INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team Ares

Architecture de réseaux de services

Rhône-Alpes

THEME COM

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2. Overall Objectives

2.1. Overall Objectives

Keywords: *ad hoc networks*, *hybrid wireless networks*, *protocols*, *services deployment and administration*.

The goal of the *ARES* project is to model and 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 through 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 provisioning. Considering the diversity and variability of the technical and environmental constraints, adaptation is a key to the success of hybrid networks.

ARES focuses on four main challenges: integrating different types of mobility, controlling cross-layer interaction, providing self-configurability and supporting quality of service (QoS).

Cross-layer interaction involves both the radio transmission capabilities of the devices and the elementary services of the middleware environment. Radio transmission capabilities influence the performance of the network. Their impact on the design of new protocols and the adaptation of existing protocols need to be studied through modeling and/or simulation. Despite middleware development is out of the scope of the project, we examine the impact of radio transmission on the specifications of the basic services used by middlewares, namely services discovery, global security, software deployment and terminal supervision.

The project does not cover the development of end-user applications based on context awareness. However, we consider existing usage scenarios in order to derive specifications for the main services provided by an hybrid network. To advance the state of the art in network support for applications, we therefore develop testbeds and experiment with prototypes.

The activities of the project are organized in three areas:

- hybrid network modeling;
- protocol design;
- services deployment and administration.

The four main challenges presented above are transversal to these research areas.

3. Scientific Foundations

3.1. Introduction

The *ARES* project deals with providing self-adaptation capabilities to network architectures: auto-configuration, auto-organization, dynamic adaptation and context discovery. We focus on interoperability aspects of wireless transmissions, protocols and services management, in a context of hybrid networks. To do that, we merge standard protocols engineering with distributed system aspects. The modeling of wireless environment (propagation, MAC, mobility) is also a fundamental activity of the ARES project.

3.2. Hybrid networks modeling

Participants: Ioan Burciu, Alexandre Caminada, Xavier Gallon, Jean-Marie Gorce, Isabelle Guérin Lassous, Nicolas Marechal, Philippe Mary, Benoit Miscopein, Pierre-François Morlat, Hervé Parvery, Guillaume de la Roche, Fabrice Valois, Guillaume Villemaud, Ruifeng Zheng.

This scientific axis aims at proposing a formal framework for the study and the evaluation of hybrid networks as defined in Section 2. The high complexity of such networks makes necessary the use of both a wide panel of different technics and several concepts of mobility.

While several solutions have been already proposed for some aspects of hybrid networks, the combination of all aspects is still challenging. Thus, adapting usual techniques used in conventional networks to the hybrid specificity, ensuring the scalability, and finding solutions as global as possible are very attractive goals. All require a formal evaluation framework.

Models for hybrid networks have two goals: to give a better understanding of the behavior of these networks and to provide a framework for protocol design. Therefore, such models should be both simple, for tractability, and realistic, for efficiency. Finding a right balance between these antinomic requirements entails a careful identification of all the relevant parameters.

Modeling hybrid networks may be performed at different levels. It is obvious that hybrid networks aim at gathering simultaneously several radio networks including different medium access techniques, mobile equipments having different mobility profiles, different traffic flows and network entities having different capacities. Taking into account all of these specific aspects is intractable, and in the modeling task it is firstly aimed to extract the set of relevant characteristics of hybrid networks. Moreover, it is crucial to work not only on usual radio interfaces but also on advanced technologies in order to anticipate future capacities. Modeling the interactions between the network layers (physical/data link, data link/network) is challenging as well as taking into account the dynamic feature of these networks. Finally, a framework for the performance evaluation of these networks should be proposed. This framework should integrate both realistic characteristics of environment and well-defined mobility and traffic models.

3.3. Protocols design

Participants: Isabelle Augé-Blum, Elyes Ben Hamida, Nicolas Boulicault, Guillaume Chelius, Yu Chen, Eric Fleury, Isabelle Guérin Lassous, Karel Heurtefeux, Jialiang Lu, Nathalie Mitton, Thomas Noël, Tahiry Rafazindralambo, Cheikh Sarr, Fabrice Theoleyre, Fabrice Valois, Thomas Watteyne.

The second main topic addressed by the *ARES* project is devoted to the study of several IP (Internet Protocol) based protocols and their interactions in order to allow an hybrid framework, *i.e.* allowing simultaneously or at least in a complementary approach, the use of ad hoc aspects, PAN (Personal Area Network) and also the infrastructure of cellular networks. This definition of an hybrid architecture is a first step towards providing an ubiquitous Internet.

The generalization of the last hop as a wireless one increases drastically the use of IP during several mobility scenarios. It is likely that mobile users will expect similar levels of service quality as wireline users. In the Internet, IP packets are transmitted from one NIC (Network Interface Card) identified by its own IP address that defines the source IP address of the IP packet, to the final NIC also identified by its own IP address that defines the destination IP address of the IP packet. IP addresses play the role of both identifier and localization. The modification of one of the IP source or destination address leads to the breakdown of all current IP communications! To overcome this major problem, a new protocol named MIP (Mobile IP) was proposed.

However, in environments where mobile hosts change their point of attachment to the network frequently, the basic Mobile IP protocol tunneling mechanism introduces network overhead in terms of increased delay, packets loss and signaling. For example, many real-time wireless applications (e.g., voice-over-IP) would experience noticeable degradation of service with frequent handoff. Establishment of new tunnels can introduce additional delays in the handoff process causing packet loss and delayed delivery of data to

applications. This delay is inherent in the round-trip incurred by Mobile IP as the registration request is sent to the home agent and the response sent back to the foreign agent. In order to handle this local movement (e.g., within a domain) of mobile hosts without interaction with the Mobile IP enabled Internet, micro-mobility protocols (Cellular IP, Hawaii, HMIP) based on hierarchical frameworks have been proposed. The cooperation of both MIP and Cellular IP leads to a structure where MIP handles the mobility of hosts between cellular networks whereas Cellular IP handles the mobility inside a cellular network.

We aim to add to this architecture the benefits of ad hoc networks since they will allow the covering of existing cellular networks to be extended. To fulfill our goal, we need to evaluate and optimize existing protocols but also propose new architectures and protocols related to the specific context of hybrid networks. Architectural aspects appear to be fundamental in our approach since only a global and broad point of view allows all aspects of hybrid networks (ad hoc networks embedded in a cellular network) and heterogeneous capacities (different communication medium, computational power, memories, power life) to be taken into account.

3.4. Secured middlewares for dynamic environments

Participants: Fatiha Benali, Amira Ben Hamida, Denis Beras, Stéphane Frénot, Samuel Galice, Noha Ibrahim, Véronique Legrand, Frédéric Le Mouël, Marine Minier, Pierre Parrend, Yvan Royon, Jacques Saraydaryan, Stéphane Ubéda.

The third axis of the *ARES* project is architecture centered. The aim is to study elementary services that an *ambient network* should provide on the top of an optimized network layer. This axis falls in the area of *middleware*. Therefore, system oriented studies are also needed. We focus on the glue between network layer and existing middleware approaches, and on the design of elementary functionalities that should be useful in any middleware.

Again, our scientific foundation is driven by the two main concepts: self-configuration and self-organization elements of the ambient network. In this context, three main orientations have been defined:

- Constrained middlewares: middlewares for dynamics systems like mobile phones, home gateways or sensor networks needs to be adapted to cope to these environments. Our activity aims at designing middleware layers that optimize some of their behaviors. We are specifically working on initial deployment size and resource consumption adaptation.
- Service deployment and administration: in a highly mobile and dynamic environment, service adaptation to the context is a key feature of the success of a support for ambient network; this *context awareness* can not be obtained without an efficient software/driver components deployment. Moreover, supervising terminals in a mobile environment is difficult; in *ambient networks* where there are no pre-existing authorities, standard procedures are usefulness. New management and control paradigms have to be developed. *ARES* has the objective to propose new supports for *Autonomous Management*, i.e. user centered solutions without any administrator.
- Global security support: security is a key feature of *ambient networks*; difficulties come from the lack of central administration. Again, new paradigms have to be proposed. *ARES* is focused on *spontaneous* trust management and is studying a global solution on the top of this basic property. More over in fast dynamic systems component can join and leave regularly, we are working on ways to improve the control of their executions.

4. Application Domains

4.1. Introduction

The *ARES* team is developing skills in the area of wireless technology. Models, methods and tools for understanding and managing wireless environments are part of the *ARES* objectives. The aim of *ARES* is to study and propose a global support for a wireless hybrid environment, *i.e.* a cellular environment where

ad hoc capacities are used both to extend the communication range of the cellular network and to give peer-to-peer communication capacities to terminals without the help of any infrastructure. There is no specific application domain *ARES* is focused on. Therefore, *ARES* team is keeping in mind some useful cases that should be deployed on top of such network environments. Our vision is that an hybrid environment perfectly fits the communication requirement of ubiquitous environment and ambient networks.

4.2. Applications in ubiquitous networks

Ad hoc networks were originally designed for military purposes but now they are reemerging as the next generation of networks. In *ARES*, we believe that the strength of an ad hoc environment is its capacity to be self-established without previous knowledge. The mobile terminal must have a set of mechanisms allowing the device to be automatically integrated and configured as part of the ad hoc network. In the *ARES* view, we add to these mechanisms the automatic discovery of *gateways* allowing ad hoc nodes to access fixed networks - or the Internet, through multihop wireless communications.

Applications considered as target for the *ARES* studies and developments are concerned with smart devices in multiple environments such as vehicles, mobile phones and personal appliances. Spontaneous networks are built with ad hoc capacities where gateways to fixed networks are viewed only as specific nodes offering a special service: access to the Internet.

The *ARES* team is more interested in applications where self-organization and self-configuration are emphasized. In this area we are currently working on the notion of *intelligent gateway* where supervision and security are the major topics.

4.3. Applications in sensor networks

Miniaturization in micro-electro-mechanical systems (MEMS) has enabled the development of a new kind of networks: *sensor networks*. Sensor networks use small objects able to monitor their close environment such as obtaining a temperature, an air or water pollution level, to detect movements or vibrations, etc. These networks also use one or more monitoring stations (also called sink stations) responsible to collect information from sensors. Using a large number of small inexpensive sensors increases the dependability of surveillance and reconnaissance systems and also decreases the vulnerability of the system to failure. To forward their data (monitoring information, request, etc.), all these nodes use multihop wireless communication.

A number of applications in many sectors exist for sensor networks. For example, commercial sector, transportation, manufacturing industry, agriculture, medicine or even military are sectors that will benefit greatly from increased surveillance. The *ARES* project is currently working with other resaerch group and compagnies in this area. Self-adaptive and self-organized are questions of active research, ranging from hardware to applications. Many topics must be studied such as topology control (addressing, localization, etc.), data communication (broadcasting, routing, gathering, etc.), architecture (hardware, system -OS-, network -communication stacks-, etc.), quality of services (response time, fiability, energy consumption, etc.) and applications (service lookup, distributed database, etc.).

4.4. Application tools for wireless networks

The application domain concerned by tools that help in the evaluation, planning and simulation of wireless networks is part of the *ARES* goals both in terms of research tools and of technology transfer. Various aspects of the modelling of wireless environments need the design of specific tools for simulation and evaluation. Some of these tools are already being transferred to operational applications for wireless networks designers. The originality of the wireless tools designed by *ARES* comes from the merging of the network aspect (MAC layer and routing layer) with a good modelling of physical links.

5. Software

5.1. AnaX: Ad hoc Network Architecture

Keywords: *ad hoc network*, *heterogeneous network*, *hybrid network*, *multi-interfaces*.

Participants: Nicolas Boulicault, Guillaume Chelius, Eric Fleury.

AnaX, Ana4 (*a.k.a.* Ananas) and Ana6, is a network architecture for both ad hoc and hybrid networks which abstracts multi-hop multi-interfaces networks into a single ad hoc network. In the AnaX architecture, ad hoc and access networks are both considered as a unique ad hoc network (hybrid network) and as a multi-link subnet in terms of IP addressing. In other words, an IP address remains valid in the whole hybrid network and mobility does not lead to addressing modification. AnaX offers a support for vertical mobility, complete TCP/IP compatibility and logical network partitionning. The software is available at http://sourceforge.net/projects/ananas.

In 2006, the porting of the Ana4 architecture for Windows XP/CE has currently been achieved to complete the already supported list of OS. Several utility softwares (ad hoc traceroute, network monitoring...) have also been developped in order to offer a full easy-to-use software suite associated to the architecture.

5.2. NAP: No Administration Protocol

Keywords: *IPv6 router auto-configuration.*

Participants: Guillaume Chelius, Eric Fleury.

In collaboration with the ARMOR project, *ARES* has proposed a protocol extending the standardized IPv6 auto-configuration mechanisms. The basic IPv6 auto-configuration process is dedicated to hosts only; it allows retrieval of a 64 bits address prefix through ICMPv6 messages, the remaining 64 bits being determined from local information. We propose to dynamically and automatically attribute subnet values to links using a distributed protocol executed by the IPv6 routers. The RSM department of the ENST Bretagne and the project had initially published an Internet Draft for the Yokohama IETF meeting (draft-chelius-router-autoconf-00.txt) which extended OSPFv3 to establish and maintain a consensus on the automatic attribution of subnet values to the network links. In 2006, the protocol proposal, called NAP for *No Administration Protocol*, was further developped in particular to be integrated with other IPv6 auotconfiguration solutions such as DHCPv6 Prefix Delegation, DSTM or L2TP. Implementation for this protocol is available for the Zebra application (http://nap.dstm.info).

5.3. Advanced OSGi

Keywords: *OSGi*, *home gateway*.

Participants: Denis Beras, Stéphane Frénot, Pierre Parrend, Yvan Royon.

OSGi[1] is a specification for making dynamic Java environments. We are involved in the Felix[2] development community and we have provided many applications (called bundles) in this context. Three major applications have been released.

- MOSGi (Managed OSGi) is a complete management infrastructure for the felix framework. It has been integrated as a standard service in the felix development trunk.
- VOSGi (Virtual OSGi) is a proposal to extend OSGi to offer a multi-user perspective. This framework enables the execution of many gateways (virtual gateway) on top of a core gateway.
- JarSigner is a client application that aims at signing deliverable bundles.

[1] http://www.osgi.com
[2] http://cwiki.apache.org/FELIX/index.html

We have also provided many autonomous bundles:

- osgiDev/osgiProv: this project aims at implementing the device service discovery from the OSGi R3 specification. It is freely available at http://ares.insa-lyon.fr/~sfrenot/devel/osgidev/. The companion project osgiProv (http://ares.insa-lyon.fr/~sfrenot/devel/osgiprov) shows how to use the device manager service. The osgiDev service is now used in other third party projects around OSGi. For example, it is used as the lower layer of the UPnP implementation provided by Domoware (Spanish team).
- tinyShell: the tiny shell is a lightweight user interface for managing the Oscar shell. This user interface was necessary to work on embedded devices such as iPaqs, as the current Swing-based user interface is too heavy to work on them. The tinyShell service has been tested on many flavours of OSGi gateways (Oscar, KnopflerFish). It is freely available at http://ares.insa-lyon.fr/~sfrenot/devel/tinygui.
- m-osgi is a OSGi extension which provides remote access to services. With M-OSGi, every service that is deployed on the gateway is automatically remotely accessible. With this extension, services are available in a totally transparent way whether they are used locally or remotely. The idea is that the service is accessed contextually, which means that if the local CPU is overloaded we use a remote execution. On the contrary, if the network bandwidth is overwhelmed, we choose to run the service locally. Finally, the adaptation is dynamic as the service is dynamically adapted according to the computer load.
- p-osgi is an extension to OSGi that enables OSGi bundles delivery through a P2P network. Each gateway hosts part of the total number of bundles. Bundles are identified by their name and each name is associated with one gateway. When a bundle has to be deployed on one specific gateway, the P2P network automatically brings it.

5.4. SOMoM:Self-Organized Mobility Management

Keywords: *ad hoc and heterogeneous network*, *wireless multi-hops networks*.

Participants: Fabrice Theoleyre, Fabrice Valois.

During the last 3 years, we investigated self-organization paradigm in order to improve the behavior of ad hoc networks or hybrid networks. We introduced a self-organization based on a virtual backbone: some mobile nodes are elected to form a connected structure, collecting the traffic. Thus, the backbone must be continuously maintained and updated to remain efficient: the algorithms are proved to be self-stabilizing. The performances evaluation highlights properties of stability, robustness, etc. Thus, based on this self-organization, SOMoM was developed: it is a routing protocol allowing to create a multihops cellular network (*hybrid network*). SOMoM is conceived so that all the backbone nodes form a distributed routing cache. The routes passing through the backbone are more stable and the overhead required for the maintenance is reduced. Moreover, some information required for the self-organization are used by SOMoM to create a default route toward the access point (fig. 1). Inversely, the access point can initiate a route discovering to find a client in the ad hoc area: this mechanism occurs seldom and is cost-effective.

The software is available at http://sourceforge.net/projects/somom. SOMoM can be used to extend, spontaneously, wireless networks over k hops. In practice, TCP flows are well-managed until k is lower than 4.

5.5. WILDE software

Keywords: *multi-resolution*, *optimization*, *wave propagation simulation*, *wireless network planning*.

Participants: Jean-Marie Gorce, Guillaume de la Roche, Guillaume Villemaud.

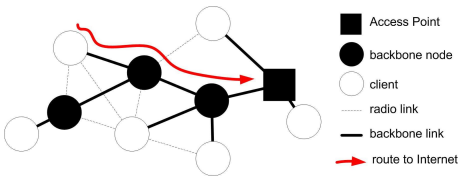

Figure 1. General behavior of SOMoM

In the context of network planning, we have developed a software in Java, implementing our propagation simulator described in Section 6. This software named WILDE (Wireless Design tool) is the heart of our developments concerning the radio link modeling. The simulator is based on a home-made propagation engine which implements a frequency-domain TLM method. This method is by now restricted to a 2D framework and the 3D framework is under development. An original multi-resolution approach has been defined, speeding up drastically the computational time.

For any information, contact Jean-Marie Gorce (Jean-Marie.Gorce@insa-lyon.fr).

5.6. WSim software

Keywords: *hardware platform emulation*, *hardware platform simulation*, *sensor network*.

Participants: Guillaume Chelius, Eric Fleury.

In the context of researches in the field of sensor networks, we have developed in collaboration with Antoine Fraboulet (INSA de Lyon) WSim, a full sensor node hardware simulator. It relies on cycle accurate full platform simulation using microprocessor instruction driven timings. The simulator is able to perform a full simulation of hardware events that occur in the platform and to give back to the developer a precise timing and performance analysis of the simulated software. WSim has been designed with respect to the following goals:

- WSim captures the behavior of the node application at a very low level, using the native code: instruction, bit, interrupt and byte radio level simulation and provides an accurate time control. The timing result of WSim has been validated with real-world systems (http://worldsens.net/) down to the clock cycle level;
- WSim is independent of any programming language and any OS since it runs the native code generated for the target microcontroller;
- WSim enables to run tuning tools on the application since many traces can be collected (execution trace, clock frequencies, interrupts, energy);
- WSim can monitor dynamic frequency scaling;
- WSim reflects the behavior of the network. At the same time, one may tune the degree of accuracy of the radio medium simulation;

For any information, contact Guillaume Chelius (Guillaume.Chelius@inria.fr) or refer to http://www.worldsens.net. WSim has been registered at the APP under IDDN 06-370012-00 and is commercialized by InsaValor.

5.7. WSNet software

Keywords: *sensor network*, *wireless network simulator*.

Participants: Guillaume Chelius, Eric Fleury.

Together with WSim and still in collaboration with Antoine Fraboulet, we have developed WSNet, a modular event-driven wireless network simulator. Its architecture consists in different blocks that model characteristics and properties of the radio medium. During one simulation, the behaviour of a block is specified using a model which is a particular implementation of the block functionalities. Models are either provided with the simulator or developped by users.

WSNet has been designed to offer a wide range of radio medium modeling, from a basic "perfect" physical layer with no collision, no path-loss and a fixed radio range to a very precise one: Rayleigh fading, multiple radio resources (codes, frequencies), correlation factors between different radio frequencies and radio codes, additive interferences, complex radio modulations, complex antenna radiation patterns, *etc*. Given this range of models, it becomes possible and very simple to test a protocol in different radio environments and to dimension and optimize it by progressively increasing the radio modeling precision and complexity.

WSNet can be used in conjunction with WSim to simulate a whole sensor network with a very high accuracy. For any information, contact Guillaume Chelius (Guillaume.Chelius@inria.fr) or refer to http://www.worldsens.net. WSNet has been registered at the APP under IDDN 06-370013-00 and is commercialized by InsaValor.

6. New Results

6.1. Hybrid networks modeling

Keywords: *graph theory*, *modeling*, *performance evaluation*, *queueing theory*, *radio propagation*.

Participants: Ioan Burciu, Alexandre Caminada, Xavier Gallon, Jean-Marie Gorce, Isabelle Guérin Lassous, Nicolas Marechal, Philippe Mary, Benoit Miscopein, Pierre-François Morlat, Hervé Parvery, Guillaume de la Roche, Fabrice Valois, Guillaume Villemaud, Ruifeng Zheng.

The two research topics studied last year have been deeply investigated: the radio link characterization and the performance evaluation of WLANs. Started in the framework of the ARC IRAMUS, the team also focused his work on modeling the behavior of sensor networks within a realistic environment.

While each of these themes is using its own theories and models, they have to collaborate in order to propose a reliable and realistic overall modeling framework.

6.1.1. Radio physical layer analysis

6.1.1.1. Multi-antenna system characterization

[38], [39], [67], [40] Actual models of the radio link in network simulators are based on very simple models (circular, threshold based receivers, non additive interferences). The development of best models is a very challenging aim but requires a perfect knowledge of the physical layer taking into account the exact radio layer implemented in wireless equipments. The only way to assess this exact implementation is a direct observation of received RF or baseband signals. The radio platform bought by INRIA Rhône-Alpes in 2004, exhibit attractive and efficient properties for this purpose, especially for WiFi based systems. This platform includes an arbitrary wave generator (AWG up to 6GHz) and a vectorial signal analyzer (up to 6GHz, with a 36MHz of bandwidth) both driven by the simulation software ADS (Agilent). This platform has been extended to offer the possibility of studying 2×2 MIMO (Multiple Input Multiple Outpout) systems. This platform has been firstly defined to simulate a complete radio link, including coding, modulation and channel model and corresponding to many standards (802.11 series, GSM, UMTS, ...). The simulated signal can be emitted, through the AWG and received by the vectorial analyzer. A full system can be thus tested over the true air medium. This platform offers also the possibility to catch true RF signals, such as those emitted by conventional IEEE 802.11 or sensor network radio interfaces for instance. The use of this platform will allow to refine our physical layer models.

This year, this operational platform (see Fig.1) has been used to evaluate the behavior of multi-antenna systems [38], [39] in real conditions. This work has been done in collaboration with France Telecom R&D, Meylan and will be extended in a near future toward an experimental assessment of the future IEEE802.11n standard. Another very important feature of future wireless interfaces is the capability of reducing both the final productive cost and the energy consumption. This can be efficiently done if *dirty* radio is authorized, namely, if usual constraints on the RF front-end can be relaxed. For this reason we have studied the impact of RF front-end impairments on performances of SIMO-OFDM receivers [67], in strong collaboration with Jacques Verdier, from LPM, INSA Lyon. Our studies focused on $OFDM$ techniques because this is the core technology of $802.11g$ and $802.11n$. This is also the basis of future multiple access technologies referred to as OFDMA.

Albeit many works focused on MIMO systems, SIMO (Single Input Multiple Output) remains up-to-date because these systems appear back-compatible with current systems, while increasing network efficiency. Multi-antenna systems often appear as too complex for low-complexity systems such as sensor networks. We show however that the use of multiple antennas in SIMO OFDM systems may allow to compensate for RF Impairments [40]. Thus, the increased processing complexity is balanced by the decreasing sensitivity to RF front-end noise.

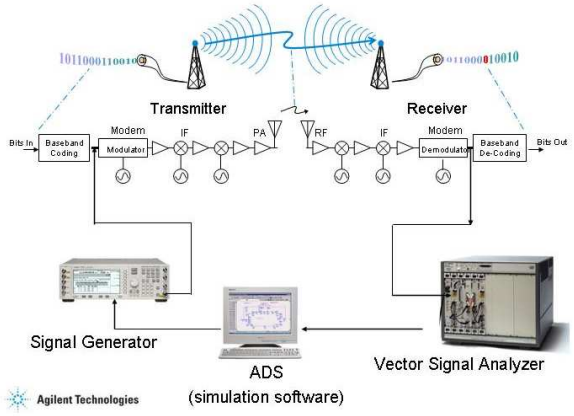

Figure 2. The radio platform includes a 2 channels VSA (vector signal analyser) and 2 synchronized AWG (arbitrary wave generators).

6.1.1.2. Reliable Propagation predictions in indoor environments , , ,

Simulating propagation in indoor environments is a difficult task due to many reflection and diffraction effects. Empirical models fail to provide reliable predictions, while deterministic approaches are often too complex to be used. Among deterministic approaches, ray-tracing based methods are the most well known, because of their scalability in terms of complexity. These methods may indeed be very fast if only few reflections are taken into account and diffraction effects are omitted. But they come with a lack of reliability. It is obvious that predictions may be more realistic while increasing the number of simulated reflected rays and if diffraction is introduced in the model. However, computational resource needs in this case drastically increase, and a tradeoff is mandatory between accuracy and efficiency. Among the deterministic approaches, ParFlow has been proposed by Chopard et al. (B. Chopard, P. Luthi and J.F. Wagen, A multi-cell coverage predictions : a massively parallel approach based on the ParFlow Method, IEEE Personnal, Indoor and Mobile Radio Communications conference, 98) in the context of GSM base station planning. This technique is a time-domain discrete approach which accurately reflects the behavior of wave propagation but requires very high

computation and time resources. Initially this method has been implemented in a parallel system to reduce the computation time.

We have proposed in 2001 a new resolution scheme (FDPF for Frequency Domain ParFlow) to solve the discrete ParFlow equations in the Fourier domain. The problem is thus written as a wide linear system. In 2002, we have solved this system in two steps taking advantage of a multi-resolution approach. The first step computes a cell-based tree structure referred to the pyramid. This step is considered as a pre-processing phase since this computation does not require the knowledge of a source location. In the second phase, a radiating source is simulated, taking advantage of the pre-processed pyramidal structure. In 2003, a new algorithm has been proposed to define an environment-based adaptive pyramidal structure avoiding artifacts near walls and other discontinuities. More precisely, a new non regular pyramidal structure which fits the particular arrangement of the indoor environment has been presented. Using of a full-space discrete simulator instead of classical ray-tracing techniques is a challenge due to the inherent high computation requests. However, we have shown that the use of a multi-resolution approach allows the main computation load to be restricted in a pre-processing phase. Concerning the simulator, A complete and formal description of the theoretical method is going to appear next year. Further, extensive works have been done to make predictions more realistic:

- A calibration process was proposed in 2005 and extensively studied during the PhD of Katia Jaffrès-Runser and has been reported this year [78]. A synthesis of this work has been submitted. Experimental measurements are used to set several parameters to fit the model with measures. These parameters are the refraction index and the attenuation coefficient of constitutive materials (walls, free-space, ...). Instead of using 'true' values of these parameters, we rather use them to adapt our simulations to the reality. More precisely, these parameters can be defined as the degrees of freedom of WILDE (the friendly name of MR-FDPF).

  To find the best set of parameters, an optimization process has been defined. This process is settled in three part: measurements, fit between measures and simulations, test and select the best parameters set. The measures have been obtained from a wide set of measurements from 5 access points, with for each one more than 300 receiving points. The fit between measures and experimental values is evaluated by the use of a RMS criteria. In order to find the best set of parameters, a search algorithm has been implemented. The algorithm we used, DIRECT, performs a tradeoff between local and global search. In this way, we have evaluated the influence of each parameter for which the simulations fit the measurements. In practice, we found that standard parameters values (*i.e.* the refraction index of air for free propagation, index of concrete for walls, ...) allows a good fit between measures and simulations (see Figure 3). Because the time needed to find all of these parameters is wide enough, we propose a more efficient optimization principle which resumes only to find a scaling factor.
- Another important feature concerns the directivity of antennas. Albeit, APs are often made with omnidirectional antennas, practical measurements often show that the radiated field is subject to non-omnidirectional radiation patterns. Indeed, radiating elements are not often perfect omnidirectional and moreover, the surrounding material (device, battery, ...) impacts the resulting radiation pattern. Because the MR-FDPF method initially used point-sources, we exploited the well-known principle of electronic beam-forming for achieving a more realistic radiation pattern synthesis [63], [78].
- The computational load is concentrated on the pre-processing phase and consists in successive matrix inversions up to a size of about 1000x1000. The first version of WILDE used the COLT library, developed at the CERN, for matrix computation. We have developed a JNI interface between the COLT procedures and a BLAS library (http://math-atlas.sourceforge.net/). The computational load then drastically reduced because the matrix inversion in JAVA was slow down due to the memory management. The computational load also depends on the way the multi-resolution is built. This problem has been extensively investigated in last year.

  The problem addressed this year is the extension of the method for the purpose of 3D simulations. The mathematical complexity drastically increases and maintaining a reasonable computational

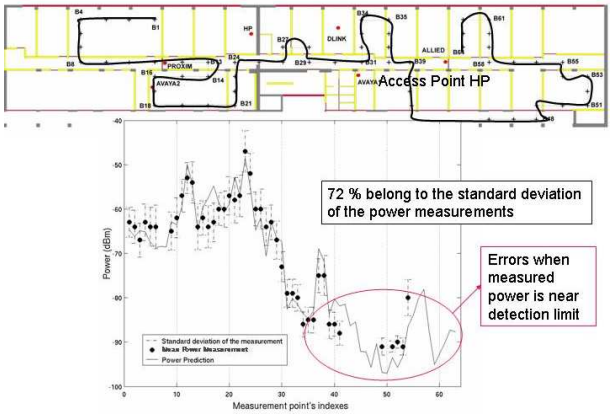

Figure 3. experimental measurements are compared to simulated values. Main errors are concentrated in areas where the signal level is low.

is challenging. The first proposition was to develop a $2,5D$ approach dedicated to multi-floored buildings [52]. the $2D$ algorithm ran for the source floor and resulting maps of flows are used as sources at other flows. This approach was shown a good trade-off between realism and complexity in the case of multi-floored building.

However, when the simulation environment includes a very high room such as a hall, the 2,5D fails to render accurately the propagation. For this reason, a full-3D implementation has been investigated [53]. The complexity is reduced by the use of an intermediate frequency (as in 2D), and a singular value decomposition (SVD) has been introduced in the computation of propagation matrices to reduce further the size of the problem. Consequent prediction accuracy and computational load reduction are now under investigation.

6.1.2. Performance evaluation in hybrid networks

6.1.2.1. Wireless LAN behavior and optimization , , , ,

The QoS of hybrid or mesh networks relies firstly on the design of the access network. The access network planning should take into account the properties of the environment (propagation) and should model the interferences between mobiles and access (AP) nodes. Then, the QoS can be assessed. The location of APs and their emission power have to be determined with care during the network planning stage. The planning problem can be tackled in different ways according to the optimization goals that have been chosen. The traditional approach computes coverage maps and selects a configuration satisfying a unique constraint on the signal level, based on a minimum threshold. The evaluation of a solution (APs configuration) relies then only on a propagation simulation computation. This simulation is often an expensive computational operation but severely reduced by the use of WILDE.

Since last year, we have proposed more efficient criteria than the only coverage requirement. These criteria are service oriented since they take into account the aim of the wireless access network. The first proposed criteria concerns the throughput of the network.

Analytical models for evaluating the behavior of wLANs are based on Markov chain modeling. The model deals with interferences using a packet error rate parameter and handles heterogeneous data throughput [35]. The MAC policy (CSMCA/CA) is accurately modeled and such a modeling provides an estimation

of the resource sharing experienced by the nodes in a given cell.. Mean throughput predictions exhibit good agreement with experimental results.

This realistic throughput model has been used to develop a throughput based objective for the wLAN planning problem [34]. In this work, this throughput objective is combined with a coverage objective and an interference minimization objective to ease the final frequency allocation done in a second step.

This second step is described in [54]. Many works devoted to this problem exploit a graph-based modeling where each AP is considered as a node and each edge refers to the radio link between both APs. This leads to an under-constrained problem because this model takes the AP's interference level (uplink) into account, instead of the interference experienced by mobile nodes (downlink). In this paper a new QoS-based FAP criterion is formulated from the overall throughput taking downlink interference into account. Our approach is shown outperforming usual graph-based FAP approaches concerning the effective SINR obtained at mobile nodes after frequency assignment.

Combining different criteria (coverage, interference minimization, throughput) appeared as a difficult task, especially for assessing the best trade-off between all constraints. Trade-offs aim at weighting constraints on the base of their relative importance. The existence of an exponentially large number of possible options makes the planning process difficult. For this purpose we focused our work on multi-objective resolution algorithms. In a multi-objective approach, the constraints are considered each one independently. All possible solutions are evaluated with respect to all objectives and are compared in a vectorial space of size N, N being the number of constraint. A solution is a member of the Pareto front if no other solution has been found which is better in all objectives The Pareto front is defined as the set. We have adapted our Tabou algorithm in a multi-objective framework. Then the combination of several criteria has been investigated [32], [10].

6.1.2.2. Performance evaluation of 802.11 unfairness using process algebra , , ,

Analytical modelling and performance evaluation of 802.11 has been widely made using classical stochastic tools as Markov chains. Such models provide a framework to evaluate throughput, collision rate, etc. Nevertheless, if we need to investigate several protocols or several network topologies, new models should be proposed each time. More, the key problem is not to model a dedicated scenario but to solve it due to the space states constraints. In our point of view, stochastic process algebra are powerfull tools to deal with wireless networks modelling because of the compositional approach and because of the use of the congruence paradigm of an algebra to reduce the space state. Thus, in these works, we use PEPA (Performance Evaluation Process Algebra): a stochastic process algebra dedicated to the study of communications systems. In [48], we developed a new analytical generic model of wireless network in order to be able to deal with different network topologies (infrastructure, hidden terminals, 3 pairs, etc.), different backoff algorithms (BEB, DIDD, etc.), different trafic assumptions (saturated case, bursty trafic), different channel properties (ideal channel, fading, etc.), different medium access strategies (TDMA, CSMA, etc.). The goal is to provide a *tool-box* in order to study the classical performance parameters of ad hoc networks and a fairness index. This generic model should be useful to design new backoff strategies in order to improve both performance and fairness. [49] focused on ad hoc network topologies only considering the famous 3-pairs and the transitive nodes one. Different backoff algorithms are considered in order to evaluate how the trade-off between performances and fairness evolved. [50] provided an analysis in depth of the hidden terminal topology. Finally, the goal of [47] is to highlight that backoff algorithms designed for ad hoc network are not efficient in the case of an infrastructure wireless network, and vice-versa. We investigated 2 topologies: infrastructure networks with n nodes ($n \geq 2$) and the classical hidden terminals topologie. In these two cases, we compared BEB, DIDD, inversed BEB and MILD.

6.1.2.3. Wireless Sensor networks sensitivity to a real physical layer , ,

The plethora of recent papers relative Wireless Sensor Networks (WSNs) allowed to provide the scientific community with several reference applications and few hard points. Energy consumption, radio resource sharing and transmission reliability are very important topics. In the frame of the ARC IRAMUS, we have worked on introducing realistic models in usual practical applications. The first problem investigated in collaboration with the INRIA project POPS, concerns the energy minimization of wide scale dense WSNs

thanks to activating/sleeping protocols aiming at reducing the number of simultaneous active nodes. In many works, the radio link is assumed perfect, which means that the radio link between two nodes is switched (on/off model). In practice the radio link in a realistic environment is rather probabilistic. Thus, a radio link always experiences an error probability, which increases with the distance. This problem is even more important with fading and shadowing. We have firstly shown that introducing a realistic radio link (i.e. a PER is associated with each link) has a great effect on activating/sleeping algorithms. Positive algorithms are more robust than conventional ones [23], [22]. We have secondly shown that a realistic energy model is needed for optimizing these algorithms [22].

The last investigated issue concerns the connectivity of WSNs. Connectivity is an important feature because it warrants that all nodes are able to transmit their sensed information to a sink. We have introduced a realistic radio link (PER) taking into account realistic channels to enhanced the connectivity model [73]. This work shown analytically that more than 50% of radio links may be 'unreliable', if a realistic channel is taken into account. This means that working with classical protocols (requiring reliable links) needs to suppress long-hop links virtually to achieve reliable transmissions. This however reduces drastically the energy efficiency of the WSN. On the opposite, this work shows that the use of opportunistic routing algorithms, able to exploit even unreliable links is a very challenging issue since these unreliable links often exist.

6.2. Protocols design

Keywords: *MAC*, *architecture*, *auto-organization*, *energy*, *hybrid networks*, *quality of service*, *wireless sensor networks*.

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6.2.1. Sensor networks

In the last quarter 2005, we launched a new and transversal activity inside the INRIA ARES project on sensor network. The mains goals are to gather the research efforts produce in the various research domains of ARES and to offer a common platform where our team may launch experimentations in situ. Our first work was the design of the node hardware. This one year investment done under the project named Worldsens[3] is now operational and we are able to test and deploy our own sensor applications. Note that this effort is done in a multidisciplinary collaboration, namely with the COMPSYS INRIA project and with the CEGELY laboratory.

In parallel to this hardware design and production, we have also invest in the development of a full integrated platform for the design, development, performance evaluation and profiling of applications for wireless sensor networks. A first main characteristic of Worldsens development platform is that once the design choices have been made, the simulation platform only handles the real application native code in order to test and validate the application at the instruction level. We do not want to impose to developers the task of rewriting their application in a particular description language or to transform low level parts of their code in order to be compliant with our simulation tools. In addition to this, we have designed our Worldsens simulation tools (WSim & WSNet) with respect to the following goals:

- Worldsens captures the behavior of the node application at a very low level, using the native code: instruction level, bit level and interrupt level.
- Worldsens reflects the behavior of the network. At the same time, one may tune the degree of accuracy from an ideal network layer where all transmitted packets are received to a network model taking into account collisions, SNR and radio propagation.
- In order to model the behavior of a global application, Worldsens handles large sensor networks, with hundred to thousand nodes.
- Worldsens handles precise timing in order to get the behavior of interruptions and byte level radio simulation.

[3] http://www.worldsens.net

In [16] and [17] we present and demonstrate the use of the Worldsens platform in the process of a fast prototyping of wireless sensor network applications & protocols.

In the CAPNET project we propose to deploy large-scale secure ambient dynamic networks so that they can be analyzed and modeled based on data obtained in real-life situations. The several and in situ test beds deployed will be an opportunity to gather large amount of experimental data in order to conduct studies on such ambient dynamics networks. One test bed will be composed of more than 200 sensor nodes, distributed to students at INSA de Lyon, in several departments. We ask them to carry them continuously in order to record not their location, but the interaction that a such dynamic network creates. Moreover, based on the knowledge of the underlying ambient networks, we will be able to deploy and test security mechanisms in order to guarantee the security of the data collected, to design strong privacy aware data gathering and also test the deployment of embedded ambient applications.

In order to setup this large experiments, a preliminary work in the design of the CAPNET application, is the design of the MAC layer and the neighbor discovery protocol. In order to get energy efficient neighbor discovery we choose to adopt a cross layer approach by designing and dimensioning both protocols (MAC & neighbor discovery) together. In [26], we analyze the impact of radio interferences on a discovery protocol. As expected, we prove that, in average a node discovers only a subset of its possible neighbors. We propose an analytical models that allow to compute the average number of neighbor as a function of the transmitting power of nodes and the density of nodes. This model allows to provision a given Hello packet protocol and to optimize it by adding sleeping periods.

6.2.2. Ad Hoc Architectural design

We have a continuous activity on the design of ad hoc architecture (namely an4 and ana6) and our main activity in 2006 was to perform support to our industrial transfers. Based on the draft of ana6. describing an IPv6 Addressing Architecture Support for mobile ad hoc networks and also a IPv4 version that introduces a 2.5 ad hoc layer, we have developed further our view of a global architecture for an ad hoc network. The notion of IPv6 connector introduced allows several network interfaces to be virtualized into a single addressable object. A host may have several ad hoc connectors and an interface may be bound to several ad hoc connectors. The ad hoc connector defines a set of addresses which indistinctly identifies all bounded interfaces. This notion of ad hoc connector is simply implemented in IPv6 by defining a third IPv6 local-use unicast address: ad hoc local addresses. Their validity is restricted to an ad hoc network. They provide a basic identification support for ad hoc nodes that can be extended by other configuration mechanisms such as stateless global address attribution. In the IPv6 architecture scheme, an ad hoc network may be at the same time, a multi-link subnet and a multi-link multi-subnet. Considering the whole ad hoc network as a multi-link subnet is achieved by matching a particular multicast scope, the subnet scope, with the ad hoc network. To support the multi-link multi-subnet vision, the notion of logical ad hoc sub-networks, also called area, is introduced. A area is a connected set of ad hoc connectors sharing a common area value. A specific range of multicast addresses is associated to each area. It enables the restriction of multicast groups to a given area. An implementation of this IPv6 ad hoc framework is now available under FreeBSD via sourceforge (http://sourceforge.net/projects/anax).

Based on previous work where we we consider the problem of interconnecting several hosts in a spontaneous hybrid and heterogeneous network, *i.e.* an environment where wired and multi-hop wireless technologies are used we develop tools to monitor and manage such heterogeneous networks. We also enhance our software development of ana4 under Linux and Windows XP. The new version support QoS capabilities at the ad hoc layer (2.5) and allow to grant a privilege on stable wireless connexions or fastest interfaces.

In [18] we address the problem of duplicate address detection in Wireless Ad Hoc Networks. Our method rely on the use of the underlying medium and we do take into account the multicast advantage provided by the wireless medium.

6.2.3. Auto-organization in large scale networks

In order to be able to use ad hoc networks on a very large scale, flat routing protocol (reactive or proactive) is not really suitable. Indeed, both routing approaches become ineffective for large scale wireless ad hoc

networks, because of link (flooding of control messages) and processing overhead (routing table computation). One well known solution to this scalability problem is to introduce a hierarchical routing by grouping geographically close nodes to each other in clusters and by using a "hybrid" routing scheme: classically proactive approach inside each cluster and reactive approach between clusters. Such an organization also presents numerous advantages such as more facility to synchronize stations in a group or to attribute new service zones.

We are also conducting works that focus on problems of fault tolerance and scale in distributed system [36], [37] Such systems motivate designs that autonomously recover from transient faults and spontaneous reconfiguration. Self-stabilization provides an elegant solution for recovering from such faults. We present algorithms in order to obtain fast Convergence in Self-stabilizing Wireless Networks. The underlying method is based on a a family of self-stabilizing vertex coloring algorithms and a trick that consist in braking symmetries in the context of wireless networks. Overall, our results show that the actual stabilization time is much smaller than the upper bound provided by previous studies.

In [24], we compare two self-organization and hierarchical routing protocols for ad hoc networks. These two protocols apply the reverse approach from the classical one, since they use a reactive routing protocol inside the clusters and a proactive routing protocol between the clusters. We compare them regarding the cluster organization they provide and the routing that is then performed over it. This study gives an idea of the impact of the use of recursiveness and of the partition of the DHT on self-organization and hierarchical routing in ad hoc networks.

In [37], we present a complexity analysis for a family of self-stabilizing vertex coloring algorithms in the context of multi-hop wireless networks. Such 'coloring' processes are used in several protocols for solving many different issues (clustering, synchronizing...). Overall, our results show that the actual stabilization time is much smaller than the upper bound provided by previous studies. Similarly, the height of the induced DAG is much lower than the linear dependency on the size of the color domain (that was previously announced). Finally, it appears that symmetry breaking tricks traditionally used to expedite stabilization are in fact harmful when used in networks that are not tightly synchronized.

6.2.4. Self-Organization with a virtual topology for hybrid networks

Two approaches of mobile ad hoc networks can be considered: the classical one where the network is viewed as flat and a more recent one where the network is structured through a logical view. In this work, the logical view is associated to a virtual topology: a virtual topology is defined as a hierarchical organization based on both backbone and clusters. The backbone constitutes a spine carrying control traffic, disseminating information in the network. The clusters provide services areas with a leader (the clusterhead). This structure has several major goals:

- To hierarchize the nodes in creating leaders and clients;
- To distribute roles taking into account the natural heterogeneity of hybrid networks;
- To create a logical view above the physical view;
- To introduce stability in a volatile environment.

In the first part of this work (year 2004), we investigated the behavior and the key properties of such self-organization. We have also introduced robustness and how to use this work to develop a mesh network in mobile ad hoc network. In 2005, self-stabilization and analytical properties was investigated. The goal was to demonstrate that it is always possible to provide a virtual topology despite the radio environment and the mobility effect. We have also shown that a local change only implies a local reconstruction on the virtual topology. The main objective was to provide layer 3 protocols taken into account this self-organization. A routing protocol (called VSR, *Virtual Structure Routing*) was proposed and a mobility management protocol too (SoMoM, *)Self-Organized Mobility Management*. These works highlighted the benefit provided by the use of a self-organisation. In 2006, intensive performance evaluation studies have been done in order to characterize how a routing protocol based on self-organization is more efficient than the classical flat approach (OLSR, DSR) or the hierarchical one (CBRP). In [62], VSR appears to be a good trade-off between pro-active and reactive protocols.

One another question is: because a self-organisation is based on *better* nodes which are more solicited for the network, bottlenecks can appear and, thus, the network capacity can decreased. We refer to the network capacity as a flow problem. In [51], an analytical framework to study the capacity in mobile ad hoc networks an hybride one is presented. The input of this model is the network topology, the routes provided by a routing protocol (OLSR for flat networks, VSR for structured one). The output provided upper and lower bounds. The main result is: in case of ad how network, the capacity is not affected by a self-organisation scheme but the capacity decreases strongly in case of hybride network.

Currently, we experiment the self-organisation scheme and the mobility management protocol using the mesh networks of the CITI laboratory. The software is available at http://sourceforge.net/projects/somom. The application is spontaneous extension of wireless networks.

6.2.5. Autonomic mechanisms for wireless sensor networks

This work is financed and supported by France Telecom R&D under CRE No 46128746 with PACIFIC team since November 2004. This research project funded the PhD thesis of Jia-Liang Lu. Mr Lu did his first year of his Ph.D. in the CITI laboratory and the two last year in the ILAB Team, FTRD Beijing, China.

The goal is to provide autonomic mechanisms for wireless sensor networks in order to allow spontaneous deployment without human intervention, without centralized control. We refer to autonomic mechanisms as self-* protocols. Self-* can be associated to self-configuration in order to configure the nodes Id. without human intervention. This mechanism provided also duplicated address detection protocol. Self-* is also associated to self-organisation where we provide a logical view of the network: the topology provided is a connected backbone. This self-organisation can be used for data-dissemination and/or data-aggregation. Finally, self-* also refer to self-healing in order to maintain active the self-organisation scheme. We provide an integrate self-configuration / self-organisation scheme. A patent is associated to this mechanism.

6.2.6. MAC protocols for ad hoc networks

The IEEE 802.11 MAC layer is known for its unfairness behavior in ad hoc networks. Introducing fairness in the 802.11 MAC protocol may lead to a global throughput decrease. It is still a real challenge to design a fair MAC protocol for ad hoc networks that is distributed, topology independent, that relies on no explicit information exchanges and that is efficient, *i.e.* that achieves a good aggregate throughput.

We have proposed a new MAC protocol based on 802.11, called MadMac, that provides more fairness than 802.11 while maintaining a good aggregated throughput in ad hoc networks [46]. MadMac is based on two main mechanisms. The first mechanisms is: a station divides its throughput by 2 at the MAC layer if it detects an activity from one or more stations. This division is done by introducing a extra waiting time before transmitting a new packet. The second mechanisms tries to fine tune this extra waiting time according to the activity/collision experiences by the station. These mechanisms are only based on information provided by the 802.11 MAC layer and its behavior is not probabilistic.

We have compared MadMac with 802.11 from fairness and efficiency points of view. These comparisons have been carried out in many basic scenarios that are known to lead to fairness issues and in more complex topologies. Results, from these simulations, show that, in most of the cases, MadMac provides a better fairness and maximizes the aggregate throughput when unfairness is solved.

Future works would be to investigate other ad hoc topologies like random topologies, and to propose an analytical evaluation of MadMac in order to make it fairer and efficient.

6.2.7. Solution to the performance anomaly of IEEE 802.11

In the widely used 802.11 standard, the so called performance anomaly is a well known issue. Several works have tried to solve this problem by introducing mechanisms such as packet fragmentation, backoff adaptation, or packet aggregation during a fixed time interval. In [45], we propose a novel approach solving the performance anomaly problem by packet aggregation using a dynamic time interval, which depends on the busy time of the wireless medium. Our solution differs from other proposition in the literature because of this dynamic time interval, which allows increasing fairness, reactivity, and in some cases efficiency. In

this work, We propose an analytical evaluation of our protocol in the classical scenario where all stations are within communication range and a detailed simulation-based evaluation. We evaluate our protocol in terms of efficiency and of fairness on many configurations not limited to one hop networks. We also compare our solution to three different approaches that belong to the three main classes of solutions solving the performance anomaly.

6.2.8. QoS in ad hoc networks: evaluation of the available bandwidth

In this work, we try to propose a more accurate mechanism to evaluate the available bandwidth than the one used in the BRuIT protocol. Such an evaluation is necessary to provide an efficient QoS protocol to manage bandwidth in ad hoc networks.

The available or residual bandwith of a link is the maximum throughput that can be injected on a link without degrading the close communications. Therefore, we have proposed a new technique to estimate the available bandwidth to wireless nodes and by extension on one-hop links in IEEE 802.11-based ad hoc networks [59]. Our technique exploits the fact that both sender and emitter can estimate channel occupancy by monitoring their vicinity. It provides a non-intrusive estimation meaning that it does not generate any additional traffic to perform the evaluation. We have also developed a protocol based on this technique which periodically broadcasts node information on it's one hop neighborhood, so the receiver is able to compute its available bandwith with the sender.
We show by simulations that our technique provides an accurate and scalable estimation of the available bandwidth on wireless links in many ad hoc configurations. However, there are some topologies in which this technique does not give accurate estimates mainly due to phenomena like collisions, but we have proposed some improvements to adapt to these constraints.

6.2.9. Energy-efficient cross-layer design for Wireless Sensor Networks

6.2.9.1. Using cross-layering for energy efficiency

The layered approach has been introduced in traditional wired networks because it clearly separates the different tasks the communication stack needs to perform. This leaves the user the possibility to build his stack, assembling interchangeable layer blocks. Yet, this approach shows to have some drawbacks for Wireless Sensor Networks (WSN). This is mainly attributed to the low-energy nature of the nodes. In a fully layered approach, a given layers has a very abstract view of lower layers, and a situation can arise in which for example the radio module of the radio is constantly on (which is an issue of the physical layer), whereas the node is scheduled in such a way that there is no data to transmit or receive (which is an issue of the MAC layer). Energy is thus lost at the interface between layers.

To alleviate this effect, the concept of cross-layering has been introduced. Using cross-layering, we make layers work together to yield the most energy-efficient solution. Working together can mean increasing the interactions between layers, or merging different layers.

6.2.9.2. Using preamble-sampling in a cross-layering approach

Approximately 80% of a node's energy is used by the radio module, when this module is on. When the radio module is active, it can be either sending/receiving a message, or idle listening (listening to the medium for a message). In fact, it has been shown that the power consumed for idle listening is very close to the power used for sending/receiving. This means that the only way to reduce power consumption of a node (hence increase the node's lifetime), is to turn off its radio as much as possible.

Preamble sampling is a clever way of turning the node's radio off. Each node chooses its own sleep/wakeup schedule independently of the others and a node transmits a preamble before each data frame which is long enough to make sure that all potential receivers will get their data. According to the duty-cycle parameter, nodes switch periodically their radios on to sample the channel. If a node finds the channel is idle, it goes back to sleep immediately. However, if it detects a preamble transmission on the channel, then it keeps its radio on until it receives the subsequent data frame. After the reception of the data frame, the node sends an ACK frame, if needed, and goes back to sleep afterward. To be effective, preamble transmission needs to be at least as long as the check interval, the period between two consecutive instants of node wakeup. In this way, a node

makes sure that all potential receivers are awake during its preamble transmission and they get the subsequent data frame.
We have applied the cross-layering approach to preamble-sampling MAC protocol. We have to take advantage of the low-energy nature of this MAC protocol, i.e. we have to build a routing layer which is tailored to preamble-sampling. With this in mind, we have designed 1hopMAC, a energy-efficient cross-layer MAC/routing protocol.

6.2.9.3. Energy consumption and neighborhood knowledge

As detailed in the above paragraphs dealing with self-organization, the main problem of a flat routing approach (as opposed to hierarchical), is that nodes needs to keep information about their neighbors. This is done by using hello message: each node broadcasts information about itself which is useful to its neighbors. Each node then builds a neighboring table, based on the received hello messages. In order to adapt to changes in topology (nodes can for example disappear because of battery exhaustion), this local broadcast needs to be done periodically. This simple proactive approach is very energy-inefficient, as information is constantly exchanged even if no useful information is brought into the network. We thus have adopted a reactive approach, in which a node learns about its neighborhood only when needed, having close to zero consumption when no useful information has to be exchanged.

6.2.9.4. The 1hopMAC protocol

We consider each node knows its geographical position, and the position of the destination node. Each node can does calculate its distance to destination. We will can this distance the metric of the node. A straightforward way to route a message from a given node to destination is to send it to the neighbor node with smallest metric (i.e. the one closest to destination). Using this simple flat routing algorithm, the message eventually reaches destination, in a multi-hop way. Nevertheless, nodes have to know there neighbors' positions. As explained before, this also involves some neighborhood knowledge. To be energy-efficient, we build this knowledge in a reactive way, and this is precisely what 1hopMAC does.

Without useful traffic, 1hopMAC behaves exactly like preamble sampling. Only when there is some information to transmit – generated or relayed by the node – it exits the preamble mode. The current node performs a sort of 3-way handshake: (1) it broadcasts a request message (2) each neighbor node hears that message and answers with a backoff time proportional to its metric and (3) the node sends the data to the node which answers first. After this, it resumes it's preamble sampling mode.

6.2.9.5. Changing the metric of the node for robustness

We have furthermore studies geographical routing techniques which guarantee delivery. Indeed, the simple greedy approach can fail. By changing the metric a node contains, we obtain an energy-efficient MAC/routing protocol for Wireless Sensor Networks which guarantees delivery.

6.2.9.6. Current and Future work

We are currently implementing 1hopMAC on GTSNetS, a network simulation developed at Georgia Tech, Atlanta, USA. The next step is to study the occurencies collisions with GTSNetS. As future work, we would like to port our solution from geographical routing to gradient based routing, in which a common destination node flood the network with a message so that each node knows it's distance to that destination. Routing can then be done by following the inverse path of that initialization message. With our protocol implemented in GTSNetS, we will be able to compare it with existing MAC protocols (e.g. IEEE 802.11), especially from a energy consumption point of view.

6.2.10. Energy constraint

We have pursued our studies on the energy consumption in wireless ad hoc and sensor networks. There has been an increased awareness of energy efficient protocols need for battery-powered devices in recent years. Though the optimization of the sensor network lifetime must take place at each stage, we focus mainly on the sensing and communication levels. Indeed, data transmission and reception using a wireless medium appears to be a highly energy consuming process. Nodes are assumed to adapt their transmission power to the minimum required to sustain communication.

In classical energy model, the amount of energy required to transmit data is proportional to the number of emitted bits and depends on both the communication range and the distance power gradient. Note that regarding this model, reception of a message is not a low cost operation and can not be neglected in comparison to the transmission cost. Indeed, the amount of energy needed for a reception is of the same order of magnitude as the one needed for transmission and is also proportional to the number of received bits. In consequence, as opposed to all the existing work done, energy aware protocols should not only try to reduce communication ranges but should also minimize the number of transmission and reception operations for each message. Our new work focuses on the determination of minimum-cost (*i.e.*, minimum energy consumption) routing. Our main contribution [15] investigate the optimal radio range that minimizes the energy globally consumed by a geographical routing process. In a first step, we consider a common radio range for all nodes. In a second step, we derive a distributed algorithm which attributes variable radio ranges to the sensor nodes. Considering a geographical greedy routing protocol and a uniform distribution of nodes in the network area, we analytically evaluate the energy cost of a multi-hop communication. This cost evaluation corresponds to the asymptotic behavior of the routing protocol and turns out to be very accurate with regard to the results obtained by simulations. We show that this cost is function of the node intensity and we use this result to deduce the optimal radio range. We evaluate this range considering two energy consumption models, the first one considering the energy consumed by transmission operations only and the second one considering both transmission and reception operations. These results can be used in two ways. First, the range of the nodes can be tuned in advance as a function of the expected intensity of nodes during an off-line planning. Second, we propose an adaptive algorithm where nodes tune their powers with regard to an on-line evaluation of the local node intensity.

6.2.11. Real-time communication in wireless sensor network

The goal of this work is to propose new protocols for real-time communication in wireless sensor networks. Critical applications need to know guarantee and bounded response times after detecting a given event. For those applications, the underlying communication network needs to guarantee a given quality of service, mainly in terms of transmission delays and fault tolerance.

Our first results let us define a new MAC protocol [65] which guarantees timeliness constraints in the Worst Case, for a one dimensional wireless sensor network. Application examples include highway car accident monitoring, production chain surveillance, and railway train tracking. Our current work focuses on comparing our real-time protocol's performances with other more classical protocol's (where in case of collision alarms are retransmitted after a random waiting time), and extending our protocol to three dimensions, by proposing a hard real-time cross-layer protocol.

6.3. Middlewares for dynamic environments

Keywords: *Middleware*, *security*, *services instrumentation and administration.*

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Our activity is divided in three axes: Constrained Middlewares, Service deployment and administration and Global security model.

6.3.1. Constrained environments

We have released extensions to the OSGi framework to enable it's execution in constrained environments. We have designed VOSGi (Virtual OSGi) framework which enable multiple instances of OSGi executed in a embedded mode. In order to reduce the initial size of virtual machines, we have developed a tool that analyses Java classes dependencies. The tool builds a specific run-time archive that contains the strict minimum of classes needed to run the application.

6.3.2. Services deployment and administration

MOSGi is a complete management framework (agent/console) for OSGi gateways. It as been released in the main code trunk of Felix project (apache incubator). It is a complete and dynamic solution based on JMX for managing remote systems.

Proposals have been done in service integration in pervasive environments. We are proposing a framework that enables service composition at run-time and in a semantic way. Services are composed through a specific integrable interface that implements various contextual behaviors.

We have released POSGi, which is a P2P (peer to peer) framework for OSGi that aims at automatically provision bundles through a P2P network. In our approach bundles are uploaded on demand when an client application needs a service. The uploading of these bundles is made through a P2P protocol.

6.3.3. Trust framework for mobile devices

The ARES project is currently working on trust models for mobile communicating smart devices (see the KAA project). An initial model we proposed is a trust management scheme matching this definition of context awareness. The solution does not make any assumptions concerning the presence of any fixed infrastructure (the terminal can be in full ad hoc mode), while the proposed architecture could take advantage of any encountered access points to contact fixed servers. We believe that trust cannot be a attributed Boolean value (trusted terminals versus compromised terminals), but must entail various levels of trust belonging to various levels of offered services. For example, a smart device equipped with a web cam can probably offer the ad hoc routing service to most of the nodes in its environment as long as the behavior of the nodes is not suspicious. The same device could allow terminals attributed with slightly more trust to access the video flow. And the same terminal will probably require a strong level of trust before allowing a foreign node to access the web cam's configuration interface. Trust is created starting from a low level and grows during the establishment of what we term an ambient community. We propose an architecture based on self-organized communities of terminals with simple mechanisms to accept nodes in an existing ambient community, to establish the appropriate levels of trust, and also to reject or detach a suspicious node. Our solution is a mixture of context awareness and recommendation schemes. The basic mechanism is built upon the notion of node history (often called credentials), which is used to build a specific shared secret. Then, nodes aggregate when exchanging data and services into an ambient community, which is the ultimate level of organization.

In 2005, we have proposed a novel cryptographic scheme to be included in the KAA framework. More precisely, the scheme is the basic foundation of the Common History Extraction (CHE) protocol. The trust decision is based on the use of informations cryptographically proved, to reduce this risk. Roughly, smart devices record past interactions between autonomous nodes in a *history* (after a bootstrap phase); to interact, nodes first search previous common met nodes in their histories; then, they mutually authenticate; and finally, they prove, using a security protocol presented here, that these common interactions really took place. If the number of such common interactions is sufficient that is, upper a certain threshold, then the interaction may occur.

The security protocol proposed is based on the notion of cryptographic ID first introduced by A. Shamir, adapted to elliptic curves by D. Boneh and M. Franklin for the cipher and used by Chen, Zhang and Kim for a signature without a trusted PKG (Private Key Generator). The main advantages to use elliptic curve identity based cryptography is the gain in size and in computational time in adequacy with small devices used in ambient networks such as PDAs or smart phones. Moreover, user's public key being or being derived from his identity, there is no requirement of public key directories. Also, key distribution being far simplified, this make ID-based cryptosystems advantageous over the traditional Public Key Cryptosystems (PKCs).

In 2006, we have performed a security analysis of this protocol regarding the most usual attacks known against ad hoc network. We have implemented our protocol on several platforms and have studied its performance considering the lack of resources in the ad hoc context. Especially, we have tried to limit the required number of exchanges between the parties. We have also performed a probabilistic evaluation on the required size of the history taking into account our threshold. We also have performed some simulations to prove the relevance of our approach.

Currently, we try to generalize our protocol and our approach in case of a community of ad hoc nodes, using some particular cryptographic tools and simulations.

6.3.4. Other security aspects

The ARES project is also working on the traditional aspects of the cryptology under two main aspects: constructions and attacks for block ciphers and stream ciphers and construction of asymmetric protocol based upon elliptic curves.

Concerning the first topic and especially the stream cipher aspect, an updated version of the stream cipher DECIM has been submitted to the European Network of Excellence ECRYPT (work package eSTREAM) because the previous version has been attack successfully.

Moreover, With the new class of attacks called algebraic attacks, it becomes dangerous to use LFSR (Linear Feedback Shift Register) as a transition function in a streamcipher dedicated to software and hardware purposes. Some other constructions oriented hardware using FCSRs have been recently proposed for the ECRYPT call for streamcipher primitives [14]. A FCSR (Feedback with Carry Shift Register) is a binary automaton with carries. All the results concerning the complexity, the provided period comes from the 2-adic theory. So, actually, we are working on this new research area.

We also are studying new propositions relevant for the second topic and we are trying to build a new identity-based aggregate signature scheme without a trusted private key generator (PKG).

7. Contracts and Grants with Industry

7.1. Contracts and Grants with Industry

Alcatel R&D The main focus of this contract is to address the concern of operators to lower their operational expenses (OPEX). Since networks are converging towards IP technology, we focus on this protocol and more specifically to its latest version: IPv6. More specifically we are interested in self-configuration of intelligent routers with respect to several of their key features: address and routing, security. This project in in collaboration with ENST Bretagne.

Embedia Those who communicate messages are always in search of attractive ways to carry their information more effectively. When placing outdoor advertising campaigns, 30-second television commercials on large screens (14.69ft x 11.02ft), displaying advertisements, video footage and general information on buildings and walls in busy metro, market, restaurant and/or nightlife districts, the main problem is to carry the messages and update the information. The key idea was to use Ana4 to build a “video billboard mesh network” in order to perform content delivery and network management without deploying a wired network. It’s always more easy to get a power supply on outside building wall than a RJ45 like plug. This project is in partnership with a newly created company which is an interactive communications solutions provider and creates an innovative state-of-the-art link between businesses and their consumers and its patented solution delivers interactive multimedia content directly to end-user devices.

Exaprotect The ARES project is involved in a strong collaboration with the Exaprotect Compagny including two PhD students. The focus of this work is the imporvement of network intrusion detection system (IDS). Network-based computer systems play an always increasing vital roles in our society but are full of security flaws on many levels. Finding and fixing all the flaws - by formal methods, is not technically feasible. If such a defense drastically reduces the threat it can not canceled all corruptions, especially the one from insider attacks. An IDS is used to detect all types of malicious network traffic and computer usage that can’t be detected by a conventional firewall. By monitoring and analyzing system behavior, IDS are suppose to detect violations of security policy. This monitoring can be done at many different levels in the systems. Although their main weakness is certainly the absence of global vision. Classical IDS have only a local and very specific view of

the system. Moreover, the majority of classical IDS use signature detection prohibiting the detection of unknown attacks. The goal of our work is to enforce this global vision of the system for an IDS. To do so we first extend the domain of monitored events to events not directly involved in security achievement. The second problem addressed isthe introduction of a behavior analysis.

France Télécom R&D The project *ARES* has several contracts with FT R&D:

FT R&D, Grenoble *ARES* has three contacts with FT R&G Grenoble (Meylan). First, *ARES* and France Telecom R&D, Meylan have contracted a collaboration in the field of multi-mode multi-antennas terminal design. This project aims to evaluate the potential of multi-antennas systems put into a multi-standard environment. The heart of the work concerns interference cancelation in an aware framework. The key point is to show how a multi-antennas terminal can exploit the spatial diversity to cancel multi-standard interferers. The efficiency should be assessed by simulations and with a demonstrator, in wLAN and *ad hoc* contexts.

Second, France Telecom R&D under CRE No 46128746 with PACIFIC team financed a work on self-configuration and self-organisation in communicating objects networks. This research project is also the PhD thesis of Jia-Liang Lu. The goal is to identify the key mechanisms to deploy communicating objects networks or sensor networks in an autonomous way. So, self-configuration, self-organization and self-healing are the main topics we study.

Finally, an agreement has been established between France Telecom R&D and INSA de Lyon (CITI Laboratory) through INRIA. This contract supports the PhD thesis of Thomas Watteyne by a government agreement (CIFRE). The contracts goal is to study and optimize wireless sensor network initialization mechanisms, from an energy point of view.

FT R&D, Caen This CRE (*Contrat de Recherche Externalise*) with FT R&D concers the study of addresses and routeurs autoconfiguration mechanisms in IPv6 SOHO netwoks. The goal is to develop a protocol suite enabling a full zero-configuration solution for IPv6 home networks. This project in in collaboration with ENST Bretagne and IMAG.

FT R&D, Lannion France Telecom R&D under CRE No 46128746 with the SPONTEX project financed a work on rates optimization in 802.11 based ad hoc networks. The goal of this project is to propose optimizations of 802.11 in a multihop context from a fairness and efficient points of view.

Sygman The regional incubator CREALYS supports the creation of a local start-up which aims to propose tools to monitor and control mobile services for GRPS/EDGE and 3G networks. Rather to use a mobile trace to monitor the cellular network behavior only, the proposition of Sygman is to monitor simultaneously both mobile application and radio environment in order to provide user-oriented investigation and performance measures. The CITI laboratory contributes to this project under an agreement between the region Rhône-Alpes, INSA Lyon (CITI) and the contractors. Our team is charged to provide the methodology of application monitoring in cellular networks. The start-up will be created in 2006 January (see http://www.sygman.com).

Worldsens Under the Worldsens label, InsaValor is commercializing the WSim and WSNet softwares that are partly developed in the *ARES* project together with sensor nodes that are developped by the *ARES* project and the CITI & CEGELY laboratories (INSA de Lyon). InsaValor is an organization associated to the INSA de Lyon and responsible for ensuring the transfer and development of the research activities carried out in the INSA de Lyon research laboratories.

8. Other Grants and Activities

8.1. Regional initiatives

CAPNET The CAPNET project is a BQR project funded by the INSA de Lyon and gathering several laboratories of the institution: CITI, CEGELY, LAI, STOICA. Its research program aims at developing a new theoretical framework and the computational tools necessary for modelling and understanding large-scale ambient dynamic networks. In this optic, CAPNET will setup a real testbed in the Télécom department of INSA de Lyon and provide the opportunity to gather a complete map of all interactions of a given population, (i.e.) the students of the department. This testbed will be created by providing SensorLogger to each of four hundred students at the INSA de Lyon. SensorLoggers have the ability to periodically logg their neighbourhood, *i.e.* all other SensorLoggers present within their radio range.

Through this testbed, the CAPNET project will be able to collect very valuable data on energy consumption in sensor networks, user mobility and interaction. Analysis of these data will lead to fundamental advances in the understanding and modeling, and thus will provide valuable models for the design of energy efficient architectures as well as applications and protocols based on user mobility. Advances will be made in our own research fields (routing, localization, positioning, and mobility modelling) as well as orthogonal fields (e.g., sociology).

8.2. National initiatives

ACI PairAPair ARES contributes as an associated member to the ACI "masse de données" PairAPair. The purpose of this ACI (http://gyroweb.inria.fr/pairapair/) is to study a global approach fot P2P systems: model, conception, analysis, implementation of P2P protocols.

ACI Sécurité FRAGILE The purpose of this ACI (http://www.lri.fr/~fragile/) is to characterize the large-scale systems as distributed systems, in order to estimate the extent to which failure tolerance can be guaranteed in various characteristic contexts, and, in case such a guarantee is possible in theory, to propose an implementation which takes into account requirements of the context of execution. The application domains for such large scale systems are sensor networks, P2P systems and grid platform.

ACI Sécurité KAA The KAA project (Knowledge Authentication Ambient) is dedicated to trust models elaboration for autonomous smart communicating devices. KAA is a collaborative research project involving research teams in computer science, mathematical modelling and social sciences. Smart devices are dynamic groups of objects which can act together cooperatively even if they are fully strangers. With a wide use of smart communicating devices, we are facing both technical and social challenges. The KAA project proposes to look for human society trust management mechanisms and to derive a technological trust model. Such a model will lead naturally to a decentralized approach that can tolerate partial information albeit one in which there is an inherent element of risk for the trusting entity. Mathematical models (dynamic graphs and stochastic models, and also models from particles interactions) will be useful to study the dynamic of the proposed models as well as performance evaluations both in term of technological constraint (CPU, bandwidth) and security efficiency (risk evaluation).

ANR SETIN RAPIDE This project has just began in november 2006 and works for 4 years. Marine Minier is responsible of the work package "MACs construction". The aim of the ANR project RAPIDE is to construct, to study and to evaluate some new stream ciphers built upon a non linear transition function (such as FCSR (Feedback with Carry Shift Register or De Bruijn sequences for example) or to better evaluate the properties of the filtering function to discard known attacks, especially the algebraic ones. This project also focuses on the construction of MAC (Message Authentication Code) from stream cipher operations.

ARESA The ANR RNRT ARESA project is focused on the design of embedded systems and Wireless Sensor Networks in the case of different scenarios as: environmental monitoring and smart buildings. The goal of the ARESA project is to:

- Explore new event-driven and asynchronous software and hardware architectures, tailored to extremely low power consumptions;

- propose new communication and organisation protocols, which are optimised in terms of energy consumption and robustness;
- find new application protocols that are designed for data fusion and aggregation;
- study new network structures which facilitate auto-configuration and auto-organisation;
- provide tools of modelling and validation, which also take into account the physical environment and the interaction thereof with the wireless sensor nodes;
- validate the developed concepts, protocols and mechanisms by means of a testbed.

The leader of the project is FTRD and the consortium is composed by: LSRINPG, TIMAINPG, VERIMAGUJF Grenoble, Coronis Systems.

IRAMUS *ARES* heads an INRIA Cooperative Research Initiative called IRAMUS (Radio Interface for multi-hop networks). This action aims to propose new trends in the two following axes: realistic modeling and simulation of the MAC-PHY layers for *ad hoc* and sensor networks. The solutions are intended to be integrated in standard network simulators.

Assessment of the PHY-MAC interface in different applicative scenarii. Indeed, low rate sensor networks or high rate *ad hoc* networks do not require the same constraints on the PHY-MAC layers.

RECAP The RECAP project is a CNRS national platform composed of the CITI laboratory, LAAS laboratory, the LIP6 laboratory and the LIFL laboratory. It aims at supporting research activities in the area of self-adaptive and self-organized networks. It addresses many topics such as topology control (addressing, location, etc.), data communication (broadcasting, routing, gathering, etc.), architecture (hardware, system -OS-, network -communication stacks-, etc.), applications (service lookup, distributed database, etc.).

SAFARI The SAFARI project aims to design, to combine and to carry out a framework of protocols and softwares required for the transparent access, the automatic configuration, the services integration and adaptation into a IPv6 network in ad hoc configurations with wired accesses. The added value of this project is the design of new protocols and software solutions based on existing standards (IPv6, multicast, proxies, active networks, etc.) and adapted to the dynamics features of the network infrastructure and of the services demand and continuity. The different partners of the project are FTR&D, ALCATEL, INRIA, LIP6 (Paris 6 University), LRI (Paris Sud University), LSIIT (Strasbourg University), LSR-IMAG (Institut National Polytechnique de Grenoble), SNCF and the École Nationale Supérieure des Télécommunications.

SVP The SVP project addresses the understanding, the conception, and the implementation of an integrated ambient architecture that would ease the optimization in the deployment of surveillance and prevention services in different types of dynamic networks. The main objective is to develop an environment which is able to accommodate a high number of dynamic entities completely dedicated to a specific service. The different partners of the project are: CEA, ANACT, APHYCARE, INRIA, UPMC/LIP6, LPBEM, Thalès. This project is founded by ANR/RNRT.

8.3. European initiatives

AEOLUS AEOLUS (Algorithmic Principles for Building Efficient Overlay Computers) is an IP project that has been started since September, 1st, 2005. The university of Patras (Greece) is the prime contractor. The goal of this project is to investigate the principles and develop the algorithmic methods for building an overlay computer that enables an efficient and transparent access to the resources of an Internet-based global computer. In particular, the main objectives of this project are:

- To identify and study the important fundamental problems and investigate the corresponding algorithmic principles related to overlay computers running on global computers.
- To identify the important functionalities such an overlay computer should provide as tools to the programmer, and to develop, rigorously analyze and experimentally validate algorithmic methods that can make these functionalities efficient, scalable, fault-tolerant, and transparent to heterogeneity.

- To provide improved methods for communication and computing among wireless and possibly mobile nodes so that they can transparently become part of larger Internet-based overlay computers.
- To implement a set of functionalities, integrate them under a common software platform in order to provide the basic primitives of an overlay computer, as well as build sample services on this overlay computer, thus providing a proof-of-concept for our theoretical results.

AMIGO AMIGO (Ambient Intelligence for the networked home environment) is an European project (IP project) inside the FP6 Work intiative. Philips is the prime contractor. AMIGO has started since september 2004. The aim is to research and develop open, standardized, interoperable middleware and intelligent user services for the networked home environment, which offers users intuitive, personalized and unobtrusive interaction by providing seamless interoperability of services and applications.

AMIGO will focus on the usability of a networked home system by developing open, standardized, interoperable middleware. The developed middleware will guarantee automatic dynamic configuration of the devices and services within this home system by addressing autonomy and composability aspects. The second focus of the Amigo project will be on improving the end-user attractiveness of a networked home system by developing interoperable intelligent user services and application prototypes. The Amigo project will further support interoperability between equipment and services within the networked home environment by using standard technology when possible and by making the basic middleware (components and infrastructure) and intelligent user services available as open source software together with architectural rules for everyone to use. The AMIGO project is a huge step towards general introduction of the networked home and towards Ambient Intelligence by solving the main technological issues that endanger the usability of a networked home system, as well as creating clear end-user benefits by introducing intelligent user services and attractive prototype applications.

COST 295 The main objective of the COST 295 (European Cooperation in the Field of Scientific and Technical Research (http://cost.cordis.lu/)) named DYNAMO for Dynamic Communication Networks – Foundation and Algorithms–, is to structure the community of researchers working on fundamental aspects of Dynamic Communication Networks.

MOSAR IP project MOSAR (Mastering hOSpital Antimicrobial Resistance and its spread into the community) . Infections caused by antimicrobial-resistant bacteria (AMRB) account for an increasing proportion of healthcare-associated infections, particularly in high-risk units such as intensive care units and surgery; patients discharged to rehabilitation units often remain carriers of AMRB, contributing to their dissemination into longer-term care areas and within the community. The overall objective of MOSAR is to gain 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 microorganisms in hospitals, now spreading into the community. Microbial genomics and human response to carriage of AMRB will be integrated with health sciences research, including interventional controlled studies in diverse hospital settings, mathematical modelling of resistance dynamics, and health economics. Results from MOSAR will inform healthcare workers and decision-makers on strategies for anticipating and mastering antimicrobial resistance. To achieve these objectives, MOSAR brings together internationally recognized experts in basic laboratory sciences, hospital epidemiology, clinical medicine, behavioural sciences, quantitative analysis and modelling, and health economics. MOSAR brings together 11 institutions recognized for their leadership in these areas, from 10 EU Member or Associated States, as well as 7 SMEs to develop and validate high-throughput automated molecular tools for detection of AMRB. A high level of co-ordination will be obtained through a professionally IT-supported and rigorous management structure, to achieve optimal synergy of the components of MOSAR. We aim to develop and validate rapid testing for

AMRB and initiate the clinical trials during the first 18 months of the project, and then to build on the infrastructure to execute the joint research programme.

MUSE MUSE is an European project inside the FP6 Work intiative. Alcatel is the prime contractor. MUSE startied by the end of 2003.

The overall objective of MUSE is the research and development of a future low cost, full service access and edge network, which enables the ubiquitous delivery of broadband services to every European citizen. The proposed project integrates studies in the following areas:

- Access and edge network architectures and techno-economical studies.
- Access and edge platforms.
- First mile solutions (DSL, optical access, fixed wireless access).
- Networking of the access network with home gateway and local networks.
- Lab trials.

The concepts of MUSE have been validated for three end-to-end deployment scenarios:

- Migration scenario featuring a hybrid access network of ATM and packet (Ethernet, IP) network elements and CPE with embedded service awareness and application enablers.
- Non-legacy scenario showing access nodes, various first mile solutions, and CPE that are optimized for native Ethernet and IPv6 throughout the home and access network.
- FTTx scenarios integrating new concepts for access technologies - VDSL, optical access, and feeders for wireless services -, and service-aware CPE.

The expected impacts and results are:

- Consensus about the future access and edge network by major operators and vendors in Europe.
- Pre-standardization work and joined position in standardisation bodies.
- Proof of concept demonstrators and lab trials by operators.

MUSE II MUSE II is the follow up of MUSE I project (see later). inside the FP6 Work intiative. Alcatel is the prime contractor. MUSE II will start by the begining of 2006.

We represent INRIA within this project. We are involved in two activities :

- designing constrained java virtual machine for xDSL Modems.
- designing an overall end to end security framework for OSGi application management.

WASP IP IST project WASP (Wirelessly Accessible Sensor Populations). An important class of collaborating objects is represented by the myriad of wireless sensors, which will constitute the infrastructure for the ambient intelligence vision. The academic world actively investigates the technology for Wireless Sensor Networks (WSN). Industry is reluctant to use these results coming from academic research. A major cause is the magnitude of the mismatch between research at the application level and the node and network level. The WASP project aims at narrowing this mismatch by covering the whole range from basic hardware, sensors, processor, communication, over the packaging of the nodes, the organisation of the nodes, towards the information distribution and a selection of applications. The emphasis in the project lays in the self-organisation and the services, which link the application to the sensor network. Research into the nodes themselves is needed because a strong link lies between the required flexibility and the hardware design. Research into the applications is necessary because the properties of the required service will influence the configuration of both sensor network and application for optimum efficiency and functionality. All inherent design decisions cannot be handled in isolation as they depend on the hardware costs involved in making a sensor and the market size for sensors of a given type. Three business areas, road transport, elderly care, and herd control, are selected for their societal significance and large range of requirements, to validate

the WASP results. The general goal of the project is the provision of a complete system view for building large populations of collaborating objects. The system incorporates networking protocols for wireless sensor nodes to hide the individual nodes from the application The tangible results of the project are: (1) A consistent chain of energy-sensitive software components, (2) Sets of cross optimised software stacks, (3) Benchmarks and a set of measurements on energy- and code- efficiency, (4) Rules for the design of configurable sensor nodes, and (5) A prototype implementation in one of the three chosen business areas The consortium consists of six industrial partners, one SME, six large research institutes and six universities. All of them have a proven experience with WSNs. The impact on European industry and research comes from the provision of an European alternative to the wireless sensor nodes originating in the US. The WASP results will be well suited for adoption by SMEs. The consortium defines an active programme to approach the appropriate SMEs and to familiarise them with the WASP results.

8.4. Visiting scientists

John Mullins has visited the *ARES* project from october 2005 until June 2006s. He is professor at the *Ecole Polytechnique de Montreal* (CA). He is currently included in the security sub-team of the Middleware axis of the *ARES* project. He is working in the area of model checking.

Yu Chen arrived in September 2005 on a postdoctoral position. She did her PhD in Texas A&M University, College Station, TX, U.S.A. Her current research focuses on the development of distributed services for wireless ad hoc networks, including mobile ad hoc networks and sensor networks. She works on protocol design that provides certain levels of reliability and theoretical analysis of the designed protocol for scenarios of interest.

8.5. International initiatives

DisMO4wNET Katia Jaffrès-Runser obtained a Marie-Curie outgoing fellowship from European community. She's going to spend 2 years at the Stevens Institute of Technology, New-Jersey, USA within the team of Dr Christina Comanisciu, and she will come back for one year in the ARES project. This project is managed by Jean-Marie Gorce.

Easy6 The PAI STAR Easy6 project aims in promoting at the IETF and increasing the impact and attractivity of the solutions proposed by the project partners, *i.e.* (*ARES* ENST Bretagne, Korean Telecom and Seoul National University (South Korea), in the fields of full IPv6 networks autoconfiguration and radio link optimizations in IPv6 mobile networks. Through the organization of two Franco-Korean workshops, one that was held in october 2005 and that will be held in march 2006, the project must also help in gathering the works performed by all partners and in developping a common solutions to the addressed ísues.

STIC Tunisie The INRIA ARES project has a join research program with the MEDIATRON research team (Prof. Sami Tabbane, Tunisia) about mobile ad hoc networks. There are two goals: first to provide realistic mobility models and second, to model radio propagation for indoor environment. The final objective is to provide realistic input parameters in order to study mobile ad hoc networks.

WIDE-STIC ASIA WIDE and CNRS has launched a collaboration on the mobility and measurement topics. This project is supported by the French and Japanese governments and will continue for two years. We exchange researcher, research information, technical results between the two countries.

- Stéphane Ubéda and Fabrice Valois have done travels to China for the french association ARIEL. The goal was to launch the fisrt French-Chinese Workshop in Telecommunications. This workshop was held in Xi'an (China) in October 2006 with french companies (FTRD, Safran, etc.), french universities (INSA Lyon, ENST, etc.) and chinese universities (BUAA, NPU, etc.) and companies (ZTE, Hua-wei, etc.). New meetinges are scheduled for 2007 to identify research teams and to launch new international collaborations.

9. Dissemination

9.1. Leadership within scientific community

Isabelle AUGÉ-BLUM is:

- Elected representative with the council of the Telecomunications Department of INSA-Lyon;
- a member of the group TAROT (Techniques Algorithmiques, Réseaux et d'Optimisation pour les Télécommunications);
- a member of the group STRQdS (Systèmes temps réel et Qualité de Service);
- a member of the ARC INRIA Iramus (Radio Interface for Multihop Networks).

Guillaume CHELIUS is:

- A member of the PAI STAR Easy6 project in collaboration with ENST Bretagne, France Telecom, Korean Telecom and the Seoul National University;
- a member of the group TAROT (Techniques Algorithmiques, Réseaux et d'Optimisation pour les Télécommunications);
- the leader of the multi-laboratory CAPNET project (BQR project sponsored by the INSA de Lyon) on sensor networks;
- the WP2 leader of the national CNRS platform on sensor and auto-organized networks (RECAP).

Éric FLEURY is:

- Co-head of the CITI Lab and vice-head of the ARES project;
- Co-chair of the Networking group ResComhttp://rescom.asr.cnrs.fr/ of the CNRS GDR ASR;
- a member of the steering committee of the Expert Group on Networking (Comité d'Experts Réseau de communication) of the CNRS;
- an expert for the OFTA (Observatoire Français des Technologies Avancées) for the ambiant computing group;
- representative for the French part of the european project COST 295;
- the leader for the INRIA Rhône-Alpes of the project FRAGILE of the ACI Sécurité;
- the leader for the INRIA Rhône-Alpes of the IP IST project WASP;
- the leader for the INRIA Rhône-Alpes of the IP project MOSAR;
- in charge for the CITI Lab and INRIA Rhône-Alpes of the ANR/RNRT SVP project;
- a member of the steering committee of the CNRS National platform on sensor network RECAP. He is also in charge for the CITI lab of the sensor platform founded by the CNRS;
- in charge for the CITI Lab and INRIA Rhône-Alpes of the RNRT SAFARI project;
- a member of the project PairAPair of the ACI Masse de Données;
- elected representative of the specialists committee in computer science (CS section 27) of INSA-Lyon;
- elected representative with the council of the Telecomunications Department of INSA-Lyon;
- reviewer and/or member of the PhD examining boards of: François INGELREST (Lille), Anh-Tuan GAI (Paris 6), Amina Meraihi NAIMI (Versaille), Lamia ROMDHANI (Telecom Paris), Emmanuel CONCHON (Toulouse) and Fabrice THEOLEYRE (INSA de Lyon);
- Member of the Jury for the *Prix de la recherche en système* of Association ACM SigOps of France.

Stéphane FRÉNOT is:

- A member of the specialists committee (section 27) of the INSA-Lyon;
- a co-Founder of the OSGi French User Group;
- a member of ObjectWeb Consortium;
- an active member in Felix Project (OSGi open-source implementation);
- a member of one PhD examining board: Vincent Cridlig, examinator, university Henri Poincaré, Nancy 1;
- INRIA representative within MUSE I and MUSE II european projects;
- PMC member of apache felix project (OSGi V4 implementation platform).

Jean-Marie GORCE is:

- the leader of the IRAMUS ARC of INRIA;
- a member of the Research group (GDR) ISIS (Information, Signal, Images and Vision) of CNRS;
- a member of the ACI Sécurité Fragile (Failure Resilience and Application Guaranteed Integrity in Large-scale Environments);
- a member of the specialists committee (section 61) of the INSA-Lyon;
- a member of the specialists committee (section 61) of UCB Lyon 1 university.

Isabelle GUÉRIN LASSOUS is:

- The leader of the team Protocols of the ARES project until September 2006;
- a member of the specialists committee (section 27) of the ENS Lyon;
- a member of the hearing committee of INRIA Rhône-Alpes;
- a member of the SPECIF committee that allocates PhD awards;
- a member of the CNRS TAROT action (Techniques Algorithmiques, Réseaux et d'Optimisation pour les Télécommunications);
- the INRIA scientific leader of the european project AEOLUS (Algorithmic Principles for Building Efficient Overlay Computers);
- the INRIA scientific leader of a contract with FT R&D, "Bandwidth problems in multihop wireless networks";
- a member of the ARC INRIA Iramus (Radio Interface for Multihop Networks);
- a member of the ACI Sécurité Fragile (Failure Resilience and Application Guaranteed Integrity in Large-scale Environments);
- a member of the project RNRT SAFARI (Ad Hoc/Wired Services: Development of an integrated network architecture);
- a member of four PhD examining boards: Nathalie Mitton (INSA de Lyon - Co-supervisor), Luigi Iannone (Paris 6), Dang Quan Nguyen (Paris 6 - reviewer) and Fanilo Harivelo (La Réunion - reviewer).

Frédéric LE MOUËL is:

- The leader of the task 3.4 "Programming and deployment framework for Amigo services" of the European Amigo project;
- a member of the French Ministerial KAA project;
- elected representative with the council of the Telecomunications Department of INSA-Lyon;
- a member of EuroSys (European ACM SIGOPS) and ASF (French ACM SIGOPS);
- a member of the OSGi French User Group.

Marine MINIER is:

- A member of the ACI sécurité project KAA (Key Authentication Ambiant);
- A member of the ANR SETIN project RAPIDE (nov. 2006 - nov 2010); responsible of the work package "MACs construction".

Fabrice VALOIS is:

- The leader of the team Protocols of the ARES project since September 2006;
- the scientific leader of a contract with FT R&D about *Self-configuration and self-organisation of wireless sensors networks*. Two teams of FTRD are involved: PACIFIC project (Grenoble) and ILAB Beijing (China);
- a member of the ARC INRIA Iramus (Radio Interface for Multihop Networks);
- in charge for the CITI Lab of the ANR RNRT ARESA (Wireless Sensors Networks project) project;
- the scientific leader of the INRIA STIC Tunisia project N°06/I15 about more accurate models for mobile ad hoc networks including both mobility models and radio propagation one;
- a member of the group TAROT (Techniques Algorithmiques, Réseaux et d'Optimisation pour les Télécommunications);
- an elected member of the specialists committee in computer sciences (section 27) of the INSA-Lyon.

Guillaume VILLEMAUD is:

- a member of the Research group (GDR) ISIS (Information, Signal, Images and Vision) of CNRS.

9.2. Conferences, meetings and tutorial organization

Guillaume CHELIUS is:

- PC member of Algotel 2006 program committee, Trégastel, France;
- PC member of the 2nd International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2006), Hong Kong, China;
- PC member of *Colloque Francophone sur l'Ingénierie des Protocoles* (CFIP 2006), Tozeur, Tunisia;
- co-organizer of the third CNRS RECAP workshop on sensor networks (Lyon, France, 2006);
- PC co-chair, submission and publication chair of the international Intersense 2006 conference;
- organization chair of the international FAWN 2006 workshop held in conjunction with the IEEE PerCom 2006 conference.

Eric FLEURY is:

- General chair of the IEEE International Workshop on Foundations and Algorithms for Wireless Networking (FAWN 2006), Pisa, Italy;
- General chair of the Colloque Francophone pour l'Ingénierie des Protocoles (CFIP 2006), Tozeur, Tunisie;
- Program Vice chair of the 2nd International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2006), Hong Kong, China;
- a member of the following technical program committees:
  - Workshop on Wireless Ad hoc and Sensor Networks (WWASN2006), Lisboa, Portugal;
  - First International Conference on Integrated Internet Ad hoc and Sensor Networks (InterSense 2006), Nice, France;
  - Second Workshop on Spatial Stochastic Models for Wireless Networks (Spaswin 2006), Boston, USA;
  - Second ACM International Workshop on Multi-hop Ad Hoc Networks: from Theory to Reality (REALMAN 2006), Florence, Italy.

Stéphane FRÉNOT is:

- a member of the following technical program committees:
  - *Ateliers OSGI* in the context of *Journées Francophones sur la Mobilité et l'Ubiquité* (Ubimob'2006), Paris, France;
  - 1st IEEE International Workshop on Services Integration in Pervasive Environments (SIPE 2006) in conjunction with the IEEE ICPS'06, Lyon, France.

Isabelle GUÉRIN LASSOUS is:

- Co-chair of the conference WONS 2006 (Third Annual Conference on Wireless On demand Network Systems and Services), Les Ménuires, France, January 2006, ares.insa-lyon.fr/wons2006;
- Program Co-Chair of ACM PE-WASUN 2006 (Third ACM International Workshop on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks - October 2006, Torremolinos, Malaga, Spain). The workshop wase held in conjunction with the 9th ACM International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2006);
- a member of the following program committees:
  - 1st International Conference on Late Advances in Networks (ICLAN 2006) Paris, France;
  - 2nd International Workshop on Localized Communication and Topology Protocols for Ad hoc Networks (LOCAN 2006), Vancouver, Canada;
  - ACM/IEEE MSWiM 2006, Torremolinos, Malaga, Spain;
  - 1st IFIP International Conference on Ad-Hoc Networking, Santiago Chile;
  - IFIP Fifth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2006), Lipari, Italy;
  - Seventh ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2006), Firenze, Italy;
  - Second International Workshop on Sensor Networks and Systems for Pervasive Computing (PerSeNS 2006), Pisa, Italy;
  - IEEE International Workshop on Foundations and Algorithms for Wireless Networking (FAWN 2006), Pisa, Italy.

Frédéric LE MOUËL is:

- a member of the following technical program committees:
  - *Ateliers OSGI* in the context of *Journées Francophones sur la Mobilité et l'Ubiquité* (Ubimob'2006), Paris, France;
  - 1st IEEE International Workshop on Services Integration in Pervasive Environments (SIPE 2006) in conjunction with the IEEE ICPS'06, Lyon, France.

Marine MINIER is:

- PC member WCC07, (International Workshop on Coding and Cryptography), Versailles, France, April 2007.

Stephane UBEDA is:

- program chair of the Communication Network track of International Conference on High Performance Computing - HiPC'2006;
- member of the *6ème Colloque Francophone sur la Modélisation des Systèmes Réactifs*;
- Editor of an Hermes collection in wireless communications.

Fabrice VALOIS is:

- member of the following technical program committees:
  - Third ACM International Workshop on Performance Evaluation of Wireless Ad Hoc, Sensor and Ubiquitous Networks (PE-WASUN'06), Malaga, Espagne;
  - Third International Workshop on Wireless Ad-hoc and Sensor Networks (IWWAN06), New-York, USA;
  - Second IEEE International Conference OnWireless and Mobile Computing, Networking and Communications (WiMob06), Montreal, Canada.

Jean-Marie Gorce, Guillaume Villemaud, Thomas Watteyne, Isabelle Auge-Blum are co-organizers, with Jean Carle (LIFL), and Mischa Dohler (France Telecom R&D) of the workshop IRAMUS in Val Thorens, January, 24-26, 2007.

9.3. Teaching activities

MASTRIA OF THE UNIVERSITY LYON 1, INSA DE LYON, UNIVERSITY LYON 2, ECL

- Jean-Marie Gorce gave a course with Mischa Dohler (FT R&D) on *Physical Layer for future wireless networks* (20h);
- Eric Fleury is the chair of the master in Networking, Telecommunications and Services inside the Master of research MastRIA of the University Lyon 1, INSA de Lyon, University Lyon 2, ECL;
- Eric Fleury gave a course on *Internet New Generation* (20h);
- Stephane Frénot gave a course on *Open application servers design* (20h);
- Isabelle Guérin Lassous and Fabrice Valois gave a course on *Autonomic Computing* (20h);
- Stéphane Ubéda and Fabrice Valois gave a course on *Theoretical tools for networks performance evaluation* (20h).

ECOLE CENTRALE DE LYON

- Isabelle Guérin Lassous gave a course on *Mobile Networks* (10h).

INSA DE LYON

- Eric Fleury, Stéphane Frénot, Jean-Marie Gorce, Marine Minier, Frédéric Le Mouël, Stéphane Ubéda, Fabrice Valois and Guillaume Villemaud are professors/teaching assistants at the INSA de Lyon;
- all the members supervised engineer projects;
- Isabelle Augé-Blum, Eric Fleury, Stéphane Frénot, Jean-Marie Gorce, Marine Minier, Frédéric Le Mouël, Stéphane Ubéda, Fabrice Valois and Guillaume Villemaud are professors/associate professors at the INSA de Lyon in the departments: Computer Science, Electrical Engineering, Telecommunications;
- Isabelle Guérin Lassous gave courses on *Ad hoc Networks* (6h) and *QoS in the Internet* (2h) to the fourth-year students;
- all the members supervised engineer projects.

OTHERS.

- Jean-Marie GORCE gave a talk called on "Physical layer modeling in wireless networks" at the Stevens Institute of Technology, New-Jersey, USA and at the *Ecole polytechnique de Montréal*, Québec, Canada.

9.4. Miscellaneous

9.4.1. Visits

- Fabrice THEOLEYRE went to the University of Waterloo (Prof. Catherine Rosenberg), Canada, from January to April 2006.
- Fabrice VALOIS has been a visiting scientist at the Montreal University (Prof. Samuel PIERRE), Canada, in June 2006.

9.4.2. Defended Habilitations

9.4.3. Defended PhDs

- Nathalie Mitton, *Auto-organisation dans les réseaux sans fil multi-sauts à grande échelle*, 27 mars 2006, jury: Bartlomiej Blaszczyszyn, Serge Fdida, Eric Fleury, Isabelle Guérin-Lassous, David Simplot-Ryl;
- Fabrice Theoleyre, *Une auto-organisation et ses applications pour les réseaux ad hoc et hybrides*, 29 septembre 2006, jury: Andrzej Duda, Serge Fdida, Eric Fleury, Thomas Noel, David Simplot-Ryl, Fabrice Valois.

9.4.4. On going PhDs

- Fatia Benali, *Alert languages for information security system*;
- Amira Ben Hamida, *Minimal autoextensible middleware for deployment in a pervasive environment*;
- Elyes Ben Hamida, *Domain-Specific Languages for sensor network MAC protocols*;
- Ioan Burciu, *Wide Band agile R/F transceiver*;
- Guillaume De La Roche, *MR-FDPF Method for the Simulation of 802.11 Radio Propagation in Indoor Environments.*;
- Samuel Galice, *Cryptographic protocols for ad hoc networks*;
- Karel Heurtefeux, *Self-organization of Wireless Sensor Networks*;
- Noha Ibrahim, *Automatic Integration of Services in Pervasive Environments*;
- Jialiang Lu, *Impact of self-* on communicating object networks*;
- Philippe Mary, *Innovative approaches for multi-antenna processing in the context of multiple radio interfaces*;
- Nicolas Marechal *Distributed optimizations of the network connectivity in sensor networks*;
- Benoit Miscopein, *MAC protocol for UWB*;
- Pierre-François Morlat, *Study of SIMO and MIMO terminals in an ad hoc or sensor network context*;
- Pierre Parrend, *Security Models, Home Gateways, Components*;
- Tahiry Rafazindralambo, *Performance Issues in Multi-Hop Wireless Networks*;
- Yvan Royon, *Multi-service, multi-user java-based environments*;
- Cheikh Sarr, *Resource estimation for quality of service in ad hoc networks*;
- Jacques Saraydaryan, *Intrusion detection by behavior and statistical analysis*;
- Thomas Watteyne, *Energy-Efficient Self-Organization for Ad-Hoc Networks*;
- Ruifeng Zhang, *Realistic Modeling and Simulation of the PHY layer in Multi-hop Sensor Networks*.

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[4] F. LAFOREST, F. LE MOUËL (editors). *Adaptation et gestion du contexte*, numéro spécial de la revue d'Ingénierie des Systèmes d'Information (ISI), vol. 11, n^{o} 5, Hermès, 2006.

[5] F. LE MOUËL, S. FRÉNOT (editors). *Proceedings of 1st IEEE International Workshop on Services Integration in Pervasive Environments (SIPE'2006)*, IEEE Press, Lyon, France, June 2006, http://ares.insa-lyon.fr/sipe06/.

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[6] N. MITTON. *Auto-organisation dans les réseaux sans fil multi-sauts à large échelle*, Ph. D. Thesis, INSA de Lyon, Mars 2006.

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Articles in refereed journals and book chapters

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