Activity Report 2011

Team SWING

Smart Wireless Networking

RESEARCH CENTER
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Team SWING

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Swing is hosted in the CITI laboratory of INSA Lyon.

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2. Overall Objectives

2.1. Overall Objectives

SWING is a joint team between INRIA Rhône Alpes and INSA Lyon that follows the end of the ARES project.

Pervasive communications and ambient networking are becoming part of more and more facets of our daily life. Probably the most popular usage is the mobile Internet access made possible by numerous access technologies, e.g. cellular mobile networks, WiFi, Bluetooth,... The access technology is becoming *transparent for the end user*, who does not care about how to access the network but is only interested in the services available and in the quality of service (QoS). A first aspect on the QoS can be made in terms of capacity, which impacts on the delay or the latency in the network. The second aspect of QoS includes robustness in a general meaning, *e.g.* lifetime, reliability and security. This complete view of QoS is ultimately constrained by system parameters and is related to energy efficiency and radio resource availability.

Beyond a simple Internet access, many other applications and services are built on the basis of pervasive communications, for which the communication is just a mean, and not a finality. Thus, the wireless link is expected to be *invisible to the end user* and constitutes the first element of the future Internet of things; to develop a complete twin virtual world fully connected to the real one.

Then, the tremendously growing needs of radio resources led the standardization industry to propose a large number of standards driven by different groups from the IEEE (802 family), ETSI (GSM), 3GPP (3G, 4G) or the Internet Society (IETF standards). Roughly speaking, the upper layers of the OSI model, from layer 3 (network) up to layer 7 (application) are nowadays mostly driven by the proposals of the IETF, while the IEEE802 standards' family offers the major contributions at layers 1 and 2 (except for cellular networks) and represents the basis of numerous famous commercially available technologies such as WiFi (802.11), Wimax (802.16), Bluetooth or Zigbee (802.15.4),...

The bottom-up approach used for designing new radio technologies is far from offering a real wireless convergence. The current development of the wireless industry is surely slowed down by the lack of radio resources and the lack of systems flexibility.

This technological bottleneck will be only overtaken if three complementary problems are solved : *terminal flexibility, agile radio resource management* and *autonomous networking*.

Terminal flexibility is advocated to obtain full-band and all-standards compliant systems by exploiting the concept of *Software Radio* introduced in a seminal paper by J. Mitola in 1991. A full software radio node is still an utopia, but many architectures based on software defined radio have now hit the market.

In parallel, the development of new standards is threatened by the radio spectrum scarcity.The increasing number of standards has led to the partial saturation of the UHF band. It will probably lead to its full saturation on the long run. However, this saturation is only 'virtual' because all equipments are fortunately not emitting all the time. This is why a solution for increasing the real capacity of the UHF band originates from *self-adaptive behavior*. In this case, flexible terminals will have to implement agile algorithms to share the radio spectrum and to avoid interference. In this context, cooperative approaches are even more promising than simple resource sharing algorithms.

Last but not least, as radio systems are going to expend into very large scale networks, multi-hop networking is becoming an important issue as widely studied in ad hoc networks, wireless sensor networks or mesh networks. In these networks, the most challenging issues concern the design of localized and/or distributed networking protocols that can cope with the topology changes, the neighborhood dynamics and the large-scale dimension of the network. Beyond classical routing problems, self-organization, self-configuration, flooding strategies or data-gathering represent the most important issues to improve the system efficiency and to provide the required framework for the Internet of Things.

These three fundamental and complementary research axes are most often evaluated independently, in different research community. From an optimization point of view, the proof of separability of these three axes is not yet stated, and we even guess it is not possible to exhibit the best solutions with such an approach. The interactions between these three axes constitute the core of the SWING proposal that will be structured around them but with strong connexions and specific identified cross-problems at the intersections.

A first common objective concerns the *end-to-end QoS*. For instance *end-to-end delay and reliability* are important issues. They are related to the network capacity, which is not clearly defined for real environments. Depending on the nodes capability, this capacity can strongly change. For instance, introducing network coding or relaying nodes may change drastically the global capacity. We can claim that the end-to-end capacity is truly not the direct extension of a single hop capacity.

A second up-to-date objective is related to the energy consumption of wireless systems. There is a clear tendency in the wireless community to address the energy consumption minimization as a primary objective. Green radio and green networking are becoming strategic issues as for instance promoted by the green touch consortium[1] in which INRIA is involved. It is expected that the energy reduction will be possible from a global approach only.

Lastly, security represents the third cross-problem we want to point out. Indeed, all the degrees of freedom that are introduced into embedded system with flexible radio, radio resource sharing, or autonomous networking, could lead to as many security holes. Security must be completely re-engineered in this context.

These three objectives can be alternatively considered as constraints or purposes, depending on the point of view. In our work, we pay a strong attention to always consider these complementary objectives. Instead of defining constrained problems, *e.g.* capacity maximization under power constraints, we will rather focus on studying Pareto optimal fronts and on proving the optimality of some algorithms with respect to these fronts.

As a conclusion, including radio node flexibility features and agile radio resource sharing capabilities together with routing and aggregation aspects within a global formulation offers a very complete framework for addressing the challenges of future wireless networks.

2.2. Highlights

CorTex Equipex FIT : cognitive radio testbed [2] FIt (Futur Internet of Things) is one of 52 winning projects in the Equipex research grant program. It will set up a competitive and innovative experimental facility that brings France to the forefront of Future Internet research. FIT is a joind project between UPMC, CNRS, INRIA, Telecom, LSIIT. It will be composed of distributed facility, heterogeneous devices, complementary components and be made of a Network Operations Center, a Cognitive Radio Tesbed, several Embedded Communication

[1] http://www.greentouch.org/

[2] *http://sdr-fit.project.citi-lab.fr/*

Objects Testbed that will upgrade an dextend the existing SensLAB sites and several Wireless OneLab Testbed. Swing leads the deployment of the Cognitive Radio Testbed located at INSA Lyon, which will offers a multi-hops PHY layer level testbed for testing cooperative communications, cognitive radio and software radio architectures.

wiplan : Indoor wireless networks planning [3] Swing has been developing an original Indoor propagation simulation tool for 10 years . This propagation engine is extended to more complex environments within the iPLAN European project in cooperation with University of Bedfordshire, University of Sheffield and Ranplan Ltd (UK) to develop a premium Indoor wireless networks planning tool. During the coming year, this propagation engine will be connected to NS-3 in the framework of the ADT Mobsim.

TAPASCologne project: vehicular mobility dataset [4] Swing has generated a large-scale urban vehicular mobility dataset, built on data made available the Institute of Transportation Systems at the German Aerospace Center (ITS-DLR). The synthetic mobility trace faithfully reprodice car traffic in the city of Cologne, Germany, covering a region of 400 square kilometers for a period of 24 hours, comprising more than 700.000 individual car trips. The dataset is a significative step forward in the simulation of vehicular mobility for network research and practictioners .

3. Scientific Foundations

3.1. General statement

SWING aims at supporting the extensive spawning of radio systems thanks to spontaneous, cooperative and self-organization mechanisms which have to offer higher QoS such as system capacity or real-time capabilities under complementary constraints such as security or energy efficiency. Its research fields cover flexible radio node design, agile radio resource sharing, and autonomous wireless networking. These three main research axis are completed by three cross-layer actions that are optimization, security, and prototyping.

As explained in the previous section, these three complementary research axes *flexible radio nodes*, *agile radio resource sharing* and *autonomous radio networking protocols* present strong interactions and have to be considered as interdependent characteristics of a unique objective : finding nodes and network architectures that will make Internet of Things (IoT) a robust and efficient reality.

3.2. Flexible Radio Node design

To cope with terminal flexibility, the terminals' complexity is constantly increasing with the multiplicity of radio interfaces on the market. It is nowadays impossible to develop an all-standards-compliant terminal since most standards are permanently under development. Therefore, the wireless convergence at the application level is possible only by superposing several radio interfaces within the same terminal. This strategy is neither cost efficient, nor optimal from the compactness points of view, and prohibiting any system adaptability. Further, the time to market of the new technologies is also slowed down, because the future evolutions are conditioned to the usual backward compatibility that often limits the capabilities of new technologies.

Since the seminal paper of J. Mitola in 1991, the concept of *Software Radio* appeared progressively as a key technology to offer adaptable and full-compliant radio systems. If a full software radio system remains futuristic, some software defined radio architectures are already on the market (picochip, EVP,Lyrtech SFF SDR, GNU radio platforms). Moreover, the concept of *cognitive radio* requires that the terminal is aware of the available radio resources on a wide set of frequencies. Several problems are still open:

- What will be the emerging hardware paradigm for software radio? Multi-processor on chip are now available but there are room for many experimental study to focus the target software radio computation model.

[3] http://wiplan.citi.insa-lyon.fr/
[4] *http://kolntrace.project.citi-lab.fr/*

- What will be the programming model for software defined radio? What will be the emerging waveform description language? Some attempts have been made to define a radio virtual machine but research direction are still widely open.
- wireless nodes design offering to the upper layers the required agile radio capabilities for self-optimizing networks is still an open problem, especially to consider simultaneously the three objectives: QoS, Energy consumption and Security.
- What kind of RF architecture do software defined radio need ? Wideband or multiband capabilities that are mandatory for dynamic spectrum sensing and resource management strongly constrain the RF design.

The first challenge is then the optimization of wireless nodes with respect to our three common objectives (QoS, Energy consumption and Security) while offering to the upper layers the required agile radio capabilities for self-optimizing networks..

3.3. Agile Radio Resource Sharing

For current systems, the radio access reliability is guaranteed by the strict reservation of a band to a specific application. This band is further divided into multiple sub-bands, allocated to specific service providers, base stations or mobile users. Such resource reservation is really too restrictive and a less stringent approach is mandatory to improve the radio resource usage efficiency.

On the opposite, the total deregulation already effective in the 2.4 GHz ISM band, already shows the inefficiency of actual uncoordinated resource sharing principles: the coexistence of more and more systems will quickly lead to unacceptable strong interference levels and hence major malfunctions. Therefore, the solutions will originate from a *self-adaptive behavior*. To achieve a true self-adaptive behavior, the radio nodes should be able to analyze their radio environment thanks to cognitive radio capabilities as mentioned in the previous challenge. Based on this knowledge, each radio node has to decide which resource it can use without impending the other (primary) users' performance. Both sensing scheduling followed by transmission scheduling necessitate the design of cognitive medium access procedures (C-MAC). If centralized approaches are possible, they however suffer from the lack of adaptability and strong algorithmic complexity. Promising approaches rather rely on *distributed algorithms* where nodes take decisions on their own knowledge. Specific mechanisms are required to ensure robustness and stability.

Complementarity, and beyond a simple decision of using a radio resource, cooperative approaches between heterogeneous radio nodes open still more perspectives to increase the system efficiency. An important issue relies on exploiting the relay channel concept introduced in 1971 by van der Meulen but mor recently extended to multiple sources and relays, while introducing simultaneously network coding capabilities. This problem is really open as the capacity bounds are not even known.

The second challenge consists in proposing distributed algorithms for resource sharing and cooperation, optimized with respect to our three common objectives (QoS, Energy consumption and Security) and exploiting cognitive radio.

3.4. Autonomous Wireless Networking

The previously described mechanisms allow to manage efficiently the radio resource in the neighborhood of a node by taking into account the different wireless interactions. Next, to support the expected massive deployment of wireless nodes on machines or things, the routing issue becomes a very complex problem and should be revisited in the context of *distributed* wireless networks, particularly if we want to take benefit from agile radio, opportunistic radio links and non-symmetric neighbors. Because of the large-scale dimension of the networks we consider that centralized approaches should be dismissed to the benefit of distributed and localized protocols: based on local information and local interactions, the aim is to synthesize a global behavior in terms of routing, data gathering, etc. The most important issues deal with capacity and resource management, activity scheduling, topology control and protocols adaptability to the evolution of the network topology. Because such features need to be human-free, they are often referred to as the *self-* paradigm* which will drive our research effort. Hence, cooperation among nodes is also a tool that can be considered at the networking layer. However, such cooperative techniques will be carefully designed since they can trigger additional overhead in the network thus reducing the benefits of adaptability. Since network topologies are constantly evolving due to the mobility of the nodes and the variability of the radio links properties, fault-tolerant protocols are needed to guarantee robustness and self-stabilization. Finally, this self-* paradigm opens critical security problems since transmission reliability and security will rely on many intermediate relays. We will look further to find mechanisms to ensure safe data transmissions in a fully interactive and reconfigurable digital world.

The third challenge deals with routing and self-organization mechanisms in large scale heterogeneous networks, optimized with respect to our three constraints (QoS, Energy consumption and Security), while exploiting cognitive and agile radio mechanisms.

3.5. Cross-layer approaches

Many teams over the world are dealing with either one or another of the previously mentioned research domains. However, putting together all skills to research some new concepts at the interface between these domains is less common. The bottom-up strategy will promote the development of realistic models from the node to the network behavior in terms of energy, complexity or performance evaluation. This strategy will also contribute to evaluate the impact of new node designs at the network level. The top-down strategy allows to define realistic scenarios, to develop large scale system requirements and specifications. This strategy will also promote the development of realistic interference models. Other aspects are truly transverse. For instance, ensuring security in distributed networks needs to be designed at the different levels, from the PHY layer security paradigm up to distributed mechanisms over large scale networks.

Our cross-layer framework is driven from three complementary points of view:

Performance and optimization – Performance evaluation and global optimization define a cross-layer axis of our project. In this action, we will be able to merge our contributions on smart wireless networks modeling using combinatorial and stochastic modeling tools. Global optimization is meant to describe system-wide behaviors and provide theoretical bounds on its performance, both by benchmarking the existing solutions and by guiding their improvement which will foster new developments. Our global optimization framework will progressively account for the software radio capabilities of the radio nodes, the properties of resource sharing algorithms and new self-* protocols. Realistic models of the wireless medium will be included, as well as refined models of adaptive protocols. This action will lead to three results : realistic models of smart wireless networks properties, global optimization and performance bounds derivation as well as distributed sub-optimal but feasible algorithms. This cross-layer axis on optimization is a necessity for developing new approaches and tools that are both efficient, provably reliable and relevant to the inherent cross-layer, dynamic and statistical nature of the systems under study.

Security – Security is one of the main cross-layer challenges of the SWING project. Security must be envisioned at each level, from hardware to routing protocols, in order to guarantee an end-to-end comprehensive security strategy. Moreover, in the context of embedded architectures, security related processing must be maintained to the least acceptable energy cost. The main challenges will then be the design of new energy efficient cryptographic primitives (in hardware and in software), the design of security mechanisms for routing protocols in order to preserve the networks from some specific attacks. The band deregulation and the on-the-fly adaptation reduces dangerously the access security. If cooperative mechanisms have to be used, the security of the various applications must be simultaneously guaranteed. Thus, security must be considered from a cross-layer perspective to allow cooperation at the physical layer while still protecting from malicious data access.

Prototyping – In SWING, we aim at addressing the challenges of smart wireless networks not only from a theoretical point of view, but also from a practical one, using simulations and prototypes. From our past experience, we acquired and developed several simulation tools. The CITI laboratory is also equipped with up-to-date radio design platforms allowing to test the embedded software radio systems, evaluate MIMO communications and perform real radio channel measurements. These skills have been acquired thanks to strong partnerships with the industrial community, which we plan to expand via new cooperations with Orange Labs, Alcatel-Lucent and other partners.

4. Software

4.1. Introduction

SWING develops several tools supporting its research like SOCLIB and Wiplan. Moreover, SWING is an active contributor to WSnet (http://wsnet.gforge.inria.fr/) a multi-hop wireless network discrete event simulator. WSnet was created in the ARES team and it is now supported by the D-NET team of INRIA Rhône-Alpes. SWING is one of the most important contributor for the design of protocol libraries in WSnet.

4.2. SOCLIB

Participant: Tanguy Risset [correspondant].

SocLib is a library of simulation models for virtual com- ponents (IP cores) for Systems on Chip. Many simulation models are under development, SocLib currently contains simulation models for processors (Mips, ARM), memories and network on chips (Spin and DSpin developed at LIP6 laboratory. SocLib permits to simulate at cycle accurate application running on embedded computing systems such as mobile phones. Swing use this platform to prototype design techniques either for embedded software or for hardware parts of signal processing applications.

See also the web page https://www.soclib.fr/trac/dev/wiki.

4.3. Wiplan

Participants: Jean-Marie Gorce [correspondant], Guillaume Villemaud, Meiling Luo, Dmitry Umansky, Tao Wang.

Wiplan is a software including an Indoor propagation engine and a wireless LAN opti- mization suite, which has been registered by INSA-Lyon. The heart of this software is the propagation simulation core relying on an original method, MR-FDPF (multi-resolution frequency domain ParFlow). The discrete ParFlow equations are translated in the Fourier domain providing a wide linear system, solved in two steps taking advantage of a multi- resolution approach. The first step computes a cell-based tree structure referred to as the pyramid. In the second phase, a radiating source is simulated, taking advantage of the pre-processed pyramidal structure. Using of a full-space discrete simulator instead of classical ray-tracing techniques is a challenge due to the inherent high computation re- quests. However, we have shown that the use of a multi-resolution approach allows the main computation load to be restricted to a pre-processing phase. Extensive works have been done to make predictions more realistic. The network planning and optimization suite is based on a multi-criteria model relying on a Tabu solver. The development of the wiplan software is a part of the european project iPLAN (IAPP-FP7 project).

See also the web page http://wiplan.citi.insa-lyon.fr.

5. New Results

5.1. Flexible Radio Node

Participants: Florin Hutu, Tanguy Risset, Jacques Verdier, Guillaume Villemaud, Cédric Levy-Bencheton.

This section summarizes the early results obtained from the research axis flexible radio nodes.

In [41], [75], a candidate architecture for LTE-Advanced receiver is proposed. Based on the combination of MIMO techniques and flexible spectrum access, LTE-Advanced terminals will require the increasing of the analog front-end complexity. To reduce the complexity of the analog front-end, an innovative architecture based on the merge between the double IQ and the code multiplexing structures is proposed. Simulation and measurement results show that, in a Gaussian case, the bit error rate is similar when using the proposed architecture and the state of the art front-end stack-up structure. A complexity evaluation study reveals significantly reduced power consumption of the proposed single front-end architecture.

The current generation of mobile terminals can communicate on multiple modes using several antennas. However, their energy consumption remains a critical parameter. In [58], [74], we explore the combination of multiple communication modes and MIMO as a possible way to reduce the energy consumption of both the terminals and the network. We propose a realistic energy model for the PHY layer of a MIMO and multi-mode terminal, taking into account the MAC layer behaviour. We show that the combination of MIMO and multi-mode provides a solution to reduce global energy consumption.

Software means programmable. Hence software defined radio means that the radio should now be programmable. We know what computer programming means, and we agree, up to a certain level, on how it should be done. But do we know what programming a radio means? Several questions are still open: what will an SDR platform look like in ten years? Will there exist software radio code? What will be the technical challenges and commercial issues behind this code? Programming is more precise than configuring or tuning, it implies a much greater level of freedom for the programmer. But it also means much cheaper implementations in many cases and in particular a re-use of the same hardware for different protocols (i.e. with different programs). This is, to our point of view [76], the main difficulty of software radio programming: reconfiguration and in particular dynamic reconfiguration. Dynamic (i.e. very fast) reconfiguration is now mandatory because some protocols, 3GPP-LTE (Third Generation Partnership Program Long Term Evolution) for instance, propose channel adapting for each frame, requiring a setting of the channel estimation parameter in a few milliseconds.

5.2. Agile radio resource sharing

Participants: Jean-Marie Gorce, Claire Goursaud, Katia Jaffrès-Runser, Nikolaï Lebedev, Guillaume Villemaud, Paul Ferrand, Philippe Mary.

This section presents our recent results concerning the realistic modeling of wireless links to develop realistic models and efficient simulations. This work include theoretical developements like symbol error outage modeling, but also some applications in the context of LTE multi-cells association, or oportunistic relaying in the context of wireless sensor networks. Other contributions about resource sharing are presented in next sections below, in the section 'network optimization' and the section 'network coding'.

In[28], we addressed the problem of finding a tractable expression for the symbol error outage (SEO) in flat Nakagami-m fading and shadowing channels. We deal with M-ary phase shift keying (M-PSK) and quadrature amplitude modulation (M-QAM) which extends our previous results on BPSK signaling. We propose a new tight approximation of the symbol error probability (SEP) holding for M-PSK and M-QAM signals which is accurate over all signal to noise ratios (SNRs) of interest. We derive a new generic expression for the inverse SEP which facilitates the derivation of a tight approximation of the SEO in a lognormal shadowing environment.

In [44], we consider on-body BAN nodes transmitting information towards a common sink, in a star topology (Body Area Networks (BAN) offer amazing perspectives to instrument and support humans in many aspects of their lives). While this setup is usual in wireless networks, the high instability of the BAN radio channel and the proximity of the body make classical communication protocols inefficient. These networks are further constrained by the low transmission power required for both battery life and health concerns. Opportunistic cooperation techniques are of great interest in such environment to ensure reliable communications. In previous works, we studied simple opportunistic relaying schemes under independent BAN links, using a packet error outage criterion. In this paper, we introduce a more realistic case where shadowing variations around the body are now assumed strongly correlated. Generally speaking, there is a lack of definitive measurements and models for the shadowing correlation in multi-hop networks, while it can play a crucial role at the higher layers. Based on the measurement and simulation results of the French BANET project, we use the BAN context as an illustrative example to exhibit how shadowing correlations have a strong impact on relaying approaches performance.

Opportunistic networking aims at exploiting sporadic radio links to improve the connectivity of a multi-hop network and to foster data transmissions. Broadcast nature of the wireless channel is an important feature that can be exploited to improve transmissions by using several potential receivers. Opportunistic relaying is thus the first brick for opportunistic networking. However, the advantage of opportunistic relaying may be balanced by energy increase related to having simultaneous active receivers. In [32], we proposed a thorough analysis of opportunistic relaying efficiency under different realistic radio channel conditions. The study aims at finding the best trade-off between two objectives: energy and latency minimizations, under a hard reliability constraint. We derive an optimal bound, namely, the Pareto front of the related optimization problem, which offers a good insight into the benefits of opportunistic routings compared with classical multi-hop routing schemes. Meanwhile, the lower bound provides a framework to optimize the parameters in physical layer, MAC layer and routing layer from the viewpoint of cross layer during the design or planning phase of a network.

This work has been extended in In [70] for relay channels. The gain induced by using relay channels in a linear network under both a capacity constraint and a realistic energy model is evaluated. We express a general model based on a convex optimization problem, allowing us to use numerical tools to obtain similar results for outer and inner bounds to the capacity of the full and half duplex relay channel. We then further the study with more complex networks based on relay channels, especially networks formed by a linear chain of nodes. We describe the Pareto optimal solutions of the minimization problem for with respect to the consumed energy and latency in such a linear network. From the simple case of the linear multi-hop network, we study the gains when implementing a linear chain of relay channels and compare these results to the simpler multi-hop transmission. This work will be published in 2012 in IEEE WCNC.

In [82] we extended this formalims derived for a linear network to a more general case: the problem of deriving fundamental trade-off bounds for wireless ad hoc networks when multiple performance criteria are of interest. It proposes a MultiObjective (MO) performance evaluation framework composed of a broadcast and interference-limited network model, a steady state performance metric derivation inspired by a discrete Markov chain formalism and formulates the associated MO optimization problem. Pareto optimal performance bounds between end-to-end delay and energy for a capacity-achieving network are given for the 1-relay and 2-relay networks and assessed through simulations.

5.3. Autonomous wireless networking

Participants: Isabelle Augé-Blum, Bernard Tourancheau, Fabrice Valois, Ibrahim Amadou, Cédric Chauvenet, Quentin Lampin, Alexandre Mouradian, Bilel Romdhani.

Designing protocols for large scale wireless sensors networks is a challenging issue, if realistic environments are considered. Finding a trade-off between energy consumption and delay, or capacity, is difficult. The most promizing ideas rely on zero-protocol approaches and on virtual coordinates use. the special case of VANETs is presented in the next section.

In [64], we focus on Wireless Sensor Networks (WSNs) in a more realistic case than classical studies and previous works: we consider wireless sensor nodes having different transmission ranges according to the environment and/or to the wireless chipset. The main consequence of this heterogeneity is the existence of asymmetric links. Such links in a WSN degrade the performance of most protocols which have not been designed to support this heterogeneity and to deal with asymmetric links: so, mainly, these links are pruned. Under this assumption, we propose a routing protocol for data collection from sensors nodes to the sink node in heterogeneous WSNs. Our proposal detects and takes benefit from asymmetric links caused by this heterogeneity. Our proposal, denoted MURA, (1) provides a high delivery ratio, (2) reduces the number of duplicated packets and (3) reduces the number of hop counts by exploiting the asymmetric links.

Due to the efficiency and scalability of greedy routing in WSNs and the financial cost of GPS chips, Virtual Coordinate Systems (VCSs) for WSNs have been proposed. A category of VCSs is based on the hop-count from the sink, this scheme leads to many nodes having the same coordinate. The main advantage of this system is that the hops number of a packet from a source to the sink is known. Nevertheless, it does not allow to differentiate the nodes with the same hop-count. We propose in [87] a novel hop-count-based VCS which aims at classifying the nodes having the same hop-count depending on their connectivity and at differentiating nodes in a 2-hop neighborhood. Those properties make the coordinates, which also can be viewed as a local identifier, a very powerful metric which can be used in WSNs mechanisms.

Duty-cycled medium access protocols allow for long lasting autonomous networks by periodically putting nodes to sleep. However, this life expectancy improvement comes at the cost of a lesser network capacity and a poor adaptability to bursty traffic loads. Indeed, existing contention algorithms do not provide efficient algorithms to dynamically elect multiple senders per wake-up periods. In [84], the medium is divided in several logical chan- nels (eg. obtained by a time/frequency division of the communication medium) and we propose to allocate them dynamically among senders. For this purpose, we propose a joint contention/scheduling algorithm, named Extended Slot Se- lection (ESS), that schedules multiple sender/receiver pairs to available logical channels.

Energy-efficient communication protocol is a primary design goal for Wireless Sensor Networks (WSNs). Many efforts have been done to save energy: MAC with duty cycle, energy-aware routing protocols, data aggregation schemes, etc. Recently, beacon-less strategies have emerged as new direction to improve considerably the WSN lifetime. However, the main contributions are not suitable to real radio environments because of hole avoiding strategies based on either planarization or explicit neighbor solicitations. We propose in [34] PFMAC (Pizza- Forwarding Medium Access Control), which combines beacon- less geo-routing and energy efficient MAC protocol via a cross- layer design to save more energy with higher reliability. PFMAC supports radio interferences, asymmetric radio links, etc. PFMAC supports a greedy forwarding strategy and, a reactive and optimized neighborhood discovery at 2-hop to deal with holes. Intensive simulations are proposed to highlight the behavior and the performance of PFMAC compared to BOSS over BMAC.

To provide for reliability in Wireless Sensor Net- works (WSNs), Medium Access Control (MAC) protocols must be adapted by mechanisms taking cross-layer approaches into account. In [51], [52], we describe AreaCast which is designed for enhancing reliability in WSNs. AreaCast is a MAC layer mechanism inde- pendent of the routing layer, but uses only local topological and routing information to provide a communication by area instead of a traditional, node-to-node communication (i.e., unicast). In AreaCast, a source node addresses a set of nodes: an explicit relay node chosen as the next hop by a given routing protocol, and k other implicit relay nodes. The neighboring nodes select themselves as implicit relays according to their location from the explicit relay node. This mechanism uses overhearing to take advantage of the inherent broadcast nature of wireless commu- nications. Without changing the routing protocol, AreaCast is able to dynamically avoid a byzantine node or an unstable link, allowing to benefit from the inherent topological redundancy of densely deployed sensor networks. Simulation results show that AreaCast significantly improves the packet delivery rate while having a good reliability-energy consumption trade-off.

Improving the network lifetime is an important design criterion for wireless sensor networks especially if we want to use standard solution like IPv6. In [38], we propose a novel approach which applies source-coding on addresses in heterogeneous IPv6 Cluster-based wireless sensor network. We formulate the problem of maximizing the network lifetime when Slepian-wolf coding is applied on addresses in network composed of line-powered and battery-powered sensors. The numerical results show that a significant network lifetime improvement can be achieved (about 25% in typical scenario). In [36], we investigates the sinks mobility in IPv6-based wireless sensors networks and specially in the new IETF proposed protocol RPL (Routing Protocol for Low power and Lossy Networks). We also show that even the mobility of sinks is not an explicit design criteria, the use of mobile sinks improves the network lifetime.

5.4. Wireless networking in VANETs

Participants: Marco Fiore, Sandesh Uppoor.

VANETS (Vehicular Ad hoc Networks) represents a challenging context for designing new protocols as it offers new challenges related to the high dynamicity of the network. In cooperation with external researchers, we derived recent results on mobility modeling and data dissemination in VANETS. This work is a part of the work on 'Autonomous wireless networking', but dedicated specially for VANETs.

Simulation is the tool of choice for the large-scale performance evaluation of upcoming telecommunication networking paradigms that involve users aboard vehicles, such as next-generation cellular networks for vehicular access, pure vehicular ad hoc networks, and opportunistic disruption-tolerant networks. The single most distinguishing feature of vehicular networks simulation lies in the mobility of users, which is the result of the interaction of complex macroscopic and microscopic dynamics. Notwithstanding the improvements that vehicular mobility modeling has undergone during the past few years, no car traffic trace is available today that captures both macroscopic and microscopic behaviors of drivers over a large urban region, and does so with the level of detail required for networking research. In [66], we present a realistic synthetic dataset of the car traffic over a typical 24 hours in a 400-km^2 region around the city of Koln, in Germany. We outline how our mobility description improves today's existing traces and show the potential impact that a comprehensive representation of vehicular mobility can have one the evaluation of networking technologies.

In [21], [30], we investigate data dissemination in vehicular networks. Content downloading in vehicular networks is a topic of increasing interest: services based upon it are expected to be hugely popular and investments are planned for wireless roadside infrastructure to support it. We focus on a content downloading system leveraging both infrastructure-to-vehicle and vehicle-to-vehicle communication. With the goal to maximize the system throughput, we formulate a max-flow problem that accounts for several practical aspects, including channel contention and the data transfer paradigm. Through our study, we identify the factors that have the largest impact on the performance and derive guidelines for the design of the vehicular network and of the roadside infrastructure supporting it.

In [45] We address cooperative caching in wireless networks, where the nodes may be mobile and exchange information in a peer-to-peer fashion. We consider both cases of nodes with large- and small-sized caches. For large-sized caches, we devise a strategy where nodes, independent of each other, decide whether to cache some content and for how long. In the case of small-sized caches, we aim to design a content replacement strategy that allows nodes to successfully store newly received information while maintaining the good performance of the content distribution system. Under both conditions, each node takes decisions according to its perception of what nearby users may store in their caches and with the aim of differentiating its own cache content from the other nodes'. The result is the creation of content diversity within the nodes neighborhood so that a requesting user likely finds the desired information nearby. We simulate our caching algorithms in different ad hoc network scenarios and compare them with other caching schemes, showing that our solution succeeds in creating the desired content diversity, thus leading to a resource-efficient information access.

Performance and reliability of content access in mobile networks is conditioned by the number and location of content replicas deployed at the network nodes. In [27], we design a practical, distributed solution to content replication that is suitable for dynamic environments and achieves load balancing. Simulation results show that our mechanism, which uses local measurements only, approximates well an optimal solution while being robust against network and demand dynamics. Also, our scheme outperforms alternative approaches in terms of both content access delay and access congestion.

5.5. Optimization in wireless networks

Participants: Jean-Marie Gorce, Nikolaï Lebedev, Hervé Rivano, Fabrice Valois, Anis Ouni, Virgile Garcia, Cengis Hasan.

In the context of the common lab between Inria and Alcatel Lucent Bell Labs and the ANR Ecoscells project, we work on optimizing wireless networks performance. In one side, we work on distributed algorithms for optimal resource allocation and/or mobile-BS asociation. On the other side, we work on mesh wireless networks optimization.

Multi-cell processing, also called Coordinated Multiple Point (CoMP), is a promising distributed technique that uses neighbor cells' antennas [48]. It is expected to be the part of next generation cellular standards such as LTE-A. Small cell networks in dense urban environments are limited by interferences and CoMP can strongly take advantage of this fact to improve cell-edge users' throughput. The present study introduces a distributed criterion for mobiles to select their optimal set of Base Stations (BS) to perform CoMP, and evaluates the impact of this association on the fairness and the total cell throughput. For that, we use a known theoretical expression for the capacity outage probability of CoMP under Rayleigh fading and evaluate the goodputs of antennas associations. The proposed criterion is used in combination with fair resource allocation to perform a joint double-objective optimization of fairness and efficiency. In [48], [91], we provide the analysis of the downlink Coordinated Multiple Point (CoMP) used in conjunction with the basic MIMO. The CoMP is the joint multi-cell transmission from several BS to mobiles, coupled here to an open-loop MIMO technique that does not require the perfect channel state knowledge. We show by simulation, that even for 4×4 MIMO transmission, the CoMP can improve the spectral efficiency for some mobiles, depending on capacity outage requirements.

In [33], we considered downlink transmission in cellular networks where we target to reduce the energy consumption by switching off some base stations by such a way that the distribution of SINR remains unchanged. This is a mean of green networking in cellular networks in downlink consideration. This paper analyzes for line and plane cases, the gain in power consumption obtained after switching off base stations. By computations we observe that the more the operational cost the more the gain in power consumption.

In [47], we propose an autonomous radio resource allocation and optimization scheme that chooses the transmit power and precoding vector among codebooks for multiple antennas transmitters to improve spectral and power efficiency and provide user fairness. Network self-optimization is an essential feature for supporting the cell densification in future wireless cellular systems. The proposed self-optimization is inspired by Gibbs sampler. We show that it can be implemented in a distributed manner and nevertheless achieves system-wide optimization which improves network throughput, power utilization efficiency, and overall service fairness. In addition, we extend the work and include power pricing to parametrize and enhance energy efficiency further. Simulation results show that the proposed scheme can outperform today's default modes of operation in network throughput, energy efficiency, and user fairness.

In [55], we focused on broadband wireless networks based on OFDMA resource management, such as LTE systems. We have investigated two optimization problems, one concerning a backhauling mesh infrastructure while the other is the allocation of modulation and coding, subcarriers and power to users in LTE. Considering a realistic SINR model of the physical layer with a fine tuned power control at each node, a linear programing model using column generation has been developed for computing power efficient schedules with high network capacity for wireless mesh backhauling networks. Correlation between capacity and energy consumption have been analyzed as well as the impact of physical layer parameters - SINR threshold and path-loss exponent. With these models, we highlight that there is no significant tradeoff between capacity and energy when the power consumption of idle nodes is important. We also show that both energy consumption and network capacity are very sensitive to the SINR threshold variation. Finally, simulation results show that compared to classic reuse schemes the proposed approach is able to pack more users into the same bandwidth, decreasing the probability of user outage.

In [62], we focus on broadband wireless mesh networks like 3GPP LTE-Advanced. This technology is a key enabler for next generation cellular networks which are about to increase by an order of magnitude the capacity provided to users. Such an objective needs a significative densification of cells which requires an efficient backhauling infrastructure. In many urban areas as well as under-developed countries, wireless mesh networking is the only available solution. Besides, economical and environmental concerns require that the energy expenditure of such infrastructure is optimized. We propose a multi-objective analysis of the correlation between capacity and energy consumption of LTE-like wireless mesh networks. We provide a linear programing modeling using column generation for an efficient computation of the Pareto front between these objectives. Based on this model, we observe that there is actually no significant capacity against energy trade-off.

In [63], broadband wireless mesh networks based on OFDMA resource management are studied considering a realistic SINR model of the physical layer with a fine tuned power control at each node. A linear programing model using column generation leads to compute power efficient schedules with high network capacity. Correlation between capacity and energy consumption is analyzed as well as the impact of physical layer parameters - SINR threshold and path-loss exponent. We highlight that there is no significant tradeoff between capacity and energy when the power consumption of idle nodes is impor- tant. We also show that both energy consumption and network capacity are very sensitive to the SINR threshold variation.

5.6. Network coding in WSN

Participants: Jean-Marie Gorce, Cédric Lauradoux, Marco Fiore, Claire Goursaud, Marine Minier, Anya Apavatjrut, Yuanyuan Zhang, Wassim Znaidi.

Network coding associatedf with Fountain codes is a very efficient approach to increase the throughput of multi-hop networks. However severa outcomes are still expected, especially to develop robust and energy efficient approaches for transmitting data over a large sacle networks. Network coding is also very promising for security issues as presented below.

Diversity is a powerful means to increase the transmission performance of wireless communications. For the case of fountain codes relaying, it has been shown previously that introducing diversity is also beneficial since it counteracts transmission losses on the channel. Instead of simply hop-by-hop forwarding information, each sensor node diversifies the information flow using XOR combinations of stored packets. This approach has been shown to be efficient for random linear fountain codes. However, random linear codes exhibit high decoding complexity. In [19], we propose diversity increased relaying strategies for the more realistic and lower complexity Luby Transform code in a linear network. Results are provided herein for a linear network assuming uniform imperfect channel states.

In [29], the exact probability that a receiver obtains N linearly independent packets among K over N received packets is computed, when the sender/s use/s random linear network coding over a Galois Field of size q. Such condition maps to the receiver's capability to decode the original information, and its mathematical characterization helps to design the coding so to guarantee the correctness of the transmission. The proposed formulation represents an improvement over the current upper bound for the decoding probability, and provides theoretical grounding to simulative results in the literature.

In [35], we focus on the proper use of fountain codes for the transmission of sporadic data in a wireless sensor network (WSN). Fountain codes offer great perspectives for the self-organization of WSNs: they self adapt to the channel error rate without any control data. When deploying fountain codes on a WSN, two problems arise. First, the size of the data transmitted by a sensor is small in comparison to the size considered traditionally with fountain codes. Second, the communications are done in an hop-by-hop fashion. It implies that the destination of the data can not acknowledge instantaneously its reception to the source. Therefore, the transmissions of useless packets for the destination can not be prevented. The flooding traffic has been evaluated as well through realistic simulations for three different relaying strategies where packets are lost due to both small scale fading and collisions for an unslotted IEEE 802.15.4 medium access layer.

Network coding has attracted the attention of many researchers in security and cryptography. We have investigated several aspects of network coding security. In [20], we propose efficient solutions to thwart pollution attacks in which an adversary injects false information into data flow. This work was further expanded in [54] to find rational strategy to minimize the energy cost and the impact of the attack. We also came to the conclusion that dealing with pollution attacks was not enough as long as the acknowledgment messages are not also protected. The risk is to suffer from a flooding attack. This goes beyond the capabilities of cryptographic solutions and we investigate the security capabilities of multipath acknowledgment in [67].

5.7. Security

Participants: Jean-Marie Gorce, Cédric Lauradoux, Marine Minier, Fabrice Valois, Wassim Znaidi, Ahmed Benfarah, Ochirkhand Erdene-Ochir, Yuanyuan Zhang.

Security is an important issue for wireless networks, especially for wireless sensor networks facing an amizing increase of the number of nodes. We review in this section all contributions related to the security issue, some of them being strongly related with the PHY layer or the networking protocols. As it can be seen below, some results are strongly connected to the models and protocols derived in the other sections.

In [59], we provide the first independent analysis of the (2^{nd}-round tweaked) 256-bit version of the SHA3 candidate SHAvite-3. By leveraging recently introduced cryptanalysis tools such as rebound attack or Super-Sbox cryptanalysis, we are able to derive chosen-related-salt distinguishing attacks on the compression function on up to 8 rounds (12 rounds in total) and free-start collisions on up to 7 rounds. In particular, our best results are obtained by carefully controlling the differences in the key schedule of the internal cipher. Most of our results have been implemented and verified experimentally.

In [50], we study a class of insider attacks called the terrorist fraud. This is a relay attack against distance bounding protocols where the prover conspires with an adversary to misrepresent the distance between himself and the verifier. In ideal situations, the adversary does not gain any knowledge about the prover's long-term secret. This makes designing a distance bounding protocol resistant to such fraud tricky: the secrets of an honest prover must be protected, while those of a dishonest one should be disclosed as an incentive not to cheat. We demonstrate that using a secret-sharing scheme, possibly based on threshold cryptography, is well suited for thwarting the terrorist fraud. Although such an idea has been around since the work of Bussard and Bagga, this is the first time that secret-sharing and terrorist fraud have been systematically studied altogether.

In [40], we deal with the problem of radio jammiing. Jamming is a major threat against wireless communications. In this paper, we evaluate the effect of jamming on an UWB link employing a PPM non-coherent receiver. We optimize the jammer parameters that are the central frequency and the bandwidth based on the metric of the signal-to-jamming ratio. The optimization depends on different system parameters such as the channel model and the integration time of the receiver.

In [23], we focus on the resiliency of wireless sensor network routing protocols against selective forwarding attacks by compromised nodes. Informally, resiliency should be understood as the capacity of the routing protocol to endure and mitigate the presence of a certain number of compromised nodes seeking to disturb the routing process. To provide for security when nodes may be compromised, cryptographic solutions must be completed by algorithmic solutions considering "beyond cryptography" approaches. After discussing the shortcomings of existing routing protocols against packet-dropping malicious nodes we describe some protocol behaviors enhancing routing resiliency under several combined routing attacks. We propose in this paper the behaviors enhancing the resiliency of routing protocols under several combined routing attacks.

5.8. Network simulation tools

Several works in 2011 have been using simulation results. Nevertheless, Swing members are strongly working on improving network simulation frameworks to provide realistic simulations. Several contributions to the simulation tools wiplan ans wsnets have been proposed.

Some contributions to WSnet concern BAN environments implementation [44] and network coding features [19], [81]. Different protocols have been also implemented for wireless sensor networks [34], [84], specifically in the context of our collaboration with Orange Labs, Grenoble.

The wiplan simulator has been developed at CITI for several years. It is based of a frequency domain ParFlow (MR-FDPF) implementation that represents a unique finite elements based method for estimating the radio propagation in complex environments. In the context of heterogeneous networks, femtocells are very promising. In order to properly simulate their behavior and their impact on the macrocell layer, it is necessary to be able to simulate the radio coverage of femtocells. Hence ParFlow is a possible deterministic model that can be used for such simulation. In [42], two implementations of ParFlow are presented: time domain and frequency domain. The performance are compared and the advantages/drawbacks of each model are investigated.

In [56] we propose to use finite difference propagation methods to evaluate the wide band properties of the fast fading. For this purpose we adapted the MR-FDPF propagation model to simulate large bandwidth by combining numerous narrow band simulations. The results are compared with a channel sounder measurement campaign covering a bandwidth of up to 70 MHz. It is verified that fading characteristics in wireless channels varies with frequency and the MR-FDPF method is capable for simulating this variation of fadings for wide band systems.

In [56], a new approach is proposed allowing extracting the fading statistics for indoor radio channels based on the electric field strength predicted with the MR-FDPF method. The performance of the proposed approach is verified both by simulations and measurements.

In [65], we propose a new hybrid modeling method for indoor-to-outdoor radio coverage prediction. The proposed method is a combination of a ray-optical channel modeling approach and the frequency domain ParFlow method. While the former is widely used for modeling outdoor propagation environments, the latter is computationally efficient and accurate for modeling indoor environments.

In [90], we propose to use finite difference propagation methods to evaluate the wide band properties of the fast fading. For this purpose we adapted the MR-FDPF propagation model to simulate large bandwidth by combining numerous narrow band simulations. The results are compared with a channel sounder measurement campaign covering a bandwidth of up to 70 MHz. It is verified that fading characteristics in wireless channels varies with frequency and the MR-FDPF method is capable for simulating this variation of fading for wide band systems.

6. Contracts and Grants with Industry

6.1. Industry

SWING has developed a strong relationship with Orange Labs through several “Contrat de Recherche Extérieur” (CRE). In 2009, three CREs with Orange Labs are supporting the thesis of:

- Ahmed Benfarah,
- Ochirkhand Erdene-Ochir,
- Quentin Lampin.

SWING also works in collaboration with SIRADEL, a french worldwide company working on wireless system simulations. A bilateral cooperation supports the PhD of Laurent Maviel, and Siradel is a membe rof the Ecoscell ANR project in which Swing is involved.

SWING started in September 2011 a strong bilateral cooperation with the Euromedia group about Body Area Networks in which Hervé PArvery and Jean-Marie Gorce are involved and the project supports the thesis of Matthieu Lauzier.

7. Partnerships and Cooperations

7.1. National Actions

7.1.1. ANR VERSO ARESA2 - “Avancées en Réseaux de capteurs Efficaces, Sécurisés et Auto-Adaptatifs” (2009-2012, 160 keuros)

Participants: Fabrice Valois, Marine Minier.

Aresa2 is a national initiative (ANR) started in december 09 and focusing on IP and Security issues in wireless sensor networks. It follows the first ANR/RNRT - Aresa. Fabrice Valois is the leader of the workpackage about self-organisation and Marine Minier is involved in the workpackage on security. The leader of Aresa2 is Orange Labs and the others partners are: Coronis Systems, VERIMAG, LIG, Télécom Bretagne and INRIA.

7.1.2. ANR - Banet - Body Area Networks and Technologies (2007-2010, 129 keuros)

Participants: Paul Ferrand, Jean-Marie Gorce, Claire Goursaud, Nikolaï Lebedev, Guillaume Villemaud.

Banet is a national initiative (ANR) started in January 2008 and focusing on Body Area Network (BAN) systems. Jean-Marie Gorce is the leader of the workpackage 'Standard air interface, network and protocol system design'. The budget for Swing is 120 keuros. Providing a framework for Body Area Networks (BAN), defining a reliable communica- tion protocol, optimizing BAN technologies and enhancing energy efficiency of network components are the major stakes of then National Project BANET, led by CEA-Leti. It aims at defining precise frameworks to design optimized and miniaturized wireless com- munication systems. These body area networks target a wide applications range, such as consumer electronics, medical care and sports.

7.1.3. ANR - ECOSCELLS - Efficient Cooperating Small Cells (2009-2012, 260 keuros)

Participants: Virgile Garcia, Jean-Marie Gorce, Nikolaï Lebedev, Anis Ouni, Cengis Hasan, Hervé Rivano, Fabrice Valois.

ECOSCELLS is a national initiative (ANR) which aims at developing algorithms and solutions to ease Small Cells Network (SCN) deployment. Theoretical studies will provide models for understanding the impact of radio channels, and to permit the definition of new algorithms exploiting a full diversity (user, spatial, interferences, etc.) of such networks. The novelty of the project is not to consider the interference as a drawback anymore, but to exploit it in order to offer an optimal resource utilization. The algorithms will be based on most recent developments in distributed algorithms, game theory, reinforcement learning. Architecture and algorithms for the backhauling network will also be proposed.

7.1.4. ANR - Rapide - Design and analysis of stream ciphers for constrained environments (2006-2011, 47 keuros)

Participants: Cédric Lauradoux, Marine Minier.

Rapide is a national initiative (ANR). Marine Minier is responsible of the work package "MACs construction". Stream ciphers are less popular than their block ciphers counterparts, due to the lack of real standards. However, they become essential as soon as we want to reach important flows for limited costs in software or hardware. The aim of this national project is to study, construct and evaluate new stream ciphers built upon a non-linear transition function and to better evaluate the properties of the filtering function to discard known attacks, especially the algebraic ones.

7.1.5. ANR INS BLOC - "block ciphers dedicated to constrained environments" (2011-2015, 80 keuros)

Participants: Marine Minier, Cédric Lauradoux.

BLOC is a research project partially funded by the French National Research Agency. It has been proposed to INS 2011 call. It aims at studying the design and analysis of block ciphers dedicated to constrained environments.

7.1.6. ANR - Cormoran - "Cooperative and Mobile Wireless Body Area Networks for Group Navigation" (2011-2014, 140 keuros)

Participants: Paul Ferrand, Jean-Marie Gorce, Claire Goursaud, Isabelle Augé-Blum.

Cormoran project targets to figure out innovative communication functionalities and radiolocation algorithms that could benefit from inter/intra-WBAN cooperation. More precisely, the idea is to enable accurate nodes/body location, as well as Quality of Service management and communications reliability (from the protocol point of view), while coping with inter-WBAN coexistence, low power constraints and complying with the IEEE 802.15.6 standard. The proposed solutions will be evaluated in realistic applicative scenarios, hence necessitating the development of adapted simulation tools and real-life experiments based on hardware platforms. For this sake, CORMORAN will follow an original approach, mixing theoretical work (e.g. modelling activities, algorithms and cross-layer PHY/MAC/NWK design) with more practical aspects (e.g. channel and antennas measurement campaigns, algorithms interfacing with real platforms, demonstrations).

7.1.7. FUI ECONHOME - "Energy efficient home networking" (2010-2014, 330 keuros)

Participants: Nikolaï Lebedev, Florin Hutu, Jean-Marie Gorce, Guillaume Villemaud.

The project aims at reducing the energy consumption of the home (multimedia) data networks, while maintaining the quality requirements for heterogeneous services and flows, and preserving, or even enhancing the overall system performance. the equipments under concern are residential gateways, set-top-boxes (STB), PLC modules, Wifi extenders, NAS. The user equipment, such as smartphones, tablets or PCs are not concerned. The approach relies on combining both individual equipments IC and system level protocols that have to be eco-designed.

7.1.8. ADR Selfnet - "Self Optimization Networking" (2008-2011, 350 keuros)

Participants: Virgile garcia, Sandesh Uppoor, Nikolaï Lebedev, Jean-Marie Gorce, Hervé Rivano, Fabrice Valois, Marco Fiore.

This action is a part of the common lab of Inria and Alcatel Lucent Bell Labs. This action groups several team of Inria with Alcatel teams and adresses different aspects of Self Networking: distributed algorithms, energy efficiency, mobility. Virgile Garcia is finihsing is PhD on distributed power management in cellular networks and Sandesh Uppoor is in his 2nd year on mobility models.

7.2. Actions Funded by the EC

7.2.1. Projet iPLAN - FP7-PEOPLE-IAPP-2008 (2009-2012, 440 keuros)

Participants: Jean-Marie Gorce, Guillaume Villemaud, Nikolaï Lebedev, Dmitry Umansky, Meiling Luo.

iPLAN (is a FP7 project of the FP7-PEOPLE-IAPP-2008 call. iPLAN (Indoor Planning) The iPlan consortium is made of the Ranplan Company, the CITI Lab- oratory and the University of Bedfordshire and proposes the study of Indoor planning and optimization models and tools. The aim is to develop fast and accurate radio propagation models, investigate various issues arising from the use of femtocells, develop an automatic indoor radio network planning and optimization and facilitate knowledge integration and transfer between project partners, to enable cross-fertilization between radio propagation modeling, wireless communications, operations research, computing, and software engi- neering.

Meiling is currently seconded full-time for 2 years in Ranplan Company, and Nikolai Lebedev is seconded full-time for 1 year.

7.2.2. DistMo4wNet - FP6 fellowship (2006-2011, 240 keuros)

Participants: Jean-Marie Gorce, Katia Jaffrès-Runser.

DistMo4wNet is a FP6 project labelled in the FP6 framework in the outgoing fellowship program. Jean-Marie Gorce is the scientific responsible of the program, and Katia Jaffres-Runser is the applicant. She was supported from January 2007 through June 2009, for two years at the Stevens Institute of Technology where she works with Pr. Cristina Comaniciu on distributed optimization of wireless networks protocols.

8. Dissemination

8.1. Leadership within the scientific community

8.1.1. Participation in Committees

Jean-Marie Gorce: nominated as a member of CNU61 in december 2011, member of the "Expert for recruiting committees of 27^{e} section" in INSA Lyon ; expert reviewer for the French National Agency for Research (ANR) and for ANRT for CIFRE projects.
Marine Minier: member of the "Expert for recruiting committees of 27^{e} section" of the Université de Nice and Université de Saint-Etienne.

H. Rivano: elected member of the CNRS National Committee and member of recruiting CNRS committees of section 07 for Chargé de Recherche et Directeur de Recherche.
Fabrice Valois: Invited professor of Shanghai JiaoTong University (February-July). Member of "atelier thématique A3 STIC-NANO " of the "Service de la Stratégie Nationale de la Recherche et de l'Innovation" for the minister of research.

8.1.2. Editorial Boards

Jean-Marie Gorce: Telecommunication Systems.
Jean-Marie Gorce: Eurasip Journal of Wireless Communications and Networking.
Tanguy Risset: Integration, the VLSI Journal.
Jean-Marie Gorce, Guillaume Villemaud: Guest editors for a special issue of Eurasip Journal of Wireless Communications and Networking on wireless channel and propagation.

8.1.3. Conferences and workshops organization

Guillaume Villemaud, Jean-Marie Gorce, Nikolai Levedev, Paul Ferrand: International Workshop on Propagation and Channel Models for Next Generation Wireless Systems (March, Lyon, France).

Hervé Rivano: Member the steering committee of ResCom in GDR ASR.

Bernard tourrencheau: Organizer of "Journées IP Capteurs" (January, Lyon, France).

Fabrice Valois: Organizer of "Journées IP Capteurs" (January, Lyon, France). Organizer and member of the steering committee of RESCOM.

8.1.4. Participation in program committees

Marco Fiore: IEEE PIMRC 2011, IEEE WoWMoM 2011, Workshop on Flexibility in Broadband Wireless Access Network 2011, WPMC 2011, IEEE VTC-Fall 2011, IEEE ExtremeCom 2011, Wireless Vehicular Communications and Networks 2011.
Jean-Marie Gorce: Crowncom 2011, GRETSI 2011, IWCLD 2011, Workshop Broadband Femtocells technology with IEEE-WCNC 2012, IEEE VTC-Spring (May, Budapest, Hungary).
Marine Minier: journées C2 2011, FSE 2011, ICDIM 2011, CIS 2011.
Fabrice Valois: Algotel 2011 (Mai, Cap Esterel, France), CFIP(Mai, Nice, France), VTC-Spring (May, Budapest, Hungary), ICC 2011 (June, Kyoto, Japan), IWCMC (June, Istanbul, Turkey), SensorComm (August Côte d'Azur, France), iCOST (October, Shanghai, China), WiMob (October, Shanghai, China), WPMC (October, Brest, France), Globecom 2011 (December, Houston, USA).

8.2. Theses, Internships

8.2.1. Theses

8.2.1.1. Theses defended in 2011

Anya Apavatjrut: "*De l'usage des codes fontaines dans les réseau de capteurs multisauts*", PhD thesis from INSA LYON, Thailand grant, 12/07/2011.

Leila Ben Saad: "*Stratégies pour améliorer la durée de vie des réseaux de capteurs sans fil*", PhD thesis from ENS LYON, MENRT grant, 23/11/2011.

Cédric Levy-Bencheton: "*Étude de relais multi-mode sous contrainte d'énergie dans un contexte de radio logicielle*", PhD thesis from INSA Lyon, MENRT grant, 28/06/2011.

Fei Yang: "*Reliable and Time-Constrained Communication in Wireless Sensor Networks*", PhD thesis from INSA LYON, CSN grant, 25/01/2011.

8.2.1.2. Theses in preparation

Ibrahim Amadou: "Towards zero control packets in WSN for energy saving", MENRT grant since 11/2008.

Ahmed Benfarah: "*Security of an UWB-IR radio link PHY/MAC layers approach*", Orange labs grant, since 11/2009.

Cédric Chauvenet: "*IPv6/6LoWPAN network architecture design over low power*", CIFRE Watteco/CITI grant, since 02/2010.

Mickael Dardaillon: "*Virtual machine for the cognitive radio*", Rhône-Alpes grant, since 10/2011.

Ochirkhand Erdene-Ochir: "Resilient secure networking for wireless sensor networks", Orange labs grant, since 10/2009.

Paul Ferrand: "*Cooperative communications in BANET*", MENRT, since 10/2009.

Virgile Garcia: "*Opportunistic radio resource sharing for next-gen cellular networks*", INRIA/Alcatel-Lucent grant, since 12/2008.

Cengis Hasan: "Optimization of resource allocation for small cells networks", Orange labs grant, since 01/2010.

Aissa Khoumeri: "low power and low cost architectures for wireless networks", FUI Ecnhome grant, since 10/2011.

Quentin Lampin: "*QOS and time-constrained WSN Networks*", Orange labs grant, since 01/10/2009.

Matthieu Lauzier: "*Design and evaluation of information gathering systems for dense mobile wireless sensor networks*", Euromedia grant, since 01/10/2011.

Meiling Luo: "*Fast and accurate radio propagation models for radio network planning*", MENRT grant, since 01/2010.

Laurent Maviel: "*Wireless heterogeneous networks dynamic planning in urban and indoor non-stationary environments*", CIFRE grant with SIRADEL, since 11/2009.

Alexandre Mouradian: "*Proposition et validation de protocoles de communication temps-réel pour les réseaux de capteurs sans fil*", ANR ARESA2 grant, since 10/2010.

Anis Ouni: "*Optimization of capacity and energy consumption in wireless mesh networks*", ECOSCells project grant, since 10/2009.

Bilel Romdhani: "*Energy-efficient networking protocols for Wireless Sensors and Actuators Networks*", Orange labs grant, since 10/2008.

Sandesh Uppoor: "*Understanding and exploiting mobility in wireless networks*", INRIA/Alcatel-Lucent grant, since 10/2010.

8.2.2. Participation in thesis Committees

Jean-Marie Gorce: thesis of Anya Apavatjrut (July, Lyon, INSA Lyon)[Director],
thesis of Leonardo Cardoso (November 2011, Supelec Paris)[examinator], thesis of Ali Osmane (December 2011, ENST Paris)[reviewer], thesis of Denis Dessales (December 2011, université de Poitiers)[reviewer], thesis of Mubashir Remhani (December 2011, UPMC Paris)[reviewer], thesis of Bastien Lyonnet (December 2011, INP Grenoble)[examinator], thesis of Ali Choumane (Juin 2011, Université de Limoges)[reviewer],

Claire Goursaud: thesis of Anya Apavatjrut (July, Lyon, INSA Lyon)[Director],

Marine Minier: thesis of Baudoin Collard (January 2011, Louvain-La-Neuve - Belgium, UCL). (October, Lyon, INSA LYON)[examinator].

Hervé Rivano: thesis of Julien Champ (December, Montpellier, ED ISS)[Examinator], thesis of Florent Hernandez (November, Montpellier, ED ISS)[Examinator].

Marco Fiore: thesis of Razvan Stanica (November, Toulouse, ENSIEEHT)[Examinator].

Bernard Tourrancheau: thesis of Leila Ben Saad (November, Lyon, ENS Lyon)[Director].

Fabrice Valois: HDR of Aline C. Viana (December, Paris, Université de Paris 6)[examinator], thesis of Yacine Mezali (december, Orsay, École Polytechnique)[reviewer], thesis of Stéphane Pomportes (December, Paris, Université Paris-Sud)[reviewer].

Guillaume Villemaud: thesis of Cédric Lévy-Bencheton (May, Grenoble, INSA Lyon)[director].

Tanguy Risset: thesis of Sajjad Khawar (February, Versailles, Université de Versailles)[reviewer], thesis of Cédric Lévy-Bencheton (May, Grenoble, INSA Lyon)[director],
thesis of Erwan Raffin (July, Rennes, Un iversité de Rennes)[reviewer],
thesis of Nicolas Pouillon (September, Paris, Université Paris 6)[Examinator].

8.2.3. Internships

Yesser Bouguerra [PFE student]: Mécanismes d'allocations d'adresses dans les réseaux multi-saut (Marco Fiore, Fabrice Valois)

Arthur Caillau [License student]: Developpement d'un outil d'étude des reseaux radio mailles (Herve Rivano)

Mickael Dardaillon [Master student]: Implementation materielle d'algorithmes de cryptographie pour les reseaux de capteurs (Tanguy Risset, Cédric Lauradoux)

Ghuzlan Hasan [Master student]: Communication IPv6 pour reseau de capteurs (Bernard Tourancheau)

Bilel Fersi [PFE student]: Voting Algorithms for Intrusion Detection in WSNs (Cedric Lauradoux, Isabelle Auge-Blum)

Antoine Fossaluzza [PFE student]: Evaluation de la propagation de signaux en environnements vehiculaires (Marco Fiore)

Fraga Fraga Iago [PFE student]: Analyse complexe de réseaux de connectivité véhiculaire (Marco Fiore)

Silvana Hernandez Jaramillo [Master student]: Evaluation des canaux de transmission de type Femtocells (Guillaume Villemaud, Florin Hutu)

Massimo Montalto [PFE student]: Evaluation de la propagation de signaux en environnements vehiculaires (Marco Fiore)

Petru Polacek [Master student]: Design of Low power, low cost physical layer architectures for the new generations of home area networks (Florin Hutu, Guillaume Villemaud)

Damien Reimert [Master student]: Environnement de simulation pour capteurs Indoor (???)

Chakroun Selima [Master student]: Mécanismes d'allocations d'adresses dans les réseaux multi-saut (Marco Fiore, Fabrice Valois)

Dounia Zaidouni [Master student]: Optimization of vehicular access in presence femto-cell road coverage (Marco Fiore, Herve Rivano)

Yin Zhang [PFE student]: Développement d'une couche MAC pour un réseau BAN (???)

8.3. Teaching

The members of SWING are heavily involved in teaching activities at Telecommunications department of INSA Lyon (master 1 and 2 level). Tanguy Risset, Jean-Marie Gorce and Fabrice Valois are professor in the Telecommunications department of INSA Lyon. Claire Goursaud and Isabelle Augé-Blum are associate professor in the Telecommunications department of INSA Lyon. Jean-Marie Gorce was the vice-head of the Telecommunications department of INSA Lyon until september 2009, and since he has been replaced by Tanguy Risset. The teaching is carried out by members of INSA Lyon as part of their teaching duties, and for INRIA/CNRS or PhD's as extra work.

Some members are involved in the teaching activity of other departments of INSA Lyon. Marine Minier is associate professor in the Computer Science department of INSA Lyon. Jacques Verdier, Florin Hutu and Guillaume Villemaud are associate professor in the Electrical Engineering department of INSA Lyon.

Nikolaï Lebedev is associate professor in the engineering school in Chemistry, Physics and Electronics, Lyon.

Bernard Tourrencheau is involved in the teaching activity at University of Lyon in different masters. Some members are also involved in administrative duties related to teaching at University of Lyon. Tanguy Risset is the responsible for the Networking program of the Master Mastria from University of Lyon, and Jean-Marie Gorce is the responsible for the Telecommunications program of the future Master EEAP from University of Lyon. Bernard Tourrencheau

Moreover, the SWING team is involved in international teaching program. Fabrice Valois is the head of a Special program of Engineering in Telecommunications between INSA Lyon and Shanghaï - Jiao Tong University.

The members of SWING also supervise several student projects and internships at all levels (Master 1 and 2, Engineering Schools).

Altogether that represents more than 2400 hours per year.

8.4. Participation in conferences and workshops

8.4.1. Participation in conferences/workshops/schools

Anya Apavatjrut: PIMRC 2011 (September, Toronto, Canada).

Ahmed Benfarah: SecureNets (May, Paris, France), Summer school on "Topics in Wireless Networks Security" (May, Milano, Italy), ICUWB 2011 (September, Bologne, Italy).

Leila Ben Saad: Journées scientifiques du cluster ISLE Semba (Octobre, Valence, France), NTMS 2011 (February, Paris, France), Sensorcomm (August, Nice, France), Wimob (October, Shanghai, China).

Cédric Chauvenet: Journées scientifiques du cluster ISLE Semba (Octobre, Valence, France).

Paul Ferrand: IWPCM (March, Lyon, France), EuCAP (April, Roma, Italy), COST IC1004 (October, Lisbonne, Portugal).

Virgile Garcia: VTC-Fall 2011 (September, San Francisco, USA), PIMRC 2011 (September, Toronto ,Canada), Séminaire Self-Net(January, Versailles, France).

Marco Fiore: IEEE Infocom 2011 (April, Shanghai, China), IEEE/IFIP MedHocNet 2011 (June, Favignana, Italy).

Katia Jaffres-Runser: NetCod 2011 (July, Beijing, China).

Nikolai Lebedev: OptNet 2011 workshop (September, Sheffield, UK).

Cédric Lauradoux: WISEC 2011 (June, Hamburg, Germany), Journées scientifiques du cluster ISLE Semba (Octobre, Valence, France).

Meiling Luo: Eucap 2011 (April, Roma, Italy), VTC-Fall 2011 (September, San Francisco, USA).

Marine Minier: FSE 2011 (February, Lyngby, Danemark), INetSec 2011 (June, Luzern, Swizerland), séminaire CCA (January, Paris, France).

Alexandre Mouradian: ETR11 (August, Brest, France), RESCOM réseaux (October, Paris, France).

Afsec (November, Paris, France), NC2 (November, Lyon, France), REVE/ResCom (November, Lyon, France), ResCom (November, Lyon, France).

Anis Ouni: PIMRC'11 (September, Toronto, Canada), VTC2011-Spring (May, Budapest, Hungary), SNOW'11 (March, Sälen, Sweden), RESCOM 2011 (October, Paris, France).

Tanguy Risset: CGO 2011 (Avril, Chamonix, France).

Hervé Rivano: Algotel 2011 (May, Cap Estérel, France), PIMRC 2011 (September, Toronto, Canada), ResCom (November, Lyon, France).

Bilel Romdhani: Journées IP Capteurs (January, Lyon, France), VTC-Spring 2011, (May, Budapest, Hungary).

Fabrice Valois: IN'Tech (January, Grenoble, France), IEEE Infocom 2011 (April, Shanghai, China), Sensor-Comm (July, Venice, Italy), ResCom (October, Paris, France), journée "Prospective Recherche : rencontres TPE/PME/PMI - recherche universitaire" (October, Paris, France).

Guillaume Villemaud: IEEE Radio Wireless Symposium 2011 (January, Phoenix, USA), European Conference on Antennas and Propagation 2011 (April, Roma, Italy), IFIP Wireless Days 2011 (October, Niagara Falls, Canada).
Cengis Hasan: NetGCoop 2011,Paris.
Jean-Marie Gorce: IC904 Cognitive radio Cost meeting, October 2011 (Barcelona), IC1004 green cooperative communications meeting, October 2011 (Lisbon), IWPCM February 2011 (Lyon).

9. Bibliography

Major publications by the team in recent years

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[17] C. LÉVY-BENCHETON. *Etude de relais multi-mode sous contrainte d'énergie dans un contexte de radio logicielle*, INSA-Lyon, June 2011.

[18] F. YANG. *Reliable and Time-Constrained Communication in Wireless Sensor Networks*, INSA-Lyon, January 2011.

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[19] A. APAVATJRUT, C. GOURSAUD, K. JAFFRÈS-RUNSER, C. COMANICIU, J.-M. GORCE. *Toward Increasing Packet Diversity for Relaying LT Fountain Codes in Wireless Sensor Networks*, in "IEEE Communications Letters", 2011, p. CL2010-1692, http://hal.inria.fr/hal-00542009/en.

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