE International Conference on Distributed Computing Systems (ICDCS-07), Toronto, to appear

2. E. Le Merrer, V. Gramoli, A. C. Viana, M. Bertier, A.-M., Kermarrec. *Energy Aware Self-organizing Density Management in Wireless Sensor Networks*, ACM MobiShare, Los Angeles, CA. September 2006.

3. M. Bertier, L. Arantes, P. Sens. *Distributed Mutual Exclusion Algorithms for Grid Applications: a Hierarchical Approach*. In Journal of Parallel and Distributed Computing (JPDC). Elsevier, 2005.

4. J. Sopena, L. Arantes, M. Bertier, P. Sens. *A Fault-Tolerant Token-Based Mutual Exclusion Algorithm Using a Dynamic Tree*. In EuroPar 2005, Lisboa, Portugal, September 2005. LNCS.

5. M. Bertier, O. Marin, P. Sens. *Performance Analysis of Hierarchical Failure Detector*. In Proceedings of the International Conference on Dependable Systems and Networks (DSN '03), San Francisco, USA, Juin, 2003.

Dr. Anne-Marie Kermarrec leads the ASAP project that she has founded in 2006, previously she joined INRIA in the PARIS team in February 2004, she was with Microsoft Research in Cambridge as a Researcher since March 2000. Before that, she obtained her Ph.D. from the University of Rennes (FRANCE) in October 1996. The subject of her thesis was an integration of replication for efficiency and high-availability in large-scale distributed shared-memory systems. She also spent one year (1996-1997) in the Computer Systems group of Vrije Universiteit in Amsterdam (The Netherlands) working in the GLOBE project in collaboration with Maarten van Steen and Andrew. S. Tanenbaum. In September 1997, she became an assistant professor at the University of Rennes 1, France where she worked on context-awareness in mobile environments in the IRISA research lab. She defended her "habilitation à diriger les recherches" (University of Rennes 1) in December 2002 on large-scale application-level multicast.

1. B. Maniymaran, M. Bertier, A.-M. Kermarrec. *Build One, Get One Free: Leveraging the Coexistence of Multiple P2P Overlay Networks* In Proceedings of the 25th IEEE International Conference on Distributed Computing Systems (ICDCS-07), Toronto, to appear

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4. L. Massoulié, E. Le Merrer, A.-M. Kermarrec, A. Ganesh. *Peer Counting and Sampling in overlay networks: random walk methods*. In PODC, Denver, Colorado, USA, 2006.

5. E. Le Merrer, A.-M. Kermarrec, L. Massoulié. *Peer-to-Peer Size Estimation in Large and Dynamic Networks: a Comparative Study*. In The 15th IEEE International Symposium on (HPDC 15), Paris, France, 2006.

9.3 INRIA POPS

Dr. Nathalie Mitton is research officer in the INRIA POPS team from September 2006. Nathalie Mitton obtained her PhD from INSA Lyon in March 2006. Her main research interests are on self-organizing and self-stabilizing wireless multi hop networks. She is a member of the technical committee of the Fourth IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS 2007). She is also involved in several international and national projects.

1. Nathalie Mitton, Eric Fleury, Isabelle Guérin-Lassous, Bruno Séricola, Bruno and Sébastien Tixeuil, *Fast Convergence in Self-stabilizing Wireless Networks*, In the 12th International Conference on Parallel and Distributed Systems (ICPADS'06), July 2006.

2. Nathalie Mitton, Eric Fleury, Isabelle Guérin-Lassous, and Sébastien Tixeuil, *Self-stabilization in self-organized Multihop Wireless Networks*, In the 2nd International Workshop on Wireless Ad Hoc Networking (WWAN'05), June 2005.

3. Nathalie Mitton, Anthony Busson, and Eric Fleury. *Efficient Broadcasting in Self-Organizing Sensor Networks.* International Journal of Distributed Sensor Networks (IJDSN)., 1(2-3), January 2006.

Pr. David Simplot-Ryl received the Graduate Engineer degree in computer science, automation, electronic and electrical engineering, a MSc and PhD degrees in computer science from the University of Lille, France, in 1993 and 1997, respectively. In 1998, he joined the Fundamental Computer Science Laboratory of Lille (LIFL), France, where he is currently professor. He receives the Habilitation degree from University of Lille, France, in 2003. His research interests include sensor and mobile ad hoc networks, mobile and distributed computing, embedded operating systems, smart objects, RFID technologies. Recently, he mainly contributes to international standardization about RFID tag identification protocols in partnership with Gemplus and TagSys companies. He writes scientific papers, book chapters and patents and he received Best paper award at 9th Intl. Conference on Personal Wireless Communications (PWC 2004). He is managing editor of Ad Hoc and Sensor Wireless Networks: An International Journal (Old City Publishing). He is currently associate editor of International Journal of Computers and Applications (Acta Press), International Journal of Wireless and Mobile Computing (Inderscience) and International Journal of Parallel, Emergent and Distributed Systems (Taylor & Francis). He is also guest editor of several special issues: IEEE Network Magazine (IEEE Communication Society), Ad Hoc Networks Journal (Elsevier), International Journal on Wireless Mobile Computing (Inderscience), International Journal of Computers and Applications (Acta Press), International Journal of Parallel, Emergent and Distributed Systems, International Journal of Wireless and Mobile Computing, and IEEE Transactions on Parallel and Distributed Systems (IEEE Computer Society). He was also chair or co-chair for international workshops at IEEE

Int. Conf. on Distributed Computing and Systems ICDCS 2004-2005 (WWAN 2004-2005), International Conference on Parallel and Distributed Systems ICPADS-2005 (SaNSO 2005), 2nd IEEE International Conference on Mobile Ad-hoc and Sensor Systems IEEE MASS 2005 (LOCAN 2005), International Conference on Integrated Internet Ad hoc and Sensor Networks (InterSense 2006). He is program committee member at a number of international conferences and workshops, such as WLN 2003-6, IFIP MOBIS 2004-5, IEEE MASS 2004 and 2007, WONS 2005-6, ICPADS-2005, UISW 2005, MED-HOC-NET 2005, AINA 2006, RTNS'2006, IEEE LCN 2006-7, ACM MobiHoc 2006-7 and OPODIS 2006. He is scientific leader of the POPS research group, common project of University of Lille, CNRS and INRIA. He is scientific coordinator of the national CNRS project RECAP on sensor and self-organizing networks.

1. J. Cartigny, D. Simplot and I. Stojmenovic. Localized minimum-energy broadcasting in ad-hoc networks. In *Proc. IEEE INFOCOM 2003*, (San Francisco, USA, 2003)

2. J. Carle, and D. Simplot-Ryl. Energy efficient area monitoring by sensor networks. *IEEE Computer Magazine* **37**, 2 (2004), 40–46.

3. F. Ingelrest, D. Simplot-Ryl, and I. Stojmenovic. Optimal Transmission Radius for Energy Efficient Broadcasting Protocols in Ad Hoc Networks. *IEEE Transactions on Parallel and Distributed Systems* **17**, 6 (2006), 536–547.

4. A. Gallais, J. Carle, D. Simplot-Ryl, and I. Stojmenovic. Localized sensor area coverage with low communication overhead. In *Proc. 4h Annual IEEE International Conference on Pervasive Computing and Communications (PerCom 2006)*, (Pisa, Italy, 2006).

5. A. Honore, H. Meunier, G. Grimaud and D. Simplot-Ryl. Efficient Packet Scheduler For Wireless Ad Hoc Networks With Switched Beam Antennas. In *Proc. IEEE 20th International Conference on Advanced Information Networking and Applications (AINA 2006)*, (Vienna, Austria, 2006).

9.4 LIP6

Dr. Marcelo Dias de Amorim is a CNRS researcher at the LIP6 laboratory of Université Pierre et Marie Curie – Paris 6. He received his Ph.D. degree from the University of Versailles in 2001. He also holds a Cum Laude Degree in Electronic Engineering and M.Sc. Degree in Electrical Engineering, respectively in 1995 and 1998, both from Universidade Federal do Rio de Janeiro (UFRJ), Brazil. In 2000, he was with the LRI Laboratory of the University of Paris Sud. From July 2001 to September 2003 he was a researcher scientist at EuronetLab. His research interests focus on self-organizing networks.

1. Marcelo D. de Amorim, Mihail L. Sichitiu, Farid Benbadis, Yannis Viniotis, and Serge Fdida, "Dissecting the Routing Architecture of Self-Organizing Networks", *IEEE Wireless Communications Magazine*, vol. 13, n. 6, pp. 98 – 104, December 2006.

2. Aline C. Viana, Marcelo D. de Amorim, Yannis Viniotis, Serge Fdida, and José F. de Rezende, "Twins: A Dual Addressing Space Representation for Self-organizing Networks", *IEEE Transactions on Parallel and Distributed Systems*, vol. 17, n. 12, pp. 1468 – 1481, December 2006.

3. Franck Legendre, Vincent Borrel, Marcelo D. de Amorim, and Serge Fdida, "Reconsidering Microscopic Mobility Modeling for Self-Organizing Networks", *IEEE Network Magazine*, vol. 20, n. 6, pp. 4 – 12, December 2006.

4. Franck Legendre, Vincent Borrel, Marcelo D. de Amorim, and Serge Fdida, "Modeling Mobility with Behavioral Rules: the Case of Incident and Emergency Situations", *Asian Internet Engineering Conference (AINTEC)*, November 2006.

5. Farid Benbadis, Marcelo D. de Amorim, and Serge Fdida, "The effect of locality on coordinates dissemination", *IEEE Internation Symposium on Personal, Indoor and Mobile Radio Communications*, Helsinki, Finland, September 2006.

Dr. Matthieu Latapy is a LIP6 permanent researcher, CNRS and university Paris 6. He completed his PhD in computer science from the university Paris 7 in 2001, and obtained his current position in 2002. His research focuses on (very) large graphs met in practice. This includes in particular the ones originating from computer science, like the internet topology, the web graph, peer-to-peer overlays and data exchanges. But it also includes many other cases, like for instance social, biological and linguistic networks. He is involved both in theoretical and practical studies on these objects: he works on the measurement of such complex networks, their analysis, their modeling, and the related algorithmics. He is the head of the national initiative aimed at coordinating French studies on large complex networks. He leads a national project about social networks on the internet, involving social and computer scientists. He also contributes to several other projects, among which MetroSec (Metrology of the internet for security and quality of services, http://www.laas.fr/METROSEC/), and the European COST 295 Dynamo (Dynamic Communication Networks, http://cost295.net/).

1. Mathieu Latapy and Clémence Magnien, "Measuring Fundamental Properties of Real-World Complex Networks," Submitted, 2007.
2. Mathieu Latapy, Clémence Magnien, and Nathalie Del Vecchio, "Basic Notions for the Analysis of Large Affiliation Networks/Bipartite Graphs," Submitted, 2006.
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4. Jean-Loup Guillaume, Mathieu Latapy, and Damien Magoni, "Relevance of Massively Distributed Explorations of the Internet Topology: Qualitative Results," *Computer Networks*, n. 50, pp. 3197–3224, 2006.
5. Jean-Loup Guillaume and Mathieu Latapy, "Complex Network Metrology," *Complex Systems*, n. 16, pp. 83–94, 2005.

Dr. Clémence Magnien is a LIP6 permanent researcher, CNRS and university Paris 6. She completed her PhD in computer science from the university Paris 7 in cooperation with the Ecole Polytechnique, in 2003. Her research interests focus on complex systems. Prior to coming to LIP6, she was with the CREA laboratory from Ecole Polytechnique. She is member of the management committee of European COST 295 Dynamo (Dynamic Communication Networks), member of the "Neuvièmes rencontres francophones sur les aspects Algorithmiques des Télécommunications (ALGOTEL'07)", and expert for the Evaluation Committee of the Italien Research (CIVR). She is also reviewer for many international journals.

1. Mathieu Latapy and Clémence Magnien, "Measuring Fundamental Properties of Real-World Complex Networks," Submitted, 2007.
2. Mathieu Latapy, Clémence Magnien, and Nathalie Del Vecchio, "Basic Notions for the Analysis of Large Affiliation Networks/Bipartite Graphs," Submitted, 2006.
3. Anne-Ruxandra Carvunis, Matthieu Latapy, Annick Lesne, Clémence Magnien, and Laurent Pezard, "Dynamics of three-state excitable units on Poisson vs power-law random networks," *Physica A*, n. 367, pp. 595–612, 2006.
4. Brice Augustin, Xavier Cuvellier, Benjamin Orgogozo, Fabien Viger, Timur Friedman, Matthieu Latapy, Clémence Magnien, and Renata Teixeira, "Avoiding traceroute anomalies with Paris traceroute," *Proc. Internet Measurement Conference (IMC'06)*, Rio de Janeiro, Brazil, October, 2006
5. Clémence Magnien, Matthieu Latapy, and Jean-Loup Guillaume, "Comparison of Failures and Attacks on Random and Scale-free Networks," *Internationale Conference on Principles of Distributed Systems (OPODIS'04)*, Grenoble, 2004.

9.5 LSIIT

Thomas Noel is Professor at the University Louis Pasteur since 2006. He is in charge of wireless and mobile researches of the Networks and Protocols team of LSIIT (Louis Pasteur University – Computer Science Laboratory). Thomas Noel was the leader of collaboration researches between research centers in Asia and laboratories of CNRS and INRIA in France (STIC Asia Project 2004 – 2006). The focus of theses collaborations is All Wireless Internet. He was invited researcher (JSPS Senior Fellowship program) to Keio Univeristy (Japan – From March to September 2005). He is the leader of the JST (Japan Science and Technology) / CNRS project on Mobilty for a New Internet (2006-2008). Thomas Noel's main research interests include several aspects of wireless communication networks and telecommunication systems. He is particularly interested in self-organized mobile networks (wireless mesh and sensor networks), mobile network architecture and protocols, Multicast and group communications.

1. A. Pelov, P. David, T. Noel, Trace Analysis of a Wireless University Network with Authentication, The Third International Workshop on Wireless Network Measurement (WiNMee) – Cyprus, april 2007
2. J. Montavont, E. Ivov, T. Noel, Analysis of Mobile IPv6 Handover Optimizations and Their Impact on Real-Time Communication, IEEE Wireless Communications and Networking Conference (WCNC) IEEE Computer Society Hong Kong – march 2007.
3. J. Lorchat, T. Noel, Overcoming the IEEE 802.11 paradox for realtime multimedia traffic, Computer Communications Elsevier pages 3507 –3515 vol. 29 num. 17 – november 2006.
4. N. Montavont, T. Noel, Fast Movement Detection in IEEE 802.11 networks, International Journal of Wireless and Mobile Computing , Wiley pages 651-671 vol. 6 num. 5 – august 2006.
5. J. Lorchat, T. Noel, Efficiency and QoS Optimizations of IEEE 802.11 Communications using Frame Aggregation, International Journal of Wireless and Mobile Computing pages 229 –238 vol. 1 num. 3/4 – 2006.

Jean-Marc Muller is a CNRS research engineer at the LSIIT Laboratory since 2003. He worked as an engineer on the Cyberte project (an RNRT project dealing with mobility and wireless communications). He was in charge of the design and development of the architecture of the project : an IPv6 multi-interfaces laptop architecture using various interfaces (WIFI, Bluetooth, GPRS) to communicate and improve mobility mecanism. He gathered by this way expertise in Linux kernel and drivers programming. He is since 2004 in charge of the network infrastructure and security of the LSIIT.

9.6 THALES

Vania Conan is project manager at Thales Communications, in Colombes, France. He received his Engineering Degree (1990) and PhD in Computer Science (1996) from Ecole des Mines de Paris, France, and a Masters Degree in Artificial Intelligence from Université Pierre et Marie Curie, Paris in 1991. Since then, he has been managing collaborative research projects at national and European levels (FP5, FP6 IST programs, ITEA Eureka cluster and French ANR). His current research topics cover wireless and ad hoc networks, from a software and IP protocol perspective. This includes wireless node architectures, communication protocols and middleware design for distributed applications.

1. J. Leguay, T. Friedman, V. Conan. " Evaluating Mobility Pattern Space Routing for DTNs ", INFOCOM 2006
2. H. Aïache, V. Conan, J. Leguay, M. Lévy, "XIAN : Cross Layer Interface for Wireless Ad hoc networks", Medhoc Net 2006, March 2006
3. J. Leguay, T. Friedman, V. Conan " DTN Routing in a Mobility Pattern Space ", WDTN'05, Pennsylvanie, August 2005.

4. R. Knopp, N. Nikaien, C. Bonnet, H. Aïache, V. Conan, S. Masson, G. Guibe, C. Le Martret, "Overview of the WIDENS Architecture, a Wireless Ad Hoc Network for Public Safety", SECON 2004 - Santa Clara, USA, 4-8 October 2004.

Jérémie Leguay is an advanced studies engineer at Thales Communications, in Colombes, France. He received his Engineering Degree (2003) from EFREI (Ecole Française d'Electronique et d'Informatique) and a Master of Science (2004) in Computer Science from Linköping University in Sweden. From 2004 to 2007 he has been a Ph.D. candidate at the Computer Science laboratory (LIP6) of Pierre & Marie Curie University and at Thales Communications where he conducted research in ad hoc and delay tolerant networking. His current research interests focus on IP protocols and applications in the contexts of wireless and delay tolerant networking.

1. J. Leguay, T. Friedman, V. Conan. " Evaluating MobySpace Based Routing Strategies in Delay Tolerant Networks ", Accepted for publication in the WCMC Special Issue on Disruption Tolerant Networking (Wiley). 2007.
2. J. Leguay, A. Lindgren, J. Scott, T. Friedman, J. Crowcroft. " Opportunistic Content Distribution in an Urban Setting ", ACM SIGCOMM 2006. Workshop on Challenged Networks (CHANTS). 2006.
3. J. Leguay, T. Friedman, V. Conan. " Evaluating Mobility Pattern Space Routing for DTNs ", INFOCOM 2006
4. H. Aïache, V. Conan, J. Leguay, M. Lévy, " XIAN : Cross Layer Interface for Wireless Ad hoc networks ", Medhoc Net, March 2006
5. J. Leguay, V. Conan, T. Friedman. " QoS Routing in OLSR with Several Classes of Service", IEEE PerCom Workshop on Pervasive Wireless Networking (PWN). 2006.

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[3] http://mondrian.pentaho.org/.

[4] http://motelab.eecs.harvard.edu/.

[5] http://prisms.cs.umass.edu/dome/index.php?page=umassdieselnet.

[6] http://reality.media.mit.edu/.

[7] http://sensorscope.epfl.ch/.

[8] http://svp.irisa.fr.

[9] http://tomcat.apache.org/.

[10] http://wasal.epfl.ch/.

[11] http://www.citi.insa-lyon.fr/project/aresa/.

[12] http://www.citysense.net/.

[13] http://www.cse.ohio-state.edu/ naik/testbed/kansei.html.

[14] http://www.haggleproject.org/.

[15] http://www.hitech-projects.com/euprojects/wasp/.

[16] http://www.mosar-sic.org/.

[17] http://www.tinyos.net/.

[18] http://www.winlab.rutgers.edu/pub/docs/focus/ORBIT.html.

[19] National coordination for micro-nanoelectronics trainings. .

[20] Onelab consortium. onelab is an open networking laboratory integrating, testing, validating and demonstrating new fixed and wireless networking technologies in real world settings and production environments. .

[21] Planetlab consortium. planetlab: An open platform for developing, deploying, and accessing planetary-scale services. .

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