IN PARTNERSHIP WITH:
Institut national des sciences appliquées de Lyon

Activity Report 2017

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

Table of contents

Project-Team SOCRATE

Creation of the Team: 2012 January 01, updated into Project-Team: 2013 July 01

Keywords:

Computer Science and Digital Science:

A1.1.2. - Hardware accelerators (GPGPU, FPGA, etc.)
A1.1.12. - Non-conventional architectures
A1.2.5. - Internet of things
A1.2.6. - Sensor networks
A1.5.2. - Communicating systems
A2.3.1. - Embedded systems
A2.6.1. - Operating systems
A5.9. - Signal processing
A8.6. - Information theory

Other Research Topics and Application Domains:

B6.2. - Network technologies
B6.2.2. - Radio technology
B6.4. - Internet of things
B6.6. - Embedded systems

1. Personnel

Research Scientist

Samir Perlaza [Inria, Researcher]

Faculty Members

Tanguy Risset [Team leader, INSA Lyon, Professor, HDR]
Florent de Dinechin [INSA Lyon, Professor, HDR]
Jean Marie Gorce [INSA Lyon, Professor, HDR]
Claire Goursaud [INSA Lyon, Associate Professor]
Florin Hutu [INSA Lyon, Associate Professor]
Kevin Marquet [INSA Lyon, Associate Professor]
Guillaume Salagnac [INSA Lyon, Associate Professor]
Leonardo Sampaio Cardoso [INSA Lyon, Associate Professor]
Guillaume Villemaud [INSA Lyon, Associate Professor, HDR]
Malcolm Egan [INSA Lyon, from Nov 2017, Associate Professor]

Post-Doctoral Fellows

Selma Belhadj Amor [Inria, until Apr 2017]
Wei Du [INSA Lyon, until Apr 2017]
Malcolm Egan [INSA Lyon, until Oct 2017]
Ayse Unsal [Inria, until Aug 2017]

PhD Students

Andrea Bocco [CEA]
Tristan Delizy [INSA Lyon]
Diane Duchemin [Inria]
Matei Istoan [Inria, until Mar 2017]

Hassan Kallam [INSA Lyon]
Nizar Khalfet [Inria]
David Kibloff [Inria]
Yuqi Mo [Sigfox]
Victor Quintero Florez [Columbia]
Yohann Uguen [INSA Lyon]

Technical staff

Gautier Berthou [Inria]
Olivier Nicolas [INSA Lyon]
Othmane Oubejja [Inria]

Administrative Assistants

Sophie Karsai [Inria]
Gaelle Tworkowski [Inria]

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).

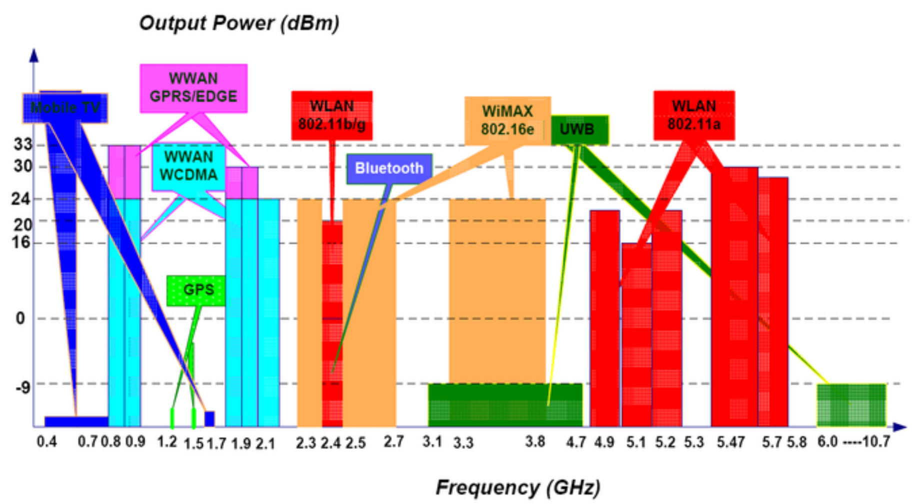

Figure 1. The most recent standards for wireless communications are developed in the UHF and VHF bands. These bands are mostly saturated (source: WPAN/WLAN/WWAN Multi-Radio Coexistence, IEEE 802 Plenary, Atlanta, USA, Nov.2007)

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 œtechnologies, 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.* [63]

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.

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 [62], 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 [54]. 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 [59], [60]. 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 [54]. 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 [59], [55].

2.2.1. SDR Technology

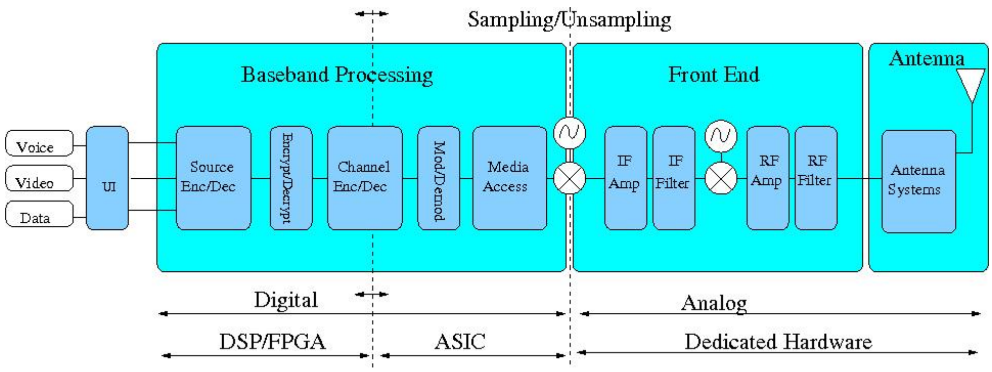

Figure 2. Radio Block Diagram, highlighting separation between digital and analog parts, as well as programmable, configurable and fixed hardware parts.

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" [61]. 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 [56].

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 [57] 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.

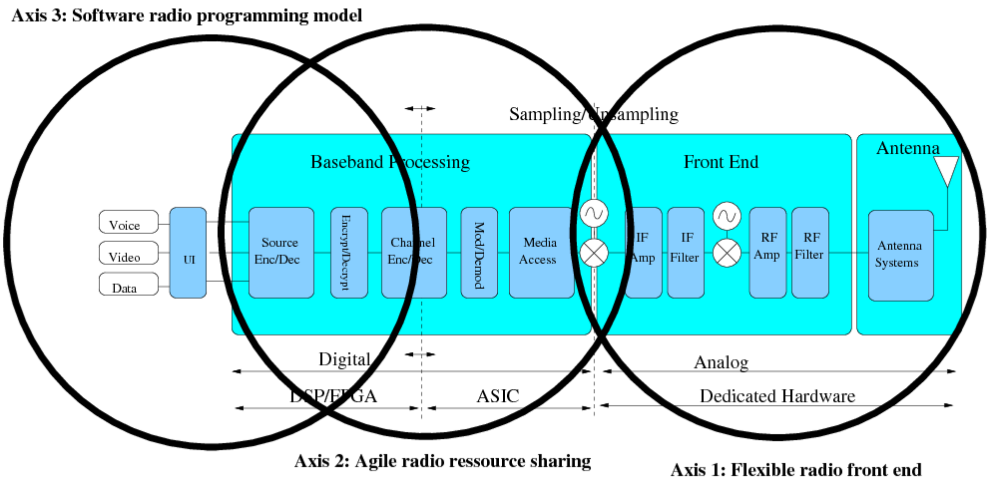

Figure 3. Center of interest for each of the three Socrate research axes with respect to a generic software radio terminal.

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.

3.3. Multi-User Communications

Participants: Jean Marie Gorce, Claire Goursaud, Samir Perlaza, Leonardo Sampaio Cardoso, Malcolm Egan.

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

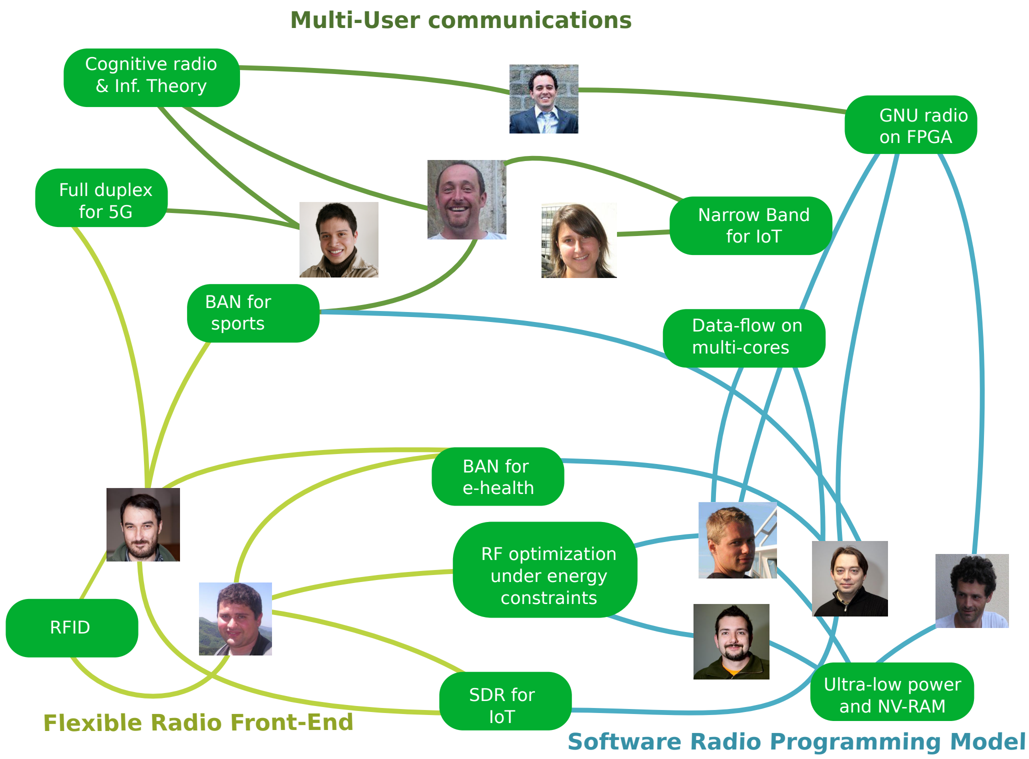

Figure 4. Inter-Axis Collaboration in Socrate: we expect innovative results to come from this pluri-disciplinary research

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).

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

4.1.1. Awards

Florent de Dinechin obtained the *community award* of the 27th International Conference on Field-Programmable Logic and Application (FPL17) for his software Flopoco, Parameterized Floating-Point Core Generator, see: https://www.fpl2017.org/awards/

4.1.2. Others

4.1.2.1. FIT/Grid5000 fusion

The mid-term evaluation of the FIT project was very well evaluated (excerpt of the report: "It is really hard to identify weaknesses of the equipment project"), FIT has also been promoted as national "Instrument de Recherche" and it is discussing with Grid5000 to apply to the status of TGIR (*Très grande infrastructure de recherche*). A ESFRI proposal has already been proposed (ESFRI is the european instrument for European Strategy on Research Infrastructures).

4.1.2.2. INSA-Lyon/Spie IoTS Chair

Spie-ICS funds a chair with the Citi-lab on IoT, Jean-Marie Gorce was the initiator of this big project (approximately 1M€ over 5 years) dedicated to Internet of Things, the Socrate team is highly involved in the Spie-IoT Chair

5. New Software and Platforms

5.1. fftweb

KEYWORDS: Experimentation - Data visualization - SDR (Software Defined Radio)
FUNCTIONAL DESCRIPTION: fftweb is a real-time spectral (FFT) visualization of one or several signal, embedded in a web page. The FFT is computed in a GNURadio block, then sent to a gateway server, which serves the web page, associated javascripts, and signal websockets. The end user only has to use the GNURadio block and and the web page, and doesn't need to bother about the internal details of the system. fftweb has been developped specially for the CorteXlab testbed but with minor adaptations, it can be used in other contexts, and also can be used to draw more generic real-time graphs, not only FFTs. Technologies: GNURadio, python, python-gevent, Javascript, D3JS

- Contact: Matthieu Imbert

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

5.3. minus

KEYWORDS: Experimentation - SDR (Software Defined Radio)
FUNCTIONAL DESCRIPTION: Minus is an experiment control system able to control, the whole lifecycle of a radio experiment in CorteXlab or any other testbed inspired by it. Minus controls and automates the whole experiment process starting from node power cycling, experiment deployment, experiment start and stop, and results collection and transfer. Minus is also capable of managing multiple queues of experiments which are executed simultaneously in the testbed.

- Contact: Matthieu Imbert

5.4. 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 JM 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: Tanguy Risset

5.5. Sytare

KEYWORDS: Embedded systems - Operating system - Non volatile memory
FUNCTIONAL DESCRIPTION: Sytare is an embedded operating system targeting tiny platforms with intermittent power. In order to make power failures transparent for the application, the system detects imminent failures and saves a checkpoint of program state to non-volatile memory. Hardware peripherals are also made persistent without requiring developer attention.

- Authors: Gautier Berthou, Tristan Delizy, Kevin Marquet and Guillaume Salagnac
- Contact: Guillaume Salagnac
- Publication: Peripheral State Persistence For Transiently Powered Systems
- URL: https://hal.inria.fr/hal-01460699

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 (FIT NOC), a set of IoT test-beds (FIT IoT-Lab), a set of wireless test-beds (FIT-Wireless) which includes the FIT/CorteXlab platform deployed by the Socrate team in the Citi lab, and finaly a set of Cloud test-beds (FIT-Cloud). 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. CorteXlab has been used for innovative experiments such as Interference Alignment in Cellular Networks for Energy Efficiency Improvement demonstrated in the GreenTouch Consortium.

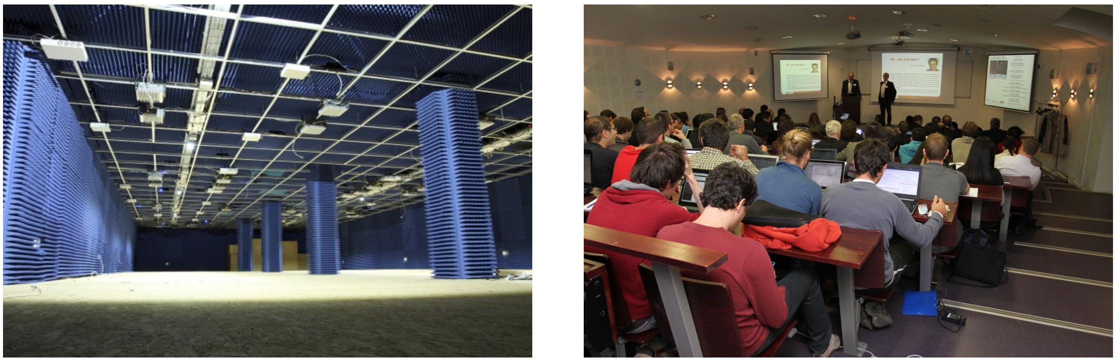

Figure 5. Photo of the FIT/CortexLab experimentation room installed and a snaptshot of the inauguration meeting

6. New Results

6.1. Flexible Radio Front-End

6.1.1. RFID tag-to-tag communication

RFID is a well-known technique for wireless authentication. Usually, such a system only consists on a reader communicating with one or several tags. The concept of passive RFID tag-to-tag communications has been recently introduced and opens new promising perspectives, especially in the field of Internet-of-Things. In this work, a simulation framework was proposed as a new tool allowing the performance evaluation of tag-to-tag radio links. The modeling takes into consideration the external source supplying the communication between tags, radiating characteristics of tag antennas, and reception system aspects. Performance results are expressed in terms of Bit Error Rate (BER) with respect to the distance between the tags and the position of the energy source relative to the position of the two tags [36], [35].

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

6.1.2. Optimization of waveforms for energy harvesting

We have studied the incidence of the modulation scheme as well as the input power on the RF to DC rectifier conversion efficiency for an energy harvesting system based on radiowaves. A commercial energy harvesting (EH) P21XXCSR-EVB evaluation board from Powercast Corporation is used as measurement target and several waveforms are employed to evaluate the rectification efficiency. With a continuous wave as reference, QPSK, QAM and OFDM waveforms usage demonstrates that digital modulated signals can lead to a better efficiency. Thus, by selecting a high peak to average power ratio (PAPR), and under certain conditions, the performance of the energy harvesting circuit is enhanced [30].

6.2. Multi-User Communications

6.2.1. Fundamental limits : contributions in Multi-User Information Theory (MU-IT)

6.2.1.1. Interference channel with feedback

In this work [29], [44], [43], the $\eta-$Nash equilibrium ($\eta-$NE) region of the two-user linear deterministic interference channel (IC) with noisy channel-output feedback is characterized for all $\eta > 0$. The $\eta-$NE region, a subset of the capacity region, contains the set of all achievable information rate pairs that are stable in the sense of an $\eta-$NE. More specifically, given an $\eta-$NE coding scheme, there does not exist an alternative coding scheme for either transmitter-receiver pair that increases the individual rate by more than η bits per channel use. Existing results such as the η-NE region of the linear deterministic IC without feedback and with perfect output feedback are obtained as particular cases of the result. We also characterized in [15] the price of anarchy (PoA) and the price of stability (PoS) of this $\eta-$NE. The price of anarchy is the ratio between the sum-rate capacity and the smallest sum-rate at an $\eta-$NE. The price of stability is the ratio between the sum-rate capacity and the biggest sum-rate at an $\eta-$NE. Some of the main conclusions of this work are the following: (a) When both transmitter-receiver pairs are in low interference regime, the PoA can be made arbitrarily close to one as η approaches zero, subject to a particular condition. More specifically, there are scenarios in which even the worst $\eta-$NE (in terms of sum-rate) is arbitrarily close to the Pareto boundary of the capacity region. (b) The use of feedback plays a fundamental role on increasing the PoA, in some interference regimes. This is basically because in these regimes, the use of feedback increases the sum-capacity, whereas the smallest sum-rate at an $\eta-$NE remains the same. (c) The PoS is equal to one in all interference regimes. This implies that there always exists an $\eta-$NE in the Pareto boundary of the capacity region. The ensemble of conclusions of this work reveal the relevance of jointly using equilibrium selection methods and channel-output feedback for reducing the effect of anarchical behavior of the network components in the $\eta-$NE sum-rate of the interference channel.

6.2.1.2. Simultaneous information and energy transmission

In this work [42], [25], [48], the fundamental limits of simultaneous information and energy transmission in the two-user Gaussian interference channel (G-IC) with and without feedback are fully characterized. More specifically, an achievable and converse region in terms of information and energy transmission rates (in bits per channel use and energy-units per channel use, respectively) are identified. In both cases, with and without feedback, an achievability scheme based on power-splitting, common randomness, rate splitting, block-Markov superposition coding, and backward decoding is presented. Finally, converse regions for both cases are obtained using some of the existing outer bounds for information transmission rates, as well as a new outer bound for the energy transmission rate.

6.2.1.3. Ultra-dense wireless networks

Ultra-dense networks represent an interesting model for future IoT networks. The analysis of these metworks relies on the association of stochastic geometry models with information theory in the finite blocklength regime. Considering an isolated wireless cell containing a high density of nodes, the fundamental limit can be defined as the maximal number of nodes the associate base station can serve under some system level constraints including maximal rate, reliability, latency and transmission power. This limit can be investigated in the downlink, modeled as a spatial continuum broadast channel (SCBC) as well as in the uplink modeled as a spatial continuum multiple access channel (SCMAC). In this work, we define the different steps towards the characterization of this fundamental limit, considering four figures of merit: energy efficiency, spectral efficiency, latency, reliabilty [13]. To address this question in the uplink scenario [10], we uses a large scale Multiple Access Channel (MAC) to model IoT nodes randomly distributed over the coverage area of a unique base station. The traffic is represented by an information rate spatial density $\rho(x)$. This model, referred to as the Spatial Continuum Multiple Access Channel, is defined as the asymptotic limit of a sequence of discrete MACs. The access capacity region of this channel is defined as the set of achievable information rate spatial densities achievable with vanishing transmission errors and under a sum-power constraint. Simulation results validate the model and show that this fundamental limit theoretically achievable when all nodes transmit simultaneously over an infinite time, may be reached even with a relatively small number of simultaneous transmitters (typically around 20 nodes) which gives credibility to the model. The results also highlight the potential interest of non-orthogonal transmissions for IoT uplink transmissions when compared to an ideal time sharing strategy. We then developed a powerful analytical model of wireless network with Superposition Coding (SC), also referred to as Non Orthogonal Multiple Access (NOMA), taking into consideration a multi cell interference limited network. This model allows to establish a closed form expression of the minimum power a base station (BS) needs to transmit to its users and to achieve a given SINR (signal to interference plus noise ratio) whatever its location in the area covered by the base station. It moreover allows to establish a closed form expression of the minimum total transmit power of a base station. These closed form expressions allow to establish performance of wireless networks, by minimizing the base stations transmit powers. As an application, we show that these closed form expressions allow to quantify the energetic performance, spectral efficiency, total throughput and the coverage of a BS, in a simple and quick way.

6.2.1.4. Broadcast channel in the Finite Blocklength regime

In order to analyse wireless networks with short packets, theoretical results in information theory for the finite blocklength regime in multi-user scenarios were missin. In [34], [33], we analyzed the performance of superposition coding for Gaussian broadcast channels with finite blocklength. To this end, we adapted two different achievability bounds, the dependence testing and the $\kappa - \beta-$bounds introduced by Polyanskiy et al. in 2010 to the broadcast setting. The distinction between these bounds lies in fixing either the input or the output distributions of the channel. For the first case of the dependence testing bound, an upper bound on the average error probability of the system is derived whereas for the latter, lower bounds on the maximal code sizes of each user are presented.

6.2.1.5. Capacity sensitivity

In this work [22], [40], a new framework based on the notion of *capacity sensitivity* is introduced to study the capacity of continuous memoryless point-to-point channels. The capacity sensitivity reflects how the capacity changes with small perturbations in any of the parameters describing the channel, even when the capacity is not available in closed-form. This includes perturbations of the cost constraints on the input distribution as well as on the channel distribution. The framework is based on continuity of the capacity, which is shown for a class of perturbations in the cost constraint and the channel distribution. The continuity then forms the foundation for obtaining bounds on the capacity sensitivity. As an illustration, the capacity sensitivity bound is applied to obtain scaling laws when the support of additive $\alpha-$stable noise is truncated.

6.2.2. Performance evaluation of large scale systems

6.2.2.1. UNB networks performance evaluation

UNB (Ultra Narrow Band) stands out as one promising PHY solution for low-power, low-throughput and long-range IoT. The dedicated MAC scheme is RFTMA (Random Frequency and Time Multiple Access), where nodes access the channel randomly both in frequency and in time domain, without prior channel sensing. This blind randomness sometimes introduces interference and packet losses. In order to quantify the system performance, we have derived and exploited a theoretical expression of the outage probability in a UNB based IoT network, when taking into account both interference due to the spectral randomness and path loss due to the propagation [14], [5]. Besides, we also proposed to use the well-known SIC (Successive Interference Cancellation) to cancel the interference in a recursive way. We provided a theoretical analysis of network performance, when considering jointly SIC and the specific spectral randomness of UNB. We analytically and numerically highlighted the SIC efficiency in enhancing UNB system performance [26].

6.2.2.2. Wireless networks on FIT/CorteXlab

In this work we study the FIT/CorteXlab platform where all radio nodes are confined to an electromagnetically (EM) shielded environment and have flexible radio-frequency (RF) front-end for experimenting on software defined radio (SDR) and cognitive radio (CR). A unique feature of this testbed is that it offers roughly 40 SDR nodes that can be accessed from anywhere in the world in a reproducible manner: the electromagnetic shield prevents from external interference and channel variability. In this work [16] we show why it is important to have such a reproducible radio experiment testbed and we highlight the reproducibility by the channel characteristics between the nodes of the platform. We back our claims with a large set of measurements done in the testbed, that also refines our knowledge on the propagation characteristics of the testbed.

One of the major goals of the 5G technology roadmap is to create disruptive innovation for the efficient use of the radio spectrum to enable rapid access to bandwidth-intensive multimedia services over wireless networks. The biggest challenge toward this goal lies in the difficulty in exploiting the multicast nature of the wireless channel in the presence of wireless users that rarely access the same content at the same time. Recently, the combined use of wireless edge caching and coded multicasting has been shown to be a promising approach to simultaneously serve multiple unicast demands via coded multicast transmissions, leading to order-of-magnitude bandwidth efficiency gains. However, a crucial open question is how these theoretically proven throughput gains translate in the context of a practical implementation that accounts for all the required coding and protocol overheads. In [3], in collaboration with Nokia Bell Labs, New Jersey, we first provide an overview of the emerging caching- aided coded multicast technique, including state-of-the-art schemes and their theoretical performance. We then focus on the most competitive scheme proposed to date and describe a fully working prototype implementation in CorteXlab, one of the few experimental facilities where wireless multiuser communication scenarios can be evaluated in a reproducible environment. We use our prototype implementation to evaluate the experimental performance of state-of-the-art caching-aided coded multicast schemes compared to state-of-the-art uncoded schemes, with special focus on the impact of coding computation and communication overhead on the overall bandwidth efficiency performance. Our experimental results show that coding overhead does not significantly affect the promising performance gains of coded multicasting in small-scale realworld scenarios, practically validating its potential to become a key next generation 5G technology.

6.2.3. Cognitive networks

6.2.3.1. Game theory based approaches

In [4], a generalization of the satisfaction equilibrium (SE) for games in satisfaction form (SF) is presented. This new solution concept is referred to as the generalized satisfaction equilibrium (GSE). In games in SF, players choose their actions to satisfy an individual constraint that depends on the actions of all the others. At a GSE, players that are unsatisfied are unable to unilaterally deviate to be satisfied. The concept of GSE generalizes the SE in the sense that it allows mixed-strategy equilibria in which there exist players who are unable to satisfy their individual constraints. The pure-strategy GSE problem is closely related to the constraint satisfaction problem and finding a pure-strategy GSE is proven to be NP-hard. The existence of at least one GSE in mixed strategies is proven for the class of games in which the constraints are defined by a lower limit on the expected utility. A dynamics referred to as the satisfaction response is shown to converge to a GSE in certain classes of games. Finally, Bayesian games in SF and the corresponding Bayesian GSE are introduced. These results provide a theoretical framework for studying service-level provisioning problems in communications networks as shown by several examples.

Device-to-device (D2D) communications can enhance spectrum and energy efficiency due to direct proximity communication and frequency reuse. However, such performance enhancement is limited by mutual interference and energy availability, especially when the deployment of D2D links is ultra-dense. In this contribution [9], we present a distributed power control method for ultra-dense D2D communications underlaying cellular communications. In this power control method, in addition to the remaining battery energy of the D2D transmitter, we consider the effects of both the interference caused by the generic D2D transmitter to others and interference from all others' caused to the generic D2D receiver. We formulate a mean-field game (MFG) theoretic framework with the interference mean-field approximation. We design the cost function combining both the performance of the D2D communication and cost for transmit power at the D2D transmitter. Within the MFG framework, we derive the related Hamilton-Jacobi-Bellman (HJB) and Fokker-Planck-Kolmogorov (FPK) equations. Then, a novel energy and interference aware power control policy is proposed, which is based on the Lax-Friedrichs scheme and the Lagrange relaxation. The numerical results are presented to demonstrate the spectrum and energy efficiency performances of our proposed approach. Index Terms—Device-to-device communication, mean field game, spectrum efficiency, energy efficiency.

6.2.3.2. Learning approaches

Fast initialization of cognitive radio systems is a key problem in a variety of wireless communication systems, particularly for public safety organizations in emergency crises. In the initialization problem, the goal is to rapidly identify an unoccupied frequency band. In this contribution [21], we formalize the initialization problem within the framework of active hypothesis testing. We characterize the optimal scanning policy in the case of at most one free band and show that the policy is computationally challenging. Motivated by this challenge for the implementation of the optimal policy and the need to cope with an unknown number of interferers larger than one, we propose the constrained DGF algorithm. We show that for strict constraints on the maximum number of observations, the constrained DGF algorithm can outperform the error probability of the state-of-the-art C-SPRT algorithm by an order of magnitude, for comparable average delays.

6.2.3.3. Asynchronous transmissions in VLC

In a visible light communications system (VLC), light sources are responsible for both illumination, communications and positioning. These light sources inevitably interfere each others at the receiver. To retain the appealing advantage that VLC systems can reuse existing lighting infrastructure, using an extra network to control or synchronize the light sources should be avoided. This work [31] proposes an uncoordinated multiple access scheme for VLC systems with positioning capability. The proposed scheme does not require a central unit to coordinate the transmission of the transmitters. Transmitters can be asynchronous with one another and with the receiver. Each transmitter is allocated a unique codeword with L chips for a system with up to $(L-1)/2$ transmitters where L is prime. Due to the linear growth in complexity with respect to number of transmitters, our proposed scheme is feasible for systems with large numbers of transmitters. Our novel decoder can minimize the effect of additive Gaussian noise at the receiver side. Simulation results show that the proposed decoder outperforms zero-forcing decoder.

6.2.4. Contributions in other application fields

6.2.4.1. Smart Grids

The advanced operation of future electricity distribution systems is likely to require significant observability of the different parameters of interest (e.g., demand, voltages, currents, etc.). Ensuring completeness of data is, therefore, paramount. In this context, an algorithm for recovering missing state variable observations in electricity distribution systems is presented in [47]. The proposed method exploits the low rank structure of the state variables via a matrix completion approach while incorporating prior knowledge in the form of second order statistics. Specifically , the recovery method combines nuclear norm minimization with Bayesian estimation. The performance of the new algorithm is compared to the information-theoretic limits and tested trough simulations using real data of an urban low voltage distribution system. The impact of the prior knowledge is analyzed when a mismatched covariance is used and for a Markovian sampling that introduces structure in the observation pattern. Numerical results demonstrate that the proposed algorithm is robust and outperforms existing state of the art algorithms.

In addition, Gaussian random attacks that jointly minimize the amount of information obtained by the operator from the grid and the probability of attack detection are presented in [38]. The construction of the attack is posed as an optimization problem with a utility function that captures two effects: firstly, minimizing the mutual information between the measurements and the state variables; secondly, minimizing the probability of attack detection via the Kullback-Leibler (KL) divergence between the distribution of the measurements with an attack and the distribution of the measurements without an attack. Additionally, a lower bound on the utility function achieved by the attacks constructed with imperfect knowledge of the second order statistics of the state variables is obtained. The performance of the attack construction using the sample covariance matrix of the state variables is numerically evaluated. The above results are tested in the IEEE $30-$Bus test system.

6.2.4.2. Molecular Communications

Molecular communications is emerging as a technique to support coordination in nanonetworking, particularly in biochemical systems. In complex biochemical systems such as in the human body, it is not always possible to view the molecular communication link in isolation as chemicals in the system may react with chemicals used for the purpose of communication. There are two consequences: either the performance of the molecular communication link is reduced; or the molecular link disrupts the function of the biochemical system. As such, it is important to establish conditions when the molecular communication link can coexist with a biochemical system. In this work [45], we develop a framework to establish coexistence conditions based on the theory of chemical reaction networks. We then specialize our framework in two settings: an enzyme-aided molecular communication system; and a low-rate molecular communication system near a general biochemical system. In each case, we prove sufficient conditions to ensure coexistence.

6.3. Software Radio Programming Model

6.3.1. Dataflow programming models

Parallel computers have become ubiquitous and current processors contain several execution cores. A variety of low-level tools exist to program these chips efficiently, but they are considered hard to program, to maintain, and to debug, because they may exhibit non-deterministic behaviors. A solution is to use the higher-level formalism of dataflow programming to specify only the operations to perform and their dependencies. This paradigm may then be combined with the Polyhedral Model, which allows automatic parallelization and optimization of loop nests. This makes programming easier by delegating the low-level work to compilers and static analyzers [41].

Existing dataflow runtime systems either focus on the efficient execution of a single data-flow application, or on scenarii where applications are known a priori. CalMAR is a Multi-Application Dataflow Runtime built on top of the RVC-Cal environment that addresses the problem of executing an a priori unknown number of dataflow applications concurrently on the same multi-core system. Its efficiency has been validated compared to the RVC-CAL traditional approach [27].

6.3.2. Environments for transiently powered devices

An important research initiative has been started in Socrate recently: the study of the new NVRAM technology and its use in ultra-low power context. NVRAM stands for Non-Volatile Radom Access Memory. Non-Volatile mémory has been extising for a while (Nand Flash for instance) but was not sufficiently fast to be used as main memory. Many emerging technologies are forseen for Non-Volatile RAM to replace current RAM [58].

Socrate has started a work on the applicability of NVRAM for *transiantly powered systems*, i.e. systems which may undergo power outage at any time. This study resulted in the Sytare software presented in a research report and at the IoENT conference [39], [37], [17] and also to the starting of an Inria Project Lab: ZEP.

The Sytare software introduces a checkpointing system that takes into account peripherals (ADC, leds, timer, radio communication, etc.) present on all embedded system. Checkpointing is the natural solution to power outage: regularly save the state of the system in NVRAM so as to restore it when power is on again. However, no work on checkpointing took into account the restoration of the states of peripherals, Sytare provides this possibility

6.3.3. Filter synthesis

[46] presents an open-source tool for the automatic design of reliable finite impulse response (FIR) filters, targeting FPGAs. It shows that user intervention can be limited to a very small number of relevant input parameters: a high-level frequency-domain specification, and input/output formats. All the other design parameters are computed automatically, using novel approaches to filter coefficient quantization and direct-form architecture implementation. Our tool guarantees a priori that the resulting architecture respects the specification, while attempting to minimize its cost. Our approach is evaluated on a range of examples and shown to produce designs that are very competitive with the state of the art, with very little design effort.

Linear Time Invariant (LTI) filters are often specified and simulated using high-precision software, before being implemented in low-precision fixed-point hardware. A problem is that the hardware does not behave exactly as the simulation due to quantization and rounding issues. The article [53] advocates the construction of LTI architectures that behave as if the computation was performed with infinite accuracy, then rounded only once to the low-precision output format. From this minimalist specification, it is possible to deduce the optimal values of many architectural parameters, including all the internal data formats. This requires a detailed error analysis that captures not only the rounding errors but also their infinite accumulation in recursive filters. This error analysis then guides the design of hardware satisfying the accuracy specification at the minimal hardware cost. This generic methodology is detailed for the case of low-precision LTI filters in the Direct Form I implemented in FPGA logic. The approach is demonstrated by a fully automated and open-source architecture generator tool, and validated on a range of Infinite Impulse Response filters.

6.3.4. Hardware computer arithmetic

In collaboration with researchers from Istanbul, Turkey, operators have been developed for division by a small positive constant [8]. 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.

[23] presents the new framework for semi-automatic circuit pipelining that will be used in future releases of the FloPoCo generator. 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.

FPGAs are well known for their ability to perform non-standard computations not supported by classical microprocessors. Many libraries of highly customizable application-specific IPs have exploited this capablity. However, using such IPs usually requires handcrafted HDL, hence significant design efforts. High Level Synthesis (HLS) lowers the design effort thanks to the use of C/C++ dialects for programming FPGAs. However, high-level C language becomes a hindrance when one wants to express non-standard computations: this languages was designed for programming microprocessors and carries with it many restrictions due to this paradigm. This is especially true when computing with floating-point, whose data-types and evaluation semantics are defined by the IEEE-754 and C11 standards. If the high-level specification was a computation on the reals, then HLS imposes a very restricted implementation space. [32]attempts to bridge FPGA application-specific efficiency and HLS ease of use. It specifically targets the ubiquitous floating-point summation-reduction pattern. A source-to-source compiler transforms selected floating-point additions into sequences of simpler operators using non-standard arithmetic formats. This improves performance and accuracy for several benchmarks, while keeping the ease of use of a high-level C description.

The previous uses a variation of Kulisch' proposal to use an internal accumulator large enough to cover the full exponent range of floating-point. With it, sums and dot products become exact operations with one single rounding at the end. This idea failed to materialize in general purpose processors, as it was considered too slow and/or too expensive in terms of resources. It may however be an interesting option in reconfigurable computing, where a designer may use use smaller, more resource-efficient floating-point formats, knowing that sums and dot products will be exact. Another motivation of this work is that these exact operations, contrary to classical floating point ones, are associative, which enables better compiler optimizations in a High-Level Synthesis context. Kulisch proposed several architectures for the large accumulator, all using a sign/magnitude representation: the internal accumulator always represents a positive significand. [52] introduces an architecture using a 2's complement representation instead, and demonstrates improvements over Kulisch' proposal in both area and speed.

Another alternative to floating point is the UNUM, a variable length floating-point format conceived to replace the formats defined in the IEEE 754 standard. [18] discusses the implementation of UNUM arithmetic and reports hardware implementation results for the main UNUM operators.

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 (2016-2017)

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 (2015-2017)

A collaboration with Sigfox to work on extension of SigFox network to multi-base station case: 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. Insa-Spie IoT Chair

The Insa-Spie IoT Chair http://www.citi-lab.fr/chairs/iot-chair/ relies on the expertise of the CITI Lab. The skills developed within the different teams of the lab integrate the study, modelling, conception and evaluation of technologies for communicating objects and dedicated network architectures. It deals with network, telecom and software matters as well as societal issues such as privacy. The chair will also lean on the skills developed at INSA Lyon or in IMU LabEx.

8.1.3. Inria Project Lab: ZEP

The ZEP project addresses the issue of designing tiny computing objects with no battery by combining non-volatile memory (NVRAM), energy harvesting, micro-architecture innovations, compiler optimizations, and static analysis. The main application target is Internet of Things (IoT) where small communicating objects will be composed of this computing part associated to a low-power wake-up radio system. The ZEP project gathers four Inria teams that have a scientific background in architecture, compilation, operating system and low power together with the CEA Lialp and Lisan laboratories of CEA LETI & LIST. The major outcomes of the project will be a prototype harvesting board including NVRAM and the design of a new microprocessor associated with its optimizing compiler and operating system.

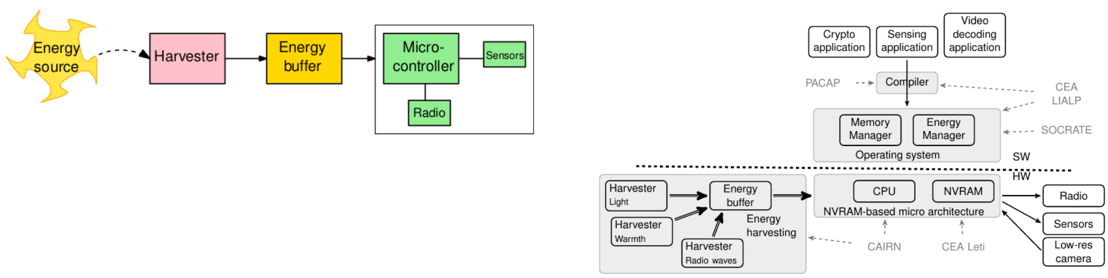

Figure 6. Example of system targeted by the ZEP project on the left, and on the right: the ZEP research program.

The scientific work (in progress) is organized around three fields :

- specific NVRAM-based architecture
- dedicated compiler pass that computes a worst-case energy consumption
- operating system managing NVRAM and energy, ensuring memory consistency across power outages

The project is illustrated by the figure 6, where PACAP, SOCRATE, CORSE, and CAIRN are the teams involved in the project.

Another important goal of the project is to structure the research and innovation that should occur within Inria to prepare the important technological shift brought by NVRAM technologies.

8.1.4. 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).

8.1.5. 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.

8.1.6. 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.

8.1.7. 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.

8.2.2. Collaborations in European Programs, Except FP7 & H2020

Socrate is very active in COST IRACON CA15104: Guillaume Villemaud is National Delegate (Alt.) and FIT/CorteXlab is identify as one of the COST platform: .

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 (Institution - Laboratory - Researcher):

Princeton (United States) - electrical engeneering departement - 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.

8.3.2. Inria International Partners

8.3.2.1. 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.
- **Technical University "Gh. Asachi" of Iasi, Romania**, Department of Electronics, Telecommunications and Information Technology. This recent collaboration has started on topics related on the theoretical aspects of the ultra-low power radio communications. Scientific-in-charge at Inria: Florin Hutu

8.4. International Research Visitors

- 2 month visit of Tarcisio F. Maciel (Federal University of Ceará, Brazil), working with Leonardo Sampaio-Cardoso on Radio Resource Allocation for Multi-User Communications: Background and Initial Perspectives for Joint Research on Resource Allocation & Massive MIMO.
- Visite and Talk of mme. Tarniceriu Technical Univsersity "Gh. Asachi" of Iasi in june.
- Visit and Talk of Mischa Dholer (King's college london) and Visa Koivunen (Aalto University, Finland) for HDR of Claire Goursaud.
- Visit and Talk of Gerhard Kramer (Technical University of Munich) for the PhD defense of Victor Quintero.

8.4.1. Visits to International Teams

8.4.1.1. Sabbatical programme

Samir M. Perlaza is currently on Sabatical year at Princeton University since July 2017.

8.4.2. Internship

- Clarissa Arraes Herculano, INSA Lyon, from Apr 2017 until Aug 2017.
- Romain Fontaine, Inria, from Jun 2017 until Jul 2017
- Fatimazhra Kninech, INSA Lyon, from Mar 2017 until Aug 2017
- Ivan Kolodziejczyk, INSA Lyon, from May 2017 until Jul 2017
- Daniel Krebs, INSA Lyon, from Apr 2017 until Sep 2017
- Thibaud Vial Nokia, from Apr 2017 until Aug 2017.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

- Claire Goursaud co-organized the GDR day on mathematical methods and tools for IoT network modeling.

9.1.2. Scientific Events Selection

9.1.2.1. Chair of Conference Program Committees

Florent de Dinechin was program chair (with Javier Bruguera from ARM) of the 24th IEEE Symposium of Computer Arithmetic. He was co-chair of the track D11 "Reconfigurable Computing" of the Design Automation and Test in Europe (DATE) conference.

9.1.2.2. Member of Conference Program Committees

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

- IEEE Computer Society Annual Symposium on VLSI (ISVLSI) 2017
- Design Automation and Test in Europe (DATE) 2017
- International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM) 2017
- International Conference on Advances in Cognitive Radio (COCORA) 2018.

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

- CROWNCOM2017
- PIMRC 2017
- EUCAP 2017.

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

- 28th IEEE International Conference on Application-specific Systems, Architectures and Processors (ASAP 2017)
- 13th International Symposium on Applied Reconfigurable Computing (ARC 2017)
- Design Automation and Test in Europe (DATE 2017)
- 25th IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM 2017)
- International Conference on Field-Programmable Technology (FPT 2017).

Malcolm Egan was a member of the following technical program committees:

- IEEE Global Communications Conference (GLOBECOM) 2017
- International Conference on Advanced Technologies for Communications (ATC) 2017
- International Conference on Recent Advances on Signal Processing, Telecommunications & Computing (SigTelCom) 2017

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

- IEEE International Global Communications Conference (GLOBECOM 2017) - Cognitive Radio Networks
- IEEE International Symposium on Personnal Indoor and Mobile Radio Communications (PIMRC 2017, track 1)
- IEEE International conference on Communications (ICC 2017, track 1)
- IEEE Wireless Communications and Networking Conference (WCNC 2017)

9.1.3. Journal

9.1.3.1. Member of the Editorial Boards

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

Claire Goursaud is associate editor for ETT and ITL, Wiley.

Jean-Marie Gorce is associate editor for Journal of Wireless Communications and Networking (JWCN), Springer.

9.1.4. Scientific Expertise

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

Guillaume Villemaud is a member of the Delphi Expert Panel on Software Defined Networks (SDN) and Network Functions Virtualisation (NFV).

Jean-Marie Gorce was appointed as scientific expert for Haute école spécialisée de Suisse occidentale and for FNRS (Belgium).

Jean-Marie Gorce is member of the Administration council (Conseil d'admistration) of ESISAR, Valence.

Jean-Marie Gorce was member of the jury for prix de thèse en signal-image de EEA-ISIS-GRETSI 2017.

9.1.5. Invited Talks

Jean-Marie Gorce gave the following invited talks:

- Toward haptic communications for IoT in 5G, in IEEE 5G Greece Summit, July 11$^{\text{th}}$, 2017.
- (Keynote speaker) Toward reliable, reactive and energy efficient bursty multi-user communications at Dependable Wireless Communications and Localization for the IoT workshop organized under the umbrella of the COST Action CA15104 (IRACON), Graz, Austria, September, 12$^{\text{th}}$, 2017.
- Fundamental limits of bursty multi-user communications, in the The Tenth Workshop on Information Theoretic Methods in Science and Engineering, 11-13 september 2017, Paris, France.

9.1.6. Research Administration

Jean-Marie Gorce is Adjoint to Scientific Director of Inria Rhônes-Alpes center.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

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 **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 : **Andrea Bocco**: *Porposition d'une unité de caclul U-NUM pour le calcul scientifique*, ANR Metalibm grant, since 12/2016.

PhD in progress : **Hassan Kallam**: *Topology aided multi-user interference management in wireless network* , Fed4PMR Insavalor project grant, since 01/2017.

PhD in progress : **Anade Akpo Dadja**: *Non assymptotic fundemental limits of impulsive radio communication* , ANR Arburst grant, since 09/2017.

PhD in progress : **Diane Duchemin**: *Distributed coding in dense IoT Network*, ANR Metalibm grant, since 01/2017.

PhD : **Victor Quintero** *Noisy Channel-Output Feedback in the Interference Channel*, École Doctorale EEA, 12/12/2017.

PhD : **Matei Istoan**: *High-performance coarse operators for FPGA-based computing*, ANR Metalibm grant, 6/04/2017.

HdR: Claire Goursaud *Contribution to the uplink PHY/MAC analysis for the IoT and BAN applications*, Doctoral School EEA, 1/12/2017

9.2.3. Juries

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

- Clément le Bas Marcos (Université de Limoges) as jury president,
- Celestin Matte (U. Lyon, dec. 2017) as examiner.

Guillaume Villemaud was a reviewer of Xiwen Jiang's thesis (Eurecom, oct. 2017).

Florent de Dinechin was a member of the jury of the following theses:

- Julie Dumas (Grenoble, dec. 2017) as examiner,
- Gael Deest (Rennes, dec. 2017) as reviewer.

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

- Ahmad M Alam (INSA Rennes, March 2017) as reviewer,
- Fayçal Aït Aoudia (Université de Rennes, Sept 2017) as reviewer,
- Quentin Bodinnier (Centrale-Supelec, Oct 2017) as reviewer,
- Louis-Adrien Dufrene (INSA Rennes, Dec 2017) as examiner,
- Victor Quintero Florez (INSA Lyon, Dec 2017) as co-advisor.

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

- Guillaume Ferré (ENSIB, Bordeaux) as reviewer,
- Matthieu Crussières (INSA Rennes, Nov 2017) as reviewer,
- Claire Goursaud (INSA Lyon, Dec 2017) as examiner.

10. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] C. GOURSAUD. *Contribution to the uplink PHY/MAC analysis for the IOT and BAN applications*, INSA de Lyon (France), December 2017, Habilitation à diriger des recherches, https://hal.archives-ouvertes.fr/tel-01662386

[2] V. QUINTERO. *Noisy Channel-Output Feedback in the Interference Channel*, Université de Lyon, December 2017, https://hal.archives-ouvertes.fr/tel-01667063

Articles in International Peer-Reviewed Journals

[3] Y. FADLALLAH, A. M. TULINO, D. BARONE, G. VETTIGLI, J. LLORCA, J.-M. GORCE. *Coding for Caching in 5G Networks*, in "IEEE Communications Magazine", February 2017, vol. 55, n^{o} 2, pp. 106 - 113 [*DOI :* 10.1109/MCOM.2017.1600449CM], https://hal.inria.fr/hal-01492353

[4] M. M. GOONEWARDENA, S. PERLAZA, A. M. YADAV, W. AJIB. *Generalized Satisfaction Equilibrium for Service-Level Provisioning in Wireless Networks*, in "IEEE Transactions on Communications", 2017, vol. 65, n^{o} 6, pp. 2427 - 2437 [*DOI :* 10.1109/TCOMM.2017.2662701], https://hal.archives-ouvertes.fr/hal-01541234

[5] Y. MO, M.-T. DO, C. GOURSAUD, J.-M. GORCE. *Up-Link Capacity Derivation for Ultra-Narrow-Band IoT Wireless Networks*, in "International Journal of Wireless Information Networks", June 2017, vol. 24, n^{o} 3, pp. 300-316, https://hal.inria.fr/hal-01610466

[6] T. C. MAI, M. EGAN, T. Q. DUONG, M. D. RENZO. *Event Detection in Molecular Communication Networks with Anomalous Diffusion*, in "IEEE Communications Letters", February 2017, https://hal.archives-ouvertes.fr/hal-01671181

[7] A. TASSI, M. EGAN, R. PIECHOCKI, A. NIX. *Modeling and Design of Millimeter-Wave Networks for Highway Vehicular Communication*, in "IEEE Transactions on Vehicular Technology", August 2017, https://hal.archives-ouvertes.fr/hal-01671182

[8] F. UGURDAG, F. DE DINECHIN, Y. S. GENER, S. GÖREN, L.-S. DIDIER. *Hardware division by small integer constants*, in "IEEE Transactions on Computers", May 2017 [*DOI :* 10.1109/TC.2017.2707488], https://hal.inria.fr/hal-01402252

[9] C. YANG, J. LI, P. SEMASINGHE, E. HOSSAIN, S. PERLAZA, Z. HAN. *Distributed Interference and Energy-Aware Power Control for Ultra-Dense D2D Networks: A Mean Field Game*, in "IEEE Transactions on Wireless Communications", February 2017, vol. 16, n^{o} 2, pp. 1205 - 1217 [*DOI :* 10.1109/TWC.2016.2641959], https://hal.archives-ouvertes.fr/hal-01432507

Invited Conferences

[10] J.-M. GORCE, Y. FADLALLAH, J.-M. KÉLIF, H. VINCENT POOR, A. GATI. *Fundamental Limits of a Dense IoT Cell in the Uplink*, in "WiOpt 2017 - 15th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks", Paris, France, Modeling and Optimization in Mobile, Ad

Hoc, and Wireless Networks (WiOpt), 2017 15th International Symposium on, IEEE, May 2017, pp. 1-6 [*DOI :* 10.23919/WIOPT.2017.7959936], https://hal.inria.fr/hal-01658931

[11] J.-M. GORCE. *Toward haptic communications for IoT in 5G*, in "IEEE 5G Thessaloniki Summit", Thessalonic, Greece, July 2017, https://hal.inria.fr/hal-01671599

[12] J.-M. GORCE. *Toward reliable, reactive and energy efficient bursty multi-user communications*, in "Dependable Wireless Communications and Localization for the IoT", Graz, Austria, September 2017, https://hal.inria.fr/hal-01671643

[13] J.-M. GORCE, P. MARY, J.-M. KÉLIF. *Towards fundamental limits of bursty multi-user communications in wireless networks*, in "WITSME 2017 – The Tenth Workshop on Information Theoretic Methods in Science and Engineering", Paris, France, P. JACQUET, J. LEPPÄ-AHO, T. ROOS (editors), Proceedings of the Tenth Workshop on Information Theoretic Methods in Science and Engineering, Paris, France, September 11-13, 2017, September 2017, vol. Publication series B, Report B-2017-3, https://hal.inria.fr/hal-01658933

[14] Y. MO, C. GOURSAUD, J.-M. GORCE. *Performance théorique de réseaux IoT basés sur UNB avec Path Loss*, in "GRETSI2017", Juan-les-Pins, France, September 2017, https://hal.inria.fr/hal-01610525

[15] V. QUINTERO, S. PERLAZA, J.-M. M. GORCE. *On the Efficiency of Nash Equilibria in the Interference Channel with Noisy Feedback*, in "European Wireless 2017. Workshop: COCOA – COmpetitive and COoperative Approaches for 5G networks", Dresden, Germany, May 2017, https://hal.archives-ouvertes.fr/hal-01492979

[16] L. SAMPAIO CARDOSO, O. OUBEJJA, G. VILLEMAUD, T. RISSET, J. M. GORCE. *Reliable and Reproducible Radio Experiments in FIT/CorteXlab SDR testbed: Initial Findings*, in "Crowncom", Lisbon, Portugal, September 2017, https://hal.inria.fr/hal-01598491

International Conferences with Proceedings

[17] G. BERTHOU, T. DELIZY, K. MARQUET, T. RISSET, G. SALAGNAC. *Peripheral state persistence for transiently-powered systems*, in "IoENT 2017 - 1st Workshop on Internet of Energy Neutral Things", Geneva, Switzerland, June 2017 [*DOI :* 10.1109/GIOTS.2017.8016243], https://hal.inria.fr/hal-01609277

[18] A. BOCCO, Y. DURAND, F. DE DINECHIN. *Hardware support for UNUM floating point arithmetic*, in "13th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME)", Taormina, Italy, June 2017, pp. 93 - 96 [*DOI :* 10.1109/PRIME.2017.7974115], https://hal.inria.fr/hal-01618698

[19] A. DUQUE, R. STANICA, H. RIVANO, C. GOURSAUD, A. DESPORTES. *Poster: Insights into RGB-LED to Smartphone Communication*, in "International Conference on Embedded Wireless Systems and Networks (EWSN)", Madrid, Spain, February 2018, https://hal.inria.fr/hal-01683605

[20] M. EGAN, L. CLAVIER, M. DE FREITAS, L. DORVILLE, J.-M. GORCE, A. SAVARD. *Wireless Communication in Dynamic Interference*, in "IEEE Global Communications Conference (GLOBECOM)", Singapore, Singapore, December 2017, https://hal.archives-ouvertes.fr/hal-01671180

[21] M. EGAN, J.-M. GORCE, L. CARDOSO. *Fast Initialization of Cognitive Radio Systems*, in "IEEE International Workshop on Signal Processing Advances in Wireless Communications", Sapporo, Japan, July 2017, https://hal.archives-ouvertes.fr/hal-01523023

[22] M. EGAN, S. M. PERLAZA, V. KUNGURTSEV. *Capacity Sensitivity in Additive Non-Gaussian Noise Channels*, in "IEEE International Symposium on Information Theory (ISIT)", Aachen, Germany, June 2017, https://hal.archives-ouvertes.fr/hal-01522950

[23] M. ISTOAN, F. DE DINECHIN. *Automating the pipeline of arithmetic datapaths*, in "Design, Automation & Test in Europe Conference & Exhibition (DATE 2017)", Lausanne, Switzerland, March 2017, https://hal.inria.fr/hal-01373937

[24] J.-M. KELIF, J.-M. GORCE, A. GATI. *Performance and Energy in Green Superposition Coding Wireless Networks: An Analytical Model*, in "GLOBECOM 2017 - IEEE Global Hub: Connecting East and West", Singapour, Singapore, December 2017, pp. 1-6, https://hal.inria.fr/hal-01658932

[25] N. KHALFET, S. PERLAZA. *Simultaneous Information and Energy Transmission in Gaussian Interference Channels with Feedback*, in "2017 - 55th Annual Allerton Conference on Communication, Control, and Computing", Urbana-Champaign-Illinois, United States, October 2017, https://hal.archives-ouvertes.fr/hal-01561756

[26] Y. MO, C. GOURSAUD, J.-M. GORCE. *On the benefits of successive interference cancellation for ultra narrow band networks : Theory and application to IoT*, in "IEEE ICC 2017 - IEEE International Conference on Communications", Paris, France, May 2017, pp. 1 - 6 [*DOI :* 10.1109/ICC.2017.7996900], https://hal.inria.fr/hal-01610465

[27] L. MOREL, M. SELVA, K. MARQUET, C. SAYSSET, T. RISSET. *CalMAR -a Multi-Application Dataflow Runtime*, in "Thirteenth ACM International Conference on Embedded Software 2017, EMSOFT'17", Seoul, South Korea, October 2017 [*DOI :* 10.1145/3125503.3125562], https://hal.inria.fr/hal-01631691

[28] M. N. OCHOA, A. GUIZAR, M. MAMAN, A. DUDA. *Evaluating LoRa Energy Efficiency for Adaptive Networks: From Star to Mesh Topologies*, in "WiMob 2017 - 13th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications", Rome, Italy, WiMob 2017 - 13th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, October 2017, https://hal.archives-ouvertes.fr/hal-01654542

[29] V. QUINTERO, S. PERLAZA, J.-M. M. GORCE, H. VINCENT POOR. *Nash Region of the Linear Deterministic Interference Channel with Noisy Output Feedback*, in "IEEE International Symposium on Information Theory (ISIT)", Aachen, Germany, June 2017, vol. Proceedings of the IEEE International Symposium on Information Theory (ISIT), https://hal.archives-ouvertes.fr/hal-01520799

[30] R. ROUSSEAU, F. D. HUTU, G. VILLEMAUD. *Analysis of an energy harvesting circuit in the presence of complex waveforms*, in "Journées Scientifiques de l'URSI: "Radiosciences au service de l'humanité"", Sophia-Antipolis, France, February 2017, https://hal.archives-ouvertes.fr/hal-01530695

[31] A. A. SAED, S.-W. HO, J.-M. GORCE, C. S. CHEN. *Minimal Noise Variance Decoder for Uncoordinated Multiple Access in VLC*, in "IEEE Vehicular Technology Conference (VTC-Spring)", Sydney, Australia, June 2017, https://hal.inria.fr/hal-01480640

[32] Y. UGUEN, F. DE DINECHIN, S. DERRIEN. *Bridging High-Level Synthesis and Application-Specific Arithmetic: The Case Study of Floating-Point Summations*, in "27th International Conference on Field-Programmable Logic and Applications (FPL)", Gent, Belgium, IEEE, September 2017, 8 p. , https://hal.inria.fr/hal-01373954

[33] A. UNSAL, J.-M. GORCE. *$\kappa\beta$ Bounds for Gaussian Broadcast Channels with Finite Blocklength*, in "GRETSI 2017", Juan-les-Pins / Antibes, France, September 2017, https://hal.archives-ouvertes.fr/hal-01643256

[34] A. UNSAL, J.-M. GORCE. *The Dispersion of Superposition Coding for Gaussian Broadcast Channels*, in "IEEE Information Theory Workshop 2017", Kaohsiung, Taiwan, November 2017, https://hal.archives-ouvertes.fr/hal-01643260

[35] L. ZHOU, F. D. HUTU, G. VILLEMAUD, Y. DUROC. *Simulation framework for performance evaluation of passive RFID tag-to-tag communication*, in "EUCAP", Paris, France, IEEE, March 2017 [*DOI :* 10.23919/EUCAP.2017.7928387], https://hal.archives-ouvertes.fr/hal-01526333

National Conferences with Proceedings

[36] L. ZHOU, F. D. HUTU, G. VILLEMAUD, Y. DUROC. *Evaluation des performances des communications tag-to-tag : modélisation et outil de simulation*, in "Journées Nationales Microondes", Sain-Malo, France, May 2017, https://hal.archives-ouvertes.fr/hal-01526328

Conferences without Proceedings

[37] G. BERTHOU, T. DELIZY, K. MARQUET, G. SALAGNAC, T. RISSET. *Sytare: Persistence de l'état des périphériques pour les systèmes à alimentation intermittente*, in "Compas'2017 - Conférence d'informatique en Parallélisme, Architecture et Système", Sophia-Antipolis, France, June 2017, https://hal.inria.fr/hal-01609303

[38] K. SUN, I. ESNAOLA, S. PERLAZA, H. VINCENT POOR. *Information-Theoretic Attacks in the Smart Grid*, in "IEEE International Conference on Smart Grid Communications", Dresden, Germany, October 2017, https://hal.archives-ouvertes.fr/hal-01574532

Research Reports

[39] G. BERTHOU, T. DELIZY, K. MARQUET, T. RISSET, G. SALAGNAC. *Peripheral State Persistence For Transiently Powered Systems*, Inria, February 2017, n° RR-9018, https://hal.inria.fr/hal-01460699

[40] M. EGAN, S. M. PERLAZA, V. KUNGURTSEV. *Capacity Sensitivity in Continuous Channels*, Inria Grenoble - Rhône-Alpes ; Czech Technical University in Prague, February 2017, n° RR-9012, https://hal.archives-ouvertes.fr/hal-01455640

[41] R. FONTAINE, L. MOREL, L. GONNORD. *Combining dataflow programming and polyhedral optimization, a case study*, Inria Rhône-Alpes ; CITI - CITI Centre of Innovation in Telecommunications and Integration of services ; LIP - ENS Lyon, July 2017, n° RT-0490, 40 p. , https://hal.archives-ouvertes.fr/hal-01572439

[42] N. KHALFET, S. PERLAZA. *Simultaneous Information and Energy Transmission in the Interference Channel*, Inria - Research Centre Grenoble – Rhône-Alpes, November 2017, n° RR-9102, pp. 1-51, https://hal.archives-ouvertes.fr/hal-01629051

[43] V. QUINTERO, S. PERLAZA, J.-M. M. GORCE, H. VINCENT POOR. *Decentralized Interference Channels with Noisy Output Feedback*, Inria - Research Centre Grenoble – Rhône-Alpes, February 2017, n° RR-9011, 37 p. , https://hal.archives-ouvertes.fr/hal-01462248

Scientific Popularization

[44] V. QUINTERO, S. M. PERLAZA, J.-M. GORCE. *Région d' η-Équilibre de Nash du Canal Linéaire Déterministe à Interférences avec Rétroalimentation Dégradée*, in "Colloque Gretsi", Juan-les-Pins, France, September 2017, https://hal.archives-ouvertes.fr/hal-01588107

Other Publications

[45] M. EGAN, T. C. MAI, T. Q. DUONG, M. DI RENZO. *Coexistence in Molecular Communications*, November 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01650966

[46] S.-I. FILIP, M. ISTOAN, F. DE DINECHIN, N. BRISEBARRE. *Automatic generation of hardware FIR filters from a frequency domain specification*, May 2017, working paper or preprint, https://hal.inria.fr/hal-01308377

[47] C. GENES, I. ESNAOLA, S. PERLAZA, L. F. OCHOA, D. COCA. *Robust Recovery of Missing Data in Electricity Distribution Systems*, August 2017, This journal paper was submitted to IEEE Transactions on Smart Grid, https://hal.archives-ouvertes.fr/hal-01574531

[48] N. KHALFET, S. PERLAZA. *Simultaneous Information and Energy Transmission in Gaussian Interference Channels*, September 2017, This paper was submitted to the 2018 International Zurich Seminar on Information and Communication, https://hal.archives-ouvertes.fr/hal-01561744

[49] Y. LIAO, W. DU, M. KARSAI, C. SARRAUTE, M. MINNONI, E. FLEURY. *Prepaid or Postpaid? That is the question. Novel Methods of Subscription Type Prediction in Mobile Phone Services*, October 2017, https://arxiv.org/abs/1706.10172 - 17 pages, 4 figures; chapter to appear in Lecture Notes in Social Networks; Eds. R. Alhajj, U. Glässer, Springer Nature (2017), https://hal.inria.fr/hal-01610931

[50] Y. UGUEN, F. DE DINECHIN, S. DERRIEN. *A high-level synthesis approach optimizing accumulations in floating-point programs using custom formats and operators*, January 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01498357

[51] Y. UGUEN, F. DE DINECHIN, S. DERRIEN. *High-Level Synthesis Using Application-Specific Arithmetic: A Case Study*, April 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01502644

[52] Y. UGUEN, F. DE DINECHIN. *Design-space exploration for the Kulisch accumulator* , March 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01488916

[53] A. VOLKOVA, M. ISTOAN, F. DE DINECHIN, T. HILAIRE. *Towards Hardware IIR Filters Computing Just Right: Direct Form I Case Study*, December 2017, working paper or preprint, http://hal.upmc.fr/hal-01561052

References in notes

[54] I. AKYILDIZ, W.-Y. LEE, M. VURAN, S. MOHANTY. *A survey on spectrum management in cognitive radio networks*, in "Communications Magazine, IEEE", April 2008, vol. 46, n^{o} 4, pp. 40 -48

[55] K. BIESECKER, J. DOBIAC, N. FEKADU, M. JONES, C. KAIN, K. RAMAN. *Software Defined Radio Roadmap*, 2008, Noblis Technical Report, for National Institute of Justice, USA

[56] EQUIPEX. *Future internet of things*, 2011, http://fit-equipex.fr/

[57] JOINT PROGRAM EXECUTIVE OFFICE (JPEO), JOINT TACTICAL RADIO SYSTEM (JTRS). *Software Communications Architecture Specification*, 2006, JTRS Standards, version 2.2.2

[58] J. S. MEENA, S. M. SZE, U. CHAND, T.-Y. TSENG. *Overview of emerging nonvolatile memory technologies*, in "Nanoscale Research Letters", 2014, vol. 9, 526 p.

[59] J. MITOLA III. *The software radio*, in "IEEE National Telesystems Conference", 1992

[60] J. MITOLA III. *Software radios: Survey, critical evaluation and future directions*, in "Aerospace and Electronic Systems Magazine, IEEE", Apr 1993, vol. 8, n^o 4, pp. 25-36

[61] P. STEENKISTE, D. SICKER, G. MINDEN, D. RAYCHAUDHURI. *Future Directions in Cognitive Radio Network Research*, 2009, NSF Workshop Report

[62] M. WEISER. *The computer for the 21st Century*, in "Pervasive Computing, IEEE", January 2002, vol. 99, n^o 1, pp. 19 -25

[63] Q. ZHANG, F. H. P. FITZEK, V. B. IVERSEN. *Cognitive radio MAC protocol for WLAN*, in "Proceedings of the IEEE 19th International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC", 2008, pp. 1-6