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Institut national des sciences appliquées de Lyon

Activity Report 2016

Project-Team SOCRATE

Software and Cognitive Radio for Telecommunications

IN COLLABORATION WITH: Centre of Innovation in Telecommunications and Integration of services

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Networks and Telecommunications

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Project-Team SOCRATE

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1.2.6. - Sensor networks
1.5.2. - Communicating systems
2.3.1. - Embedded systems
2.6.1. - Operating systems
5.9. - Signal processing
7.8. - Information theory

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6.2. - Network technologies
6.2.2. - Radio technology
6.4. - Internet of things
6.6. - Embedded systems

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2. Overall Objectives

2.1. Introduction

The success of radio networking relies on a small set of rules: *i)* protocols are completely defined beforehand, *ii)* resource allocation policies are mainly designed in a static manner and *iii)* access network architectures are planned and controlled. Such a model obviously lacks adaptability and also suffers from a suboptimal behavior and performance.

Because of the growing demand for radio resources, several heterogeneous standards and technologies have been introduced by the standard organizations or industry by different workgroups within the IEEE (802 family), ETSI (GSM), 3GPP (3G, 4G) or the Internet Society (IETF standards) leading to the almost saturated usage of several frequency bands (see Fig. 1).

These two facts, obsolescence of current radio networking rules on one hand, and saturation of the radio frequency band on the other hand, are the main premises for the advent of a new era of radio networking that will be characterized by self-adaptive mechanisms. These mechanisms will rely on software radio technologies, distributed algorithms, end-to-end dynamic routing protocols and therefore require a cross-layer vision of “cognitive wireless networking”: *Getting to the meet of Cognition and Cooperation, beyond the inherent communication aspects: cognition is more than cognitive radio and cooperation is not just relaying. Cognition and cooperation have truly the potential to break new ground for mobile communication systems and to offer new business models.* [61]

From a social perspective, pervasive communications and ambient networking are becoming part of more and more facets of our daily life. Probably the most popular usage is mobile Internet access, which is made possible by numerous access technologies, e.g. cellular mobile networks, WiFi, Bluetooth, etc. The access technology itself 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 this service.

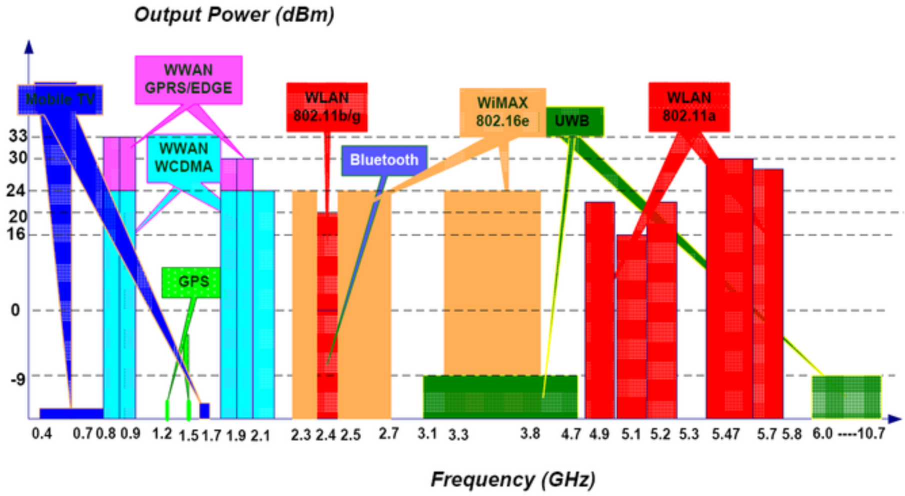

Figure 1. The most recent standards for wireless communications are developed in the UHF and VHF bands. These bands are mostly saturated (source: WPAN/WLAN/WWAN Multi-Radio Coexistence, IEEE 802 Plenary, Atlanta, USA, Nov.2007)

Beyond simple Internet access, many other applications and services are built on the basis of pervasive connectivity, for which the communication is just a mean, and not a finality. Thus, the wireless link is expected to even be *invisible to the end user* and constitutes the first element of the Future Internet of Things [60], to develop a complete twin virtual world fully connected to the real one.

The way radio technologies have been developed until now is far from offering a real wireless convergence [52]. The current development of the wireless industry is surely slowed down by the lack of radio resources and the lack of systems flexibility.

One can get rid of this technological bottleneck by solving three complementary problems: *terminal flexibility, agile radio resource management* and *autonomous networking*. These three objectives are subsumed by the concept of *Software Radio*, a term coined by J. Mitola in his seminal work during the early 90's [57], [58]. While implementing everything in software nodes is still an utopia, many architectures now hitting the market include some degree of programmability; this is called Software-Defined Radio. The word "defined" has been added to distinguish from the ideal software radio. A software *defined* radio is a software radio which is defined for a given frequency range and a maximal bandwidth.

In parallel, the development of new standards is threatened by the radio spectrum scarcity. As illustrated in Fig. 1, the increasing number of standards already causes partial saturation of the UHF band, and will probably lead to its full saturation in the long run. However, this saturation is only "virtual" because all equipments are fortunately not emitting all the time [52]. A good illustration is the so-called "white spaces", i.e. frequency bands that are liberated by analog television disappearing and can be re-used for other purposes, different rules are set up in different countries. In this example, a solution for increasing the real capacity of the 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.

With Software-Defined Radio technology, terminal flexibility is at hand, many questions arise that are related to the software layer of a software radio machine: how will this kind of platform be programmed? How can we write programs that are portable from one terminal to another? Autonomous networking will only be reached after a deep understanding of network information theory. Thus, given that there will be many ways for transmitting data from one point to another, what is the most efficient way in terms of throughput? power consumption? etc. Last but not least, agile Radio Resource sharing is addressed by studying MIMO and multi-standard radio front-end. This new technology is offering a wide range of research problems. These three topics: software programming of a software radio machine, distributed algorithms for radio resource management and multi-standard radio front-end constitute the research directions of Socrate.

2.2. Technological State of the Art

A Software-Defined Radio (SDR) system is a radio communication system in which computations that in the past were typically implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented as software programs [57], [53].

2.2.1. SDR Technology

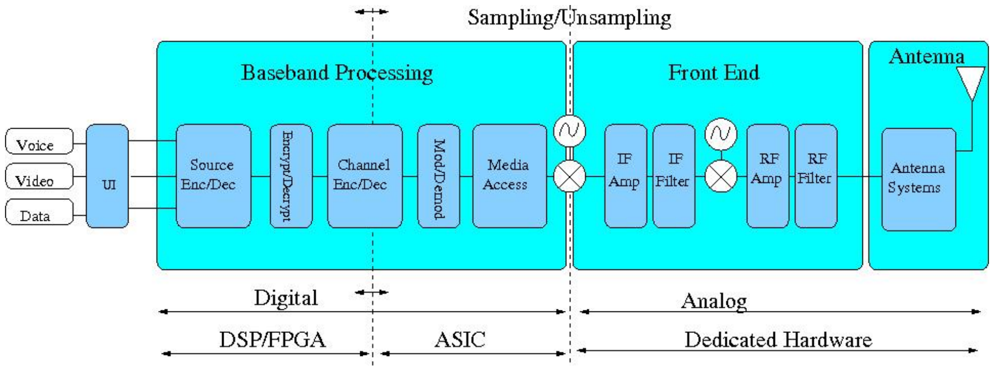

Figure 2. Radio Block Diagram, highlighting separation between digital and analog parts, as well as programmable, configurable and fixed hardware parts.

The different components of a radio system are illustrated in Fig. 2. Of course, all of the digital components may not be programmable, but the bigger the programmable part (DSP/FPGA part on Fig. 2), the more *software* the radio. Dedicated IPs. In this context, IP stand for *Intellectual Properties, this term is widely used to designated dedicated special-purpose circuit blocks implemented in various technologies: Asic,* FPGA*,* DSP*, etc.* are needed, for these IP it is more suitable to use the term *configurable* than programmable. In a typical SDR, the analog part is limited to a frequency translation down to an intermediate band which is sampled and all the signal processing is done digitally.

2.2.2. SDR Forum Classification

To encourage a common meaning for the term "SDR" the SDR Forum (recently renamed *Wireless Innovation Forum* (http://www.wirelessinnovation.org) proposes to distinguish five tiers:

- *Tier 0 – Hardware Radio:* The radio parameters cannot be changed, radio is implemented only with hardware components.
- *Tier 1 – Software Controlled Radio:* A radio where only the control functions are implemented in software, baseband processing is still performed in hardware, the radio is able to switch between different hardware.

- *Tier 2 – Software-Defined Radio:* The most popularly understood definition of SDR: the radio includes software control of modulation, bandwidth, frequency range and frequency bands. Conversion to digital domain still occurs after frequency conversion. It is currently implemented using a wide range of technologies: Asics, FPGAs, DSPs, etc.
- *Tier 3 – Ideal Software Radio:* Digital conversion occurs directly at the antenna, programmability extends to the whole system.
- *Tier 4 – Ultimate Software Radio:* Same reconfigurability capabilities as in Tier 3, but with a switching between two configurations in less than one millisecond.

The main restriction to build an ideal software radio is sampling rate: sampling at a high rate is not an easy task. Following the Shannon-Nyquist theorem, sampling the RF signal at a rate greater than twice the frequency of the signal is sufficient to reconstruct the signal. Sampling can be done at lower rate (decimation), but errors can be introduced (aliasing) that can be corrected by filtering (dirty radio concept). Building an SDR terminal implies a trade-of between sampling frequency and terminal complexity. For instance, sampling at 4.9 GHz would require a 12-bit resolution ADC with at least 10GHz sample rate which is today not available with reasonable power consumption (several hundreds Watt).

2.2.3. Cognitive Radio

SDR technology enables *over the air programming* (Otap) which consists in describing methods for distributing new software updates through the radio interface. However, as SDR architectures are heterogeneous, a standard distribution method has not emerged yet.

Cognitive Radio is a wireless communication system that can sense the air, and decide to configure itself in a given mode, following a local or distributed decision algorithm. Although Tier 3 SDR would be an ideal platform for cognitive radio implementation, cognitive radios do not have to be SDR.

Cognitive Radio is currently a very hot research topic as show the dozens of sessions in research conferences dedicated to it. In 2009, the American National Science Foundation (NSF) held a workshop on “Future Directions in Cognitive Radio Network Research” [59]. The purpose of the workshop was to explore how the transition from cognitive radios to cognitive radio *networks* can be made. The resulting report indicated the following:

- Emerging cognitive radio technology has been identified as a high impact disruptive technology innovation, that could provide solutions to the *radio traffic jam* problem and provide a path to scaling wireless systems for the next 25 years.
- Significant new research is required to address the many technical challenges of cognitive radio networking. These include dynamic spectrum allocation methods, spectrum sensing, cooperative communications, incentive mechanisms, cognitive network architecture and protocol design, cognitive network security, cognitive system adaptation algorithms and emergent system behavior.

The report also mentioned the lack of cognitive radio testbeds and urged *“The development of a set of cognitive networking test-beds that can be used to evaluate cognitive networks at various stages of their development”*, which, in some sense strengthens the creation of the Socrate team and its implication in the FIT project [55].

2.3. Scientific Challenges

Having a clear idea of relevant research areas in SDR is not easy because many parameters are not related to economical cost. For instance, military research has made its own development of SDR for its particular needs: US military SDR follows the SCA communication architecture [56] but this is usually not considered as a realistic choice for a commercial SDR handset. The targeted frequency band has a huge impact as sampling at high rates is very expensive, and trade-offs between flexibility, complexity, cost and power consumption have a big influence on the relative importance of the hot research topics.

Here are the relevant research domains where efforts are needed to help the deployment of SDR:

- *Antennas and RF Front-Ends:* This is a key issue for reducing interference, increasing capacity and reusing frequency. Hot topics such as wake-up radio or multi protocol parallel radio receivers are directly impacted by research on Antennas. Socrate has research work going on in this area.
- *Analog to Digital Converters:* Designing low-power high frequency ADC is still a hot topic rather studied by micro-electronics laboratories (Lip6 for instance in France).
- *Architecture of SDR systems:* The ideal technology for embedded SDR still has to be defined. Hardware prototypes are built using FPGAs, Asics and DSPs, but the real challenge is to handle a Hardware/Software design which includes radio and antennas parts.
- *Middleware for SDR systems:* How to manage, reconfigure, update and debug SDR systems is still an open question which is currently studied for each SDR platform prototype. Having a common programming interface for SDR systems in one research direction of Socrate.
- *Distributed signal processing:* Cognitive, smart or adaptive radios will need complex decision algorithms which, most of the time will need to be solved in a distributed manner. Socrate has clearly a strong research effort in that direction. Distributed information theory is also a hot research topic that Socrate wishes to study.

3. Research Program

3.1. Research Axes

In order to keep young researchers in an environment close to their background, we have structured the team along the three research axes related to the three main scientific domains spanned by Socrate. However, we insist that a *major objective* of the Socrate team is to *motivate the collaborative research between these axes*, this point is specifically detailed in Section 3.5. The first one is entitled "Flexible Radio Front-End" and will study new radio front-end research challenges brought up by the arrival of MIMO technologies, and reconfigurable front-ends. The second one, entitled "Multi-user communication", will study how to couple the self-adaptive and distributed signal processing algorithms to cope with the multi-scale dynamics found in cognitive radio systems. The last research axis, entitled "Software Radio Programming Models" is dedicated to embedded software issues related to programming the physical protocols layer on these software radio machines. Figure 3 illustrates the three regions of a transceiver corresponding to the three Socrate axes.

3.2. Flexible Radio Front-End

Participants: Guillaume Villemaud, Florin Hutu.

This axis mainly deals with the radio front-end of software radio terminals (right of Fig 3). In order to ensure a high flexibility in a global wireless network, each node is expected to offer as many degrees of freedom as possible. For instance, the choice of the most appropriate communication resource (frequency channel, spreading code, time slot,...), the interface standard or the type of antenna are possible degrees of freedom. The *multi-** paradigm denotes a highly flexible terminal composed of several antennas providing MIMO features to enhance the radio link quality, which is able to deal with several radio standards to offer interoperability and efficient relaying, and can provide multi-channel capability to optimize spectral reuse. On the other hand, increasing degrees of freedom can also increase the global energy consumption, therefore for energy-limited terminals a different approach has to be defined.

In this research axis, we expect to demonstrate optimization of flexible radio front-end by fine grain simulations, and also by the design of home made prototypes. Of course, studying all the components deeply would not be possible given the size of the team, we are currently not working in new technologies for DAC/ADC and power amplifiers which are currently studied by hardware oriented teams. The purpose of this axis is to build system level simulation taking into account the state of the art of each key component.

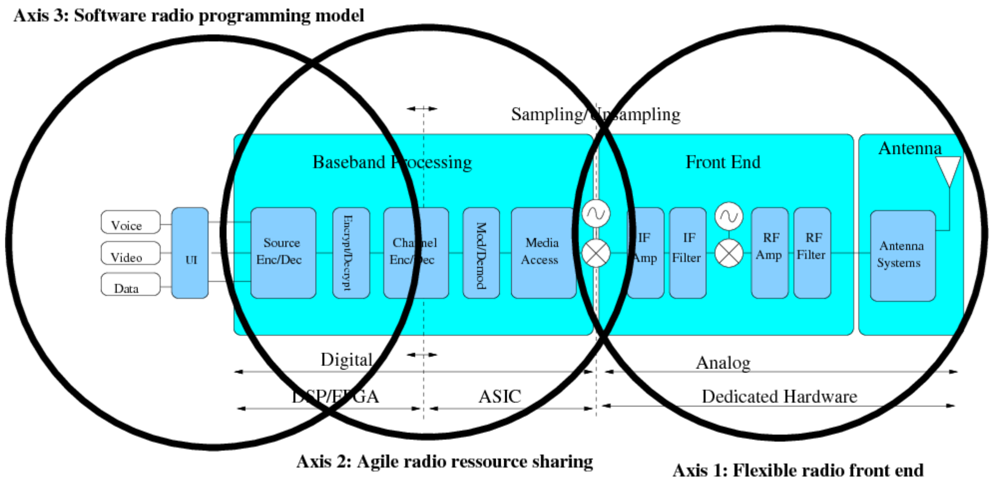

Figure 3. Center of interest for each of the three Socrate research axes with respect to a generic software radio terminal.

3.3. Multi-User Communications

Participants: Jean-Marie Gorce, Claire Goursaud, Nikolai Lebedev, Samir Perlaza, Leonardo Sampaio-Cardoso.

While the first and the third research axes deal with the optimization of the cognitive radio nodes themselves from system and programming point of view, an important complementary objective is to consider the radio nodes in their environments. Indeed, cognitive radio does not target the simple optimization of point to point transmissions, but the optimization of simultaneous concurrent transmissions. The tremendous development of new wireless applications and standards currently observed calls for a better management of the radio spectrum with opportunistic radio access, cooperative transmissions and interference management. This challenge has been identified as one of the most important issue for 5G to guarantee a better exploitation of the spectrum. In addition, mobile internet is going to support a new revolution that is the *tactile internet*, with real time interactions between the virtual and the real worlds, requiring new communication objectives to be met such as low latency end to end communications, distributed learning techniques, in-the-network computation, and many more. The future network will be heterogeneous in terms of technologies, type of data flows and QoS requirements. To address this revolution two work directions have naturally formed within the axis. The first direction concerns the theoretical study of fundamental limits in wireless networks. Introduced by Claude Shannon in the 50s and heavily developed up to today, Information Theory has provided a theoretical foundation to study the performance of wireless communications, not from a practical design view point, but using the statistical properties of wireless channels to establish the fundamental trade-offs in wireless communications. Beyond the classical *energy efficiency - spectral efficiency* tradeoff, information theory and its many derivations, i.e., network information theory, may also help to address additional questions such as determining the optimal rates under decentralized policies, asymptotic behavior when the density of nodes increases, latency controled communication with finite block-length theory, etc... In these cases, information theory is often associated to other theoretical tools such as game theory, stochastic geometry, control theory, graph theory and many others.

Our first research direction consists in evaluating specific mulit-user scenarios from a network information theory perspective, inspired by practical scenarios from various applicative frameworks (e.g. 5G, Wifi, sensor networks, IoT, etc...), and to establish fundamental limits for these scenarios. The second research direction is related to algorithmic and protocol design (PHY/MAC), applied to practical scenarios. Exploiting signal processing, linear algebra inspired models and distributed algorithms, we develop and evaluate various distributed algorithms allowing to improve many QoS metrics such as communication rates, reliability, stability, energy efficiency or computational complexity.

It is clear that both research directions are symbiotic with respect to each other, with the former providing theoretical bounds that serves as a reference to the performance of the algorithms created in the later. In the other way around, the later offers target scenarios for the former, through identifying fundamental problems that are interesting to be studied from the fundamental side. Our contributions of the year in these two directions are summarized further in the document.

3.4. Software Radio Programming Model

Participants: Tanguy Risset, Kevin Marquet, Lionel Morel, Guillaume Salagnac, Florent de Dinechin.

Finally the third research axis is concerned with software aspect of the software radio terminal (left of Fig 3). We have currently two actions in this axis, the first one concerns the programming issues in software defined radio devices, the second one focusses on low power devices: how can they be adapted to integrate some reconfigurability.

The expected contributions of Socrate in this research axis are :

- The design and implementation of a "middleware for SDR", probably based on a Virtual Machine.
- Prototype implementations of novel software radio systems, using chips from Leti and/or Lyrtech software radio boards.
- Development of a *smart node*: a low-power Software-Defined Radio node adapted to WSN applications.
- Methodology clues and programming tools to program all these prototypes.

3.5. Inter-Axes Collaboration

Innovative results come from collaborations between the three axes. To highlight the fact that this team structure does not limit the ability of inter-axes collaborations between Socrate members, we list below the *on-going* research actions that *already* involve actors from two or more axes, this is also represented on Fig 4.

- *Optimizing network capacity of very large scale networks*. 2 Phds started in October/November 2011 with Guillaume Villemaud (axis 1) and Claire Goursaud (axis 2), respectively.
- *SDR for sensor networks*. A PhD started in 2012 in collaboration with FT R&D, involving people from axis 3 (Guillaume Salagnac, Tanguy Risset) and axis 1 (Guillaume Villemaud).
- *CorteXlab*. The 3 axes also collaborate on the design and the development of CorteXlab.
- *body area networks applications*. Axis 2 and axis 3 collaborate on the development of body area networks applications in the framework of the FUI Smacs project. Jean-Marie Gorce and Tanguy Risset co-advised Matthieu Lauzier.
- *Wiplan and NS3*. The MobiSim ADT involves Guillaume Villemaud (axis 1) and Jean-Marie Gorce (axis 2).
- *Resource allocation and architecture of low power multi-band front-end*. The EconHome project involves people from axis 2 (Jean-Marie Gorce,Nikolai Lebedev) and axis 1 (Florin Hutu). 1 Phd started in 2011.
- *Virtual machine for SDR*. In collaboration with CEA, a PhD started in October 2011, involving people from axis 3 (Tanguy Risset, Kevin Marquet) and Leti's engineers closer to axis 2.
- *Relay strategy for cognitive radio*. Guillaume Villemaud and Tanguy Risset were together advisers of Cedric Levy-Bencheton PhD Thesis (defense last June).

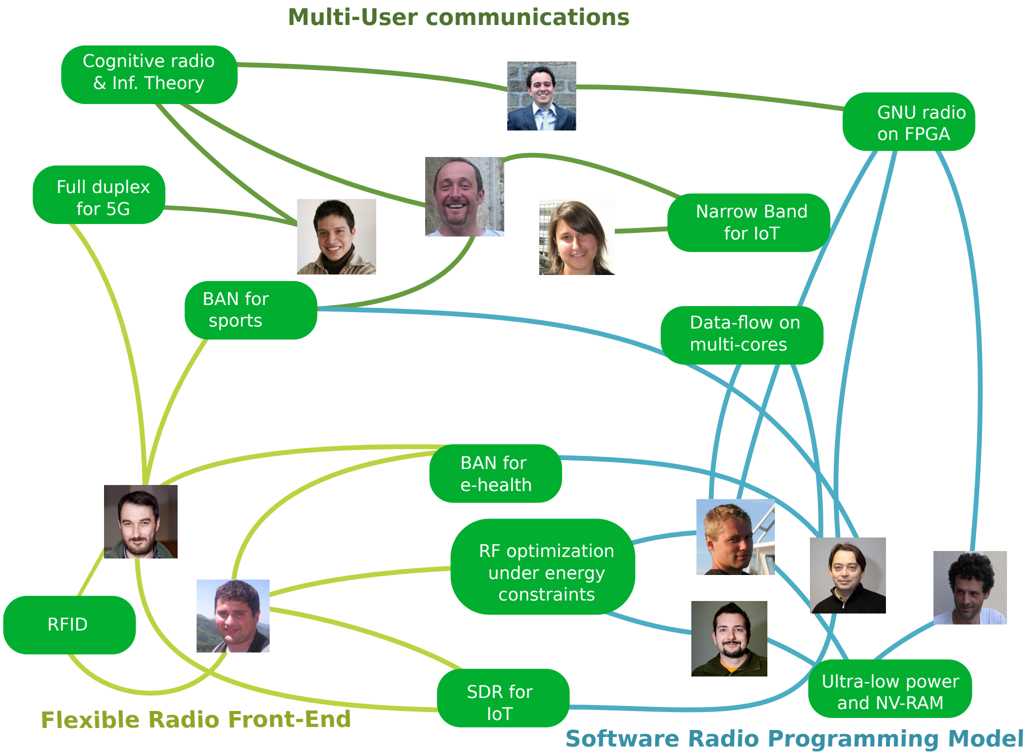

Figure 4. Inter-Axis Collaboration in Socrate: we expect innovative results to come from this pluri-disciplinary research

Finally, we insist on the fact that the *FIT project* will involve each member of Socrate and will provide many more opportunities to perform cross layer SDR experimentations. FIT is already federating all members of the Socrate team.

4. Highlights of the Year

4.1. Highlights of the Year

- The SPIE group's digital services subsidiary, and INSA Lyon announce their joint inauguration of a teaching and research chair in the Internet of Things (IoT). Backed by the CITI laboratory (Centre of Innovation in Telecommunications and Integration of service), this chair is being set up within the context of the future technological and social upheaval entailed by the Internet of Things. It will closely involve the skills of the laboratory within the IoT theme and will aim to develop and promote the know-how of SPIE ICS, the first digital services provider to appoint a chair, and INSA Lyon, through a research program aimed at innovation. Jean-Marie Gorce will be responsible for administration the chair funding within the Citi lab.
- The numap memory profiling library (developped in the team during Manuel Selva's PhD work) has been officially integrated into the Turnus dataflow profiler. Turnus [54] is a profiler dedicated to dynamic dataflow programs.
- Samir M. Perlaza and Selma Belhadj Amor delivered the tutorial **"Simultaneous Energy and Information Transmission"** in: (a) **International Conference on Telecommunications** (ICT), Thessaloniki, Greece, May, 2016; (b) **International Conference on Cognitive Radio Oriented Wireless Networks** (CROWNCOM), Grenoble, France, May, 2016; (c) **European Wireless Conference** (EW), Oulu, Finland, May, 2016, together with Ioannis Kikridis (University of Cyprus, Cyprus).

5. New Software and Platforms

5.1. FloPoCo

Floating-Point Cores, but not only
KEYWORD: Synthesizable VHDL generator
FUNCTIONAL DESCRIPTION

The purpose of the open-source FloPoCo project is to explore the many ways in which the flexibility of the FPGA target can be exploited in the arithmetic realm.

- Participants: Florent Dupont De Dinechin, Nicolas Brunie, Matei Istoan and Antoine Martinet
- Partners: CNRS - ENS Lyon - UCBL Lyon 1 - UPVD
- Contact: Florent Dupont De Dinechin
- URL: http://flopoco.gforge.inria.fr/

5.2. WSNet

KEYWORD: Network simulator
FUNCTIONAL DESCRIPTION

WSNet is a modular event-driven simulator targeted to Wireless Sensor Networks. Its main goals are to offer scalabiliy, extensibility and modularity for the integration of new protocols/hardware models and a precise radio medium simulation. We still hope to find the proper resource to make WSNet evolve into a wireless capillary network simulator suitable for conducting simulations at the urban scale.

- Participants: Rodrigue Domga Komguem, Quentin Lampin, Alexandre Mouradian and Fabrice Valois
- Partner: CEA-LETI
- Contact: Guillaume Chelius
- URL: https://gforge.inria.fr/projects/wsnet-3/

5.3. WiPlan

FUNCTIONAL DESCRIPTION

Wiplan is a software including an Indoor propagation engine and a wireless LAN optimization 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), proposed by Jean-Marie Gorce in 2001 and further extended. The discrete ParFlow equations are translated in the Fourier domain providing a large 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 requests. However, we have shown that the use of a multi-resolution approach allows the main computational load to be restricted to a pre-processing phase. Extensive works have been done to make predictions more realistic.

- Contact: Jean-Marie Gorce
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5.4. FFTweb

KEYWORD: Spectrum Analyser , Data visualization , SDR

FUNCTIONAL DESCRIPTION

Visualisation tool use in CorteXlab to visualize the spectrum (or any kind vector signal) occuring in the CorteXlab room. FFTweb is a fundamental debugging and demonstration component for FIT/CorteXlab user.

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5.5. Minus

KEYWORD: Experiment Handler , SDR

FUNCTIONAL DESCRIPTION

Handling and deployement of experiment on the Cognitive radio platform FIT/CorteXlab. On CorteXlab, the user does not have direct access to the SDR nodes, he has access to a server from which Minus deploys the programs on the different SDR nodes.

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5.6. Platform - FIT/CortexLab

FIT(Future Internet of Things) is a french Equipex (Équipement d'excellence) which aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. FIT is be composed of four main parts: a Network Operations Center (NOC), a set of IoT test-beds (IoT-Lab), a set of wireless OneLab test-beds, and a cognitive radio test-bed (CorteXlab) deployed by the Socrate team in the Citi lab. In 2014 the construction of the room was finished see Figure 5. SDR nodes have installed in the room, 42 industrial PCs (Aplus Nuvo-3000E/P), 22 NI radio boards (USRP) and 18 Nutaq boards (PicoSDR, 2x2 and 4X4) can be programmed from internet now.

A very successfully inauguration took place int 2014 [1], with the noticable venue of Vincent Poor, Dean of School of Engineering and Applied Science of Princeton University. Since that date, the platform is open to public experiments.

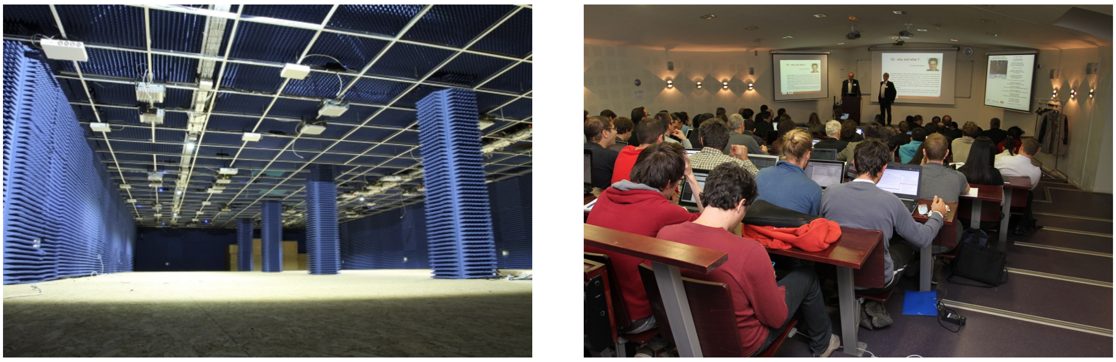

Figure 5. Photo of the FIT/CortexLab experimentation room installed and a snaptshot of the inauguration meeting

6. New Results

6.1. Flexible Radio Front-End

6.1.1. Wake-Up Radio

The last decades have been really hungry in new ways to reduce energy consumption. That is especially true when talking about wireless sensor networks in general and home multimedia networks in particular, since electrical energy consumption is the bottleneck of the network. One of the most energy-consuming functional block of an equipment is the radio front end, and methods to switch it off during the time intervals where it is not active must be implemented. This previous study has proposed a wake-up radio circuit which is capable of both addressing and waking up not only a more efficient but also more energy-consuming radio front end. By using a frequency footprint to differentiate each sensor, awaking all the sensors except for the one of interest is avoided. The particularity of the proposed wake-up receiver [22] is that the decision is taken in the radio-frequency part and no baseband treatment is needed. The global evaluation in theory and in simulation was performed, and a first testbed of this technology was fabricated, demonstrating that this principle actually works in practice [21].

[1] http://www.inria.fr/centre/grenoble/actualites/inauguration-reussie-de-la-plateforme-cortexlab-equipex-fit

6.1.1.1. Full-Duplex

An important work was done in this axis previously around Full-Duplex systems, in order to enhance throughput, flexibility, and, potentially security of wireless links. A PhD thesis grant from DGA and Inria has allowed us to extend this through a collaboration with axis 2, focusing on Physical layer security mechanisms based on Full-Duplex systems. Starting by a theoretical study of the secrecy capacity in the presence of an eavesdropper, this work studies [13] the duality between wiretap channels and state-dependent channels. This represents a basic framework to extend in a near future this study to Full-Duplex scenarios, where the Full-Duplex capability of a node could increase the secrecy of the wireless communication.

6.1.1.2. SDR for SRDs

The technologies employed in urban sensor networks are permanently evolving, and thus the gateways of these networks have to be regularly upgraded. The existing method to do so is to stack-up receivers dedicated to one communication protocol. However, this implies to have to replace the gateway every time a new protocol is added to the network. A more practical way to do this is to perform a digitization of the full band and to perform digitally the signal processing, as done in Software-Defined Radio (SDR). The main hard point in doing this is the dynamic range of the signals: indeed the signals are emitted with very different features because of the various propagation conditions. It has been proved that the difference of power between two signals can be so important that no existing Analog-to-Digital Converter (ADC) is able to properly digitize the signals. We propose a solution to reduce the dynamic range of signals before digital conversion. In this study [9], the assumption is made that there is one strong signal, and several weak signals. This assumption is made from the existing urban sensor networks topology. A receiver architecture with two branches is proposed with a “Coarse Digitization Path” (CDP) and a “Fine Digitization Path” (FDP). The CDP allows to digitize the strong signal and to get data on it that is used to reconfigure the FDP. The FDP then uses a notch filter to attenuate the strong signal (and then to reduce the dynamic range of the signals) and digitizes the rest of the band.

6.2. Multi-User Communications

6.2.1. Fundamental Limits

6.2.1.1. Approximate Capacity Region of the Gaussian Interference Channel with Feedback

An achievability region and a converse region for the two-user Gaussian interference channel with noisy channel-output feedback (G-IC-NOF) are presented [42], [30], [43], [47]. The achievability region is obtained using a random coding argument and three well-known techniques: rate splitting, superposition coding and backward decoding. The converse region is obtained using some of the existing perfect-output feedback outer-bounds as well as a set of new outer-bounds that are obtained by using genie-aided models of the original G-IC-NOF. Finally, it is shown that the achievability region and the converse region approximate the capacity region of the G-IC-NOF to within a constant gap in bits per channel use.

6.2.1.2. Full Characterization of the Capacity Region of the Linear Deterministic Interference Channel with Feedback

The capacity region of the two-user linear deterministic (LD) interference channel with noisy output feedback (IC-NOF) has been fully characterized [29]. This result allows the identification of several asymmetric scenarios in which implementing channel-output feedback in only one of the transmitter-receiver pairs is as beneficial as implementing it in both links, in terms of achievable individual rate and sum-rate improvements w.r.t. the case without feedback. In other scenarios, the use of channel-output feedback in any of the transmitter-receiver pairs benefits only one of the two pairs in terms of achievable individual rate improvements or simply, it turns out to be useless, i.e., the capacity regions with and without feedback turn out to be identical even in the full absence of noise in the feedback links.

6.2.1.3. Full Characterization of the Information Equilibrium Region of the Multiple Access Channel

The fundamental limits of decentralized information transmission in the K-user Gaussian multiple access channel (G-MAC), with $K \geqslant 2$, are fully characterized [38]. Two scenarios are considered. First, a game in which only the transmitters are players is studied. In this game, the transmitters autonomously and independently tune their own transmit configurations seeking to maximize their own information transmission rates, $R_1, R_2, \cdots, R_K$, respectively. On the other hand, the receiver adopts a fixed receive configuration that is known a priori to the transmitters. The main result consists of the full characterization of the set of rate tuples $(R_1, R_2, ..., R_K)$ that are achievable and stable in the G-MAC when stability is considered in the sense of the η-Nash equilibrium (NE), with $\eta > 0$ arbitrarily small. Second, a sequential game in which the two categories of players (the transmitters and the receiver) play in a given order is presented. For this sequential game, the main result consists of the full characterization of the set of rate tuples $(R_1, R_2, ..., R_K)$ that are stable in the sense of an η-sequential equilibrium, with $\eta > 0$.

6.2.1.4. Full Characterization of the Information-Energy Capacity Region of the Multiple Access Channel with Energy Harvester with and without Feedback

The fundamental limits of simultaneous information and energy transmission in the two-user Gaussian multiple access channel (G-MAC) with and without feedback have been fully characterized [10], [15]. More specifically, all the achievable information and energy transmission rates (in bits per channel use and energy-units per channel use, respectively) are identified. In the case without feedback, an achievability scheme based on power-splitting and successive interference cancelation is shown to be optimal. Alternatively, in the case with feedback (G-MAC-F), a simple yet optimal achievability scheme based on power-splitting and Ozarow's capacity achieving scheme is presented. Two of the most important observations in this work are: (a) The information-energy capacity region of the G-MAC without feedback can be a proper subset of the information-energy capacity region of the G-MAC-F and (b) Feedback can at most double the energy rate when the information transmission rate is kept fixed at the sum-capacity of the G-MAC.

6.2.1.5. Full Characterization of the Information-Energy Equilibrium Region of the Multiple Access Channel with Energy Harvester

The fundamental limits of decentralized simultaneous information and energy transmission in the two-user Gaussian multiple access channel (G-MAC) have been fully characterized for the case in which a minimum energy transmission rate b is required for successful decoding [14], [39]. All the achievable and stable information-energy transmission rate triplets (R_1, R_2, B) are identified. R_1 and R_2 are in bits per channel use measured at the receiver and B is in energy units per channel use measured at an energy-harvester (EH). Stability is considered in the sense of an η-Nash equilibrium (NE), with $\eta > 0$ arbitrarily small. The main result consists of the full characterization of the η-NE information-energy region, i.e., the set of information-energy rate triplets (R_1, R_2, B) that are achievable and stable in the G-MAC when: (a) both transmitters autonomously and independently tune their own transmit configurations seeking to maximize their own information transmission rates, R_1 and R_2 respectively; (b) both transmitters jointly guarantee an energy transmission rate B at the EH, such that $B > b$. Therefore, any rate triplet outside the η-NE region is not stable as there always exists one transmitter able to increase by at least η bits per channel use its own information transmission rate by updating its own transmit configuration.

6.2.1.6. Duality Between State-Dependent Channels and Wiretap Channels

A duality between wiretap and state-dependent channels with non-causal channel state information at the transmitter has been established [13]. First, a common achievable scheme is described for a certain class of state-dependent and wiretap channels. Further, state-dependent and wiretap channels for which this scheme is capacity (resp. secrecy capacity) achieving are identified. These channels are said to be dual. This duality is used to establish the secrecy capacity of certain state-dependent wiretap channels with non-causal channel state information at the transmitter. Interestingly, combatting the eavesdropper or combatting the lack of state information at the receiver turn out to be two non-concurrent tasks.

6.2.1.7. Energy efficiency - Spectral Efficiency (EE-SE) Tradeoffs in Wireless RANs

Even for a point-to-point communication, the Shannon capacity can be interpreted for a Gaussian channel as a fundamental spectral and energy efficiency (SE-EE) trade-off. Extending this fundamental trade-off in the context of multi-user communications is not straightforward as it may depend on many parameters. We proposed in [8] a simple and effective method to study this trade-off in cellular networks, an issue that has attracted significant recent interest in the wireless community. The proposed theoretical framework is based on an optimal radio resource allocation of transmit power and bandwidth for the downlink direction, applicable for an orthogonal cellular network. The analysis is initially focused on a single cell scenario, for which in addition to the solution of the main SE-EE optimization problem, it is proved that a traffic repartition scheme can also be adopted as a way to simplify this approach. By exploiting this interesting result along with properties of stochastic geometry, this work is extended to a more challenging multi-cell environment, where interference is shown to play an essential role and for this reason several interference reduction techniques are investigated. Special attention is also given to the case of low signal to noise ratio (SNR) and a way to evaluate the upper bound of EE in this regime is provided. This methodology leads to tractable analytical results under certain common channel properties, and thus allows the study of various models without the need for demanding system level simulations.

6.2.1.8. Spatial Continuum Channel Models

In the context of the deployment of Internet of Things (see next section for more details about our protocol developments), it is expected that a unique cell could serve millions of radio nodes transmitting sporadic short packets. In [18] and [41], our objective is to study this problem from an information theory point of view to derive the fundamental limit in terms of maximal information rates that can be transmitted in such a dense cell. This work proposes a new model called spatial continuum asymmetric channels to study the channel capacity region of asymmetric scenarios in which either one source transmits to a spatial density of receivers or a density of transmitters transmit to a unique receiver. This approach is built upon the classical broadcast channel (BC) and multiple access channel (MAC). For the sake of consistency, the study is limited to Gaussian channels with power constraints and is restricted to the asymptotic regime (zero-error capacity). The reference scenario comprises one base station in Tx or Rx mode, a spatial random distribution of nodes (resp. in Rx or Tx mode) characterized by a probability spatial density of users $u(x)$ where each of them requests a quantity of information with no delay constraint, thus leading to a requested rate spatial density $\rho(x)$. This system is modeled as an ‚àû‚àíuser asymmetric channel (BC or MAC). To derive the fundamental limits of this model, a spatial discretization is first proposed to obtain an equivalent BC or MAC. Then, a specific sequence of discretized spaces is defined to refine infinitely the approximation. Achievability and capacity results are obtained in the limit of this sequence while the access capacity region $\mathcal{C}(Pm)$ is defined as the set of requested rates spatial densities $\rho(x)$ that are achievable with a transmission power Pm. The uniform capacity defined as the maximal symmetric achievable rate is also computed.

6.2.1.9. Finite Block-Length Coding in Wireless Networks

In the context of IoT, the information to be transmitted will be divided in very small packets especially when control and commands will be transmitted over the network. The classical asymptotic information theory relies on the statistic properties of channels and information sources, when the coding block-length tends to infinity. Therefore this framework is not appropriate to study the fundamental limits of short packets transmission over wireless networks. Fortunately, information theory is not only about the asymptotic regime. Shannon himself derived the preliminary foundations of a theory for finite block-length. Later, Gallager extended this framework. Recently this question gained interest after the work of Y. Polyanskiy which extended former results on finite block length to Gaussian channels. This fundamental contribution opens a way for studying wireless networks under finite block-length regime. But this relatively new paradigm suffers from strong problems relative to the compexity of the underlying estimation problem. Starting to work on this topic in the framework of the associated team with Princeton, we exploited in [35] the recent results on the non-asymptotic coding rate for fading channels with no channel state information at the transmitter and we analyzed the goodput in additive white Gaussian noise (AWGN) and the energy-efficiency spectral-efficiency (EE-SE) tradeoff where the fundamental relationship between the codeword length and the EE is given. Finally, the true outage probability in Ricean and Nakagami-m block fading channels is investigated and it is proved that the asymptotic outage capacity is the Laplace approximation of the average error probability in finite blocklength regime. This preliminary work constitutes one of the starting point for our future works in the framework of the ANR project ARBURST.

6.2.2. Algorithm and Protocol Design for Multi-User Communication Scenarios

6.2.2.1. Interference Management in OFDM/MIMO Wireless Networks

Modern cellular networks in traditional frequency bands are notoriously interference-limited especially in urban areas, where base stations are deployed in close proximity to one another. The latest releases of Long Term Evolution (LTE) incorporate features for coordinating downlink transmissions as an efficient means of managing interference. In [4], we review recent field trial results and theoretical studies of the performance of joint transmission (JT) coordinated multi-point (CoMP) schemes. These schemes revealed, however, that their gains are not as high as initially expected, despite the large coordination overhead. These schemes are known to be very sensitive to defects in synchronization or information exchange between coordinating bases stations as well as uncoordinated interference. In this article, we review recent advanced coordinated beamforming (CB) schemes as alternatives, requiring less overhead than JT CoMP while achieving good performance in realistic conditions. By stipulating that, in certain LTE scenarios of increasing interest, uncoordinated interference constitutes a major factor in the performance of CoMP techniques at large, we hereby assess the resilience of the state-of-the-art CB to uncoordinated interference. We also describe how these techniques can leverage the latest specifications of current cellular networks, and how they may perform when we consider standardized feedback and coordination. This allows us to identify some key roadblocks and research directions to address as LTE evolves towards the future of mobile communications.

Among the different techniques described above, we studied in [32] an interference Alignment (IA) technique that, in a large sense, makes use of the increasing signal dimensions available in the system through MIMO and OFDM technologies in order to globally reduce the interference suffered by users in a network. In this paper, we addressed the problem of downlink cellular networks, the so-called interfering broadcast channels, where mobile users at cell edges may suffer from high interference and thus, poor performance. Starting from the downlink IA scheme proposed by Suh et al., a new approach is proposed where each user feeds back multiple selected received signal directions with high signal-to-interference gain. A exhaustive search based scheduler selects a subset of users to be served simultaneously, balancing between sum-rate performance and fairness, but becomes untractable in dense network scenarios where many users send simultaneous requests. Therefore, we develop a sub-optimal scheduler that greatly decreases the complexity while preserving a near-optimal data rate gain. More interestingly, our simulations show that the IA scheme becomes valuable only in correlated channels, whereas the matched filtering based scheme performs the best in the uncorrelated scenarios.

6.2.2.2. Performance of Ultra-NarrowBand Techniques for Internet of Things

This section makes echo to the section entitled Spatial Continuum Channel Models where fundamental limits are studied for a similar scenario. In this section, we investigate the scenario for an existing PHY layer technology, Ultra Narrow Band (UNB) technique, proposer by Sigfox. The ALOHA protocol is regaining interest in the context of the Internet of Things (IoT), especially for UNB signals (dedicated to long range and low power transmission in IoT networks). In this case, the classical assumption of channelization is not verified anymore, modifying the ALOHA performances. Indeed, UNB signals suffer from a lack of precision on the actual transmission carrier frequency, leading to a behavior similar to a frequency unslotted random access. More precisely, the channel access is Random-FTMA, where nodes select their time and frequency in a random and continuous way. The frequency randomness prevents from allocating orthogonal resources for transmission, and induces uncontrolled interference.

In [19], the success probability and throughput of ALOHA is generalized to further describe frequency-unslotted systems such as UNB. The main contribution of this work is the derivation of a generalized expression of the throughput for the random time-frequency ALOHA systems, when neglecting channel attenuation. Besides, this study permits to highlight the duality of ALOHA in time and frequency domain.

Besides, in [26] and [27], to introduce diversity, we propose the use of replication mechanism to enhance the reliability of UNB wireless network. Considering the outage probability, we theoretically evaluate the system performance and show that there exists an optimal number of transmissions. Finally, we highlight that this number of repetitions can be easily optimized by considering a unique global parameter.

Finally, in [28], we also take into consideration the channel effect for such specific network. Indeed, the UNB randomness leads to a new behavior of the interference which has not been theoretically analyzed yet, when considering the pathloss of nodes located randomly in an area. In this work, in order to quantify the system performance, we derive and exploit a theoretical expression of the packet error rate in a UNB based IoT network, when taking into account both interference due to the spectral randomness and path loss due to the propagation.

6.2.2.3. Algorithms and Protocols for BANs

Body Area Networks (BANs) represent a challenging area of research for networking design. Indeed, the topology of these networks differe significantly from classical networks. BANs are dynamic, multi-scale, energy limited and require real time protocols for many applications related to localization. Our work is related to the design of dynamic protocols to gather and exploit localization information in dynamic BANs. Our first contribution is related to the context of group navigation and was developed in the framework of the FUI SMACS project dealing with the localisation of runners during bike races. The problem is to develop fast and reliable protocols to dynamically gather mobility information from moving nodes toward moving sinks.

Our second contribution is relative to the mobility of a single BAN and with the objective of improving localization algorithms based on ranging measures between nodes spread on the body. This work was done in the framework of the ANR CORMORAN project with the PhD of Arturo Gimenez-Guizar who defended his PhD in October 2016 [1].

6.2.2.3.1. Information Gathering in a Group of Mobile Users

In [16], we propose an efficient approach to collect data in mobile wireless sensor networks, with the specific application of sensing in bike races. Recent sensor technology permits to track GPS position of each bike. Because of the inherent correlation between bike positions in a bike race, a simple GPS log is inefficient. The idea presented in this work is to aggregate GPS data at sensors using compressive sensing techniques. We enforce, in addition to signal sparsity, a spatial prior on biker motion because of the group behaviour (peloton) in bike races. The spatial prior is modeled by a graphical model and the data aggregation problem is solved, with both the sparsity and the spatial prior, by belief propagation. We validate our approach on a bike race simulator using trajectories of motorbikes in a real bike race.

6.2.2.3.2. MAC Protocols and Algorithms for Localization at the Body Scale

In this work [20], we have considered the positioning success rate for localization applications deployed in Wireless Body Area Networks (WBAN). Localization is performed with Ultra Wide Band (UWB) pulses, which permits to estimate distances as defined by 3 Way Ranging protocol (3WR). Two channels are considered : the empirical channel CM3, and with our model obtained from our measurement campaign. We first evaluate the positioning loss when considering an aggregation and broadcast scheduling strategy (A&B) upon TDMA MAC. We highlight the channel effects depending on the targeted receiver sensitivity. We then improve the performances by proposing a cooperative algorithm based on conditional permutation of anchors.

6.2.3. Cyber-Physical Systems

6.2.3.1. Attacks in the Electricity Grids

Multiple attacker data injection attack construction in electricity grids with minimum-mean-square-error state estimation has been studied for centralized and decentralized scenarios [6], [11]. A performance analysis of the trade-off between the maximum distortion that an attack can introduce and the probability of the attack being detected by the network operator is considered. In this setting, optimal centralized attack construction strategies are studied. The decentralized case is examined in a game-theoretic setting. A novel utility function is proposed to model this trade-off and it is shown that the resulting game is a potential game. The existence and cardinality of the corresponding set of Nash Equilibria (NEs) of the game is analyzed. Interestingly, the attackers can exploit the correlation among the state variables to facilitate the attack construction. It is shown that attackers can agree on a data injection vector construction that achieves the best trade-off between distortion and detection probability by sharing only a limited number of bits offline. For the particular case of two attackers, numerical results based on IEEE test systems are presented.

6.2.3.2. Recovering Missing Data in Electricity Grids

The performance of matrix completion based recovery of missing data in electricity distribution systems has been analyzed [17]. Under the assumption that the state variables follow a multivariate Gaussian distribution the matrix completion recovery is compared to estimation and information theoretic limits. The assumption about the distribution of the state variables is validated by the data shared by Electricity North West Limited. That being the case, the achievable distortion using minimum mean square error (MMSE) estimation is assessed for both random sampling and optimal linear encoding acquisition schemes. Within this setting, the impact of imperfect second order source statistics is numerically evaluated. The fundamental limit of the recovery process is characterized using Rate-Distortion theory to obtain the optimal performance theoretically attainable. Interestingly, numerical results show that matrix completion based recovery outperforms MMSE estimator when the number of available observations is low and access to perfect source statistics is not available.

6.3. Software Radio Programming Model

6.3.1. Dataflow programming model

The advent of portable software-defined radio (SDR) technology is tightly linked to the resolution of a difficult problem: efficient compilation of signal processing applications on embedded computing devices. Modern wireless communication protocols use packet processing rather than infinite stream processing and also introduce dependencies between data value and computation behavior leading to dynamic dataflow behavior. Recently, parametric dataflow has been proposed to support dynamicity while maintaining the high level of analyzability needed for efficient real-life implementations of signal processing computations. The team developed a new compilation flow [5] that is able to compile parametric dataflow graphs. Built on the LLVM compiler infrastructure, the compiler offers an actor-based C++ programming model to describe parametric graphs, a compilation front end for graph analysis, and a back end that currently matches the Magali platform: a prototype heterogeneous MPSoC dedicated to LTE-Advanced. We also introduce an innovative scheduling technique, called microscheduling, allowing one to adapt the mapping of parametric dataflow programs to the specificities of the different possible MPSoCs targeted. A specific focus on FIFO sizing on the target architecture is presented. The experimental results show compilation of 3GPP LTE-Advanced demodulation on Magali with tight memory size constraints. The compiled programs achieve performance similar to handwritten code.

The memory subsystem of modern multi-core architectures is becoming more and more complex with the increasing number of cores integrated in a single computer system. This complexity leads to profiling needs to let software developers understand how programs use the memory subsystem. Modern processors come with hardware profiling features to help building tools for these profiling needs. Regarding memory profiling, many processors provide means to monitor memory traffic and to sample read and write memory accesses. Unfortunately, these hardware profiling mechanisms are often very complex to use and are specific to each micro-architecture. The numap library [44], [31] is dedicated to the profiling of the memory subsytem of modern multi-core architectures. numap is portable across many micro-architectures and comes with a clean application programming interface allowing to easily build profiling tools on top of it.

This numap library as been officially integrated into Turnus, a profiler dedicated to dynamic dataflow programs.

6.3.2. Implementation of filters and FFTs on FPGAs

In collaboration with two researchers from Inria AriC, we have worked on a digital filter synthesis flow targeting FPGAs [46]. Based on a novel approach to the filter coefficient quantization problem, this approach produces results which are faithful to a high-level frequency-domain specification. An automated design process is also proposed where user intervention is limited to a very small number of relevant input parameters. Computing the optimal value of the other parameters not only simplifies the user interface: the resulting architectures also outperform those generated by mainstream tools in accuracy, performance, and resource consumption.

In collaboration with researchers from Isfahan, Iran, a multi-precision Fast Fourier Transform (FFT) module with dynamic run-time reconfigurability has been proposed [3] to trade off accuracy with energy efficiency in an SDR-based architecture. To support variable-size FFT, a reconfigurable memory-based architecture is investigated. It is revealed that the radix-4 FFT has the minimum computational complexity in this architecture. Regarding implementation constraints such as fixed-width memory, a noise model is exploited to statistically analyze the proposed architecture. The required FFT word-lengths for different criteria, (bit-error rate (BER), modulation scheme, FFT size, and SNR) are computed analytically and confirmed by simulations in AWGN and Rayleigh fading channels. At run-time, the most energy-efficient word-length is chosen and the FFT is reconfigured until the required application-specific BER is met. Evaluations show that the implementation area and the number of memory accesses are reduced. The results obtained from synthesizing basic operators of the proposed design on an FPGA show energy consumption saving of over 80 %.

6.3.3. Tools for FPGA development

The pipeline infrastructure of the FloPoCo arithmetic core generator has been completely overhauled [34], [23]. From a single description of an operator or datapath, optimized implementations are obtained automatically for a wide range of FPGA targets and a wide range of frequency/latency trade-offs. Compared to previous versions of FloPoCo, the level of abstraction has been raised, enabling easier development, shorter generator code, and better pipeline optimization. The proposed approach is also more flexible than fully automatic pipelining approaches based on retiming: In the proposed technique, the incremental construction of the pipeline along with the circuit graph enables architectural design decisions that depend on the pipeline. These allow pipeline-dependent changes to the circuit graph for finer optimization. This is particularly important for the filter structures already mentioned [46].

In parallel, we also started to study the integration of arithmetic optimizations in high-level synthesis (HLS) tools [48]. HLS is a big step forward in terms of design productivity. However, it restricts data-types and operators to those available in the `C` language supported by the compiler, preventing a designer to fully exploit the FPGA flexibility. To lift this restriction, a source-to-source compiler may rewrite, inside critical loop nests of the input `C` code, selected floating-point additions into sequences of simpler operator using non-standard arithmetic formats. This enables hoisting floating-point management out the loop. What remains inside the loop is a sequence of fixed-point additions whose size is computed to enforce a user-specified, application-specific accuracy constraint on the result. Evaluation of this method demonstrates significant improvements in the speed/resource usage/accuracy trade-off.

6.3.4. Computer Arithmetic

In collaboration with researchers from Istanbul, Turkey, operators have also been developed for division by a small positive constant [49]. The first problem studied is the Euclidean division of an unsigned integer by a constant, computing a quotient and a remainder. Several new solutions are proposed and compared against the state of the art. As the proposed solutions use small look-up tables, they match well the hardware resources of an FPGA. The article then studies whether the division by the product of two constants is better implemented as two successive dividers or as one atomic divider. It also considers the case when only a quotient or only a remainder are needed. Finally, it addresses the correct rounding of the division of a floating-point number by a small integer constant. All these solutions, and the previous state of the art, are compared in terms of timing, area, and area-timing product. In general, the relevance domains of the various techniques are very different on FPGA and on ASIC.

On the software side, we have also shown, in collaboration with researchers from LIP and the Kalray company, that correctly rounded elementary functions can be implemented more efficiently using only fixed-point arithmetic than when classically using floating-point arithmetic [24]. A purely integer implementation of the correctly rounded double-precision logarithm outperforms the previous state of the art, with the worst-case execution time reduced by a factor 5. This work also introduces variants of the logarithm that input a floating-point number and output the result in fixed-point. These are shown to be both more accurate and more efficient than the traditional floating-point functions for some applications.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

7.1.1. Research Contract with Orange Labs (2015-2017)

The goal of this project "PErformances Théoriques des réseaux cellulaires pour la 5G" No. F05151 (50KEuro) is to develop a theoretical approach allowing to study the energy efficiency spectral efficiency tradeoff for 5G networks, by revisiting information theory for dense networks and short packets transmissions.

7.1.2. Research Contract with Bosch (2015-2016)

This contract between Bosch and two project-teams (AriC and Socrate) focusses on the evolution of high-performance embedded controllers.

7.1.3. Research Contract with Sigfox (2015-2016)

A collaboration with Sigfox to work on extension of Sigfox Network to dense cities: 2 years of engineering associated to a Cifre grant

7.1.4. Research Contract with Atlantic

Socrate has a collaborative contract with Atlantic, around wireless communications in HVAC systems.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. Equipex FIT- Future Internet of Things

The FIT projet is a national equipex (*equipement d'excellence*), headed by the Lip6 laboratory. As a member of Inria, Socrate is in charge of the development of an Experimental Cognitive Radio platform that is used as test-bed for SDR terminals and cognitive radio experiments. This has been operational since 2014 and is maintained for a duration of 7 years. To give a quick view, the user will have a way to configure and program through Internet several SDR platforms (MIMO, SISO, and baseband processing nodes).

8.1.2. ANR - MetalibM

The goal of the Metalibm - "Automatic Generation of Function and Filters" (2014-2017, 200 keuros) project is to provide a tool for the automatic implementation of mathematical (libm) functions. A function f is automatically transformed into machine-proven C code implementing an polynomial approximation in a given domain with given accuracy. This project is led by Inria, with researchers from Socrate and AriC; PEQUAN team of Laboratoire d'Informatique de Paris 6 (LIP6) at Université Pierre et Marie Curie, Paris; DALI team from Université de Perpignan Via Domitia and Laboratoire d'Informatique, Robotique et Microélectronique de Montpellier (LIRMM); and SFT group from Centre Européen de Recherche Nucléaire (CERN).

8.1.3. FUI SMACS

The SMACS projet - “SMart And Connected Sensors” (2013-2016, 267 keuros) targets the deployement of an innovating wireless sensor network dedicated to many domains sport, health and digital cities. The projet involves Socrate (Insavalor), HIKOB and wireless broadcasting company Euro Media France. The main goal is to develop a robust technologie enabling real-time localization of mobile targets (like cyclist for instance), at a low energy (more generaly low cost). The technology will be demonstrated at real cycling races (Tour de France 2013 and 2014). One of the goal is to include localisation information with new radio technology. Another subject of study is distributed wireless consensus algorithms for maintaining a neighborhood knowledge with a low energy budget that scales (more than 200 cycles together)

8.1.4. ADT Sytare

The SYTARE project (Développement d’un SYsTème embArqué faible consommation à mémoiRE persistante - ADT Inria 2015-2017) aims to develop and study novel operating system mechanisms for NVRAM-based embedded systems. The term NVRAM collectively describes an emerging generation of memory technologies which are both non-volatile and byte-addressable. These two properties together make the classical RAM+ROM memory architecture obsolete, and enable the design of embedded systems running on intermittent power. This is very attractive in the context of energy-constrained scenarios, for instance systems harvesting their power from the environment. But working with NVRAM also poses novel challenges in terms of software programming. For instance, application state consistency must be guaranteed accross reboots, even though the system includes both NVRAM and volatile elements (e.g. CPU, hardware peripherals). The SYTARE project is funded by Inria via the ADT program.

8.1.5. ADT CorteXlab

The Socrate project-team is in charge of the FIT/CorteXlab platform (section 5.6). This platform (ADT Inria 2015-2017) makes use of many complex technologies from signal processing to computer science through micro-electornics and FPGA. The objectiv of the CorteXlab ADT is to maintain a support to the user of the FPGA-based platform of CorteXlab and to provide tutorial and running experiment that will help them in builing experimentation using the PicoSDR machines.

8.1.6. Taiwan III

In the context of the MoU signed between Inria and The National Science Council of Taiwan. Taiwan’s Institute for Information Industry (III) and Socrate signed a one-year contract on 5G M2M (2015-2016) for a research proposal containing two items: a first to study the OFDMA-based RACH access from theoretical or mathematical models and a second to set up an experiment in CorteXlab that will emulate a given number of M2M device using a narrow band radio protocol and record the resulting radio environment.

8.1.7. ANR - Ephyl

The general objective of the project EPHYL - “Enhanced PHY for Cellular Low Power Communication IoT” (2016-2019, 183 keuros) is to investigate coming and future LPWA technologies with the aim to improve coverage, data rate and connectivity while keeping similar level of complexity and power consumption at the node for the access. New waveforms enablers will be investigated and trialled in order to increase the efficiency of future systems and to provide efficient and fair access to the radio resource. The proposed new waveforms should comply with system constraints and with the coexistence of multiple communications.

8.1.8. ANR - Arburst

In this project Arburst - “Acheivable region of bursty wireless networks” (2016-2020, 195 KEuros), we propose an original approach complementary to other existing projects. Instead of proposing one specific technical solution, our objective is to define a unified theoretical framework devoted to the study of IoT networks fundamental limits. We aim at establishing the fundamental limits for a decentralized system in a bursty regime which includes short packets of information and impulsive interference regime. We are targeting the fundamental limits, their mathematical expression (according to the usual information theory framework capturing the capacity region by establishing a converse and achievability theorems). We will use the recent results relative to finite block-length information theory and we will evaluate the margin for improvement between existing approaches and these limits and we will identify the scientific breakthrough that may bring significant improvements for IoT/M2M communications. This project will contribute to draw the roadmap for the development of IoT/M2M networks and will constitute a unified framework to compare existing techniques, and to identify the breakthrough concepts that may afford the industry the leverage to deploy IoT/M2M technical solutions.

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

8.2.1.1. CYBERNETS

Title: Cybernetic Communication Networks: Fundamental Limits and Engineering Challenges

Programm: H2020

Duration: June 2015 - June 2017

Coordinator: Inria

Inria contact: Samir M. Perlaza

This Reintegration Panel proposal, CYBERNETS, focuses on the study of Cybernetic Communication Networks (CCN). CCNs are wireless networks that are context-aware, possess learning capabilities and artificial intelligence to guarantee reliability, efficiency and resilience to changes, failures or attacks via autonomous, self-configuring and self-healing individual and network behavior. Typical examples of CCNs are beyond-5G cellular systems and critical communication systems, e.g., law enforcement, disaster relief, body- area, medical instruments, space, and indoor/outdoor commercial applications. A practical implementation of a CCN requires extending classical communication systems to embrace the dynamics of fully decentralized systems whose components might exhibit either cooperative, non-cooperative or even malicious behaviors to improve individual and/or global performance. In this context, CYBERNETS aims to develop a relevant understanding of the interactions between information theory, game theory and signal processing to tackle two particular problems from both theoretical and practical perspectives: (I) use of feedback and (II) behavior adaptation in fully decentralized CCNs. In the former, the main objectives are: (i) to determine the fundamental limits of data transmission rates in CCNs with feedback; and (ii) to develop and test in real-systems, transmit-receive configurations to provide a proof-of-concept of feedback in CCNs. For the achievement of these practical objectives, CYBERNETS relies on the world-class testbed infrastructure of Inria at the CITI Lab for fully closing the gap between theoretical analysis and real-system implementation. In the latter, the main objectives are: (i) to identify and explore alternatives for allowing transmitter-receiver pairs to learn equilibrium strategies in CCNs with and without feedback; (ii) to study the impact of network-state knowledge on scenarios derived from the malicious behavior of network components.

8.2.1.2. COM-MED

Title: COMMunication systems with renewable Energy micro-griD

Programm: H2020

Duration: October 2016 - October 2019

Coordinator: Inria

Inria contact: Samir M. Perlaza

A smart micro-grid is a small-scale power-grid system consisting of a number of distributed energy sources and loads which is responsible to ensure power sufficiency in a small area. The effectiveness of a smart micro-grid depends on the proper implementation of a communications and networking system which monitors, controls and manages the grid's operations. Due to the ever growing worldwide energy consumption, the need of an efficient framework for managing the way power is distributed and utilized has increased. The main objective of the project COM-MED is to study the fundamental interplay between communications and power networks in the context of smart micro-grids and renewable energy sources. On one hand, we study advanced signal processing techniques and communications methods to optimize the operation of smart micro-grid systems. On the other hand, we focus on mobile communications networks with renewable energy base-stations (BSs) and we investigate communications and networking techniques that take into account both data traffic and energy profiles to support high quality-of-service (QoS). The objectives of each technical WP have been assigned in such a way as to ensure that the project's target is realized during the project's time period. The theoretical results derived from the WPs 3, 4 and 5 will be tested using the telecommunication network of MTN in Cyprus but also the state-of-the-art equipment of the CITI/Inria research lab in France. The outcome of this project will provide a theoretical framework for the optimal cooperation between communications networks and power networks in the context of smart micro-grids and renewable energy sources. This is in line with the objectives of the call's theme "Renewable Energy" and is of paramount importance for the Mediterranean area. The consortium of the project has the expertise and the infrastructure to implement the objectives set and to bring the project to a successful end.

8.3. International Initiatives

8.3.1. Inria Associate Teams Not Involved in an Inria International Labs

8.3.1.1. CoWIN

Title: Cognitive Wireless Networks from Theory to Implementation

International Partner: Princeton University, School of Engineering and Applied Science. Princeton N.J. USA. Prof. H. Vincent Poor

Start year: 2015

See also: https://project.inria.fr/cowin/

The objective of this team is to strengthen the research efforts on emerging software radio and cognitive radio technologies. The team will count on: first, the cognitive radio test-bed CorteXlab recently set up by the Socrate team within the FIT Equipex, second the leading position of Vincent Poor's team in the field of network information theory and third the Orbit Platform of Rutgers university. The goal is to lead research in both the information theory community and the applied research community so as to reinforce the link between both communities. This work will concern architecture and programs of software radio equipments, distributed and cognitive algorithms for radio resource allocation, cognitive radio scenario experimentations, fundamental limits of cooperative wireless channels and the set up of common experimental infrastructure and protocols for research on cognitive wireless networks.

8.3.1.2. Informal International Partners

Socrate has strong collaborations with several international partners.

- **Princeton University**, School of Applied Science, Department of Electrical Engineering, NJ. USA. This cooperation with Prof. H. Vincent Poor is on topics related to decentralized wireless networks. Samir M. Perlaza has been appointed as Visiting Research Collaborator at the EE Department for the academic period 2016-2017. Scientific-Leaders at Inria: Samir M. Perlaza and Jean-Marie Gorce.
- **Technical University of Berlin**, Dept. of Electrical Engineering and Computer Science, Germany. This cooperation with Prof. Rafael Schaffer is on secrecy and covert communications. Scientific-Leaders at Inria: Samir M. Perlaza.

- **National University Singapore (NUS)**, Department of Electrical and Computer Engineering, Singapore. This collaboration with Prof. Vincent Y. F. Tan is on the study of finite block-length transmissions in multi-user channels and the derivation of asymptotic capacity results with non-vanishing error probabilities. Scientific-Leaders at Inria: Samir M. Perlaza
- **University of Sheffield**, Department of Automatic Control and Systems Engineering, Sheffield, UK. This cooperation with Prof. Inaki Esnaola is on topics related to information-driven energy systems and multi-user information theory. Scientific-in-charge at Inria: Samir M. Perlaza.
- **Rutgers University**, Winlab, Orbit testbed. This cooperation with Ivan Seskar is related to experimental wireless testbed. Orbit has been one of the first wireless testbeds of its type. Tanguy Risset and Leonardo Sampaio-Cardoso have visited Winlab and I. Seskar visited the Socrate team for one week. Their collaboration is on the development of tools to ease experiment handling on wireless testbeds: visualisation, synchronization etc. Scientific-Leader at Inria: Tanguy Risset
- **University of Arizona**, Department of Electrical and Computer Engineering, Tucson, AZ, USA. This cooperation with Prof. Ravi Tandon is on topics related to channel-output feedback in wireless networks. Scientific-Leader at Inria: Samir M. Perlaza.
- **University of Cyprus**, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, Cyprus. This cooperation with Prof. Ioannis Krikidis is on topics related to energy-harvesting and wireless communications systems. Scientific-Leaders at Inria: Guillaume Villemaud and Samir M. Perlaza.
- **Universidade Federal do Ceará**, GTEL, Departamento de Teleinformática, Fortaleza, Brazil. This recently started cooperation with Prof. Tarcisio Ferreira Maciel is on topics related to the optimization of radio ressources for massive MIMO in 5G and 5G-like wireless communications systems. Scientific-in-charge at Inria: Leonardo Sampaio-Cardoso.
- **Universidad Nacional del Sur**, LaPSyC laboratory, Bahía Blanca , Argentina. This cooperation with Prof. Juan Cousseau is on topics related to Full-Duplex communications and Interference Alignment. Scientific-in-charge at Inria: Guillaume Villemaud.
- **Bell Labs New Jersey, USA**, This cooperation with Prof. Antonia Tulino (affiliated to Bell Labs and to University of Napoli, Italy) is on caching in wireless networks. The objective is to demonstrate the efficiency of caching at the edge of wireless networks through experimentations on CorteXlab. This work will be published in 2017 in a special issue of IEEE Communication magazine (Yasser Fadlallah, Antonia M. Tulino, Dario Barone, Giuseppe Vettigli, Jaime Llorca and Jean-Marie Gorce: Coding for caching in 5G networks, IEEE Communication Magazine, 2017, accepted for publication). Scientific leader at Inria : Jean-Marie Gorce.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Dr. Martin Kumm, from University of Kassel, spent one week at CITI to work on FPGA arithmetic.

8.4.2. Short-Term Visits to International Teams

- Samir M. Perlaza was visiting the Department of Automatic Control and Systems Engineering at the University of Sheffield, UK, hosted by Prof. Iñaki Esnaola.
- Samir M. Perlaza and David Kibloff were visiting the Department of Telecommunication Systems at the Technical University of Berlin, Germany, hosted by Prof. Rafael Schaefer.
- Selma Belhadj Amor was visiting the Center for Wireless Communication and Signal Processing Research (CWCSPR), ECE Department, New Jersey Institute of Technology (NJIT), USA, hosted by Prof. Osvaldo Simeone.
- Florin Hutu was visiting the Department of Electrical and Electronics Engineering", University of Buea, Cameroun, hosted by Pr. Emmanuel Tanyi.

- Lionel Morel was visiting the SCI-STI-MM Multimedia Group at École Polytechnique Fédérale de Lausanne, hosted by Dr Marco Mattavelli.

8.4.2.1. Research Stays Abroad

- Selma Belhadj Amor was hosted by the Electrical Engineering Department at Princeton University, New Jersey, USA, as a Visiting Scholar. Host: Prof. H. Vincent Poor.
- Selma Belhadj Amor hosted by the Electrical and Computer Engineering Department at the National University Of Singapore (NUS), Singapore. Host: Prof. Vincent F. Y. Tan.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. General Chair, Scientific Chair

Jean-Marie Gorce was one of the general chairs in the following conferences:

- GDR-ISIS Meeting: "Wireless networks: decentralized problems and solutions", held in Telecom ParisTech, March, 15, 2016.
- Workshop : "Inclusive Radio Communications for 5G and beyond", held in conjunction with the conference IEEE PIMRC, September 4-7, 2016, Valencia, Spain.

9.1.2. Chair of Conference Program Committees

Florent de Dinechin is a PC chair of the Arith 2017 conference.

9.1.3. Member of the Conference Program Committees

Samir M. Perlaza was a member of the technical program committee of the following conferences:

- IEEE Wireless Communications and Networking Conference (WCNC). 19-22 March 2017, San Francisco, CA. PHY and Fundamentals Track.
- 3rd Workshop on Physical-layer Methods for Wireless Security. Workshop taking place at IEEE CNS 2016 in Philadelphia, PA, USA, Oct 17-19, 2016.
- Workshop on Wireless Energy Harvesting Communication Network. Workshop taking place at IEEE Global Communications Conference (GLOBECOM) in Washington, DC USA, Dec. 8, 2016.
- IEEE WCNC 2016 Workshop on Green and Sustainable 5G Wireless Networks (GRASNET). April 3, 2016, Doha, Qatar
- 6th International Conference on Game Theory for Networks (GameNets). May 10-12, 2016, Kelowna, BC, Canada.

Jean-Marie Gorce was a member of the following technical program committees:

- IEEE APCC(22th Asia-Pacific Communication Conference, Yogyakarta-Indonesia, August 25-27 2016).
- IEEE PIMRC Fundamental & PHY (27th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications , Valencia, Spain, September 4-7, 2016).
- IEEE GLOBECOM Cognitive Radio Networks (Washington, DC, USA, December, 4-8, 2016).
- IEEE ICC Cognitive Radio Networks (IEEE International Conference on Communications, Malaysia, May 23-27 2016).

Guillaume Villemaud was a member of the following technical program committees:

- CROWNCOM2016
- VTC spring 2016
- PIMRC 2016
- EUCAP 2016.

Tanguy Risset was a member of the following technical program committees:

- IEEE Computer Society Annual Symposium on VLSI (ISVLSI) 2016.
- Design Automation and Test in Europe (DATE) 2016.
- International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM) 2016 .

Florent de Dinechin was a member of the following technical program committees:

- 12th International Symposium on Applied Reconfigurable Computing (ARC 2016)
- 23rd IEEE Symposium on Computer Arithmetic (Arith)
- 27th Annual IEEE International Conference on Application-specific Systems, Architectures and Processors (ASAP 2016)
- IEEE International Conference on Field Programmable Technologies (FPT 2016)
- Design Automation and Test in Europe (DATE) 2016, track D11.
- 24th IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM 2016)
- Conférence d'informatique en Parallélisme, Architecture et Système (ComPAS 2016)

9.1.4. Member of the Editorial Boards

Guillaume Villemaud is an associate editor of Annals of Telecommunications (Springer).

Jean-Marie Gorce is an associate editor of Telecommunications Systems (Springer) and Journal of Wireless communications and Networking (Springer).

9.1.5. Invited Talks

S. Perlaza, "On the Benefits of Feedback in Wireless Communications". Invited talk at the Department of Telecommunications, CentraleSupélec, Gif-sur-Yvette, France, December 2, 2016.

G. Salagnac "Peripheral State Persistence For Transiently Powered Systems" at the 3rd edition of the LIP Seminar on Languages Compilation and Semantics. France, November 3 2016.

S. Perlaza, "On the Benefits of Feedback in Wireless Communications". Invited talk at the Department of Electrical Engineering and Computer Science, Technical University of Berlin, Berlin, Germany, November 18, 2016.

J.M. Gorce, "Energy-Capacity Fundamental Limits in a Cell with Dense Users" at Lundis de la radio, Orange Labs, Issy les Moulineaux, France, September 26, 2016.

S. Belhadj Amor, "Simultaneous Energy and Information Transmission". Invited talk at the School of Engineering and Applied Science, Princeton University, Princeton NJ, USA, April 21, 2016.

S. Belhadj Amor, "Simultaneous Energy and Information Transmission". Invited talk at the Center for Wireless Communication and Signal Processing Research (CWCSPR), ECE Department, New Jersey Institute of Technology (NJIT), Newark NJ, USA, April 15, 2016.

S. Perlaza, "Simultaneous Wireless Information and Energy Transmission". Invited talk at the University of Sheffield. Department of Automatic Control and Systems Engineering, Sheffield, UK, April 6, 2016.

T. Risset, "FIT/CorteXlab: A new testbed for cognitive radio experimentation". Invited talk at the Colorado-state University Fort Collins, Computer science departement, Sep. 2016.

T. Risset "Compilation of Parametric Dataflow Applications for Software-Defined-Radio-Dedicated MPSoCs" at the 2rd edition of the LIP Seminar on Languages Compilation and Semantics. Lyon, France, June 24 2016.

T. Risset, "Experimenting Cognitive Radio Communication on FIT/CorteXlab". Invited talk at R2-Lab inauguration, Nice, France, Nov. 2016.

9.1.6. Leadership within the Scientific Community

Guillaume Villemaud is National Delegate (Alt.) for the COST IRACON.

9.1.7. Scientific Expertise

Guillaume Villemaud was reviewer of ANR projects and CIFRE grants.

Jean-Marie Gorce is a member of the following committees:

- Jury prix de thèse 2017 Signal Image et Vision, soutenu par l'association GRETSI, le GDR ISIS et le club EEA.
- Jury for the digital Impulse Innovation price, May, 2016.

Tanguy Risset is member of the Administration council (Conseil d'administration) of the GRAME institute (centre national de création musicale).

9.1.8. Tutorials in International Conferences

- S. Belhadj Amor and S. M. Perlaza, "Simultaneous Energy and Information Transmission". Tutorial at the 11th EAI International Conference on Cognitive Radio Oriented Wireless Networks (Crowncom), Grenoble, France, May 29, 2016.
- S. Belhadj Amor, S. M. Perlaza, and I. Krikidis, "Simultaneous Energy and Information Transmission". Tutorial at the European Wireless (EW) conference, Oulu, Finland, May 18, 2016.
- S. Belhadj Amor and S. M. Perlaza, "Simultaneous Energy and Information Transmission". Tutorial at the 23rd International Conference on Telecommunications, Thessaloniki, Greece, May 16, 2016.
- J.M. Gorce, "Fundamental Limits of Bursty Multi-user Wireless Networks for IoT", at the summer school RESCOM on 5G and Internet of Things, from 13th to 17th June 2016, Guidel Plage, France.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Jean-Marie Gorce is the head ot the Telecommunications department of Insa Lyon.

Tanguy Risset and Jean-Marie Gorce and are professors at the Telecommunications Department of Insa Lyon.

Florent de Dinechin is a professor at the Computer Science Department of Insa Lyon.

Claire Goursaud is an associate professor at the Telecommunications department of Insa Lyon.

Leonardo Sampaio-Cardoso is an associate professor at Insa Lyon (Premier Cycle).

Guillaume Salagnac and Kevin Marquet are associate professors at the Computer Science Department of Insa Lyon.

Guillaume Villemaud and Florin Hutu are associate professor at the Electrical Engineering Department of Insa Lyon.

Samir M. Perlaza and Jean-Marie Gorce teach the course on Network Information Theory at École Normale Supérieure de Lyon.

9.2.2. Supervision

PhD in progress **Tristan Delizy** *memory management for normally-of NV-RAM based systems*, Insa-Lyon, (Region ARC6) since 09/2016.

PhD in progress **Yohan Uguen** *Synthesis of arithmetic operators*, Insa-Lyon, (Mininstry of research) since 09/2016.

PhD in progress **Yuqi Mo** *Scaling of Iot Communication issuers*, Insa-Lyon, since 09/2015.

PhD in progress **David Kibloff** *New strategy for Physical Layer Security in wireless networks: self-jamming using Full-Duplex Transceivers*, École Doctorale EEA de Lyon, funded by Inria-DGA grant since 10/2015.

PhD in progress **Victor Quintero** *Fundamental Limits of Decentralized Cognitive Radio Networks*, École Doctorale EEA de Lyon, funded by Colciencias since 02/2014.

PhD in progress **Nizar Khalfet** *Stochastic Energy Sources to Power Communication Systems*, École Doctorale EEA de Lyon, funded by EU Project COM-MED since 10/2016.

PhD in progress : **Matei Istoan**: *High-performance coarse operators for FPGA-based computing*, ANR Metalibm grant, since 01/2014.

PhD : **Arturo Jimenez Guizar**: *Cooperative communications in Body Area Networks*, ANR Cormoran grant, 27/10/2016.

PhD : **Matthieu Vallerian**: "*Radio Logicielle pour réseau de capteurs*", CIFRE/Orange, 15/06/2016.

9.2.3. Juries

Jean-Marie Gorce was a member of the jury of the following thesis:

- PhD Ehsan Ebrahimi Khaleghi, Advanced techniques of Interference Alignment : Application to Wireless Networks (Telecom ParisTech, January 2016), (as a reviewer).
- PhD Bhanukiran Perabathini, fundamental limits of energy efficiency in wireless networks (CentraleSupélec, January 2016), (as a reviewer).
- PhD Abraham Kaboré, Study of detection-correction error codes for MAC/PHY layers in smart grid networks (University Limoges, March 2016), (as a veviewer).
- PhD Marwa Chami, Optimization of cognitive systems with successive interference cancellation and relaying (CNAM, Paris, May 2016), (as a reviewer).
- PhD Jan Oksanen, Machine learning methods for spectrum exploration and exploitation (University of Aalto, September 2016), (as an opponent).
- PhD Wenjie Li, Robust information gathering and dissemination in wireless sensor networks (CentraleSupélec, November 2016), (as a reviewer).
- PhD Raphael Massin, On the Clustering of Mobile Ad Hoc Networks (Telecom ParisTech, November 2016), (as a reviewer).
- PhD Zheng Chen, User-Centric Content-Aware Communication in Wireless Networks (CentraleSupélec, December 2016), (as a reviewer).
- HdR Frédéric Guilloud, contributions to error correction codes and to digital communications toward communications with short frames (Telecom Brest, December 2016).

Samir M. Perlaza was a member of the jury of the following thesis:

- PhD Chao He, "Broadcasting with delayed CSIT: Finite SNR analysis and heterogeneous feedback". Defended at CentraleSupélec on December 2 2016, Gif-sur-Yvette, France.

Florin Hutu was a member of the jury of the following thesis:

- PhD Jeremy Hyvert, "Techniques de conception d'oscillateurs contrôlés en tension faible bruit de phase en bande Ku intégrés sur silicium en technologie BiCMOS" (Université de Poitiers, September 2016).

Guillaume Villemaud was a member of the jury of the following thesis:

- PhD Roman IGUAL PEREZ, "Platform hardware/software for the energy optimization in a node of wireless sensor networks", Univ. de Lille 1.
- Mohammad ABDI ABYANEH, "Génération des signaux agrégés en fréquences dans le contexte de LTE-A". Telecom Paristech.
- Shiqi CHENG, "Characterization and modeling of the polarimetric MIMO radio channel for highly diffuse scenarios". Univ. de Lille 1.

Tanguy Risset was a member of the jury of the following thesis:

- Marcos Aurelio Pinto Cunha (U. Grenoble, Jan. 2016) as jury president .
- Xiguang Wu (CentraleSupélec, Mar. 2016), as reviewer.
- Shaoyang MEN (U. Nantes, Oct. 2016) jury president.

Florent de Dinechin was a reviewer in the habilitation thesis of Roselyne Chotin-Avot (LIP6, Paris).

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Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] A. GUIZAR. *Cooperative communications with Wireless Body Area Networks for motion capture*, INSA Lyon, September 2016, https://hal.archives-ouvertes.fr/tel-01412953

[2] M. VALLÉRIAN. *A flexible infrastructure for collecting and processing data from a urban sensor network*, Université de Lyon opérée au sein de l'INSA Lyon, June 2016, https://hal.inria.fr/tel-01416750

Articles in International Peer-Reviewed Journals

[3] H. ABDOLI, H. NIKMEHR, N. MOVAHEDINIA, F. DE DINECHIN. *Improving Energy Efficiency of OFDM Using Adaptive Precision Reconfigurable FFT*, in "Circuits, Systems, and Signal Processing", October 2016 [*DOI :* 10.1007/s00034-016-0435-z], https://hal.inria.fr/hal-01402231

[4] G. C. ALEXANDROPOULOS, P. FERRAND, J.-M. GORCE, C. B. PAPADIAS. *Advanced coordinated beamforming for the downlink of future LTE cellular networks*, in "IEEE Communications Magazine", July 2016, vol. 54, n^o 7, pp. 54 - 60, Arxiv: 16 pages, 6 figures, accepted to IEEE Communications Magazine [*DOI :* 10.1109/MCOM.2016.7509379], https://hal.inria.fr/hal-01395615

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[9] M. VALLERIAN, F. D. HUTU, G. VILLEMAUD, B. MISCOPEIN, T. RISSET. *A parallel unbalanced digitization architecture to reduce the dynamic range of multiple signals*, in "Radio Science", April 2016 [*DOI :* 10.1002/2015RS005885], https://hal.archives-ouvertes.fr/hal-01312986

Invited Conferences

[10] S. BELHADJ AMOR, S. M. PERLAZA. *Fundamental Limits of Simultaneous Energy and Information Transmission*, in "23rd International Conference on Telecommunications", Thessaloniki, Greece, Proceedings of the 23rd International Conference on Telecommunications, May 2016, Special Session 3: Exploiting interference towards energy efficient and secure wireless communications, https://hal.archives-ouvertes.fr/hal-01277160

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