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INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team POPS

System & Networking for Portable Objects Proved to be Safe

Lille - Nord Europe

THEME COM

Table of contents

Joint team with LIFL (CNRS and Lille University - USTL), located in Lille, created on September 2nd, 2004.

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2. Overall Objectives

2.1. Introduction

Keywords: *Embedded operating system*, *POPS*, *ad hoc networks*, *exo-kernel*, *mobility*, *smart card*, *wireless networking*, *wireless sensor networks*.

The POPS research group studies solutions to improve programmability, adaptability and reachability of "POPS" (Portable Objects Proved to be Safe). The POPS family contains small and limited devices like smart cards, RFID tags (see Fig. 1) [42], wireless sensors (see Fig. 3) [38] or personal digital assistants. Such small devices are characterized by limited resources, high mobility, frequent disconnections, low-bandwidth communications, passive (no battery) or limited battery life and reduced storage capacity. Moreover, in spite of these constraints and because of the use in an untrusted environment, users and applications require high security level for POPS. The development of applications integrating POPS suffers from lack of "*reachability*" of such platforms. For instance, software development is penalized by exotic and limited operating systems. Indeed, POPS, such as smart cards, are difficult to program and high level of expertise is needed to produce software. Some efforts were taken recently with the advent of Java Cards [35], PalmOS or Windows CE. But Java Card offers a very small part of Java API and a typical application written in Java cannot be directly translated to Java Card. POPS mobility induces sudden and frequent disconnections, long round trip times, high bit error rates and small bandwidth. Hence, POPS systems have to adapt themselves to application requirements or modification of the environment.

Figure 1. Example of RFID tags.

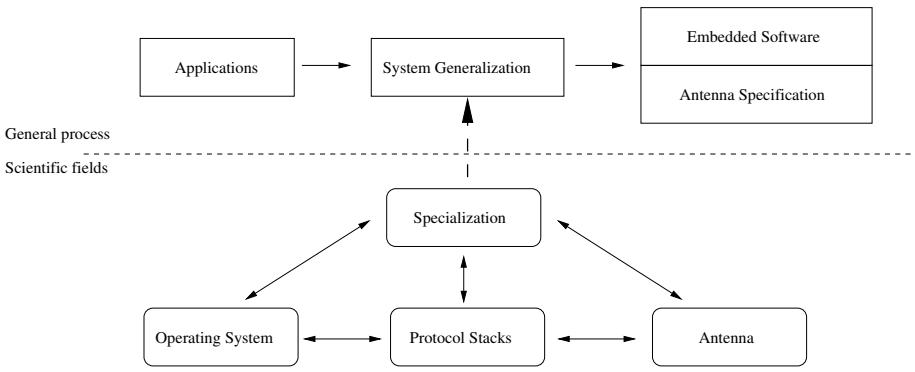

Figure 2. POPS' thematics and objectives.

Indeed, the application should guide the system. Therefore, the POPS research group aims to propose a generic approach allowing any application to specialize the system according to its own needs and characteristics (See Fig. 2). Since POPS are limited in capacity, specializing the system for the application will allow to embed much less code and functionalities.

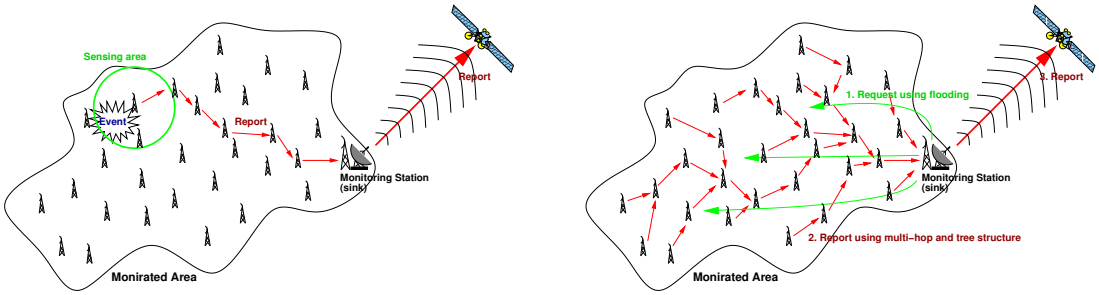

Figure 3. Example of a sensor network with event-driven (left) and on-demand (right) models.

POPS research action takes advantage of its strong partnership with Gemplus/Gemalto since more than 19 years. This collaboration brings both partners (the POPS research group of INRIA and Gemplus/Gemalto) to high level of expertise in embedded operating system design and mobile networking which are our two main research activities.

2.1.1. Embedded Operating Systems

We focus our activities on "adaptability" and on "connectivity" of embedded platforms dedicated to POPS. From then on, our researches have evolved around the smart card. In fact, in the nineties (birth date of POPS research group) smart card was the only valuable and industrially deployed POPS. Smart card integration in database management systems, smart card integration in Corba (using the Card Object Adapter), open platform for smart card (the first smart card virtual machine), have been milestones of the POPS research. More recently, we have focused our attention (according to our industrial inputs) on embedded operating system techniques, enabling "on-card" type checking and bytecode compression. Today, smart card manufacturers and other emerging POPS manufacturers have to deal with new technological 'lock-in' inside and outside the mobile object. Dedicated operating systems are now powerful enough to run dynamically downloaded applications in a safe way. Typically, Java Card loads and runs a Java-like bytecode. Nevertheless, "Java-like" means "non-Java". Embedded virtual machines do not support standard abstractions. And so, Java applications cannot be deployed in a limited embedded system. On the other hand, embedded applications do not limit their needs to the Java APIs. To overcome these limitations, we will focus on two complementary studies:

1. Firstly we study a new architectural way to embed a Java virtual machine. Conventional virtual machines are not operating systems but they overlap the abstractions proposed by the system. We plan to define a Java virtual machine designed to be the operating system (the virtual machine will manage the hardware itself).
2. Java is one of the possible hardware abstractions. However different applications require different abstractions: file-system, database systems, and so on. Camille OS is a smart card Exo-kernel enabling the download of different hardware abstractions in a safe way. In this way Camille ensures POPS "adaptability" to the applications requirements. Nevertheless some critical system extensions (enhanced IO protocols for example) need additional guaranties: real-time properties and hardware resources control.

2.1.2. Mobile Networking

POPS also have a non-conventional communication interface. Due to their mobility, they have transient and unpredictable communications with other entities. This fact motivates our focusing on the ad hoc network communication model which is the most flexible model.

Indeed wireless ad hoc networks [44], [36], [37], [34] encompass a wide range of self-organized network types, including sensor, mobile ad hoc, personal area, and rooftop/mesh networks. The design of data communication techniques in multi-hop ad hoc networks comprises challenges at all layers of communication: physical, medium access control (MAC), network, transport and application layers. This research project concentrates on the network layer. The network layer problems can be divided into three groups: data communication, service access, and topology control problems. Data communication problems include routing, quality-of-service routing, geocasting, multicasting, and broadcasting. The protocols need to minimize the communication overhead (since bandwidth in wireless communication is typically limited) and the power consumption of battery operated POPS. In service access problems, such as multi-hop wireless Internet (hybrid network, see Fig. 4), the goal is to provide or receive services from a fixed infrastructure with other hosts serving as relays if necessary. Topology control problems include neighbor discovery problems (detecting neighboring nodes located within transmission radius) and network organization problems (deciding what communication links to establish with neighboring nodes, operating sleeping period and adjusting transmission radii). Secure routing faces the following challenges: node selfishness, threats using modification of routing information, misrepresenting identity, fabrication of routing messages by one node, or between two malicious nodes (wormhole attack), and self-organized public-key management and authentication services. The main paradigm shift is to apply localized (or greedy) schemes as opposed to existing protocols requiring global information. Localized algorithms are distributed algorithms where simple local node behavior achieves a desired global objective. Localized protocols provide scalable solutions, that is, solutions for wireless networks with an arbitrary number of nodes, which is one of the main goals of this research project.

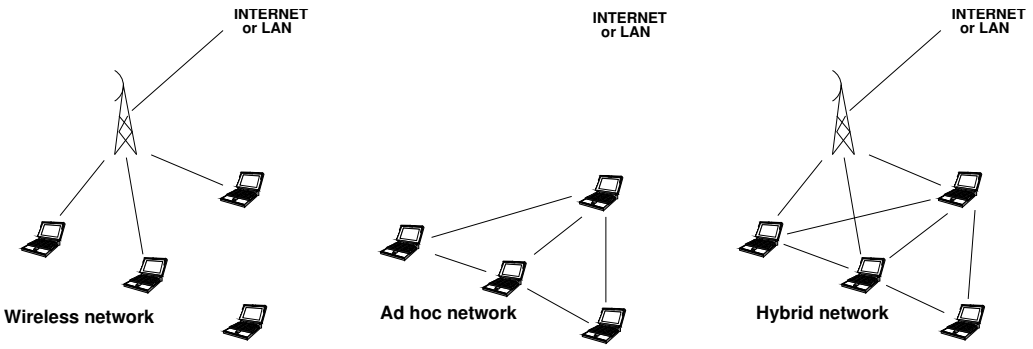

Figure 4. From wireless network to hybrid networks.

2.2. Highlights of the year

HECTOR [32] is an energy efficient routing protocol based on virtual coordinates. To the best of our knowledge, it is the first and only routing protocol for sensor networks which is at the same time delivery guarantee, based on virtual coordinates and energy efficient.

In [25], we proposed EtE. EtE is to be highlighted since it is a georouting based on geographical coordinates, which is memory-less, scalable, guaranteed-delivery and energy-efficient. EtE outperforms all existing solutions and consumes less than 10% energy than the optimal centralized algorithm, by providing paths with weak stretch factor.

In the SVP project we proposed a new Java Framework dedicated to the sensors (MicaZ). As far as we know the "*motlets*" APIs are the very first available implementation of a Java infrastructure in this constrainted devices. This prototype is also a proof of concept for the JITS (i.e. Java In The Small) technologies.

In [13] Gilles Grimaud *et al.* presents the research work done on the secure deployment of critical software in constrained devices. We provide a new way to embed deployed software unit and to support object oriented abstraction of the memories. The software security is enforced by the underlying deployment environment in order to provide confidentiality, integrity and availability. This issue is exacerbated by the necessity of cooperation between components distributed by various software providers mutually suspicious.

3. Scientific Foundations

3.1. Scientific Foundations

Keywords: *Embedded operating system*, *POPS*, *ad hoc networks*, *exo-kernel*, *mobility*, *smart card*, *wireless networking*, *wireless sensor networks*.

The POPS research group investigates solutions to enhance programmability, adaptability and reachability of small objects designated as "POPS" (Portable Objects Proved to be Safe). The POPS set includes small devices like smart cards, RFID tags or personal digital assistant which are characterized by limited resources, high mobility and high security level in spite of untrusted environment. The development of applications integrating POPS suffers from lack of "*reachability*" of these platforms. Indeed, most POPS are not easy to program and high level of expertise is needed to produce software for such limited operating systems and devices. Moreover, POPS mobility induces sudden and frequent disconnections, long round trip times, high bit error rates and small bandwidth.

We believe that the "system and networking" approach makes sense in the context of portable objects proved to be safe. We have demonstrated that the application-driven approach can be very efficient for customization of embedded software. We propose to focus on the following objectives where sensors are privileged platforms:

3.1.1. Customization of evolving and communicating systems

We propose to address the two following problems based on our work on customization of Java-stems:

1.1 Dynamical customization: It corresponds to what we proposed in the previous proposal: "The ability to adapt a POPS system while it is running (after it has been issued) can be an important differentiation factor to ensure the durability of the system, the update of the applications it can run, and its capacity to adapt to new usages and environments. The more POPS are complex (and expensive) and general purpose, the more these requirements are important. Dynamic configuration is clearly in the objectives of the Camille action since the system is designed to support dynamic extensions of the operating system kernel via techniques such as dynamic linking, on-the-fly compilation, and verifiable typed intermediate language." In means that we have to study how we can design a specialized system – where functionalities could be removed – which is able to evolve in order to get new functionalities while preserving safety of already installed applications.

Our goal is also to promote the JITS platform for POPS.

1.2 Optimization of the communication stack: The goal is to study the architecture of the communication stack in sophisticated cases (*i.e.* not limited to serial link) and in particular for objects with wireless capabilities. This is illustrated by the Figures 2 and 5. In the latter, we illustrate the case of a sensor network application. The "selection engine" takes a "model of the application" (including model of the network) and the "specification of the hardware". A set of protocols of each layer are evaluated according to "cost function" and the "selection engine" generates the combination of protocols which is optimal for the application and the hardware.

From our interaction with industrial partners, we see that it is also important to consider application layers and in particular http.

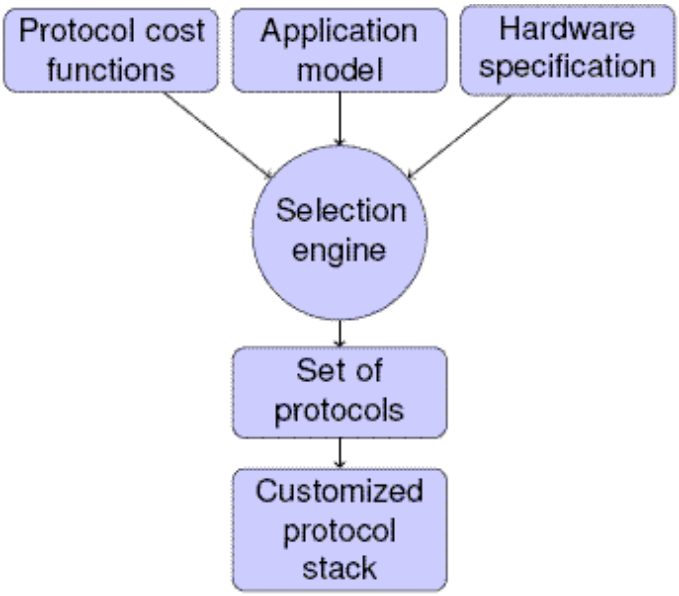

Figure 5. Complete scheme of the generation of the communication stack.

3.1.2. Realistic wireless networking

We show that the unit-disk graph model is not realistic and that an excellent and sophisticated algorithm can be jeopardized in the real world. Our approach is to consider realistic physical layer (*e.g.* Log-normal shadowing model). Moreover, it is necessary to validate results analytically, with simulators, but also with real experimentations.

We propose to investigate the two following objectives:

2.1 Position-based algorithms: The main advantage of this family of protocol is that they are both localized and memoryless. It means that these protocols are robust since they do not need a huge quantity of information (1-hop or 2-hop knowledge in most of cases) and that it can support an arbitrary number of simultaneous flows since intermediate nodes do not need to store information. We will investigate (i) protocols based on geographical coordinates (*e.g.* GPS coordinates) and (ii) protocols based on virtual coordinates when geographical coordinates. Our goal is to propose energy-efficient protocols with guaranteed delivery for the different kind of protocols: unicast, multicast, data collection (for sensors), topology control, etc.

In particular, we are interested in data collection with data fusion and we think that such techniques can be applied in RFID applications where RFID readers can be assimilated to sensors. Depending on the application, the network can apply different filters in order to limit the amount of data which is sent to the sink.

2.2 Hardware-software optimizations: We will focus on low consumption radio interface for wireless sensors. More precisely, we believe that energy constrained objects can take advantage of smart antenna technologies. This area seems very promising on paper but it raises a lot of implementation problems. In the context of a partnership with IEMN (Institut d'Electronique, de Microélectronique et de Nanotechnologie), we want to experiment the implementation of a full communication stack dedicated to smart antennas (physical layer, MAC layer, etc.).

4. Application Domains

4.1. Application Domains

Keywords: *Telecommunication*, *ambient computing*, *banking application*, *environment*, *military area*.

We believe that it is necessary to validate proposition with analysis, simulations and real experimentations. In order to achieve this, we will focus on three specific targets which are:

- **Smartcards** which are the core of our 19-years partnership with Gemalto.
- **Sensors motes**. In the SensLab project, we will have a real experimental platform.
- **COM platform** which is developed in the hard-soft project with IEMN and which allows the experimentation of smart antenna implementation.

The relationship between objectives and platforms are underlined in Table 1. It is clear that JITS platform is the ideal platform to support our experimentations.

Table 1. Objectives vs Platforms.

	Smartcards	**Sensor motes**	**COM platform**
1.1 Dynamical customization	X	X	-
1.2 Communication stack optimization	X	X	X
2.1 Position-based algorithms	-	X	X
2.2 Hardware-software optimizations	-	-	X

We will also explore these problems in two new application domains which are (i) sensor and actuator networks – also called SANET – and (ii) wireless mesh networks.

In SANET, we consider active nodes in a sensor network denoted as actuators and the whole network will support the breakthrough functionality, which is necessary for massively deployed heterogeneous sensor networks pervading our everyday life. We envision actuators as independent participants in the network, *e.g.*, autonomous robots or other devices capable of acting upon their environment. They are resource rich nodes that can autonomously move and affect the sensor network operations, either by being a mobile data sink or actively inserting, removing, and relocating sensor nodes. Moreover, actuator nodes can perform actions on the environment, based on the sensed environment and some intelligent decision logic. For example, they can turn on water sprinklers to stop assumed fire when high temperature reports are received from nearby sensors.

The second application domain is wireless mesh networks which are similar to wireless LAN (typically WIFI) where access points are connected with wireless link. Some access point in the network are connected to internet – these nodes are called gateway. The network works like an ad hoc network or a hybrid wireless network where nodes are fixed and where traffic is massively directed to the gateways (like in wireless sensor networks).

5. Software

5.1. Java In The Small

Keywords: *Java-OS*, *embedded system*.

Participants: Gilles Grimaud, Kevin Marquet [Contact], David Simplot-Ryl.

Initial goal of Java was to allow high level software development on small devices. Eventually it found success and promotion with software deployment on the Web, and more recently as a solution for huge enterprise servers and massive parallel computing. Today small targets are still supported, but with dedicated (Java-like) APIs and VMs. These specific technologies dramatically restrain the context in which Java applications can be deployed.

JITS focuses on these technologies and on enhancements to allow the use of a real Java Runtime Environment and a Java Virtual Machine everywhere by targeting tiny devices such as SmartCards. These devices usually don't use a Virtual Machine layer over an OS, but expect the Virtual Machine to be the OS. This is possible thanks to the JVM features which can be presented as a specific hardware abstraction for most of them.

JITS platform can be found at the URI http://jits.gforge.inria.fr/.

5.2. CAMILLE NG

Keywords: *Exo-kernel*, *embedded system*, *extensibility*, *real-time*.

Participants: Nadia Bel Hadj Aissa [Contact], Gilles Grimaud.

The Camille operating system (a dedicated exo-kernel) aims at supporting the various hardware resources used in smart cards, without specializing abstractions. The architecture principle is very similar to the MIT Exo-Kernel principles and concepts. The Camille OS provides the following three basic characteristics. Portability is inherited from the use of an intermediate code and by a limited set of hardware primitives. Security is ensured by a code-safety checking (which uses a PCC-like algorithm) at loading time. Extensibility is provided through a simple representation of the hardware that at the root of the system does not predefine any abstraction. Thus, applications have to build or import abstractions which match their requirements.

The usual downside of extensibility is performance. For some parts of the OS that require efficiency, Camille uses Just-in-Time techniques to compile intermediate code into native one. Increased performances also come from the exo-kernel approach that does not introduce abstraction penalties in the core of the OS. Because smart cards have limited computing power, additional hardware independent optimizations are also performed out of the card, while the source code is translated to FACADE. A more precise description of Camille, and experimental results as well can be found in [43]. The Camille prototype demonstrates the feasibility of an extensible smart card OS that has reasonable footprint: 17 KB of native code in which 3.5 KB for code verification, 8.5 KB for native code generation, and the rest for hardware multiplexing.

CAMILLE NG platform can be found at the URI http://www2.lifl.fr/~grimaud/CAMILLE/Index.

5.3. STatic Alias aNalyser

Keywords: *Information flow*, *bytecode analysis*.

Participants: Isabelle Simplot-Ryl, Dorina Ghindici [Contact].

STAN is a Java abstract analyser that allows static alias analysis and checking of information flow. Moreover, STAN targets small systems, like embedded systems. The STAN tool statically checks already compiled source code and annotates the .class files with verifiable signatures at loading time. STAN is dedicated to embedded systems and adapted to their constraints, supports mobile code, easy to use.

STAN can be found at the URI http://www2.lifl.fr/~ghindici/STAN/.

5.4. Lite Embedded C++ Objects

Keywords: *Framework*, *embedded*.

Participants: Gregory Guche [Contact], Nathalie Mitton, David Simplot-Ryl.

LECO aims at developing small and midsize applications for tiny devices, using Object concepts to design high-level and low-level abstractions. LECO does not embed any VM nor manage the devices' memory but provides a simple application design, a minimal framework and a lifecycle model where reusability is the keyword. Furthermore, the come along API allows to write drivers and composite objects through abstraction and specialization. The dynamic memory management is delegated to the developers or to the software deployers, responsible to populate the memory according the applications needs thanks to ready-to-set-and-to-use objects pools. Last but not least, LECO can still use for its own existing C sources, and can be easily ported to others OO languages, where abstract analysis and enhancements tools are available.

LECO can be found at the URI http://www.lifl.fr/POPS/.

6. New Results

6.1. Activity Scheduling in Wireless Sensor Networks

Keywords: *Networked sensors*, *activity scheduling*, *energy conservation*.

Participants: Jean Carle, Antoine Gallais, David Simplot-Ryl.

In this context, wireless sensor networks are made up of lots of devices deployed over a distant or sensitive field to be monitored. Full coverage, energy efficiency, and connectivity are critical requirements of such a network. Energy consumption is balanced by taking advantage of the redundancy induced by the deployment of nodes. Some nodes are active while others are in sleep mode, thus using less energy. The area coverage problem is to determine a small number of sensors that still cover the same area as the whole network. The activity scheduling problem is a subclass of the area coverage problem where connectivity of the active nodes subset must also be provided, so that monitoring reports can reach the sink stations. Last results are resume here:

In [14], we propose several localized sensor area coverage protocols for heterogeneous sensors, each with arbitrary sensing and transmission radii. The approach has a very small communication overhead since prior knowledge about neighbor existence is not required. Each node selects a random time out and listens to messages sent by other nodes before the time out expires. Sensor nodes whose sensing area is not fully covered (or fully covered but with a disconnected set of active sensors) when the deadline expires decide to remain active for the considered round and transmit an activity message announcing it. There are four variants in our approach, depending on whether or not withdrawal and retreat messages are transmitted. Covered nodes decide to sleep, with or without transmitting a withdrawal message to inform neighbors about the status. After hearing from more neighbors, active sensors may observe that they became covered and may decide to alter their original decision and transmit a retreat message. Our simulations show a largely reduced message overhead while preserving coverage quality for the ideal MAC/physical layer. Compared to an existing method (based on hello messages followed by retreat ones and where excessive message loss contributed to excessive coverage holes), our approach has shown robustness in a model with collisions and/or a realistic physical layer.

In [27], [28], we propose a deep analysis and some enhancements of a localized algorithm for area coverage, based on Surface Coverage Relays (SCR) and able to build con- nected active nodes sets that fully cover the area. We first enhanced the critical phase of our protocol (the relay selection) and show that the number of active nodes can be drastically reduced. We then raise the issue of the robustness of the protocol once a realistic physical layer is simulated. Our algorithm proved itself to be an interesting solution as it remained able to still ensure high coverage level under realistic physical layer conditions. We also added the possibility to lonely tune the overall proportion of active nodes through a new parameter used during local relay selection phases.

6.2. Self-organization and Topology Control for Small Devices

Keywords: *Clustering*, *multi-hop wireless communications*, *routing*, *self-organization*, *topology control*.

Participants: Fadila Khadar, Nathalie Mitton, David Simplot-Ryl.

Modeling a wireless network as a graph where nodes represent wireless entities and where edges represent the ability to communicate between two entities (because each is within the transmission range of the other), a local coloring of the nodes at distance d (*i.e.* having two nodes at distance d or less assigned a distinct color) can be enough to solve a wide range of problems. Therefore, in [17], we analyze the longest increasing contiguous sequence or maximal ascending run of random variables with common uniform distribution but not independent. This allows us to provide theoretical bound on the size of a cluster or stabilization time of algorithms run on the top of a wireless network.

6.3. Energy Efficient Broadcasting

Keywords: *Energy efficiency*, *broadcasting*, *hybrid networks*, *multi-hop wireless communications*.

Participant: David Simplot-Ryl.

Among the common problems studied in ad hoc and sensor networks is broadcasting. In such communication, a message is sent from a given host to all the other ones in the network. Applications of this process are numerous: route discovery, synchronization... The simplest and most widely used approach to broadcast is blind flooding, where each node that receives the packet for the first time forwards it to its neighborhood. This method obviously ensures a total coverage of the network, provided that the latter is connected. However, as mobile objects rely on a battery, it is mandatory for the broadcast protocol to be energy efficient. Blind flooding causes redundancy of packets, resulting in unnecessary collisions and especially huge waste of energy. Optimization of broadcasting is generally done by reducing the quantity of needed relaying nodes, or by limiting the transmission power at each host. Of course, all these optimizations must preserve the reliability of the protocol.

In [16], we investigate broadcasting and energy preservation in ad hoc networks. One of the best known algorithm, the Broadcast Incremental Power (BIP) protocol, constructs an efficient spanning tree rooted at a given node. It offers very good results in terms of energy savings, but its computation is centralized and it is a real problem in ad hoc networks. Distributed versions have been proposed, but they require a huge transmission overhead for information exchange. Other localized protocols have been proposed, but none of them has ever reached the performances of BIP. In this paper, we propose and analyze an incremental localized version of this protocol. In our method, the packet is sent from node to node based on local BIP trees computed by each node in the broadcasting chain. Local trees are constructed within the khop neighborhood of nodes, based on information provided by previous nodes, so that a global broadcasting structure is incrementally built as the message is being propagated through the network. Only the source node computes an initially empty tree to initiate the process. Discussion and results are provided where we argue that $k = 2$ is the best compromise for efficiency. We also discuss potential conflicts that can arise from the incremental process. We finally provide experimental results showing that this new protocol obtains very good results for low densities, and is almost as efficient as BIP for higher densities.

There are a number of proposals to achieve energy-efficient broadcasting in wireless multihop networks using directional antennas. However, these proposals are based on centralized algorithms, which require global knowledge of the topology of the network. Such global protocols are not suitable for ad hoc networks because of the high number of control messages required to gather such global information. In [15], we propose several localized algorithms, where each node needs to know only geographic position of itself and its neighbors. We also introduce a new energy consumption model for directional antennas, which generalizes models commonly used. Our first protocol is called DRBOP and it follows the one-to-one communication model to reach to all nodes following the relative neighborhood graph (RNG). RNG preserves connectivity and can be locally computed by each node without any message exchange. Each node that receives a message for the first time from one of its RNG neighbors will rebroadcast it to each of its remaining RNG neighbors separately. The transmission power is adjusted for each transmission to the minimal necessary for reaching the particular neighbor. Since the average degree of RNG is about 2.5, approximately 1.5 rebroadcasts are done by each node to its neighbors. Next, we describe DLBOP, where RNG is replaced by the local minimum spanning tree (LMST) graph, which is a localized topology resembling the minimum spanning tree. We then observe that, for very dense networks, it is more energy-efficient to reach more than one neighbor at a time. A one-to-many

protocol efficient for dense networks is proposed. We then describe an efficient localized protocol, which adaptively switches (without any threshold) between one-to-one and one-to-many communication models and is efficient for both sparse and dense networks. Our simulation results show that for different energy models, the adaptive protocol is able to achieve a competitive performance compared to centralized algorithms while having a fully localized operation.

6.4. Networking Issues in Wireless Networks

Keywords: *Medium Access Control*, *Routing*, *georouting*, *multi-hop wireless communications*.

Participants: Nathalie Mitton, Tahiry Razafindralambo, David Simplot-Ryl.

Sensor networks are specialized ad hoc networks composed of a large number of self organizing nodes/devices. They are used in a wide range of applications, such as monitoring, security, and data-gathering. Through this collaboration, we wish to address the protocol stack issues to efficiently deploy sensor networks. We mainly focus our researches on layer 3 (routing) and layer 2 (Medium access control) and especially consider fairness issues in MAC protocols and energy consumption and position awareness in routing protocols.

In [19] and [18] we propose two protocols for ad hoc networks which address two different fairness aspects. In [19], we try to provide each node with the same number of accesses to the channel. This solution uses local information such as channel occupancy to adapt the access frequency of each node. This scheme prevents each node from monopolizing the channel, which increases the fairness in the whole network. In [18], we address temporal fairness. This solution is also based on local information. Each node adapts its occupation based on the maximum perceived occupation on the channel by aggregating the packet transmission. The two proposed solutions can be fine tuned to fit the requirements of different applications and thus allow a wide range of Medium Access Control solutions that can help developers to provide fairness solutions to any kind of ad hoc networks.

In [32] and [25] we address layer 3 issues in wireless sensor networks especially focusing on energy efficiency. To the best of our knowledge, the HECTOR protocol, introduced in [32] is the first protocol that is energy efficient, guaranteed delivery and is based on virtual coordinates. The coordinates used in HECTOR are a combination of tree coordinates named *labels* [40] and landmarks coordinates [39], [41]. In our algorithm, the node currently holding the packet forwards it to its neighbor that optimizes ratio of power cost over distance progress with landmark coordinates, among nodes that reduce landmark coordinates and do not increase tree coordinates. If such a node does not exist then forwarding is made to the neighbor that reduces tree based distance and optimizes power cost over tree distance progress ratio.

In [25], we address geographic routing based on geographic coordinates by introducing EtE. EtE is to our knowledge, the first georouting protocol which is both energy-efficient and guarantees delivery. It is a Greedy-Face-Greedy algorithm in which both steps are energy optimized. Face routing is optimized by running the planarization over a CDS graph, which allows to enlarge the edges of the faces. Then, an energy weighted shortest path is performed to reach the extremity of the Face. Simulations show that EtE consumes less than 10% more than the optimal centralized solution.

In [26], we present a localized geographic multicast scheme, MSTEAM, based on the construction of local minimum spanning trees (MSTs), that requires information only on 1- hop neighbors. A message replication occurs when the MST spanning the current node and the set of destinations has multiple edges originated at the current node. Destinations spanned by these edges are grouped together, and for each of these subsets the best neighbor is selected as the next hop. This selection is based on a cost over progress metric, where the progress is approximated by subtracting the weight of the MST over a given neighbor and the subset of destina- tions to the weight of the MST over the current node and the subset of destinations. Since such greedy scheme may lead the message to a void area (i.e., no neighbor providing pos- itive progress), we propose a new multicast generalization of the well-known face recovery mechanism. We provide a theoretical analysis proving that MSTEAM is loop-free, and achieves delivery of the multicast message as long as a path to the destinations exists. Our results demonstrate that MSTEAM outperforms the best existing localized multicast scheme, and is almost as efficient as a centralized scheme in high densities.

6.5. Security for Mobile Devices

Keywords: *Access control*, *Networked sensors*, *Security*, *Selfishness*.

Participants: Michael Hauspie, David Simplot-Ryl, Isabelle Simplot-Ryl, Thomas Soete, Nadia Bel Hadj Aissa, Dorina Ghindici, Gilles Grimaud.

In [31] one fundamental task of wireless sensor networks (WSNs) is to collect useful information from the sensory field and answer users' queries. In order to make effective use of the gigantic amount of individual sensor readings, it is essential to equip WSNs with scalable and energy-efficient data gathering mechanisms. Distinct characteristics of WSNs, e.g., large node density, unattended operation mode, high dynamicity and severe resource constraints, pose a number of design challenges on sensor data gathering schemes. An ever-increasing number of research activities have been carried out on this fundamental and attractive research issue. In this paper, we survey some existing solutions, with an emphasis on four data-centric storage-based methods, i.e., Geographic Hash Table (GHT), Distributed Index for Multi-dimensional range query (DIM), double ruling information brokerage, and landmark-based information storage and retrieval, which cover a range of design choices. We comparatively discuss advantages and disadvantages of the four schemes in detail, in accordance with several important design factors including communication overhead, communication hotspots, fault-tolerance and query locality. We seek to present advances on the topic, to trigger new ideas and to help extend existing techniques to increasingly complicated future protocols.

In [30] software systems, containing security vulnerabilities, continue to be created and released to consumers. We need to adopt improved software engineering practices to reduce the security vulnerabilities in modern systems. These practices should begin with stated security policies and end with systems which are quantitatively, not just qualitatively, more secure. Currently, contracts have been proposed for reliability and formal verification; yet, their use in security is limited. In this work, we propose a contract-based security assertion monitoring framework (CB_SAMF) that is intended to reduce the number of security vulnerabilities that are exploitable, spanning multiple software layers, to be used in an enhanced systems development life cycle (SDLC).

In [20] the volume of E-commerce transactions has considerably increased in the last several years. One of the most important aspects of such progress is the efforts made to develop and deploy dependable and secure payment infrastructures. Among these infrastructures is electronic cash, which is an attempt to reproduce the characteristics of paper cash in online transactions. Electronic cash schemes have so far been the purpose of a significant amount of research work. Although real-life deployments of such schemes are expected to take place in highly distributed environments, limited attention has been paid in the literature on underlying architectural issues. So far the focus has mostly been on addressing only security issues. However, for real-life deployment, distributed processing criteria such as performance, scalability, and availability are of prime importance. In this paper, through a survey of the literature, we identify and analyze the different distributed architectural styles underlying existing e-cash schemes. We discuss the strengths and limitations of these architectures with respect to fundamental system distribution criteria. In light of such discussion, we make some recommendations for designing effective distributed e-cash systems from an architectural perspective.

In [29], in the multiapplicative context of smart cards, a strict control of underlying information flow between applications is highly desired. In this paper we propose a model to improve information flow usability in such systems by limiting the overhead for adding information flow security to a Java Virtual Machine. We define a domain specific language for defining security policies describing the allowed information flow inside the card. The applications are certified at loading time with respect to information flow security policies. We illustrate our approach on the LoyaltyCard, a multiapplicative smart card involving four loyalty applications sharing fidelity points.

6.6. Software Customization for Small Devices

Keywords: *JVM optimization*, *JavaOS*, *memory management*.

Participants: Gilles Grimaud, Kevin Marquet, Simon Duquesnoy.

Embedded systems such as smart cards, RFID tags or sensors are present more and more around us, but are still relatively hard to program (because of the poorness of development tools like debuggers and unusual processing and memory constraints). A new trend consists in embedding Web servers in small devices, making both access and application development easier (Web applications are easy to use and well known by developers).

Web server like AJAX is technically hard to apply for embedded web server, because of the hardware limitations of targeted embedded systems (often some MHz of CPU frequency and only a few kilo-bytes of RAM), in contrast to the heaviness of usual Web servers (and Web protocols). In [24], we present a cross-layer analysis of the TCP/IP protocols when used for dynamic Web applications over HTTP. We test existing embedded Web servers and we analyze theirs performances. Starting from these analysis, we propose new solutions for an efficient and memory-lightweight Web server conception. We implemented all our propositions, giving a new embedded Web server, able to serve efficiently dynamic Web applications with a RAM usage of less than one kilo-byte without any underlaying operating system.

In [21], we first propose a new TCP performance model in the context of embedded Web servers: instead of the usual macroscopic and asymptotic TCP performance approximation, we describe a finegrained model for local connections with tiny devices. We then present a taxonomy of various content served by Web applications. We describe new strategies to serve efficiently each kind of Web content, both in terms of time and memory charge. Thanks to our model, we mathematically prove the relevance of our approach. We finally measure the effective benefits of our proposals thanks to a real use case implementation on a smart card. Our prototype, named Smews, makes a gap with state of the art solutions both in terms of performance and memory charge. Our experiments show that the fine-grained model we proposed is extremely precise.

7. Contracts and Grants with Industry

7.1. Gemplus/Gemalto partnership

Participants: Gilles Grimaud [Scientific responsible], Kevin Marquet, David Simplot-Ryl.

Since its creation, POPS has been supported by Gemplus/Gemalto within the framework of a partnership agreement that lasts since 19 years. Gemplus/Gemalto has been continuously supported the POPS research activities though fundings and the sharing of experiences and problems between POPS and Gemplus/Gemalto Labs researchers.

POPS has been a provider of innovative technologies for Gemplus/Gemalto thanks to several major patents (including those for a secure interpreter, a database card, a loader-linker of code, or communication protocols for tags), and thanks to thesis and projects such as: the card interpreter CAVIMA (1991), the “blank card” model (1991 and 1995), the CQL card and its integration in ODBC (from 1991 to 1994), a 32-bit RISC architecture for smart cards (1996), a programmable open card and its integration in object-oriented systems (1996), the language for the GemXplore 98 cards (1997), the integration of smart cards in transactional systems (1999), optimized communication protocols for tags (from 1999 to 2001 with Gemplus/Gemalto Tags), the card system CAMILLE (2000), or the card with multiple execution contexts.

Gemplus/Gemalto and POPS have also gained benefits from this partnership through National or European projects in which they participate altogether: CASCADE (IST 4^{th} framework), CESURE (RNRT), COMPiTV (RNTL), RESET (IST 5^{th} framework), and INSPIRED (IST 6^{th} framework).

At that present time, their partnership is mainly focused on embedded operating system research activities (JITS, Camille, and OS customization).

7.2. European FP6 IST IP “Wirelessly Accessible Sensor Populations” (WASP) 2006-2009

Participants: Jean Carle [contact], Gilles Grimaud, Michael Hauspie, Fadila Khadar, Nathalie Mitton, David Simplot-Ryl [contact].

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 organization of the nodes, towards the information distribution and a selection of applications. The emphasis in the project lays in the self-organization and the services, which link the application to the sensor network. 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:

- A consistent chain of energy-sensitive software components.
- Sets of cross optimized software stacks.
- Benchmarks and a set of measurements on energy- and code- efficiency.
- Rules for the design of configurable sensor nodes.
- A prototype implementation in one of the three chosen business areas.

List of participants: Philips Research Eindhoven, Philips Forschung Laboratorium, IMEC, CSEM, TU/e, Microsoft Aachen, Health Telematic Network, Fraunhofer IIS, Fokus, IGD, Wageningen UR, Imperial College London, STMicroelectronics, INRIA, Univ of Lille, Ecole Polytechnique Federale Lausanne, Cefriel, Centro Ricerce Fiat, Malaerdalen University, RWTH Aachen, SAP, Univ of Paderborn

http://www.wasp-project.org/.

7.3. European FP7 ICT IP “Advanced Sensors and lightweight Programmable middleware for Innovative Rfid Enterprise applications” (ASPIRE) 2008-2010

Participants: Nathalie Mitton [contact], Loïc Schmidt, David Simplot-Ryl.

ASPIRE will research and provide a radical change in the current RFID deployment paradigm through innovative, programmable, royalty-free and privacy friendly middleware. This new middleware paradigm will be particular beneficial to European SME, which are nowadays experiencing significant cost-barriers to RFID deployment.

European networked enterprises in general and SME in particular are still reluctant to adopt RFID, since they perceive RFID as unprofitable or too risky. This is largely due to the fact that the adoption of RFID technology incurs a significant Total Cost of Ownership (TCO). ASPIRE will significantly lower SME entry costs for RFID technology, through developing and providing a lightweight, royalty-free, innovative, programmable, privacy friendly, middleware platform that will facilitate low-cost development and deployment of innovative RFID solutions. This platform will act as a main vehicle for realizing the proposed swift in the current RFID deployment paradigm. The ASPIRE middleware platform will take into account innovative European developments in the area of ubiquitous RFID-based sensing (i.e., physical quantities sensing (temperature, humidity, pressure, acceleration), mobile sensing) towards enabling novel business cases that ensure high ROI (Return on Investment). The ASPIRE RFID middleware paradigm, as well as the unique and novel characteristics of the ASPIRE middleware platforms are thoroughly described in this proposal.

List of participants: Aalborg University - CTiF (Danemark), INRIA-ObjectWeb (France); INRIA-POPS (France), Université Joseph Fourrier - Grenoble University - LIG Laboratory (France), Research and Education Laboratory in Information Technologies - Athens Information Technology (Greece), Melexis technologies SA (Switzerland), Open Source Innovation Ltd (United Kingdom), NORMAPME European Office of Crafts, Trades and SMEs for Standardisation (Belgium), Dimitropoulos - VICOP LTD (Greece), Pole Traceability Valence PV (France), Instituto Telecomunicaoes (Italy).

http://www.aspire-project.eu/.

7.4. ANR RNRT "SurVeiller Prévenir" (SVP) 2006-2008

Participants: Gilles Grimaud, Grégory Guche, Nathalie Mitton [contact], David Simplot-Ryl.

This project is a RNRT project (Réseau National de la Recherche en Télécommunications http://www.telecom.gouv.fr/rnrt/).

The SVP project (SuperVise and Protect) proposes to study the realization and the experimentation of an integrated pervading architecture in order to make easier the conception, the deployment and the optimal exploitation of supervising and protecting services over different kinds of dynamic networks. Its main goal is to develop and deploy an environment able to embed a great amount of dynamic and communicating entities, each dedicated to a specific service.

In order to propose a generic architecture, the project aims to study the basic technological blocks needed to the development of supervising and preventing applications : interconnection between sensor nodes (localization, positioning, addressing, routing, etc) and providing of advanced functions (sensor network and data management and scheduling).

To validate our process, the project aims to develop and deploy two platforms of experiment in vivo and scenarios application software different and additional in term of coverage of problems. The first one is based on a process of quantification of the physical activity of the users by a non intrusive wireless biometric device for aspects of optimization of the resources. The second scenario is that of the seaport, notably the Autonomous Harbor of The Havre for aspects of positioning and localization in an complex radio environment.

List of participants: ANACT, APHYCARE, CEA Leti, INRIA POPS, INRIA ARES, INRIA R2D2, INRIA PARIS, LIP6, LPBEM, Institut Maupertuis, Thales.

7.5. ANR RNRT "Réseaux hétérogènes Intelligents pour Situations de Risques" (RISC) 2007-2010

Participants: Jean Carle [contact], David Simplot-Ryl, Michael Hauspie, Nathalie Mitton.

This project is a RNRT project (Réseau National de la Recherche en Télécommunications url-http://www.telecom.gouv.fr/rnrt/).

The RISC project (Réseaux hétérogènes Intelligents pour Situations de Risques) focuses on heterogeneous networks in the context of civil safety. The goal is to study and define the communication from physical to network layer process in a crosslayer optimization. This network is heterogeneous since it contains mobile and static nodes, with variable bandwidth. Furthermore, some nodes have the ability to monitor the environment. This heterogeneity comes from realistic deployment where different kind of nodes must operate in the same global network. For example, in safety operation context, mobile nodes are human with portable radio in the field of operations, fixed nodes correspond to radios infrastructure link to external world (i.e. headquarters). Sensors are also used to support current action: Static sensors are used to monitor the environment. Mobile sensors could be placed on human to monitor either environmental constants or human biological constants during operation.

The project is organized around two axes:

- Research and implementation of innovative technical methods taking into account heterogeneity of the network and in-use constraints.
- Crosslayer optimization which guaranty significant improvement for the performances. In the context of mobile ad hoc wireless environment, heterogeneity tighten up the need of crosslayering methods.

List of participants: CRESTIC, ENST Paris, ETIS, LIFL, RTS Electronics, Thales Communication.

http://risc.univ-reims.fr/.

7.6. ANR RNTL "Mesure de performances et caractéristiques de plates-formes embarquées Java-Card" (MESURE) 2006-2008

Participants: Gilles Grimaud [contact], Kevin Marquet, Hervé Meunier, David Simplot-Ryl.

This project is a RNTL project (Réseau National de recherche et d'innovation en Technologies Logicielles

The MESURE project is a pre-competitive project which aims at developing a set of tools to measure performance of microchip cards (smart cards). The open platforms used today in big mobile phone, payment, and electronic documents (IDs, passports) applications are built on open Java Card platforms.

The main objective of the project is to offer to the whole smart-card industry a tool to measure products. Today, such a tool does not exist in the industrial landscape, despite some tools developed internally by the designers and some important users. The existing tools are proprietary, really specific and not one is accepted by the whole industry.

The expected results by the end of the MESURE project are :

- The possibility for the smart-card industry to use a tool which can measure the performances and evaluate the characteristics of the Java platform.
- Having the opportunity to compare on criteria other than the price and the reliability.
- The definition of a point of reference which products can be compared to, performance wise.

List of participants: CNAM-CEDRIC (P. Paradinas), USTL-LIFL (G. Grimaud), Trusted Labs (E. Vétillard).

7.7. "Infrastructure pour le COMmerce du futur" (ICOM) 2007-2009

Participants: Nathalie Mitton [contact], Loic Schmidt, David Simplot-Ryl.

This project is lead in the framework of the competitiveness cluster of trade industry of Nord-Pas de Calais PICOM (Pôle des Industries du COMmerce). Trade industry are being in constant evolution. The massive apparition of the Internet, the increasing exigence of quality of service, the ubiquitous and pervasive informatics shatter the traditional trade practices, their economical and organizational models.

ICOM (Infrastructure pour le COMmerce du futur) aims at helping enterprises regarding a fast and easy deployment of new applications using new technologies and infrastructures from ubiquitous informatics. It will provide a smart infrastructure which hides the heterogeneity of identifiers (RFID, NFC, bar code) and manages data storage and request routing to provide scalability.

List of participants: Athos Origin (H. Jost), Auchan (B. Courouble), Décathlon (E. Lecointe), La Poste (J. Estienne), La Redoute (F. Gitton), INRIA-ASAP (A. Viana), INRIA-ADAM (L. Duchien), INRIA-POPS (N. Mitton), GS1 (S. Cren), ORANGE France (D. Dufresne).

http://risc.univ-reims.fr/.

7.8. ANR RNRT “Very large open wireless sensor networks” (SensLab) 2008-2010

Participants: Nathalie Mitton [contact], David Simplot-Ryl, Julien Vandaële.

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

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

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

List of participants: INRIA-ARES, INRIA-ASAP, INRIA-POPS, Thales Communication S.A. (V. Conan), UPMC-LIP6, ULP-LSIIT. http://www.senslab.info/.

7.9. INRIA ADT "Software and Hardware Toolbox for the Wireless Sensor Network Testbed" (SensTools) 2008-2009

Participants: Nathalie Mitton [contact], David Simplot-Ryl, Julien Vandaële.

The main and most important goal of the SensTOOLS ADT project is to foster the design, development, tuning, and experimentation of real large scale sensor network applications. Sensor networks have recently emerged as a premier research topic. However, due to their massively distributed nature, the design, implementation, and evaluation of sensor network applications, middleware, and communication protocols are difficult and time-consuming tasks. The purpose of the SensTOOLS is to provide both software and hardware toolboxes in order to offer to the developer appropriate tools and methods for designing, testing and managing his/her large scale large scale wireless sensor network applications.

List of participants: INRIA-ARES, INRIA-ASAP, INRIA-POPS.

7.10. ARC “CApacité des Réseaux radio MAillé (CARMA)” 2007-2008

Participants: Nathalie Mitton [contact], David Simplot-Ryl, Marie-Émilie Voge.

Wireless mesh network deployment is a major technological and economic stake and a decisive step toward a ubiquitous network. Mesh networks meet multi hop wireless communications very well studied in the context of ad hoc networks, when having the same target of coverage if a given area as a sensor network and the same needs of controlling from a telecommunication operator having to offer a guaranteed quality of service.

The goal of CARMA is to study and analyze the capacity of such mesh networks, major criterion of QoS. Then, it is mandatory to combine complementary theoretical approaches (deterministic bounds, stochastic tools, graph theory, etc) to develop methods and tools for modeling and evaluating the capacity provided by a mesh network. Then, we will aim at optimizing this capacity to enhance the network behavior. To do it, CARMA turns toward cross-layer approaches to approach the optimal behavior and provide a efficient deployment suitable and adaptive to applications. CARMA aims for it at providing communication protocols acting simultaneously at the MAC layer and the routing aspects. At last, protocols will be validated through theoretic tools, simulations and experiments.

List of participants: INRIA - ARES (G. Chelius, F. Valois), INRIA - MASCOTTE (D. Coudert, H. Rivano), INRIA-POPS and LSR - DRAKKAR (A. Duda, F. Theoleyre).

http://golgoth.inria.fr/wiki/Contrats/ARCINRIACARMA.

7.11. FUI "DEveloppement de CARTon Electronique" (DECARTE) 2008-2010

Participants: Nathalie Mitton [contact], David Simplot-Ryl.

The DECARTE project, labelized by the competitiveness clusters MAUD (Matériaux Utilisations et Développement Durable), of the Trade Industry PICOM (Pôle de compétitivité de l'Industrie et du COMmerce), PFA (Pôle de compétitivité Filiaire Aquatique) and Textil (Uptex Pôle de compétitivité textile innovant) consists in demonstrating the technical feasibility and economic integration of a RFID system printed on packaging during their manufacturing process in mass production. So with a new feature of a non-visual low unit cost, these new electronic packages will offer the opportunity to develop communicating solutions all along the distribution chain.

List of participants: Cartonneries de Gondardennes (Bertrand Helle), Cascades Blendecques, Etik Ouest, Gic, Cartonneries de Gondardennes, CTP, INRIA POPS, IEMN and IFTH.

7.12. CNRS national platform "Sensor and Self-Organized Networks" (RECAP)

Participants: Jean Carle [contact], Antoine Gallais, Michael Hauspie, Fadila Khadar, Nathalie Mitton, David Simplot-Ryl [contact].

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 multi-hop wireless communication.

Self-adaptive and self-organized are questions of active research in a number of different research communities, ranging from hardware to applications. Many topics must be study such as topology control (addressing, localization, etc.), data communication (broadcasting, routing, gathering, etc.), architecture (hardware, system -OS-, network -communication stacks-, etc.), applications (service lookup, distributed database, etc.). The RECAP project is a CNRS national platform which aims to support research activities in this area. RECAP is organized in four sub-projects: Applications, Data Communication, Topology Control, and System Architecture.

List of participants: CITI INSA Lyon (E. Fleury), LAAS (M. Diaz), LIFL (J. Carle), LIP6 (M. Dias de Amorim), IRISA (P. Quinton), LSIIT (T. Noël), LSR (A. Duda). http://www2.lifl.fr/sensor/.

7.13. ANR SESUR 2007 "Securing Flow of INformation for Computing pervasive Systems" (SFINCS) (2008-2010)

Participants: Dorina Ghindici, Gilles Grimaud, Samuel Hym, Isabelle Simplot-Ryl [project leader].

The upsurge of a globally interconnected network of devices have had a deep impact on the environment, habits and even typology of computing devices end-users. These advances changed our behaviour in a lot of beneficial ways but also gave way to new threats that feed decades-old fears about liberty. Preserving privacy and security are thus more than ever at the heart of service users and providers concerns.

In an open, heterogeneous and highly concurrent context, enforcing private and business data confidentiality requires, beyond basic access control, fine-grained control over data usage by the various actors. This problem is known from the literature as information flow control. Information flow analysis has been actively investigated for several years, leading to a rich theory. This problem has usually been tackled from a type-checking or static analysis viewpoint. However, it appears that this rich theory has been scarcely applied in the industry.

The SFINCS project aims at studying application of this theory on practical use-cases to identify bottlenecks that prevent wider industrial adoption of information flow control techniques. To this end, project SFINCS brings together complementary partners: From case studies provided by industrial partners, academic partners shall enrich information flow theory to take into account practical issues preventing thorough analysis of ubiquitous software systems. Provided case studies come from distance selling services and mobile telephony and thus will provide a wide array of the diverse problems encountered in the enforcement of needed security and privacy properties.

This project addresses varied problems:

- Software engineering and programming problems, like analysis of programs using shared libraries through public APIs or external streams (eg. XML),
- Theoretical problems about information analysis, like tracking information in arrays or collections,
- Security engineering problems, like expressing of security rules or selective authorization of information leaking through safe channels (eg. using cryptography).

List of participants: LIFL (G. Grimaud, S. Hym, I. Simplot-Ryl), LIF, Univ. of Provence (J.-M. Talbot), VERIMAG (Laurent Mounier, Michael Périn, Yassine Lakhnech, Pascal Lafoucarde), NORSYS/SI3SI (Pascal Flamant, Arnaud Bailly), Trusted Labs (Anthony Ferrari, Erci Vétillard).

http://sfincs.gforge.inria.fr/.

7.14. International Relationship

We have research activities with international partners as:

- Edgar Chavez, Univ. Morelia, Mexico,
- Essia H. Elhasfi, Riverside University, Los Angeles, USA,
- Ivan Stojmenović, Univ. Ottawa, Canada.
- Issa Traoré, Univ. of Victoria, Canada.

Isabelle Simplot-Ryl is member of the Creol project (CREOL: A formal framework for reflective component modeling) of the University of Oslo funded by the Research Council of Norway through the strategic program IKT-2010.

7.15. Visits and Invitations of Researchers

- Prof. Ivan Stojmenović from the University of Ottawa was invited in Lille for three monthes from September to November 2008.
- Associate Professor Issa Traoré from the University of Victoria, Canada was invited for 6 monthes in 2008.
- Prof. David Simplot-Ryl was visiting professors at the University of Ottawa in August 2008.

8. Dissemination

8.1. Editorial Activities

- **David Simplot-Ryl** is managing editor of *Ad Hoc & Sensor Wireless Networks: An International Journal (AHSWN)* (Old City Publishing), associate editor of *International Journal of Computers and Applications (IJCA)* (ACTA Press), member of editorial board of *International Journal of Wireless and Mobile Computing (IJWMC)* (Inderscience) and of editorial board of *International Journal of Parallel, Emergent and Distributed Systems (IJPEDS)* (Taylor & Francis). He is guest-editor of a special issue of *Journal of Computer Communications* (Elsevier) on "Sensor-Actuator Networks (SANETs)" in 2007.

8.2. Organization Committees and Program Committees (Conferences, Workshops, Schools)

- **Jean Carle** was program committee member of several international events such as :
  - *3rd International Workshop on Localized Communication and Topology Protocols for Ad hoc Networks (LOCAN 2008* (Atlanta, Georgia, September 29 - October 02).
  - *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) 2008*, (Cannes, 16-18 September).
  - *9th ACIS International Conference on Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing (SNPD2008)* (August 6 - 8, Phuket, Thailand).
  - *Second Workshop sur la Cohérence Des Données en Univers Réparti (CDUR 2008)* (Lyon, France, June 23-27).
- **Gilles Grimaud** is general co-chair of:
  - *Eighth Smart Card Research and Advanced Application IFIP Conference (CARDIS 2008)*, (Ehgam, UK, September 2008), program co-chair,
- **Gilles Grimaud** is involved in the program committee of international events:
  - *The 8th WG 8.8/11.2 International Conference CARDIS 2008 (Program co-chair), Royal-Holloway, University of London, UK, September*,
  - *ACM SigOps/ASF CFSE'08, Fribourg, Switzerland, February*,
  - *ACM SIGAPP & ACP SIGPLAN, Pinciples and Practice of Programming in Java 2007, Lisbon, Portugal, September*.
- **Michael Hauspie** is a program committee member of:
  - *The 7th ACS/IEEE International Conference on Computer Systems and Applications 2009*
  - *IADIS International Conference Wireless Applications and Computing 2009*
  - *International Conference on Mobile Communications and Pervasive Computing (MCPC 2009)*
  - *Second ACM Workshop on Sensor Actor Networks (SANET 2008)*

  He is publicity chair:
  - *Second ACM Workshop on Sensor Actor Networks (SANET 2008)*
- **Nathalie Mitton** is a program committee member of:
  - *11^{es} Rencontres Francophones sur les Aspects Algorithmiques de Télécommunications (Algotel-2009)* Carry le Rouet, France, June 16-19, 2009.
  - *Sixth Workshop on Wireless Ad hoc and Sensor Networks (WWASN2009)*, Montreal, Canada, June 2009.

- *2nd International Workshop on Localized Algorithms and Protocols for Wireless Sensor Networks (LocAlgos 2008)*, Santorini Island, Greece. June 2008.
- *4th International Workshop on Localized Communication and Topology Protocols for Ad hoc Networks (LOCAN 2008)* , Atlanta, Georgia, USA. September 29, 2008,
- *1st ACM Workshop on Sensor Actor Networks (SANET 2008)* (Hong-Kong, China, May, 2008).
- *9es Journées doctorales en Informatique et Réseaux (JDIR 2008)* (Villeneuve d'Ascq, France, Jan., 2008).
- *10es Journées doctorales en Informatique et Réseaux (JDIR 2009)* (Belfort, France, Feb. 2-4, 2009).

She is publicity chair:

- *7th ACS/IEEE International Conference on Computer Systems and Applications (AICCSA-2009)* (Rabat, Morocco, May 10-13, 2009).

She is a member of the steering and organizing committee of the first ICTF (International Contactless Technologies Forum) hold on June 11-12 in Lille.

- **David Simplot-Ryl** is general co-chair of:
  - *4th International Workshop on Localized Communication and Topology Protocols for Ad hoc Networks (LOCAN 2008)*, (Atlanta, Georgia, USA, 2008, September 29-October 2, 2008), organized in conjunction with the *5th IEEE International Conference on Mobile Ad Hoc and Sensor Systems (MASS-2008)*,
  - *5th Workshop on Wireless Ad hoc and Sensor Networks (WWASN2008)*, (Beijing, China, 2008, June 17-20), held in conjunction with the *The International Conference on Distributed Computing Systems (ICDCS 2008)*.
  - *2nd International Workshop on Energy Optimization in Wireless Sensor Networks*, (August 25-31, 2008 - Cap Esterel, France).
  - *6th Workshop on Wireless Ad hoc and Sensor Networks (WWASN2009)*, (Montreal, Canada, June 22-26, 2009) organized in conjunction with the *The International Conference on Distributed Computing Systems (ICDCS 2009)*.

  He is program chair, vice-chair or co-chair of:
  - *10ème Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications (AlgoTel 08)* (Saint Malo, France, May 14-16, 2008).
  - *7th International Conference on Ad-hoc Networks and wireless (ADHOC-NOW 2008)*, (Nice, France, September 10-12, 2008).

  He is member of several program committees:
  - *The First ACM International Workshop on Heterogeneous Sensor and Actor Networks (HeterSanet 2008)*, (Hong Kong SAR, China, May 27, 2008), organized in conjunction with ACM MobiHoc 2008,
  - *3rd International Conference on Digital Telecommunications (ICDT 2008)*, (June 29 - July 5, 2008 - Bucharest, Romania).
  - *2008 IFIP Conference on Wireless Sensor and Actor Networks*, (Ottawa, Ontario, Canada, July, 2008)
  - *2008 International Workshop on Mobile IPv6 and Network-based Localized Mobility Management (MobiWorld 2008)*, (I-Lan, Taiwan, September 10-12, 2008),
  - *33rd IEEE Conference on Local Computer Networks (LCN 2008)*, (Montreal, Quebec, Canada, 14-17 October 2008),

  - *14th Intl Conference on Parallel and Distributed Systems (ICPADS'08)*, (Melbourne, Victoria, Australia, 8th-10th December, 2008),
  - *2nd Joint IFIP Wireless and Mobile Networking Conference (WMNC'09)*, (September 9-11, 2009 Gdansk, Poland).

- **Isabelle Simplot-Ryl** is a program committee member of several international events:
  - *6th International Conference on Ubiquitous Computing and Intelligence (UIC-09)*, (Brisbane, Australia, July 7–10, 2009).
  - *2nd International Conference on Dependability (DEPEND 2009)*, (Athens, Greece, June 14–19, 2009).
  - *3rd International Workshop on Intelligent, Mobile and Internet Services in Ubiquitous Computing (IMIS 2009)*, (Fukuoka, Japan, March 16-19, 2009), in conjunction with CISIS 2009.
  - *3rd International Conference on Multimedia and Ubiquitous Engineering (MUE'09)*, (Qingdao, China, June 4-6 2009).
  - *1st International Workshop on Multimedia, Information Privacy and Intelligent Computing Systems (MPIS'08)*, (Jiaosi, Yilan, Taiwan, December 9-10 2008), in conjunction with the 2008 IEEE Asia-Pacific Services Computing Conference.
  - *33rd IEEE Conference on Local Computer Networks (LCN 2008)*, (Montreal, Canada, 20-23 October 2008.
  - *3rd International Symposium on Smart Home (SH'08)*, (Hainan Island, China, December 13-15, 2008), in conjunction with FGCN 2008).
  - *The Ad-Hoc and Sensor Networking Symposium (ICC'2009-AHSNET)*, (Dresden, Germany, June 14-18, 2009), in conjunction with IEEE ICC'2009.
  - *5th International Conference on Ubiquitous Intelligence and Computing (UIC 08)*, (Oslo, Norway, June 23-25, 2008).
  - *Eighth Smart Card Research and Advanced Application IFIP Conference (CARDIS 2008)*, (Ehgam, UK, September 2008).
  - *2nd International Workshop on Interactive Multimedia & Intelligent Services in Mobile and Ubiquitous Computing 2008 (IMIS 2008)* (Busan, Korea, April 24-26, 2008), in conjunction with MUE2008.
  - *9es Journées Doctorales en Informatique et Réseaux (JDIR'08)*, (Lille, Janvier 2008).

8.3. Invited Talks and Seminars

- **David Simplot-Ryl** gave a number of invited talks:
  - Localized Position-Based Routing in Wireless Sensor and Ad Hoc Networks, *2nd International Workshop on Localized Algorithms and Protocols for Wireless Sensor Networks (LOCALGOS 2008)* (Santorini Island, Greece) [22],
  - Robustness in Wireless Sensor and Actuator Networks, *1er Workshop sur la Sécurité des Réseaux Autonomes et Spontanés* (Loctudy, France) [23].

8.4. Teaching

- **Jean Carle** is director of a vocational degree in computer sciences (licence professionnelle). He is also in charge of lecture in Mobile Networking for master degree in computer science, of lectures in *Networking and Data Communication* to under degree in computer science (IUT 1st and 2nd year) and in *Algorithm* to under degree in computer science (IUT 1st year).

- **Gilles Grimaud** is in charge of lectures in *Embedded Systems* for research master (DEA), of lecture in *Security of Networks and Systems* for professional master (DESS), of lecture in *Operating Systems Architecture* for master of computer science (maîtrise), and of lecture in *Networking* in computer science degree (licence).
- **Michael Hauspie** is in charge of lectures in *Software engineering*, *Networking*, *Operating Systems* and *Network services administration* in under degree in computer science and vocational degree in computer science (IUT 1^{st} and 2^{nd} year/licence professionnelle).
- **Samuel Hym** is in charge of lectures in *Specification and Verification of Softwares* to first-year master students.
- **Nathalie Mitton** is in charge of lectures in *Mobile Networking* for research master (DEA), in *Networking for Autonomous Systems* for professional master (DESS) and in *Transmission and Protocols* for vocational degree in computer science (licence professionnelle).
- **Tahiry Razafindralambo** is in charge of lecture in *Networking for Autonomous Systems* for professional master (DESS).
- **Isabelle Simplot-Ryl** was head of the computer science department of the IUT-A until may 2008. She is in charge of lectures in systems programming to under degree in computer science and vocational degree in computer science (IUT 2^{nd} year/licence professionnelle), and of Lectures in Security in master.
- **Marie-Emilie Voge** is in charge of lectures in *Algorithms and simulations for wireless networks* to research master students (master TAC) and in *Algorithmics* in computer science applied to enterprise management degree (licence MIAGE).

8.5. Miscellaneous Scientific Animation

- **David Simplot-Ryl** was referee or examiner for several PhD thesis and Habilitation thesis:
  - Jia Liang Lu (CITI, INSA Lyon, directed by Fabrice Valois, referee),
  - Thomas Watteyne (CITI, INSA Lyon, directed by Stéphane Ubéda and Isabelle Augé-Blum, chair),
  - Emil Ivov (LSIIT, Univ. Strasbourg I, directed by Thomas Noël, chair),
  - Vincent Borrel (LIP6, UPMC, directed by Marcelo Dias di Amorim and Serge Fdida, referee),
  - Fabrice Peyrard (LATTIS, Univ. Toulouse II, habilitation, referee),
  - Mohammad Nassiri (LIG, Univ. Grenoble, directed by Andrzej Duda, referee),
  - Ghazi Al Sukkar (INT Evry, directed by Hossam Afifi, referee).
- **Gilles Grimaud** is a member of the steering committee of French Chapter of ACM SigOps. He is also is a member of the IFIP Working group 8.8 (SmartCards) and a member of the CSE of Lille university and Valenciennes University.
- **David Simplot-Ryl** is a member of the working group of OFTA (Observatoire Français des Technologies Avancées) on Ambient Computing directed by Valérie Issarny. He is member of the scientific committee of GDR ASR of CNRS.
- **Nathalie Mitton** is member of the technology development committee (CDT).
- **Nathalie Mitton** was referee or examiner for following PhD thesis:
  - Philippe Leroux (Université de Laval, Québec, Canada, directed by Prof. Sébastien Roy),
  - Fehmi Ben Abdesslem (LIP6, Univ. MPC, directed by Prof. Serge Fdida and Dr. Marcelo Dias de Armorim),

- **The POPS team** has organized the "9es Journées Doctorales en Informatique et Réseaux" which was held at Villeneuve d'Ascq from January 16th to January 18th 2008.

9. Bibliography

Major publications by the team in recent years

[1] N. BEL-HADJ-AISSA, G. GRIMAUD, V. BENONY. *Bringing Worst Case Execution Time Awareness to an Open Smart Cards OS*, in "Proc. 13th IEEE Conf. on Embedded and Real-Time Computing Systems and Applications (RTCSA 2007), Daegu, Korea", 2007, p. 497-503.

[2] J. CARLE, D. SIMPLOT-RYL. *Energy Efficient Area Monitoring by Sensor Networks*, in "IEEE Computer", vol. 37, 2004, p. 40–46.

[3] J. CARTIGNY, D. SIMPLOT-RYL. *Border Node Retransmission Based Probabilistic Broadcast Protocols in Ad-Hoc Networks*, in "Telecommunication Systems", vol. 22, n^{o} 1-4, 2003, p. 189–204.

[4] J. CARTIGNY, D. SIMPLOT-RYL, I. STOJMENOVIC. *Localized Minimum-Energy Broadcasting in Ad-hoc Networks*, in "Proc. IEEE INFOCOM'2003, San Francisco, USA", 2003, p. 2210- 2217.

[5] E. CHAVEZ, N. MITTON, H. TEJEDA. *Routing in Wireless Networks with Position Trees*, in "Proc. 6th Int. Conf. on AD-HOC Networks & Wireless (Ad Hoc Now'07), Morelia, Mexico", 2007, p. 32-45.

[6] D. DEVILLE, A. GALLAND, G. GRIMAUD, S. JEAN. *Smart Card Operating Systems: Past Present and Future*, in "Proc. 5th NORDU/USENIX Conference (NordU2003), Vasteras, Sweden", Best paper award, 2003.

[7] E. ELHAFSI, N. MITTON, D. SIMPLOT-RYL. *Cost over Progress Based Energy-efficient Routing Protocol over Virtual Coordinates in Wireless Sensor*, in "Proc. IEEE Int. Workshop: From Theory to Practice in Wireless Sensor Networks (t2pWSN 2007), Helsinki, Finland", 2007, p. 1-6.

[8] A. GALLAIS, J. CARLE, D. SIMPLOT-RYL, I. STOJMENOVIC. *Localized Sensor Area Coverage with Low Communication Overhead*, in "Proc. 4th Annual IEEE Int. Conf. on Pervasive Computing and Communications (PerCom 2006), Pisa, Italy", 2006, p. 661 - 672.

[9] G. GRIMAUD, Y. HODIQUE, I. SIMPLOT-RYL. *On the Use of Metatypes for Safe Embedded Operating System Extension*, in "International Journal of Parallel, Emargent and Distributed Systems (IJPEDS)", vol. 22, n^{o} 1, 2007, p. 1–13.

[10] F. INGELREST, N. MITTON, D. SIMPLOT-RYL. *A Turnover based Adaptive HELLO Protocol for Mobile Ad Hoc and Sensor Networks*, in "Proc. 15th Annual Meeting of the IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS 2007), Istanbul, Turkey", 2007.

[11] F. INGELREST, D. SIMPLOT-RYL. *Localized Broadcast Incremental Power Protocols for Wireless Ad Hoc Networks*, in "Wireless Networks", 2007, p. 28 - 33.

Year Publications

Doctoral Dissertations and Habilitation Theses

[12] D. GHINDICI. *Information flow analysis for embedded systems: from practical to theoretical aspects*, Ph. D. Thesis, Univ. Lille 1, December 2008.

[13] G. GRIMAUD. *Déploiements Sécurisés de Logiciels Critiques au sein d'Environnements Contraints*, Ph. D. Thesis, HDR, Univ. Lille 1, France, November 2008.

Articles in International Peer-Reviewed Journal

[14] A. GALLAIS, J. CARLE, D. SIMPLOT-RYL, I. STOJMENOVIC. *Localized Sensor Area Coverage with Low Communication Overhead*, in "IEEE Transactions on Mobile Computing", vol. 5, n^{o} 7, 2008, p. 661–672.

[15] J. IGUCHI-CARTIGNY, P. M. RUIZ, D. SIMPLOT-RYL, I. STOJMENOVIC, C. M. YAGO. *Localized Minimum-energy Broadcasting for Wireless Multihop Networks with Directional Antennas*, in "IEEE Transactions on Computers", to appear, 2008.

[16] F. INGELREST, D. SIMPLOT-RYL. *Localized Broadcast Incremental Power Protocol for Wireless Ad Hoc Networks*, in "Wireless Networks", vol. 14, n^{o} 3, 2008, p. 309–319.

[17] N. MITTON, K. PAROUX, B. SÉRICOLA, S. TIXEUIL. *Ascending runs in dependent uniformly distributed random variables: Application to wireless networks*, in "Methodology and Computing in Applied Probability", n^{o} 11009, 2008.

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[19] T. RAZAFINDRALAMBO, I. GUERIN-LASSOUS. *Increasing fairness and efficiency using the MadMac protocol in ad hoc networks*, in "Ad Hoc Networks", vol. 6, May 2008, p. 408-423.

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Invited Conferences

[21] S. DUQUENNOY, G. GRIMAUD. *Embedding Web servers in pocket devices*, in "Smart University - The art of Java Card 3.0 Programming, Sophia Antipolis, France", invited talk, 09 2008.

[22] D. SIMPLOT-RYL. *Localized Position-Based Routing in Wireless Sensor and Ad Hoc Networks*, in "2nd International Workshop on Localized Algorithms and Protocols for Wireless Sensor Networks (LOCALGOS 2008), Santorini Island, Greece", invited talk, 2008.

[23] D. SIMPLOT-RYL. *Robustness in Wireless Sensor and Actuator Networks*, in "1er Workshop sur la Sécurité des Réseaux Autonomes et Spontanés, Loctudy, France", invited talk, 2008.

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[24] S. DUQUENNOY, G. GRIMAUD, J.-J. VANDEWALLE. *Haute performance pour serveurs Web embarqués*, in "Proc. 9èmes Journées Doctorales en Informatique et Réseau (JDIR'08), Villeneuve d'Ascq, France", 2008.

[25] E. H. ELHAFSI, N. MITTON, D. SIMPLOT-RYL. *End-to-End Energy Efficient Geographic Path Discovery With Guaranteed Delivery in Ad Hoc and Sensor Networks.*, in "Proc. 19th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'08), Cannes, France", September 2008.

[26] H. FREY, F. INGELREST, D. SIMPLOT-RYL. *Localized Minimum Spanning Tree Based Multicast Routing with Energy-Efficient Guaranteed Delivery in Ad Hoc and Sensor Networks*, in "Proc. IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WOWMOM 2008), New Port Beach, USA", 2008.

[27] A. GALLAIS, J. CARLE. *Etude et extension des relais de couverture de surface dans les réseaux de capteurs*, in "Proc. Colloque Francophone sur l'Ingénierie des Protocoles (CFIP 2008), Les Arcs, France", 2008.

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