INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team POPS

System & Networking for Portable Objects Proved to be Safe

Futurs

THEME COM

Activity Report

2006

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1. Team

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2. Overall Objectives

2.1. Overall Objectives

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) [58], wireless sensors (see Fig. 3) [52] 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 [49], 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.

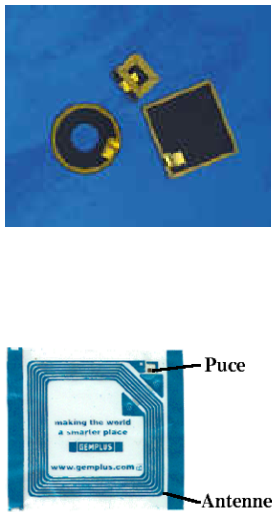


Figure 1. Example of RFID tags.

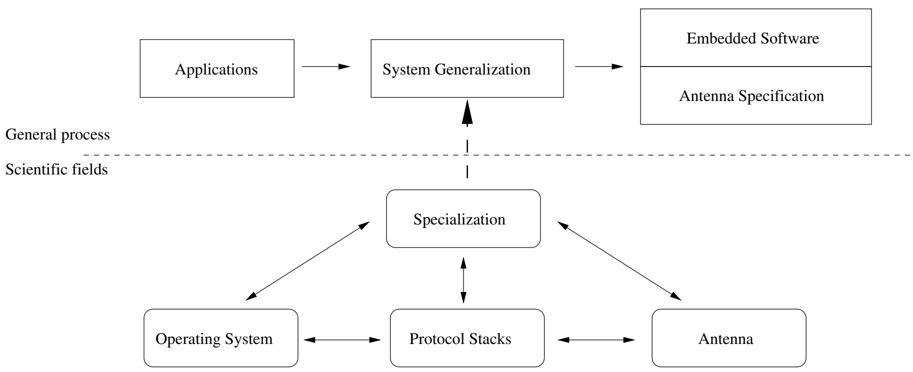
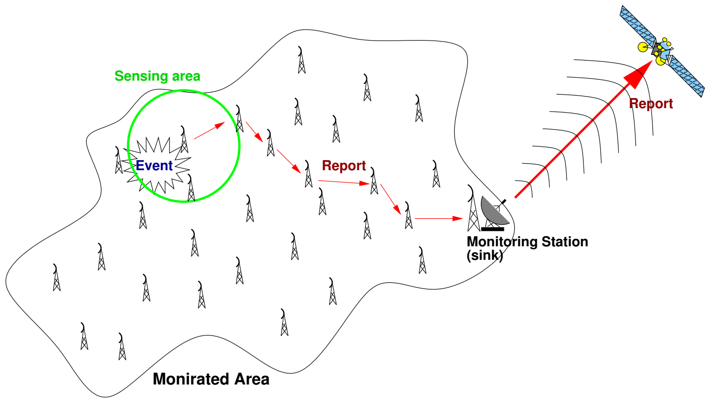


Figure 2. POPS' thematics and objectives

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.

Event-driven model



On-demand model

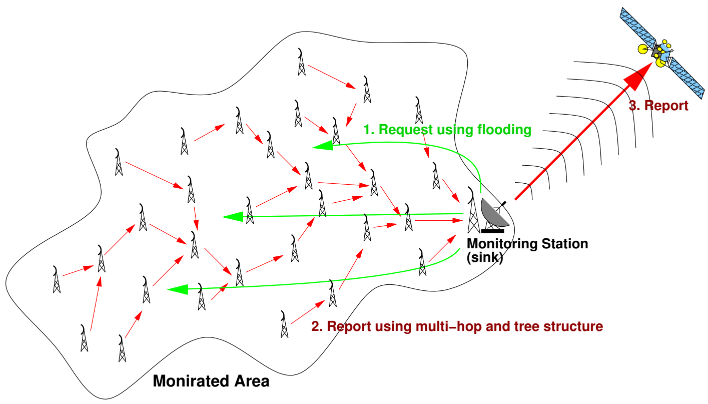


Figure 3. Example of a sensor network with event-driven and on-demand models.

POPS research action takes advantage of its strong partnership with Gemplus/Gemalto since more than 17 years. This collaboration brings both partners (the POPS research group of LIFL 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 three 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 ensure 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 [71], [50], [51], [48] cover 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 has 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 power consumption by 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 problem (detecting neighboring nodes located within transmission radius) and network organization problem (deciding what communication links to establish with neighboring nodes, sleeping period operations 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.

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*.

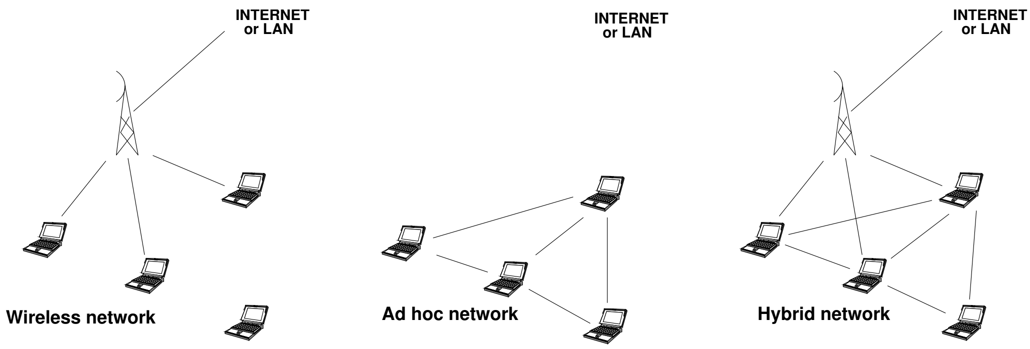


Figure 4. From wireless network to hybrid networks.

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.

Hence, POPS systems have to adapt themselves to applications requirements or modifications of their environment. In this context, we are conducting research in the two following connected areas:

- **Embedded Operating Systems**, focusing on operating systems and virtual machines scalability (in terms of memory, microchip performance and energy) where smart cards are our reference target. Our main activities deal with the scalability of Java abstractions (the "Java in the Small" sub-project) and efficient, extensible and safe hardware management (the "Camille NG" sub-project).
- **Mobile Networking**, focusing on communication protocols on wireless network architectures, in ad hoc or wireless LAN mode, using or not fixed infrastructure. Our protocols aim to ensure secure connectivity and QoS enhancement of dense large networks which are constituted of small devices with high mobility.

POPS software architecture has never stopped evolving. Since birth of smart cards (for instance) in the early eighties, we can distinguish four different generations of software architectures, from the rough, monolithic "smart card mask" to the ultra light "post-issuance" open kernel. Nevertheless, all software generations are still used today. A rough monolithic smart card OS is the only way (known by the industry) to product low-end/low-cost smart cards. "Post-issuance OS" like Java Card are sold for the high-end market.

The smart card example has shown that embedded software is a huge family. In fact, according to the limited capabilities provided by the hardware, an embedded application offers "limited" functionality. Nevertheless the omnipresence of the POPS (over 10^9 smart card around the world today) implies a great diversity of software. And the Subscriber Identification Module (SIM) inserted in our GSM, is very different from sensors used in wireless sensor networks. All of them are supported by a powerless hardware with limited resources (memory, CPU and energy). They all suppose the use of dedicated APIs and tools. They are built over dedicated underlying operating systems...

Supporting at the same time the whole set of abstractions used by each possible embedded application is obviously impossible. To overcome this technological lock our research group has proposed to embed the use of Exo-Kernel architecture [57]. Exo-kernel architecture consists in suppressing any abstraction consideration in the (Operating System) kernel design.

Basically if we consider the conception of a conventional file system, we can define three internal layers (see Fig. 5). In a conventional "monolithic OS" The bottom layer manages the hardware, allocating sectors, or flash memory pages, programming the burn of data, etc...The second layer implements basic software to simulate a virtual device easier to administrate and to use: "the file system". The top layer manages the software security by controlling the files access. In a μ-kernel, the 'kernel' of the operating system does not support a preferred abstraction but only manage (in a preferred way) the hardware and offer a safe and secure access for different abstractions implementations. In this way, μ-kernels allows the coexistence of multiple hardware abstractions. But recent results contest the performances of such OS architectures. In an operating system the performances of provided abstractions are greatly improved when they are correlated to the adequate hardware management. That's why Exo-Kernels architects claim that "the exo-kernel must offer a safe hardware exposition without any abstraction". Software applications must be able to access the hardware and manage it according to their own goals. It is the best way to ensure dynamic adaptability to the applications requirement.

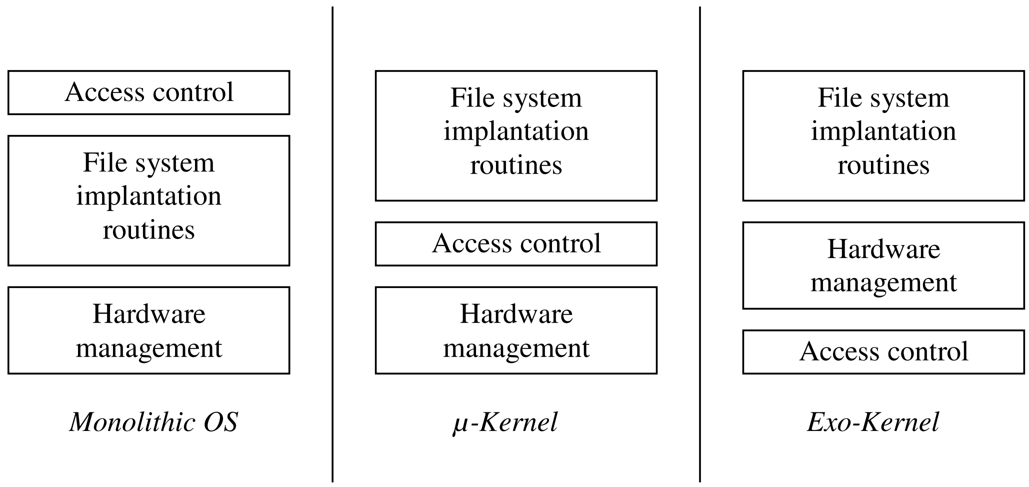


Figure 5. From monolithic OS to exo-kernel architecture.

We have proved the feasibility of this kind of kernel in a tiny device. However, it is an incomplete purpose because some hot OS topics can be loaded in a safe way. Safety is ensured statically, while the OS component is loaded. The Kernel Trusted Computing Base uses the "Proof Caring Code" principles [66]. Nevertheless, the current Camille OS defines security in terms of confidentiality and integrity, not in term of availability. Problems are related to Real Time software and Resource Control. These goals are one of our next actions called Camille NG.

Smart card is probably one of the most limited devices in the POPS family. Important industrial efforts were made to invite Java developers to deploy Java software on cards. Nevertheless tiny operating systems like Java Card OS does not really satisfy Java developers. In this way, our work around Camille (supporting dynamic extensions of the embedded OS) looks insufficient. In fact Camille enables multiple hardware abstractions justified by multiples applications needs. However, real powerful abstractions, like those proposed by Java technologies, were clearly not deployed in POPS. To invite conventional software designer to deploy they work on POPS we propose to study new OS approach to deploy Java In The Small.

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

The most suitable kind of network for POPS are wireless ad hoc networks which cover a wide range of self-organized network types. Ad hoc networks are multi-hop networks consisting of wireless autonomous hosts, where each host may serve as a router to assist traffic from other nodes. Wireless ad hoc networks cover a wide range of network scenarios, including sensor, mobile ad hoc, personal area, and rooftop/mesh networks. Sensors provide service to monitoring stations. Mobile ad hoc networks are pure infrastructure-less networks used in disaster relieves, conferences, hospitals, campus and battlefield environments, with laptops, palmtops, cellular phones or other devices serving as nodes. Rooftop/mesh networks provide high-speed wireless Internet access to homes and offices.

Nodes (hosts) in an ad hoc network can be static or mobile, and can switch between active and sleeping modes. The control is distributed, thus each POPS makes independent decisions following a common pre-established protocol. An ad hoc network may be linked to a fixed infrastructure (to receive or provide service) or can function on its own. Wireless networks of sensors are likely to be widely deployed in the near future because they greatly extend our ability to monitor and control the physical environment from remote locations and improve our accuracy of information obtained via collaboration among sensor nodes and online information processing at those nodes. Networking these sensors will revolutionize information gathering and processing in many situations (*e.g.* monitoring and reporting fires, chemicals, intruders etc.). Home or office appliances can be networked in a personal area network, with input from a fixed station or mobile human. Rooftop networks are static networks with nodes placed on top of buildings. They are applied in the mesh-networking approach, where the neighborhood is ‘seeded’ by the installation of a ‘neighborhood access point’ (NAP), a radio base-station connected to the Internet via a high-speed connection. Homes and offices within range of this NAP install antennas of their own, enabling them to access the Internet at high speed. Each of these homes and offices can also act as a relay for other homes and offices beyond the range of the original NAP. As the mesh grows, each node communicates only with its neighbors, which pass Internet traffic back and forth from the NAP. It is thus possible to cover large area quickly and cheaply. For providing fixed-wireless access, the mesh approach is technically superior to the traditional ‘point-to-multipoint’ radio approach. It requires much less power, offers multiple paths for choosing the fastest route, is robust and scales up easily. Ad hoc networks will make communication technology useful for people everywhere regardless of nature and availability of backbone infrastructures.

In a crowded environment, such as sport arena, phones could pass traffic from other phones to base stations in adjacent cells, thus boosting capacity. Reduced power also reduces the interferences when a call is multi-hopped to the same base station instead of being directly transmitted. Calls between users within the arena could be handled locally, without loading the cellular network.

Commercial developments of wireless networks have been so far basically limited to the single hop scenarios, with one link between a mobile node and the fixed infrastructure (*e.g.* cellular telephony), or between two mobile/wireless nodes (*e.g.* Bluetooth short range technology). Single-hop wireless networks already pose significant challenges due to limited bandwidth and battery power restrictions. A multi-hop wireless network can be modeled as a graph, with two nodes joined by an edge if and only if they are able to directly communicate with each other. The most popular model in literature is the model of a unit disk graph. In such a unit disk graph, a message sent by any node reaches simultaneously all its neighbors whose distance to the transmitting node is no more than the transmission radius, which is equal for all nodes. Variations of the model includes adding obstacles, having different transmission radii for each node, or introducing minimum and maximum transmission radii, where nodes closer than minimum radius receive message, farther than maximum radius, do not receive message, and uncertain reception in between the two radii.

The selections of best data communication protocols at the network layer are certainly affected by developments, current and future, on other layers below and above the network layer. For instance, the physical layer decides whether omni directional or directional antennas are used. If antennas are omni directional, which is a typical assumption, then a message sent by one node can be simultaneously received by all its neighbors (so called one-to-all model). Some recent developments exploit the use of directional ‘smart’ antennas, fixed narrow beam (reaching only one neighbor, one-to-one model), wide fixed beam, or variable angular size beam antennas (one-to-many models). The ultra-wideband (UWB) transmission involves transmitting very short pulses on a wide range of frequencies simultaneously at low power. Such pulses, less than billionth of a second long, pass unnoticed by conventional radio receivers, but can be detected by a UWB receiver. Information is encoded into streams of pulses, millions of which can be sent every second, by varying their polarity or their timing relative to an apparently random but pre-arranged schedule. UWB received a massive boost in February 2002, when it received limited approval for transmissions up to about ten meters. UWB is capable of data rate of over 100 megabits per second on such short distances. Work is well advanced on the standard to enable UWB devices to locate and communicate with each other. Ad hoc networking is expected to receive further boost after adopting UWB transmission. Infrastructure-less, ad hoc UWB networks are also called 5G.

The current ‘popular’ choices, or dilemmas, at the medium access control (MAC) layer is between IEEE 802.11 where all POPS communicate on the same channel, and the Bluetooth that uses frequency hopping and master-slave relations. The design of medium access layer for UWB transmission is under way. UWB supports existing 802.11, 802.15.3 and HiperLan MAC standards but they do not exploit position-aware information enabled by UWB.

The research on wireless ad hoc, sensor and local area networks is booming recently within both computer science and electrical engineering communities. Both ACM and IEEE organize symposia exclusively dedicated to ad hoc networks, now in the second and third years of existence. This is in addition to increasing number of papers on ad hoc networks at main events such as IEEE INFOCOM, ACM MOBICOM, IEEE ICC, IEEE Int. Symp. on Computers and Communications, IEEE Parallel and Distributed Symposium, and IEEE Int. Conf. Distributed Computing. Despite of the enormous interest in ad hoc networks (due to upcoming commercial applications), satisfactory solutions for some fundamental problems in their operation, such as routing, broadcasting, multicasting, and network organization, are still not found.

4. Application Domains

4.1. Application Domains

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

Application domain of our research activities is very wide since it concerns domains commonly addressed by smart object issues:

- individual authentication in information systems, like in banking system (bank smartcards), mobile phone system (SIM cards) or wireless networking (smartcard for Wi-Fi),
- adaptable and robust networking, like in infrastructure less communication system (military communication system or emergency communication system),
- ambient computing which uses intensively POPS,
- environment surveillance systems which can use wireless sensor networks.

5. Software

5.1. Java In The Small

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

Participants: Alexandre Courbot [Corresponding author], Gilles Grimaud, Kevin Marquet, 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.

5.2. CAMILLE NG

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

Participants: Nadia Bel Hadj Aissa [Corresponding author], 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 Camille split architecture is described in Fig. 6.

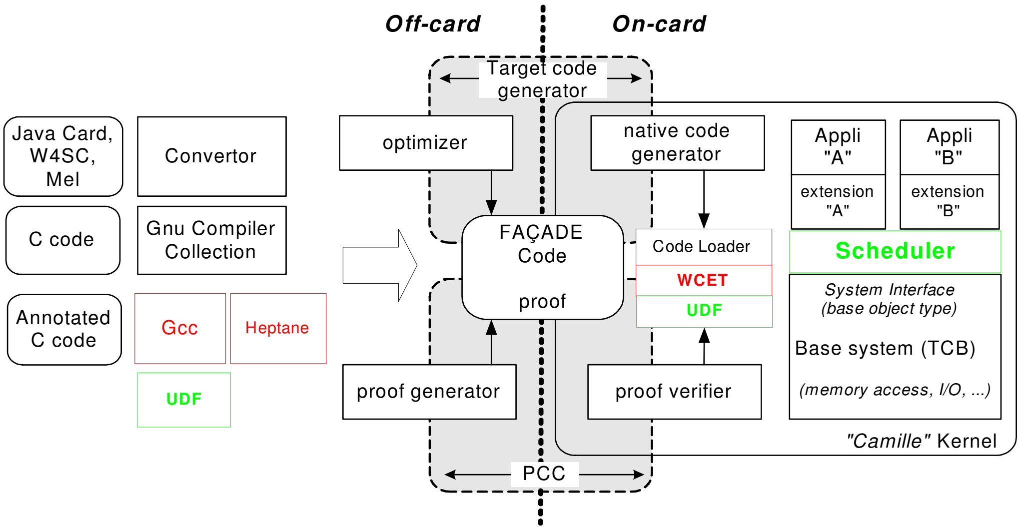


Figure 6.

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 [60]. 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.

5.3. SimTag: a simulator for anti-collision protocol design for RFID Tags

Keywords: *RFID tags*, *anti-collision*.

Participant: David Simplot-Ryl.

SimTag is a simulator dedicated to anti-collision protocols. It includes protocols from ISO-18000-3 standard [59] and allows to test numerous parameters. It has been used by engineers from Gemplus/Gemalto and TagSys to tune their own protocols that are now included in standards.

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

6. New Results

6.1. Activity Scheduling in Wireless Sensor Networks

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

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

In [24], we propose several localized sensor area coverage protocols, for arbitrary ratio of sensing and transmission radii. Sensors are assumed to be time synchronized, and active sensors are determined at the beginning of each round. The approach has a very small communication overhead since prior knowledge about neighbor existence is not required. Each node selects a random timeout and listens to messages sent by other nodes before the timeout 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 a message announcing their activity status. There are four variants in our approach, depending on whether or not negative and retreat messages are transmitted. Covered nodes decide to sleep, with or without transmitting a negative acknowledgment 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. Experimental results with ideal MAC layer show that, for a similar number of selected active sensors, our methods significantly reduce number of messages to decide activity compared to existing localized protocol, where nodes send hello message followed by negative acknowledgments from passive nodes. We also consider a MAC layer with collisions, and show that existing compared method, for dense networks, fails to cover the area reasonably (nodes may decide to sleep since some withdrawal messages are not received, creating coverage holes). Our methods, however, still remain robust in terms of high area coverage with reasonable amount of active nodes, despite some message collisions.

In [27], we assess the impact of a realistic radio channel by introducing a packet error rate depending on the signal-to-noise ratio. After introducing some radio channel models and presenting some existing solutions to the area coverage problem, experimental results show how area coverage protocols can behave under realistic physical layer assumptions. We finally observe that power consumption models also remain simplistic and that one existing protocol can be further optimized to considerably increase the network lifetime with its activity scheduling.

We further studied in [26] the impact of a realistic radio channel on activity scheduling and area coverage in sensor networks. Indeed, most of the previous work in this area has been studied within an ideal environment, where messages are always correctly received. In this paper, we follow the path opened in [38] by arguing that protocols developed with such an assumption can hardly provide satisfying results in a more realistic world. To strengthen this point of view, we replace the classic unit disk graph model by the lognormal shadowing model, and analyze some existing solutions. The results show that either the resulting area coverage is not sufficient or the percentage of active nodes, and thus energy consumption, is very high. To solve these problems, we present an original method, where a node decides to turn off when there exists in its neighborhood a covering set of nodes, and that this set is sufficiently reliable (i.e. the risk is lower than a given threshold). This reliability is based on link probabilities that may be obtained thanks to the signal-to-noise ratio of previous transmissions. We provide experimental results for a static threshold, and present some methods to dynamically compute the threshold based on the local density of nodes. These results show that our solution is very efficient as it preserves area coverage while minimizing the quantity of working nodes.

For sensor networks considered in [23], any physical point of the field needs to be monitored by at least one sensor. Energy consumption is balanced by taking advantage of the redundancy induced by the random deployment of nodes. Some nodes are active while others are in sleep mode. Area coverage protocols aim at turning off redundant sensor nodes while preserving satisfactory monitoring by the set of active nodes. To increase reliability or security, coverage of any point by k sensors may be required. Such k coverage minimizes the risk of possibly missed event or false alerts. By using such k-coverage, it can also be possible to correlate data to obtain data as pertinent as possible. The problem addressed here consists in building k distinct subsets of active nodes (layers), in a fully decentralized manner, so that each layer covers the area. In our protocol, each node selects a waiting timeout, listening to messages from neighbors. Activity messages include the layer at which a node has decided to be active. Depending on the physical layer used for sensing modeling, any node can evaluate if the provided coverage is sufficient for each layer. If so, node can sleep, otherwise it selects a layer to be active. Here, we describe a localized area coverage protocol able to maintain an area k-covered under realistic physical layer assumptions for both sensing and communicating modules.

6.2. Efficient MAC Layer for RFID and Wireless Devices

Keywords: *MAC layer*, *RFID*, *Wireless communication*, *fairness*.

Participants: Hervé Meunier, David Simplot-Ryl, François Ingelrest, Gilles Grimaud.

The first result in this area concerns anti-collision protocols for RFID tags. RFID is a technology for tracking objects that is expected to be widely adopted in very near future. A reader device sends probes to a set of RFID tags, which then respond to the request. A tag is recognized only when it is the only one to respond to the probe. Only reader has collision detection capability. The problem we consider here is to minimize the number of probes necessary for reading all the tags, assuming that the number of tags is known in advance. Well known binary and n-ary partitioning algorithms can be applied to solve the problem for the case of known number of tags. In [19] (preliminary results have been published in [64]), we propose a new randomized hybrid tag identification protocol which combines the two partitioning algorithms into a more efficient one. The new scheme optimizes the binary partition protocol for small values of n (*e.g.* $n = 2, 3, 4$). The hybrid scheme then applies n-ary partition protocol on the whole set, followed by binary partition on the tags that caused collision. We proved analytically that the expected number of time slots in the hybrid algorithm with known number of users is $< 2.20 \cdot n$. Performance of these algorithms was also evaluated experimentally, and an improvement from $e.n$ to approximately $2.15 \cdot n$ was obtained.

The last results in MAC layer address the fairness and efficiency of medium access in wireless an ad hoc network. The IEEE 802.11 MAC layer is known for its low performances in wireless ad hoc networks. For instance, it was shown in the literature that two independent emitters nodes can easily monopolize the medium, preventing other nodes to send packets. The protocol we introduce in this article is a simple variation of the original 802.11 MAC layer which significantly increases the fairness while maintaining a high effective bandwidth. Its principle consists in avoiding systematic successive transmissions by the same emitter through the probabilistic introduction of a waiting time, a virtual NAV, after each emission. The probability to set a

NAV is adaptively computed depending on the perceived utility of the previous virtual NAV. This protocol, called PNAV (Probabilistic NAV) [13], is shown to be efficient by simulation and is compared to another 802.11 adaptation.

Another way to enhance the MAC layer in wireless networks is using beam forming antennas and ULB modulations. Using beam forming antennas and ULB modulations in ad hoc networks have been recently focused on, as they allow to drastically improve ad-hoc network performances. This new technological context implies revisiting common network algorithms. When considering an multi-sector antenna uncommon with an uncommon high switch delay, packets have to be efficiently scheduled on beams at the MAC layer level, in order to improve the network capacity. We consider two optimization criteria: the network throughput and the maximum delay of packets. In [35], we propose and study a MAC scheduler, FIFO TBW, efficiently reducing the overhead due to beam switching delays. We give a first approach to to estimate the window duration parameter.

6.3. Energy Efficient Broadcasting

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

Participants: François Ingelrest, David Simplot-Ryl, Fadila Khadar.

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.

As power adjustment is a mechanism of prime importance for energy preservation, we proposed in [9] an original broadcasting method based on the concept of optimal communication range. The latter is theoretically computed thanks to the considered energy model, and is the best compromise between the spent energy at each node and the quantity of relays. More precisely, the minimal transmission energy needed for correct reception by a neighbor at distance r is proportional to $r^\alpha + c$, α and c being two environment-dependent constants. We demonstrated the existence of an optimal transmission radius, computed thanks to a hexagonal tiling of the network area, that minimizes the total power consumption for a broadcasting task. We theoretically proved that its value is equal to $r_{\text{opt}} = \sqrt[\alpha]{\frac{2c}{\alpha-2}}$, and experimentally confirmed this value thanks to simulations. Our analysis remains valid even if energy needed for packet receptions is charged. Moreover, we proposed two localized broadcasting protocols, based on derived 'target' radius, that remain competitive for all network densities. The first one, TR-LBOP, computes the minimal radius needed for connectivity and increases it up to the target one after having applied a neighbor elimination scheme on a reduced subset of direct neighbors. It is an enhancement of one of our previous protocol [54], and is especially targeted at ad hoc networks due to the use of neighbor elimination scheme where nodes must keep their radio equipment on. In the second one, TR-DS, each node first considers only neighbors whose distance is no greater than the target radius (which depends on the power consumption model used), and neighbors in a localized connected topological structure such as RNG or LMST. Then, a connected dominating set is constructed using this subgraph. Nodes not selected for the set may turn off their radio module, which is a very efficient behavior for nodes in a sensor network. Finally, some experimental results for both protocols were given, as well as comparisons with other existing protocols. These results show that our protocols are very competitive with existing ones.

To further reduce energy savings, we studied a well-known centralized and very efficient protocol named BIP (Broadcast Incremental Power), which constructs an efficient spanning tree rooted at a given node. Its efficiency is due to its consideration of the coverage obtained thanks to a single omnidirectional transmission, instead of considering all links separately. It offers very good results in terms of energy savings, but its computation is centralized and it is a real problem in ad hoc or sensor networks. Distributed versions have been proposed, but they all require a huge transmission overhead for information exchange. Other localized protocols have been proposed, as our previously presented TR-LBOP and TR-DS protocols, but none of them has ever reached the performances of BIP. We thus proposed and analyzed in [8] an incremental and localized version of this protocol, named LBIP for Localized BIP. 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 k-hop 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 provided experimental results showing that this new protocol obtains very good results for low densities, and is almost as efficient as BIP for higher ones. LBIP is currently one of the most efficient localized broadcasting known scheme.

We explored another area in broadcasting by focusing on robustness instead of energy preservation. We thus considered the removal of a strong hypothesis, broadly spread in the ad hoc and sensor networks community, referred to as the unit disk graph. The latter defines the communication area of each device to be a perfect circle. However, it is now commonly accepted that this assumption used to model the physical layer in wireless networks does not reflect real radio transmissions, and that the lognormal shadowing model better suits to experimental simulations. Previous work on realistic scenarios focused on unicast, while broadcast requirements are fundamentally different and cannot be derived from unicast case. Therefore, broadcast protocols must be adapted in order to still be efficient under realistic assumptions. We therefore studied in [38] the well-known multipoint relay protocol (MPR). In the latter, each node has to choose a set of neighbors to act as relays in order to cover the whole 2-hop neighborhood. We gave experimental results showing that the original method provided to select the set of relays does not give good results with the realistic model. We also provided three new heuristics in replacement and their performances which demonstrate that they better suit to the considered model. The first one maximizes the probability of correct reception between the node and the considered relays multiplied by their coverage in the 2-hop neighborhood. The second one replaces the coverage by the average of the probabilities of correct reception between the considered neighbor and the 2-hop neighbors it covers. Finally, the third heuristic keeps the same concept as the second one, but tries to maximize the coverage level of the 2-hop neighborhood: 2-hop neighbors are still being considered as uncovered while their coverage level is not higher than a given coverage threshold, many neighbors may thus be selected to cover the same 2-hop neighbors. We showed by simulations that these modifications greatly increase robustness, at the cost of a slightly higher energy expense.

A chapter for the *Handbook of Computer Networks* [16] has been written, where we describe two broadcast protocols which were demonstrated to be the best ones. In this chapter, we considered only the case where all nodes have fixed and same transmission range, which is common assumption in most literature. The two selected protocols are reliable: a protocol is reliable if it guarantees that the packet will be delivered to all nodes connected to the source, assuming ideal MAC layer. These two protocols are based on neighbor designating and self-pruning paradigms. In the (neighbor designating) multipoint relay (MPR) protocol, list of neighbors that should retransmit the packet is included in the message, so that all 2-hop neighbors are covered. In the (self-pruning) connected dominating sets (CDS) based broadcast protocol, a subset of nodes is selected so that other nodes are neighbors to at least one node from the set. We also describe the neighbor elimination scheme (NES) as an additional mechanism to increase performance of both approaches. We provided experimental comparison of these key algorithms which demonstrates that the NES can greatly improve the performance of any underlying protocol. We also showed very competitive performance of localized schemes compared to a greedy centralized scheme.

We finally considered efficient QoS algorithms in ad hoc networks. Current routing protocols use a best effort strategy to select the path between a source and a destination. Recently, mobile ad hoc networks are facing a new challenge, quality of service (QoS) routing. QoS is concerned with choosing paths that provide the required performances, specified mainly in terms of the bandwidth and the delay. In [41] we proposed a QoS routing protocol. Each node forwards messages to their destination based on the information received during periodically broadcasts. It uses two different sets of neighbors: one to forward QoS compliant application messages and another to disseminate local information about the network. The former is built based on 2-hop information knowledge about the metric imposed by the QoS. The latter is selected in order to minimize the number of sent broadcasts. We provide simulation results to compare the performances with similar QoS protocols.

In [42], [20], we consider the broadcasting problem in sensor networks where the nodes have no prior knowledge of their neighbourhood. We describe several Area-based Beaconless Broadcasting Algorithms (ABBAs). In $2D$, on receiving the packet (together with geographic coordinates of the sender), each node calculates the ratio P of its perimeter, along the circle of transmission radius, that is not covered by this and previous transmissions of the same packet. The node then sets or updates its timeout to be inversely proportional to P. If the perimeter becomes fully covered, the node cancels retransmissions. Otherwise, it retransmits at the end of the timeout interval. The protocol is reliable, that is, all nodes, connected to the source, are guaranteed to receive the packet, assuming an ideal MAC layer. We also describe three 3D-ABBAs, one of them being reliable. These three protocols are based on covering three projections, covering particular points on intersection circles and covering intersection points of three spheres. Our protocols are the first reliable broadcasting protocols, other than blind flooding.

In [40], we present a way for broadcasting based on a topology control. We indeed present a way of controlling topology in wireless ad hoc networks while using a realistic physical layer. We first define the notion of connectivity in probabilistic physical layer. In a λ-connected network, all transmissions between any two devices has a probability of being done correctly greater or equal to λ. We then propose a topology reduction that preserves λ-connectivity. This topology reduction can be used to broadcast data.

6.4. Self-organization and Clustering for Small Devices

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

Participants: Nathalie Mitton, David Simplot-Ryl, François Ingelrest, Farid Naït-Abdesselam.

Due to the dynamics of wireless *ad hoc* networks and the terminal specificities (limited memory size and computing capacities), the routing protocols for fixed networks are not adapted. *Ad hoc* routing protocols proposed in the MANET working group at IETF[1] are all flat routing protocols, with no hierarchy. If flat routing protocols (proactive[2] and reactive[3] routing protocols) are quite effective on small and medium size networks, they are not suitable for large scale or very dense networks because of bandwidth and processing overheads they generate [70], [62]. A common solution to this scalability problem is to introduce a hierarchical routing.

A hierarchical routing relies on a self-organization of the network in a specific partition, called *clustering*: the terminals are gathered into clusters according to some criteria, each cluster being identified by a special node called *cluster-head*. In this way, nodes store full information concerning nodes in their cluster and only partial information about other nodes. In addition to its scalable feature, such an organization also presents numerous advantages as to synchronize mobile nodes in a cluster or to attribute new service zones. Based on this partition, different routing policies are used in and between clusters:

(i) either proactive routing in the clusters and reactive routing between the clusters, which is the most common approach in the literature [61], [68],

(ii) or reactive routing in the clusters and proactive routing between the clusters [69], [65].

[1] http://www.ietf.org/html.charters/manet-charter.html
[2] Nodes permanently keep a view of the topology. All routes are available as soon as needed.
[3] Routes are searched on-demand. Only active routes are maintained.

In [31], we study the second approach of the hierarchical routing, *i.e.* using a reactive routing in the clusters and a proactive routing between the clusters. Such a hierarchical routing implies an indirect routing, *i.e.* the routing is performed in two steps: the look-up step that locates the destination node and the routing step to directly join it. Such an approach for hierarchical routing seems to us more scalable and more promising than the first one. Indeed, most of the clustering algorithms found in the literature provide a constant number of clusters when the intensity of nodes increases [55], [63], [67]. Thus, when the node density increases, there are still $O(n)$ nodes per cluster and using a proactive routing scheme in each cluster implies that each node still stores $O(n)$ routes, which is not more scalable than flat routing.

As far as we know, nowadays, in the literature, only two works propose this reverse hierarchical routing approach. They mainly differ in the self-organized structure they provide. The first one is called the density-based protocol [65] and uses a simple clustering structure. The second one is SAFARI [69] and uses a recursive hierarchical clustering structure. Both protocols use a DHT to perform the indirect routing.

In this paper, we compare SAFARI and the density-based protocol to analyze the impact of the use of recursiveness in the self-organization. Comparisons are lead regarding to the clustering structure provided and the quality of each indirect routing step (look-up and final routing). We will see that the main differences concern the stabilization time and the way the DHT has to be implemented over the resulting clustering structure.

Along with the on-going advances in low-power electronics and the tremendous need for sensor technology, small and low-cost sensors have emerged in the last few years. Sensors are aimed at monitoring a wide geographical area for a variety of applications that include disaster recovery operation, event detection, and surveillance or monitoring of a phenomenon of interest. Most of sensed environments are usually inaccessible for human beings (e.g. a volcanic area). The success of a sensor network is heavily dependent on two key resources, namely communication bandwidth and nodes energy. To tackle these two constraints, a large body of pioneering research work has been done. Most of these researches consider the design of sensor networks where sensors are interconnected via a wireless terrestrial network (e.g. terrestrial base stations). Compared to wireless networks, satellite communication systems offer an array of advantages. Effectively, in addition to their inherent multicast capabilities and flexible deployment features, satellite systems are able to provide coverage to extensive geographic areas and interconnect among remote networks. As a consequence, there is an important interest to use satellites in large-scale deployment of sensors. This work describes the architecture of a global sensor network based on a constellation of LEO satellites. The considered sensor network is heterogeneous: Two types of sensor nodes are envisioned. One type does the sensing and relays the gathered data to the other type that performs data aggregation and communicates it directly to the satellites. The main challenging tasks in the design of the architecture are explored, and adequate solutions are provided. A set of data dissemination techniques is then presented. Following this, a mathematical model is developed to evaluate the energy use of the sensors. Open research issues for the realization of such architecture are finally discussed [44].

In [39], we focused on the construction of small connected dominating sets, where all nodes are either dominant or neighbor of a dominant node. As a basis for our work, we used a heuristic given by Dai and Wu in [56] for constructing such a set. Their approach, in conjunction with the elimination of message overhead by Stojmenović, has been recently shown to be an excellent compromise with respect to a wide range of metrics. In this paper, we presented an enhanced definition to obtain smaller sets in the specific case where 2-hop information is considered. In our new definition, a node u is not dominant if there exists in its 2-hop neighborhood a connected set of nodes with higher priorities that covers u and its 1-hop neighbors. This new rule requires the same level of knowledge used by the original heuristic: only neighbors of nodes and neighbors of neighbors must be known to apply it. However, it takes advantage of some topological knowledge originally not taken into account, that may be used to deduce communication links between 1-hop and 2-hop neighbors. We provided the proof that the new set is a subset of the one obtained with the original heuristic. We also gave the proof that our set is always dominating for any graph, and connected for any connected graph. Two versions were considered: with topological and positional information, which differ in whether or not nodes are aware of links between their 2-hop neighbors that are not 1-hop neighbors. An algorithm for locally applying the concept at each node was described. We finally provided experimental data that demonstrates the superiority of our rule in obtaining smaller dominating sets. A centralized algorithm was used as a benchmark in the comparisons. The overhead of the size of connected dominating set is reduced by about 15% with the topological variant and by about 30% with the positional variant of our new definition.

6.5. Routing Issues in wireless Networks

Keywords: *Routing*, *multi-hop wireless communications*.

Participants: David Simplot-Ryl, Farid Naït-Abdesselam.

Sensor networks are deployed to gather some useful data from a field and forward it toward a set of base stations or sinks for data analysis and decision making. Each sensor node is endowed with a finite amount of energy, and each byte transmission or reception costs a certain fixed fraction of energy as well as a variable fraction that depends on the distance between sender and receiver for transmissions. Routing in sensor networks has so far been considered from the perspective of maximizing the time until the first node in the network exhausts its battery energy under a deterministic traffic pattern. This approach does not respond necessarily to most sensor network applications requirements as it fails to encompass the majority of applications where the data transfer is triggered by non periodic events. Moreover, most sensor networks contain a lot of redundant sensors which produce redundant information and as such sensor applications can continue to function very well even when some nodes exhaust their battery energy. This work considers the problem of lifetime maximization from another perspective. That is, given the initial amount of battery energy the aim is to determine how much data can each source transmit until the network is partitioned (i.e., until the nodes cannot find end-to-end routes to the sink). In addition, to respond to some specific applications' requirements, when determining such nodal data volume distribution, fairness is taken into account. In fact, maximizing the volume of data collected at the sinks until some particular set of nodes exhaust their battery and partition the network is more desirable. We call this problem the maximum data collection routing. In this work we formulate the problem of maximum data collection routing for sensor networks as a utility maximization problem subject to energy constraints, and invoke Lagrange relaxation, duality and sub-gradient technique to solve the problem. We then propose a distributed algorithm to enable implementation in real networks. Different performance aspects of the obtained algorithm are considered, particularly the problem of path oscillation, which is well known to happen in any routing algorithm where the link costs are functions of the traffic load. We propose solutions to address this oscillation problem, and study the performance of the distributed algorithm by simulation [37], [36], [45].

6.6. Security for Mobile Devices

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

Participants: David Simplot-Ryl, Michael Hauspie.

Most protocols developed for ad hoc networks for cooperation issues usually consider that nodes are cooperative. Indeed, in military or emergency applications such collaboration can be assumed. However, ad hoc networks also have a great potential in civilian applications (for extending wireless Internet connectivity for example) where many nodes typically do not belong to a common authority. In such context, malicious nodes could try to cheat in their interaction with peers on network. A main cheat action would be to not participate to routing by not forwarding any packet. This cheating form is called selfishness, where nodes try to maximize their own welfare for example to save some battery power. Even non malicious nodes may yield to temptation to avoid cooperation since the cost of the participation to network functionalities may be very high for individual nodes: a simple estimation says than when the average number of hops from source to destination is 5 in an ad-hoc network then 80% of the energy spent by a node to send packets is dedicated to packet forwarding for other nodes.

Several algorithms exist in the literature to prevent such selfishness, mostly based on reputation mechanism and virtual currency mechanism. The idea is most of the time either to reward cooperating nodes or to punish misbehaving nodes. Virtual currency mechanisms are more robust to attacks. Moreover, they could easily be adapted to network using directional antennas whereas reputation mechanisms are mostly based on monitoring communication of other nodes.

In [33], we propose an enhancement of two major currency based algorithms : nuglets [53] and sprite [72]. Our modification allow them to guess the price of a route before using it. Thanks to that, nodes can select cheapest path (which are the one using nodes that are not starving of energy) to reach their destination and therefore avoid the nodes which have only limited energy. The lifetime of the network is then augmented.

In [34], we propose a local algorithm to detect selfish nodes and to punish them by dropping their packets. We show through simulations that with only limited knowledge, malicious nodes can be detected and their throughput dropped with a significant amount so that they can not benefit anymore of the network if they continue to act as malicious nodes.

6.7. Secured Mobile Code for Small Devices

Keywords: *Mobile code*, *System software components*, *code safety*, *secured software*.

Participants: Nadia Bel Hadj Aissa, Gilles Grimaud.

Most of classical safety and security properties rely on the fact that all the system is known during conception phase, *i.e.* Hardware and software parts. Nevertheless, new software is loaded on embedded system, *Post-Issuance* – *i.e.* while the sensor, the smart card or the RFID Tags is widely deployed –. In the context of post-issuance these assumptions – the whole system is known – cannot be true because the mobile code is deployed on heterogeneous hardware and unknown software environment. On the other hand, these small devices have not enough computational resources enforce themselves the required security on the loaded applications.

In [21], we propose a distributed method which allows generating a portable WCET pre-computation, including automatic loop detection, which is given with the mobile code. This pre-computation – which is automatic and do not use annotations – is verified by the mobile host by using a lightweight proof which is embedded in the mobile in PCC manner. We present experimental results by applying our method on the kernel of a smartcard dedicated operating system that proves the validity of the proposed method. In this way the embedded system can predict and allow the installation of an application according to the excepted temporal deadlines.

In [32], [29], [30], we detail a solution to guarantee safe interaction to components that are willing to collaborate in an extensible operating system that guaranties isolation. We focus on components used in extensible operating systems for smart objects. We propose a simple way to verify the behaviour of some components using an extension of the type system by addition of argument passing mode information to the method signatures (is the argument read, written, or remembered as reference, aliases?). We present a formalization of a PCC-like algorithm (off- card proof generator and on-card proof verifier) to statically check the mode type of the components in the CAMILLE exokernel for smart cards. We apply our technique to ensure trust between collaborative real time extensions with the aim of supporting *safe* dynamic loading of scheduling policy.

We present in [15] an extensible system for small secure embedded devices. We advocate the use of a typed intermediate language as a transformation of various high level languages. We present an extensible type system that unifies in a unique hierarchy some type systems from various source languages and ensures integrity and confidentiality. To increase execution efficiency and use flexibility, we propose a dynamic binding mechanism that allows the programmer to describe the bindings of his code without breaking the type system. We also design the whole type system so that future addition of new kinds of objects has as little impact as possible.

6.8. Software Customization for Small Devices

Keywords: *Code specialization*, *JVM customization*, *JavaOS*.

Participants: Alexandre Courbot, Gilles Grimaud.

In a first time we have studied the smart card and small device evolution to refine our vision of the new technological lock for dedicated operating system. This case-study is a central element allowing us to concentrate our effort on real innovations rather than on inapplicable results. It was made possible by an effective and efficient partnership with the industry. The quality of this preliminary work is now attested by our significant technological transfer and by the success of our accepted patents.

According to our preliminary studies[4] we have attention on the use of pre-deployment also called the romization process. In this context pre-deployment means deployment on a virtual environment and projection of this virtual environment on the real hardware. This specific kind of deployment allows us to apply dedicated, static and aggressive customizations of the deployed software and under laying operating system. Ahead-of-Time compilation is a part of our romization process. However, native code is much bigger than Java bytecode, which severely limits or even forbids these practices for devices with memory constraints. In [22], we describe and evaluate a method for reducing natively compiled code by suppressing runtime exception check sites, which are emitted when compiling bytecodes that may potentially throw runtime exceptions. This is made possible by completing the Java program with JML annotations, and using a theorem prover in order to formally prove that the compiled methods never throw runtime exceptions. Runtime exception check sites can then safely be removed from the generated native code, as it is proved they will never be entered. We have experimented our approach on several card-range and embedded Java applications, and were able to remove almost all the exception check sites. Results show memory footprints for native code that are up to 70% smaller than the non-optimized version, and sometimes as low than 115% the size of the Java bytecode when compiled for ARM thumb.

7. Contracts and Grants with Industry

7.1. Gemplus/Gemalto partnership

Participants: Alexandre Courbot, 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 16 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 4th framework), CESURE (RNRT), COMPiTV (RNTL), RESET (IST 5th framework), and INSPIRED (IST 6th framework).

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

[4] take a look on the Raweb2005

7.2. IST-2002-507894 INSPIRED “Integrated Secure Platform for Interactive Personal Devices” (IP)

Participants: Nadia Bel Hadj Aissa, Gilles Grimaud [contact], David Simplot-Ryl [INRIA representative].

More than other IT domains, the smart card industry is facing the challenge to reinvent itself in the fast moving high-tech area where seamless connection, mobility and security are key aspects. This breakthrough is only possible by changing the fundamentals of the smart card and by creating a new and open technology platform.

The smart card has been successful in providing a first generation of secure, personalized and portable device to millions of users principally in off-line applications such as bank and telecom. INSPIRED will develop the second generation called Trusted Personal Device (TPD) to provide Trust and Security to users and on-line services in the future ambient intelligence and ubiquitous computing environments.

The concept of an individual object representing the root of trust is the paradigm which definitely made the success of the smart card. INSPIRED intends to rely and it and to extend it for the next generation of secure communicating devices.

These devices will have different form factors and features depending of the targeted applications. INSPIRED aims at defining the common technical foundations to allow cost-efficient product developments of devices with extended features and performances that can better be integrated in heterogeneous networks.

The INSPIRED consortium gathers the large majority of the stakeholders in the European smart card arena including the major smart card manufacturers, vendors of chips and sensors for smart cards and leading research institutes. The consortium also includes companies representing users from dynamic market segments such as telecom, electronic ID, on-line services and digital rights management for requirements and concept definition and the validation of the project results.

INSPIRED is in-line with the RTD requirements identified by the RESET road map and will deliver the industry standard architectures for next generation devices that will overcome current technology heterogeneity and limitations.
List of participants: Gemplus/Gemalto (France), Schlumberger (France), Giesecke & Devrient (Germany), Oberthur Card Systems (France), Orga (Germany), Philips Semiconductors (Germany), Orange (France), Universidad Rovira i Virgili (Spain), Atmel (France), University of Twente (Netherlands), INRIA (France), Universite Catholique de Louvain (Belgium), Infineon (Germany), NDS (Israel), Activcard (France) and Everbee (France).

7.3. European FP6 IST IP "Wirelessly Accessible Sensor Populations" (WASP) 2006-2009

Participants: Jean Carle, 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

7.4. RNRT "SurVeiller Prévenir" (SVP) 2006-2009

Participants: Jean Carle, Gilles Grimaud, Fadila Khadar, Nathalie Mitton [contact], Farid Naït-Abdesselam, David Simplot-Ryl, Thomas Soete.

This project is a RNRT project (Réseau National de la Recherche en Télécommunications.

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. 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.

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.

7.6. 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 dinnovation en Technologies Logicielles http://www.rntl.org/).

The MESURE project aims to develop a set of tools for measuring the performances of cards with micro-processors (smart cards). Today, smart cards used for mobile telephony, payment and electronic documents (Id, passport,etc), are built over Java Card Platforms.

The main objective of the project is to give to the whole industry of the smart card a tool of measure of the performances of products. Today such a tool does not exist in the industrial world. Existing tools are very specific and none is accepted by the whole community.
List of participants: CNAM-CEDRIC, Université des Sciences et Technologies de Lille (LIFL/POPS), Trusted Labs.

8. Other Grants and Activities

8.1. ACI Sécurité Informatique SPOPS “Système pour POPS” (2003-2006)

Participants: Gilles Grimaud [contact], David Simplot-Ryl.

The project has achieved significant results in two directions:

- static enforcement of security policies;
- development of Java-based operating systems and preliminary design of a security architecture for component update.

List of participants: LIFL Univ. Lille 1 POPS (G. Grimaud), INRIA Sophia Antipolis (G. Barthe) and Université de Rennes (C. Bidan)

8.2. ACI Sécurité Informatique "models and Protocols for SEcuRity in wireless Ad hoC networks (SERAC)" (2004-2007)

Participants: Farid Naït-Abdesselam [contact], David Simplot-Ryl, Thomas Soete.

The ACI Project SERAC, funded by the French Ministry of Education and Research, conducts research activities on security in the context of Mobile Ad Hoc Networks. The area of security in ad hoc networks steel partly or not completely explored. High level security requirements for ad hoc networks are basically identical to security requirements for any other communication systems, and include the following services: authentication, confidentiality, integrity, non-repudiation, access control, and availability. However, similar to wireless communication systems (like GSM), which have additional challenges for the implementation of aforementioned services when compared to fixed networks, ad hoc networks can be viewed as an even more extreme case, requiring even more sophisticated, efficient and well designed security mechanisms.
List of participants: USTL (F. Naït-Abdesselam), INRIA Rocquencourt (D. Augot, P. Mühlethaler) and GET (J. Leneutre, A. Cavalli).

8.3. Regional project "Home Communications (COM'DOM)" (2005-2007)

Participants: Gilles Grimaud, Michael Hauspie, François Ingelrest, Hervé Meunier, Farid Naït-Abdesselam [contact], David Simplot-Ryl, Thomas Soete.

The COM'DOM project, funded by the region Nord Pas de Calais, conducts research for designing high data rate radio interface, operating at the 60 GHz frequencies, for high speed wireless communications in wireless ad hoc networks. At the same time it focuses in designing a coupled radio-fiber optics switches to extend indoor connectivity of a wireless ad hoc networks. Beside, the hardware conception and development, researchers involved in this project think in the design of new medium access protocol suitable for smart antennas, as well as the design of new routing and optimization protocols for ad hoc networks.
List of participants: LIFL (F. Naït-Abdesselam) and IEMN (N. Rolland).

8.4. Regional Project "MOdèles et InfraStructures pour Applications ubIQUitairES (MOSAIQUES)" (2005-2007)

Participants: Alexandre Courbot, Gilles Grimaud [contact], David Simplot-Ryl.

Proliferation of hardware and software sensors and others pervasive technologies, motivates the Mosaiques studies on software context-awareness. Context-based software conception and deployment seems the most natural substrate for theses technologies, because it provides the right separation of concerns. However, context-aware software needs to be supported by efficient, distributed, extensible and scalable software technologies. In Mosaiques we studies different ways to overcome theses technological locks.

Combining methodological principles (first axis), dedicated infrastructure supports (second axis), and adaptability validation (last axis) will satisfy the required ability to perform execution of a pervasive software environment over heterogeneous ubiquitous computing supports. In this context the POPS contribution is related to extensible and scalable software infrastructure for constrained devices.
List of participants: LIFL (L. Duchien), LAMIH (S. Lecomte), TRIGONE (A. Derycke), INRETS (C. Gransart), Ecole des Mines de Douai (N. Bouraqadi).

8.5. ARC INRIA "Radio Interface for multi-hop wireless networks (IRAMUS)" (2005-2006)

Participants: Jean Carle [contact], Antoine Gallais, François Ingelrest, Hervé Meunier, David Simplot-Ryl.

We participate at the Cooperative Research Initiative from INRIA 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 should be integrated in standard network simulators.
- Assessment of of PHY-MAC interface in different applicative scenarios. Indeed, low rate sensor networks or high rate ad-hoc networks do not require the same constraints on the PHY-MAC layers.

List of participants: INRIA ARES (J.-M. Gorce), INRIA POPS (J. Carle), IREENA (J.-F. Diouris), FT R&D (P. Senn).

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

Participants: Jean Carle [contact], Antoine Gallais, Julien Graziano, Michael Hauspie, Francois Ingelrest, 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).

8.7. ACI Sécurité Informatique "(CLADYS)" (2004-2007)

Participants: Farid Naït-Abdesselam [contact], Thomas Soete.

Mobile ad hoc networks are able to provide fast and efficient network deployment capabilities in a wide variety of scenarios where a fixed networking infrastructure is not possible. These types of networks offer new challenging security problems due primarily to their wireless network interface, allowing easy eavesdropping and injection of messages, and to their distributed infrastructure-less topology. The security in mobile ad hoc networks has been analyzed individually at different layers of the communication protocols. In this project we are investigating a cross layer approach to provide a novel global assessment of the network by analyzing the risk and vulnerabilities across communication protocol layers under different kind of adversarial settings. However, there is an inherent trade-off between the performance of a network and its security . In this work we explore possible evaluations of security threats versus the cost of prevention and reaction to such threats. We consider different kind of adversaries with different capabilities. We are investigating the effect of these capabilities on the different layers and the network as a whole. Such a study will help identify the importance of layered security in this infrastructure-less wireless setting.

The network assumptions are fundamental for the type of security mechanism we can deploy. Ideally the communication and security properties we want the network to have under any type of adversarial setting are: access control, availability, and end to end message integrity, authenticity, and confidentiality. However, not all of these properties are easily achieved. Some properties even have mutual conflicting goals: providing integrity, authenticity and confidentiality incur in extra computation and bandwidth from the network, which can produce a decrease in network performance, functionality and ultimately, it can affect its availability. Therefore, due to the limited resources in ad hoc networks, the tradeoff between improved security, vulnerability and network performance need to be closely examined and taken into consideration in this project. Much of the efforts will be toward the study of cross layer interactions for detecting attacks and to provide intrusion detection and tolerance, along with graceful degradation designs for network survivability.
List of participants: USTL (F. Naït-Abdesselam), UVSQ J. Ben-Othman, ENST J. Leneutre, Univ. Avigno A. Benslimane.

8.8. International Relationship

We have research activities with international partners as:

- Piet Demeester, Univ. Gent, Belgium,
- Ivan Stojmenović, Univ. Ottawa, Canada.

8.9. Visits and Invitations of Researchers

- Prof. Ivan Stojmenović from the University of Ottawa was invited in Lille for two month in May and June 2006.
- Prof. Brahim Bensaou from the Hong Kong University of Science and Technology was invited in Lille in December 2005 for two weeks, and for two months in June and July 2006.
- Prof. David Simplot-Ryl was visiting professor at the University of Ottawa in August 2006.

9. Dissemination

9.1. 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 several special issues:
  - *IEEE Transactions on Parallel and Distributed Systems* (IEEE Computer Society) on “Localized communication and topology protocols for ad hoc networks” 2006,
  - *International Journal of Parallel, Emergent and Distributed Systems* (Taylor & Francis) on “System and Networking for Smart Objects” 2006,
  - *Journal of Computer Communications* (Elsevier) on “Sensor-Actuator Networks (SANETs)” to appear in 2007.

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

- **Jean Carle** was program committee member of several international events such as :

- – *4th IEEE International Conference on Pervasive Computing and Communications (PerCom 06)* (Pisa, Italy, March 13-17)
  – *1st International Conference on Integrated Internet Ad Hoc and Sensor Networks (Intersense 2006)* (Nice, France, May 30-31).
  – *IEEE International Conference on Communications (ICC 2006)* (Istanbul, Turkey, June 11-15).
  – *2nd International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2006)* (Hong Kong, China, December 13-15).
  – *IADIS International Conference on Applied Computing 2007 (IADIS AC 2007)* (Salamanca, Spain, February 17-20).

- **Gilles Grimaud** is involved in the program committee of national and international events:
  – *5th French conference on operating system (CFSE'06)* organized in conjunction with RenPar'17 and SympA'2006 (October 4-6, Perpignan, France).
  – *IADIS International Conference on Applied Computing 2006 (IADIS AC 2006)* (San Sebastien, Spain, February 25-26).

- **Michaël Hauspie** is a program committee member of:
  – *IADIS International Conference on Applied Computing 2006 (IADIS AC 2006)* (San Sebastien, Spain, February 25-26).
  – *IADIS International Conference on Applied Computing 2007 (IADIS AC 2007)* (Salamanca, Spain, February 17-20).

- **Nathalie Mitton** is a program commitee member of:
  – *4th IEEE International Conference on Mobile Ad Hoc and Sensor Systems (MASS-2007)* (Pisa, Italy, October 8-11, 2007).

  She is publicity chair:
  – *4th IEEE International Conference on Mobile Ad Hoc and Sensor Systems (MASS-2007)* (Pisa, Italy, October 8-11, 2007).

- **Farid Naït-Abdesselam** is a program committee member of several international events:
  – *4th ACM International Workshop on Mobility Management and Wireless Access (ACM MobiWac 2006)*, (Malaga, Spain, October 2-6) organized in conjunction with the *9-th ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (ACM/IEEE MSWiM 2006)*,
  – *IADIS International Conference on Applied Computing 2006 (IADIS AC 2006)* (San Sebastien, Spain, February 25-28, 2006),
  – *IEEE International Conference on Local Computer Networks (IEEE LCN 2006)* (Tampa, Florida, USA, November 12-16, 2006),
  – *1st IEEE International Workshop on Practical Issues in Building Sensor Network Applications (SenseApp 2006)* (Tampa, Florida, USA, November 12-16, 2006) to be held in conjunction with *IEEE International Conference on Local Computer Networks (IEEE LCN 2006)*,
  – *IEEE Global Telecommunications Conference (IEEE GLOBECOM 2006)*, (San Francisco, California, USA, Nov. 27, 2006).
  – *IADIS International Conference on Applied Computing 2007 (IADIS AC 2007)* (Salamanca, Spain, February 17-20, 2007),

  - *2nd IEEE International Workshop on Practical Issues in Building Sensor Network Applications (SenseApp 2007)* (Dublin, Ireland, October 15-18, 2007) to be held in conjunction with *IEEE International Conference on Local Computer Networks (IEEE LCN 2007)*,
  - *IEEE International Conference on Local Computer Networks (IEEE LCN 2007)* (Dublin, Ireland, October 15-18, 2007),
  - *IEEE International Conference on Communications (IEEE ICC 2007)* (Glasgow, Scotland, UK, June 24-28, 2007),
  - *First International Workshop on Next Generation Networks for First Responders and Critical Infrastructures (NetCri07), in conjunction with 26th IEEE International Performance Computing and Communications Conference* (New Orleans, Louisiana, USA, April 11-13, 2007),
  - *Second International Workshop on eSafety and Convergence of Heterogeneous Wireless Networks (eSCo-Wi'07)*, in conjunction with the *26th IEEE International Performance Computing and Communications Conference* (New Orleans, Louisiana, USA, April 11-13, 2007),
  - *IEEE Global Telecommunications Conference (IEEE GLOBECOM 2007)*, (Washington DC, USA, November 26-30, 2007).

- **David Simplot-Ryl** is general of general co-chair of:
  - *1st International Conference on Integrated Internet Ad hoc and Sensor Networks (InterSense 2006)*, (Nice, France, May 29-31, 2006),
  - *4th International Workshop on Wireless Ad hoc and Sensor Networking (WWASN 2007)*, (Toronto, Canada, 2007) organized in conjunction with the *27th IEEE International Conference on Distributed Computing Systems (ICDCS-2007)*,
  - *2nd International Workshop on Localized Communication and Topology Protocols for Ad hoc Networks (LOCAN 2006)*, (Vancouver, Canada, October 9-12, 2006) to be held in conjunction with *the 3rd IEEE International Conference on Mobile Ad Hoc and Sensor Systems (MASS-2006)*
  - *First International Workshop on RFID*, (Lille, France, November 30, 2006), also member of international advisory committee,
  - *International Workshop on Interactive Multimedia & Intelligent Services in Mobile and Ubiquitous Computing 2007 (IMIS-07)*, (Seoul, Korea, April 26-28, 2007),
  - *4th Workshop on Wireless Ad hoc and Sensor Networks (WWASN2007)*, (Toronto, Canada, June 25, 2007) a full day workshop held in conjunction with the *The International Conference on Distributed Computing Systems (ICDCS 2007)*.

  He is program chair or co-chair of:
  - *International Workshop on Wireless Ad hoc and Sensor Networks (WWASN2006)*, (Lisboa, Portugal, July 4-7, 2006) organized in conjunction with the *26th International Conference on Distributed Computing Systems (ICDCS-2006)*,
  - *4th IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS 2007)*, (Pisa, Italy, October 8-11, 2007, vice program chair.

  He is award chair of:
  - *4th International Conference on Ubiquitous Intelligence and Computing (UIC-07)*, (Hong-Kong, China, July, 11-13, 2007

  He was publicity chair of:

- *1st International Workshop On Foundations And Algorithms For Wireless Networking (FAWN'2006)*, (Pisa, Italy, March 13, 2006) organized in conjunction with the *4th Annual IEEE International Conference on Pervasive Computing and Communications (PerCom 2006)*.

He is member of several program committees:

- *3rd Annual Conference on Wireless On demand Network Systems and Services (WONS 2006)*, (Les Ménuires, France, January 18-20, 2006),
- *1st International Workshop On Foundations And Algorithms For Wireless Networking (FAWN'2006)*, (Pisa, Italy, March 13, 2006) organized in conjunction with the *4th Annual IEEE International Conference on Pervasive Computing and Communications (PerCom 2006)*,
- *20th IEEE International Conference on Advanced Information Networking and Applications (AINA2006)*, (Vienna, Austria, April 18-20, 2006),
- *7th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2006)*, (Florence, Italy, May 22-25, 2006),
- *14th International Conference on Real-Time and Network Systems (RTNS'2006)*, (Poitiers, France, May 30-31, 2006),
- *IFIP Fifth Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net 2006)*, (Lipari, Italy, June 14-17, 2006),
- *IFIP 1st International Conference on Ad-Hoc Networking*, (Santiago, Chile, August 20-25, 2006),
- *International Conference on Digital Telecommunications (ICDT 2006)*, (Cap Esterel, Côte d'Azur, France, August 29-31, 2006),
- *3rd International Conference on Ubiquitous Intelligence and Computing (UIC-06)*, (Wuhan and Three Gorges, China, September 3-6, 2006),
- *2nd International Workshop on Wireless and Sensor Networks Security (WSNS'06)*, (Vancouver, Canada, October 9-12, 2006) held in conjunction with *The 3rd IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS 2006)*,
- *3rd International Conference on Mobile Computing and Ubiquitous Networking (ICMU2006)*, (London, UK, October 11-13, 2006),
- *International Workshop on Energy Efficient Wireless Sensor Networks (EEWSN06)*, (Changsha, China, October 21-23, 2006) to be held in conjunction with *The 5th International Conference on Grid and Cooperative Computing (GCC 2006)*,
- *6th International Workshop on Wireless Local Networks (WLN 2006)*, (Tampa, Florida, November 14-17, 2006) to be held in conjunction with *The 31st IEEE Conference on Local Computer Networks (LCN 2006)*,
- *31st IEEE Conference on Local Computer Networks (LCN 2006)*, (Tampa, Florida, November 14-17, 2006),
- *10th International Conference On Principles Of Distributed Systems (OPODIS 2006)*, (Bordeaux, France, December 12-15, 2006),
- *2nd International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2006)*, (Hong Kong, China, December 13-15, 2006),
- *1st International Conference on New Technologies, Mobility and Security (NTMS'2007)*, (Paris, France, April 30-May 3, 2007),
- *International Workshop on Service, Security and its Data management for Ubiquitous Computing (SSDU-07)*, (Nanjing, China, May 22-25, 2007) in conjunction with *PAKDD 2007*,

- *International Workshop on Wireless Sensor Networks*, (Marrakesh, Morocco, June 4-8, 2007) in conjunction with *NOTERE 2007 (New Technologies of Distributed Systems NOuvelles TEchnologies de la REpartition)*,
- *2nd International Conference on Body Area Networks (BodyNets 07)*, (Florence, Italy, June 11-13, 2007),
- *8th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2007)*, (Montréal, Canada, September 9-14, 2007),
- *2nd International Workshop on Trustworthiness, Reliability and services in Ubiquitous and Sensor neTworks (TRUST 2007)*, (Taipei, Taiwan, December 10-13, 2007) in Conjunction with *EUC 2007*.

9.3. Invited Talks and Seminars

- **Jean Carle** gave an invited talk:
  - Ordonnancement de l'activité et réseaux auto-organisés. *Deuxième workshop CNRS RECAP - Réseaux de capteurs* (Rennes, France, 2006).
- **David Simplot-Ryl** gave a number of invited talks:
  - Localized topology control for wireless sensor networks. *3rd Workshop of the COST Action 295 DYNAMO, Dynamic Communication Networks: Foundations and Algorithms*, (Les Ménuires, France, 2006).
  - RFID Privacy and data protection: what are the policy options to go forward? *European Commission RFID Public Consultation. Workshop on RFID Security, Data Protection & Privacy, Health and Safety Issues* (Brussels, Belgium, 2006).
  - Localization and Coverage Problems in Wireless Sensor Networks. *SENZATIONS'06, Summer School on Applications of Wireless Sensor Networks* (Novi Sad, Serbia, 2006).
  - RFID. *5th International Conference on AD-HOC Networks & Wireless, Summer School in Wireless Sensor Networks* (Ottawa, Canada, 2006).
  - Beyond Smartcards and RFID: Smart Sensors. *Smart University, Ubiquitous computing: State of the art and challenges for the software infrastructure* (Sophia Antipolis, France, 2006).
  - Activity scheduling in Wireless Sensor Networks. *Second Workshop on Mobile multimedia communication systems and networks* (Liège, Belgium, 2006).

9.4. Teaching

- **Jean Carle** is in charge of lecture in Mobile Networking for research masters in computer science (ex-DEA), of lectures in Networking and Data Communication to under degree in computer science and vocational degree in computer science (IUT 2nd year/licence professionnelle).
- **Gilles Grimaud** is in charge of lecture 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).
- **Michaël Hauspie** is director of vocational degree in computer science (licence professionnelle) and in charge of lecture in *Software engineering*, *Networking* and *Operating Systems* in under degree in computer science and vocational degree in computer science (IUT 1st and 2nd year/licence professionnelle).
- **Nathalie Mitton** is in charge of lecture in *Mobile Networking* for research master (DEA),

- **Farid Naït-Abdesselam** was responsible of numerous lectures in *Network engineering* and *Mobile Networking* for research and professional masters in computer science (DEA, DESS, ENIC).

9.5. Miscellaneous Scientific Animation

- **David Simplot-Ryl** was referee or examiner for several PhD thesis and Habilitation thesis:
  - François Ingelrest (LIFL, Univ. Lille 1), advisor,
  - Alexandre Courbot (LIFL, Univ. Lille 1), advisor,
  - Fabrice Theoleyre (CITI, INSA Lyon, directed by Eric Fleury),
  - Julien Montavont (LSIIT, Univ. Strasbourg, directed by Thomas Noël), chair,
- **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 a member of the steering RFID 2006. He is member of the scientific committee of GDR ASR of CNRS.

10. Bibliography

Major publications by the team in recent years

[1] N. BEL-HADJ-AISSA, G. GRIMAUD, D. SIMPLOT-RYL. *A Distributed and Verifiable Loop Bounding Algorithm for WCET Computation on Constrained Embedded Systems*, in "Proc. 14th International Conference on Real-Time and Network Systems (RTNS2006), Poitiers, France", 2006.

[2] J. CARTIGNY, D. SIMPLOT, I. STOJMENOVIĆ. *Localized Minimum-Energy Broadcasting in Ad-hoc Networks*, in "Proc. IEEE INFOCOM'2003, San Francisco, USA", 2003.

[3] C. CHAUDET, G. CHELIUS, H. MEUNIER, D. SIMPLOT-RYL. *Adaptive Probabilistic NAV to Increase Fairness in Ad Hoc 802.11 MAC Layer*, in "Ad Hoc & Sensor Wireless Networks", vol. 2, n° 2, 2006, p. 105–125.

[4] A. COURBOT, G. GRIMAUD, J.-J. VANDEWALLE, D. SIMPLOT-RYL. *Application-Driven Customization of an Embedded Java Virtual Machine*, in "Proc. Second International Symposium on Ubiquitous Intelligence and Smart Worlds (UISW2005), Nagasaki, Japan", Lecture Notes in Computer Science, vol. 3823, Springer-Verlag, Berlin, 2005, p. 81–90.

[5] A. COURBOT, M. PAVLOVA, G. GRIMAUD, J.-J. VANDEWALLE. *A Low-Footprint Java-to-Native Compilation Scheme Using Formal Methods*, in "Proc. 7th IFIP Conference on Smart Card Research and Advanced Applications (CARDIS'06), Tarragona, Spain", Lecture Notes in Computer Science, Springer-Verlag, Berlin, 2006.

[6] A. GALLAIS, J. CARLE, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *Localized sensor area coverage with low communication overhead*, in "Proc. 4h Annual IEEE International Conference on Pervasive Computing and Communications (PerCom 2006), Pisa, Italy", 2006.

[7] A. GALLAIS, H. PARVERY, J. CARLE, J.-M. GORCE, D. SIMPLOT-RYL. *Efficiency Impairment of Wireless Sensor Networks Protocols under Realistic Physical Layer Conditions*, in "Proc. 10th IEEE International Conference on Communication Systems (ICCS 2006), Singapore", 2006.

[8] F. INGELREST, D. SIMPLOT-RYL. *Localized Broadcast Incremental Power Protocols for Wireless Ad Hoc Networks*, in "Wireless Networks", to appear, 2006.

[9] F. INGELREST, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *Optimal Transmission Radius for Energy Efficient Broadcasting Protocols in Ad Hoc Networks*, in "IEEE Transactions on Parallel and Distributed Systems", vol. 17, n^{o} 6, 2006, p. 536–547.

[10] T. TALEB, F. NAÏT-ABDESSELAM, A. JAMALIPOUR, K. HASHIMOTO, N. KATO, Y. NEMOTO. *Design Guidelines for a Global and Self-Managed LEO Satellites-Based Sensor Network*, in "Proc. 49th annual IEEE Global Telecommunications Conference (GLOBECOM 2006), San Francisco, California, USA", 2006.

Year Publications

Doctoral dissertations and Habilitation theses

[11] A. COURBOT. *Spécialisation tardive de systèmes Java embarqués pour petits objets portables et sécurisés*, Ph. D. Thesis, Univ. Lille 1, France, September 2006.

[12] F. INGELREST. *Protocoles Localisés de Diffusion et Économie d'Énergie dans les Réseaux Ad Hoc et de Capteurs*, Ph. D. Thesis, Univ. Lille 1, France, June 2006.

Articles in refereed journals and book chapters

[13] C. CHAUDET, G. CHELIUS, H. MEUNIER, D. SIMPLOT-RYL. *Adaptive Probabilistic NAV to Increase Fairness in Ad Hoc 802.11 MAC Layer*, in "Ad Hoc & Sensor Wireless Networks", vol. 2, n^{o} 2, 2006, p. 105–125.

[14] H. FREY, D. SIMPLOT-RYL. *Handbook of Applied Algorithms: Solving Scientific, Engineering, and Practical Problems*, to appear, chap. Localized Topology Control Algorithm for Ad Hoc and Sensor Networks, John Wiley and Sons, 2007.

[15] 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)", to appear, 2006.

[16] H. GUO, F. INGELREST, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *The Handbook of Computer Networks*, to appear, chap. Broadcasting in Ad Hoc and Sensor Networks, John Wiley and Sons, 2007.

[17] F. INGELREST, D. SIMPLOT-RYL. *Localized Broadcast Incremental Power Protocols for Wireless Ad Hoc Networks*, in "Wireless Networks", to appear, 2007.

[18] F. INGELREST, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *Optimal Transmission Radius for Energy Efficient Broadcasting Protocols in Ad Hoc Networks*, in "IEEE Transactions on Parallel and Distributed Systems", vol. 17, n^{o} 6, 2006, p. 536–547.

[19] A. MICIC, A. NAYAK, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *A Hybrid Randomized Protocol for RFID Tag Identification*, in "Sensor Review", vol. 26, n^{o} 2, 2006, p. 147–154.

[20] F. OVALLE-MARTINEZ, A. NAYAK, I. STOJMENOVIĆ, J. CARLE, D. SIMPLOT-RYL. *Area Based Beaconless Reliable Broadcasting in Ad Hoc and Sensor Networks*, in "International Journal of Sensor Networks", vol. 1, n° 1-2, 2006, p. 20-33.

Publications in Conferences and Workshops

[21] N. BEL-HADJ-AISSA, G. GRIMAUD, D. SIMPLOT-RYL. *A Distributed and Verifiable Loop Bounding Algorithm for WCET Computation on Constrained Embedded Systems*, in "Proc. 14th International Conference on Real-Time and Network Systems (RTNS2006), Poitiers, France", 2006.

[22] A. COURBOT, M. PAVLOVA, G. GRIMAUD, J.-J. VANDEWALLE. *A Low-Footprint Java-to-Native Compilation Scheme Using Formal Methods*, in "Proc. 7th Smart Card Research and Advanced Application IFIP Conference (CARDIS'06), Tarragona, Spain", Lecture Notes in Computer Science, Springer-Verlag, Berlin, 2006.

[23] A. GALLAIS, J. CARLE, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *Ensuring K-Coverage in Wireless Sensor Networks under Realistic Physical Layer Assumptions*, in "Proc. 5th IEEE Conference on Sensors (Sensors 2006), Daegu, Korea", 2006.

[24] A. GALLAIS, J. CARLE, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *Localized sensor area coverage with low communication overhead*, in "Proc. 4h Annual IEEE International Conference on Pervasive Computing and Communications (PerCom 2006), Pisa, Italy", 2006.

[25] A. GALLAIS, F. INGELREST, J. CARLE, D. SIMPLOT-RYL. *Maintien de la Couverture de Surface dans les Réseaux de Capteurs avec une Couche Physique Réaliste*, in "Proc. Colloque Francophone sur l'Ingénierie des Protocoles (CFIP 2006), Tozeur, Tunisia", E. FLEURY, F. KAMOUN (editors). , Hermes, 2006, p. 153–164.

[26] A. GALLAIS, F. INGELREST, J. CARLE, D. SIMPLOT-RYL. *Preserving Area Coverage in Sensor Networks with a Realistic Physical Layer*, in "Proc. 26th IEEE INFOCOM'07, Anchorage, Alaska", short paper to appear, 2007.

[27] A. GALLAIS, H. PARVERY, J. CARLE, J.-M. GORCE, D. SIMPLOT-RYL. *Efficiency Impairment of Wireless Sensor Networks Protocols under Realistic Physical Layer Conditions*, in "Proc. 10th IEEE International Conference on Communication Systems (ICCS 2006), Singapore", 2006.

[28] A. GALLAIS, H. PARVERY, J. CARLE, J.-M. GORCE, D. SIMPLOT-RYL. *Impact du lien radio sur les performances des protocoles de couverture de surface pour réseaux de capteurs*, in "Proc. 8èmes Rencontres francophones sur les aspects algorithmiques de télécommunications (AlgoTel 2006), Trégastel, France", Best PhD Student Paper Award, 2006.

[29] D. GHINDICI, G. GRIMAUD, I. SIMPLOT-RYL. *Embedding Verifiable Information Flow Analysis*, in "Proc. Annual Conference on Privacy, Security and Trust (PST06), Toronto, Canada", 2006.

[30] D. GHINDICI, G. GRIMAUD, I. SIMPLOT-RYL, I. TRAORE, Y. LIU. *Integrated Security Verification and Validation: Case Study*, in "Proc. 2nd IEEE LCN Workshop on Network Security (WNS 2006), Tampa, Florida", 2006.

[31] B. GONCALVES, N. MITTON, I. GUÉRIN-LASSOUS. *Comparison of two Self-Organization and Hierarchical Routing Protocols for Ad Hoc Networks*, in "Proc. 2nd International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2006), Hong-Kong, China", 2006.

[32] G. GRIMAUD, Y. HODIQUE, I. SIMPLOT-RYL. *Can small and open embedded systems benefit from escape analysis?*, in "Proc. Workshop on Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems (ICOOOLPS'2006)", 2006.

[33] M. HAUSPIE, I. SIMPLOT-RYL. *Cooperation in Ad Hoc Networks: Enhancing the Virtual Currency Based Models*, in "Proc. 1st ACM International Conference on Integrated Internet Ad hoc and Sensor Networks (InterSense 2006), Nice, France", 2006.

[34] M. HAUSPIE, I. SIMPLOT-RYL. *Enhancing Nodes Cooperation in Ad Hoc Networks*, in "Proc. 4th Annual Conference on Wireless On demand Network Systems and Services (WONS 2007), Obergurgl, Austria", to appear, IEEE Press, 2007.

[35] A. HONORE, H. MEUNIER, G. GRIMAUD, D. SIMPLOT-RYL. *Efficient Packet Scheduler For Wireless Ad Hoc Networks With Switched Beam Antennas*, in "Proc. IEEE 20th International Conference on Advanced Information Networking and Applications (AINA 2006), Vienna, Austria", 2006.

[36] K. HUNG, B. BENSAOU, J. ZHU, F. NAÏT-ABDESSELAM. *Maximum Data Collection Least-Cost Routing in Energy Constrained Wireless Sensor Networks*, in "Proc. 31st Annual IEEE Conference on Local Computer Networks (IEEE LCN), Tampa, Florida, USA", 2006.

[37] K. HUNG, J. ZHU, B. BENSAOU, F. NAÏT-ABDESSELAM. *Energy-Aware Fair Routing in Wireless Sensor Networks with Maximum Data Collection*, in "IEEE International Conference on Communications (IEEE ICC 2006), Istanbul, Turkey", 2006.

[38] F. INGELREST, D. SIMPLOT-RYL. *Maximizing the Probability of Delivery of Multipoint Relay Broadcast Protocol in Wireless Ad Hoc Networks with a Realistic Physical Layer*, in "Proc. 2nd International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2006), Hong Kong, China", Best student paper award, 2006.

[39] F. INGELREST, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *Smaller Connected Dominating Sets in Ad Hoc and Sensor Networks based on Coverage by Two-Hop Neighbors*, in "Proc. 2nd International Conference on Communication System Software and Middleware, Bangalore, India", to appear, 2007.

[40] F. KHADAR, D. SIMPLOT-RYL. *Connectivity and topology control in wireless ad hoc networks with realistic physical layer*, in "Proc. Third International Conference on Wireless and Mobile Communications (ICWMC 07), Guadeloupe, French Caribbean", 2007.

[41] L. MORARU, D. SIMPLOT-RYL. *QoS Preserving Topology Advertising Reduction for OLSR Routing Protocol for Mobile Ad Hoc Networks*, in "Proc. 3rd Annual Conference on Wireless On demand Network Systems and Services (WONS 2006), Les Ménuires, France", 2006.

[42] F. OVALLE-MARTINEZ, A. NAYAK, I. STOJMENOVIĆ, J. CARLE, D. SIMPLOT-RYL. *Area Based Beaconless Reliable Broadcasting in Ad Hoc and Sensor Networks*, in "Proc. AlgoSensor 2006, Venice, Italy", 2006.

[43] D. SIMPLOT-RYL, I. SIMPLOT-RYL. *Connectivity Preservation and Key Distribution in Wireless Sensor Networks*, in "Proc. 3rd International Conference on Ubiquitous Intelligence and Computing (UIC 2006),

Wuhan and Three Gorges, China", J. MA, H. JIN, L. YANG, J. TSAI (editors). , Lecture Notes in Computer Science, vol. 4159, Springer-Verlag, Berlin, 2006, p. 988–997.

[44] T. TALEB, F. NAÏT-ABDESSELAM, A. JAMALIPOUR, K. HASHIMOTO, N. KATO, Y. NEMOTO. *Design Guidelines for a Global and Self-Managed LEO Satellites-Based Sensor Network*, in "Proc. 49th annual IEEE Global Telecommunications Conference (GLOBECOM 2006), San Francisco, California, USA", 2006.

[45] J. ZHU, K. HUNG, B. BENSAOU, F. NAÏT-ABDESSELAM. *Tradeoff between Network Lifetime and Fair Rate Allocation in Wireless Sensor Networks with Multi-path Routing*, in "9th ACM-IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (ACM/IEEE MSWiM), Malaga, Spain", 2006.

Internal Reports

[46] D. GHINDICI, G. GRIMAUD, I. SIMPLOT-RYL. *Embedding Verifiable Information Flow Analysis*, Technical Report, n° 2006-03, LIFL, Univ. Lille 1, France, april 2006, http://www.lifl.fr/evenements/publications/2006-03.pdf.

[47] G. GRIMAUD, Y. HODIQUE, I. SIMPLOT-RYL. *A verifiable Lightweight Escape Analysis Supporting Creational Design Patterns*, Research Report, n° 5937, INRIA, France, 06 2006, https://hal.inria.fr/inria-00081200.

References in notes

[48] M. ILYAS (editor). *The Handbook of Ad Hoc Wireless Networks*, CRC Press, 2003.

[49] *Java Card Web Site*, http://java.sun.com/products/javacard.

[50] C. PERKINS (editor). *Ad Hoc Networking*, Addison Wesley, 2001.

[51] I. STOJMENOVIĆ (editor). *Handbook of Wireless Networks and Mobile Computing*, John Wiley & Sons, 2002.

[52] I. AKYILDIZ, W. SU, Y. SANKARASUBRAMANIAM, E. CAYIRCI. *Wireless Sensor Networks: a Survey*, in "Computer Networks", vol. 38, 2002, p. 393–422.

[53] L. BUTTYÁN, J.-P. HUBAUX. *Enforcing Service Availability in Mobile Ad-Hoc WANs*, in "Proc. of the 1st ACM Interational Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2000), Boston, Massachusetts", ACM, 2000, p. 87–96.

[54] J. CARTIGNY, F. INGELREST, D. SIMPLOT, I. STOJMENOVIĆ. *Localized LMST and RNG based Minimum-Energy Broadcast Protocols in Ad Hoc Networks*, in "Ad hoc Networks", vol. 3, n° 1, 2005, p. 1–16.

[55] G. CHEN, F. GARCIA, J. SOLANO, I. STOJMENOVIĆ. *Connectivity-based k-hop clustering in wireless networks*, in "35th Annual Hawaii International Conference on System Sciences (HICSS'02), Hawaii, USA", January 2002.

[56] F. DAI, J. WU. *Distributed Dominant Pruning in Ad Hoc Networks*, in "Proc. IEEE 2003 Int. Conf. on Communications (ICC 2003), Anchorage, AK, USA", 2003.

[57] D. R. ENGLER, M. F. KAASHOEK. *Exterminate All Operating System Abstractions*, in "Proc. 5th IEEE Workshop on Hot Topics in Operating Systems, Orcas Island, USA", 1995.

[58] K. FINKENZELLER. *RFID Handbook: Radio-Frequency Identification Fundamentals and Applications*, John Willey & Sons, 1999.

[59] GEMPLUS/TAGSYS. *18000-3 Anti-collision protocol 13.56MHz RFID Tag*, 2002, ISO/IEC JTC 1/SC 1/GW 4/SG 3.

[60] G. GRIMAUD. *CAMILLE : un Système d'Exploitation Ouvert pour Carte à Microprocesseur*, Ph. D. Thesis, Univ. Lille 1, December 2000.

[61] P. KRISHNA, N. H. VAIDYA, M. CHATTERJEE, D. K. PRADHAN. *A Cluster Based Approach For routing In Dynamic Networks*, in "ACM SIGCOMM", ACM, April 1997, p. 49–65.

[62] B.-J. KWAK, N.-O. SONG, L. MILLER. *On the scalability of ad hoc networks*, in "Communications Letters, IEEE", vol. 8, 2004, p. 503- 505.

[63] C. R. LIN, M. GERLA. *Adaptive Clustering for Mobile Wireless Networks*, in "IEEE Journal of Selected Areas in Communications", vol. 15, n^{o} 7, 1997, p. 1265–1275.

[64] A. MICIC, A. NAYAK, D. SIMPLOT-RYL, I. STOJMENOVIĆ. *A Hybrid Randomized Protocol for RFID Tag Identification*, in "Proc. IEEE International Workshop on Next Generation Wireless Networks 2005 (IEEE WoNGeN'05), Goa, India", 2005.

[65] N. MITTON, E. FLEURY. *Distributed Node Location in clustered multi-hop wireless networks.*, in "AINTEC'05, Bangkok, Thailand", December 2005.

[66] G. C. NECULA. *Proof-Carrying Code*, in "Proc. 24th ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages, Paris, France", 1997.

[67] N. NIKAEIN, H. LABIOD, C. BONNET. *DDR-Distributed Dynamic Routing Algorithm for mobile ad hoc networks*, in "MobiHoc, Boston, MA, USA", November, 20th 2000.

[68] C. PERKINS. *Ad hoc networking.*, Addison-Wesley, 2001.

[69] R. RIEDI, P. DRUSCHEL, Y. C. HU, D. B. JOHNSON, R. BARANIUK. *SAFARI: A Self-Organizing Hierarchical Architecture for Scalable Ad Hoc Networking Networking.*, Research report, n^{o} TR04-433, Rice University, February 2005.

[70] C. SANTIVANEZ, B. MCDONALD, I. STAVRAKAKIS, R. R. RAMANATHAN. *On the Scalability of Ad Hoc Routing Protocols.*, in "INFOCOM, New-York, USA", June 2002.

[71] C.-K. TOH. *Ad Hoc Mobile Wireless Networks: Protocols and Systems*, Prentice Hall, 2001.

[72] S. ZHONG, J. CHEN, Y. R. YANG. *Sprite: A Simple, Cheat-Proof, Credit-Based System for Mobile Ad-Hoc Networks*, in "Proc. of 22nd Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2003), San Francisco, CA, USA", IEEE, 2003.