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Activity Report 2018

Project-Team SOCRATE

Software and Cognitive radio for telecommunications

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

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Networks and Telecommunications

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Project-Team SOCRATE

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

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A1.1.10. - Reconfigurable architectures
A1.1.12. - Non-conventional architectures
A1.2.5. - Internet of things
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Other Research Topics and Application Domains:

B6.2. - Network technologies
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B6.4. - Internet of things
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2. Overall Objectives

2.1. Introduction

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

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

These two facts, obsolescence of current radio networking rules on one hand, and saturation of the radio frequency band on the other hand, are the main premises for the advent of a new era of radio networking that will be characterized by self-adaptive mechanisms. These mechanisms will rely on software radio Åtechnologies, 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.* [56]

From a social perspective, pervasive communications and ambient networking are becoming part of more and more facets of our daily life. Probably the most popular usage is mobile Internet access, which is made possible by numerous access technologies, e.g. cellular mobile networks, WiFi, Bluetooth, etc. The access technology itself is becoming *transparent for the end user*, who does not care about how to access the network but is only interested in the services available and in the quality of this service.

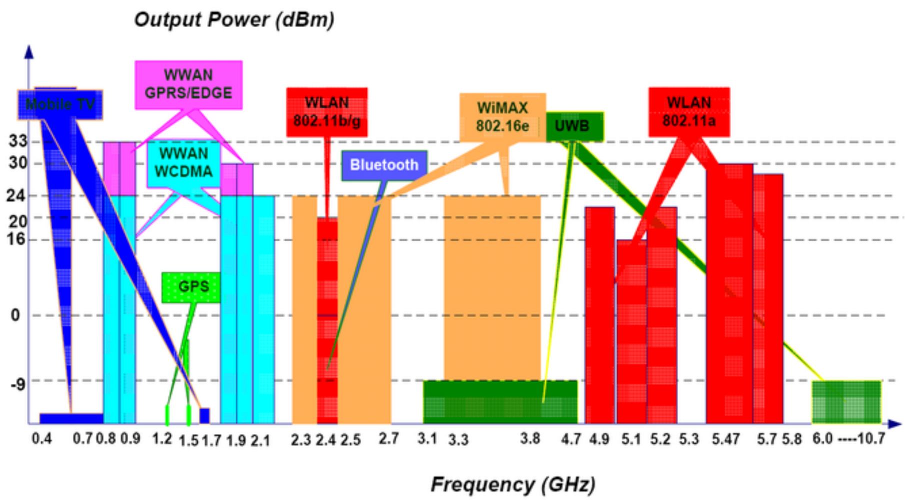

Figure 1. The most recent standards for wireless communications are developed in the UHF and VHF bands. These bands are mostly saturated (source: WPAN/WLAN/WWAN Multi-Radio Coexistence, IEEE 802 Plenary, Atlanta, USA, Nov.2007)

Beyond simple Internet access, many other applications and services are built on the basis of pervasive connectivity, for which the communication is just a mean, and not a finality. Thus, the wireless link is expected to even be *invisible to the end user* and constitutes the first element of the Future Internet of Things [54], 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 [43]. 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 [51], [52]. 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 [43]. 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 [51], [44].

2.2.1. SDR Technology

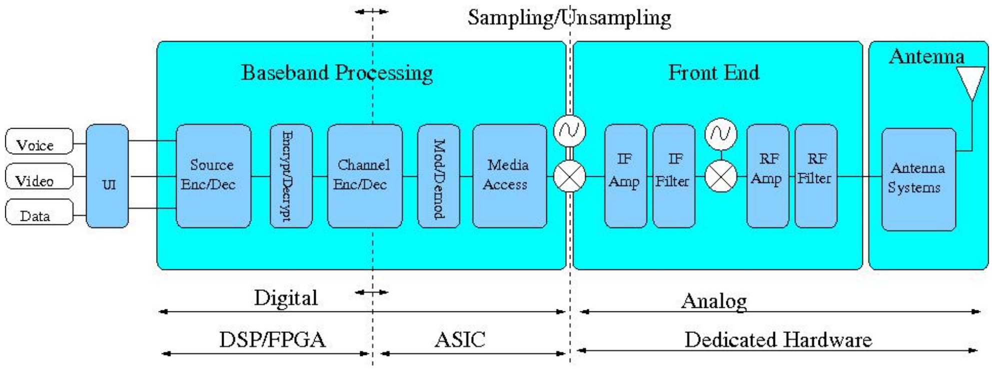

Figure 2. Radio Block Diagram, highlighting separation between digital and analog parts, as well as programmable, configurable and fixed hardware parts.

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" [53]. 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 [46].

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 [49] 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*. The first one is entitled "Flexible Radio Front-End" and will study new radio front-end research challenges brought up by the arrival of MIMO technologies, and reconfigurable front-ends. The second one, entitled "Multi-user communication", will study how to couple the self-adaptive and distributed signal processing algorithms to cope with the multi-scale dynamics found in cognitive radio systems. The last research axis, entitled "Software Radio Programming Models" is dedicated to embedded software issues related to programming the physical protocols layer on these software radio machines. Figure 3 illustrates the three regions of a transceiver corresponding to the three Socrate axes.

3.2. Flexible Radio Front-End

Participants: Guillaume Villemaud, Florin Hutu.

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

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

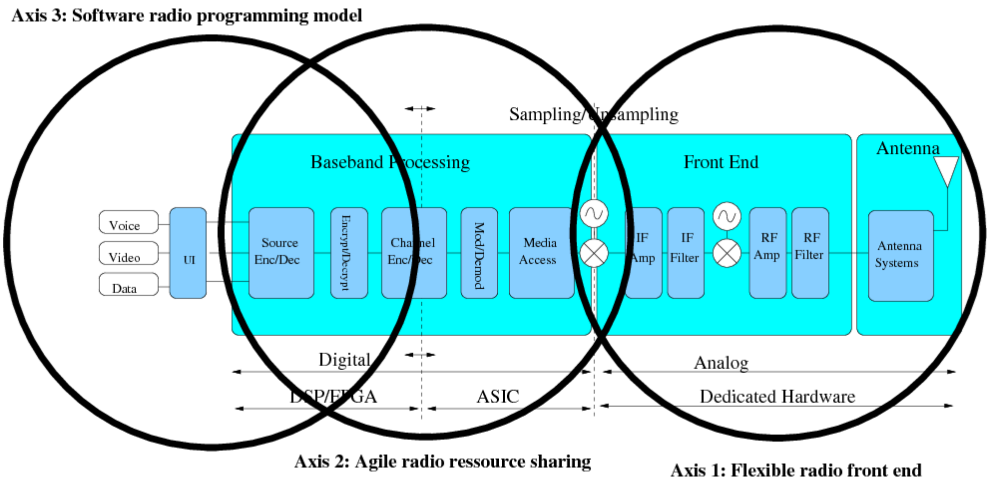

Figure 3. Center of interest for each of the three Socrate research axes with respect to a generic software radio terminal.

3.3. Multi-User Communications

Participants: Jean Marie Gorce, Claire Goursaud, 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, 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. Evolution of the Socrate team

In 2018 the Socrate team has decided to split in two teams: the Maracas team will consist of the activities of Socrate Axis 2 and be directed by Jean-Marie Gorce, and the Socrate team which will consist in the Axis 1 and 3 of the current version of Socrate. This change is explicit since september 2018 as the Maracas team is created.

4. Highlights of the Year

4.1. Highlights of the Year

4.1.1. Various

Two new workshop organized by the team in relation with CorteXlab:

- First French GNU Radio days: https://gnuradio-fr-18.sciencesconf.org/
- ISP-IoT : First Winter School on Information Theory and Signal Processing for Internet of Things : https://isp-iot.sciencesconf.org

4.1.2. Awards

The PhD of Victor Quintero (former PhD in Socrate) received the best PhD award in the area of digital society in Nov 2018.

Samir M. Perlaza is Visiting Research Collaborator (Honorific Position) Oct. 2018; Term 2018 - 2019. Department of Electrical Engineering, Princeton University

Samir M. Perlaza has been awarded a "Make our Planet Great Again" Fellowship, Sep. 2018 by Embassy of France in the United States of America and Thomas Jefferson Foundation in New York, NY.

The article *Karatsuba with Rectangular Multipliers for FPGAs* , presented by Florent de Dinechin, obtained the Best Paper Award of the Arith 2018 conference in Amherst, MA.

BEST PAPER AWARD:

[17]
M. KUMM, O. GUSTAFSSON, F. DE DINECHIN, J. KAPPAUF, P. ZIPF. *Karatsuba with Rectangular Multipliers for FPGAs*, in "ARITH 2018 - 25th IEEE International Symposium on Computer Arithmetic", Amherst, United States, IEEE, June 2018, pp. 13-20, Best paper award [*DOI :* 10.1109/ARITH.2018.8464809], https://hal.inria.fr/hal-01773447

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.
NEWS OF THE YEAR: FloPoCo has been enhanced in 2019 with a last-bit accurate IIR filter generator and a generator of parallel FFT cores, among others.

- Participants: Florent Dupont De Dinechin and Luc Forget
- 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: Tristan Delizy, Gautier Berthou, Guillaume Salagnac, Kevin Marquet and Tanguy Risset
- Contact: Guillaume Salagnac
- Publication: Peripheral State Persistence For Transiently Powered Systems
- URL: https://hal.inria.fr/hal-01460699

6. New Results

6.1. Multi-User Communications

Activities in axis 2 primarily focus on communicating multi-user systems. They represent the core of the research activity that will be pursued in Maracas team.

The first pillar of our research concerns the evaluation of fundamental limits of wireless systems (e.g. capacity) often express as a fundamental tradeoff : energy efficiency - spectral efficiency tradeoff, rate versus reliability, information versus energy transfert,... Our work relies mostly on information theory, signal processing, estimation theory and game theory.

The second pillar concerns the evaluation of real systems and their performance is confronted to the above mentioned fundamental limits. These activities rely on strong collaborations with industry (Nokia, Orange, SigFox, Sequans, SPIE-ICS,...) We also manage the FIT/CorteXlab testbed offering a remote access to a worldwide unique platform.

Beyond these two pillars, we also explore new research areas where our background is relevant. These prospective activities are performed with external collaborations and prepare the future activity of Maracas team. This year we explored molecular communications (supported by an Inria exploratory project), smart grids in collaboration with Sheffield, VLC in association with Agora team or Privacy preservation in collaboration with Privatics team.

6.1.1. Fundamental limits in communications

6.1.1.1. Variations on point to point capacity and related tools

In [31] discrete approximations of the capacity are introduced where the input distribution is constrained to be discrete in addition to any other constraints on the input. For point-to-point memoryless additive noise channels, rates of convergence to the capacity of the original channel are established for a wide range of channels for which the capacity is finite. These results are obtained by viewing discrete approximations as a capacity sensitivity problem, where capacity losses are studied when there are perturbations in any of the parameters describing the channel. In particular, it is shown that the discrete approximation converges arbitrarily close to the channel capacity at rate $O(\Delta)$, where Δ is the discretization level of the approximation. Examples of channels where this rate of convergence holds are also given, including additive Cauchy and inverse Gaussian noise channels.

In [30] the properties of finite frames are explored. Finite frames are sequences of vectors in finite dimensional Hilbert spaces that play a key role in signal processing and coding theory. We studied the class of tight unit-norm frames for $\mathbb{C}^d$ that also form regular schemes, called tight regular schemes (TRS). Many common frames that arise in applications such as equiangular tight frames and mutually unbiased bases fall in this class. We investigate characteristic properties of TRSs and prove that for many constructions, they are intimately connected to weighted 1-designs—arising from quadrature rules for integrals over spheres in $\mathbb{C}^d$ with weights dependent on the Voronoi regions of each frame element.

6.1.1.2. Interference channel with feedback

The interference channel is a well-known model used to represent simultaneous transmissions in a wireless environment. In the framework of Victor Quintero's PhD, we explored the performance of this model with noisy feedbacks.

In [35], an achievable η-Nash equilibrium (η-NE) region for the two-user Gaussian interference channel with noisy channel-output feedback is presented for all $\eta \geq 1$. This result is obtained in the scenario in which each transmitter-receiver pair chooses its own transmit-receive configuration in order to maximize its own individual information transmission rate. At an η-NE, any unilateral deviation by either of the pairs does not increase the corresponding individual rate by more than η bits per channel use.

In [6], the capacity region of the linear deterministic interference channel with noisy channel-output feedback (LD-IC-NF) is fully characterized. The proof of achievability is based on random coding arguments and rate splitting; block-Markov superposition coding; and backward decoding. The proof of converse reuses some of the existing outer bounds and includes new ones obtained using genie-aided models. Following the insight gained from the analysis of the LD-IC-NF, an achievability region and a converse region for the two-user Gaussian interference channel with noisy channel-output feedback (GIC-NF) are presented. Finally, the achievability region and the converse region are proven to approximate the capacity region of the G-IC-NF to within 4.4 bits.

6.1.1.3. Wiretap channel

The Wiretap channel allows to address the secrecy constraint in an information theory framework. In [13], an analysis of an input distribution that achieves the secrecy capacity of a general degraded additive noise wiretap channel is presented. In particular, using convex optimization methods, an input distribution that achieves the secrecy capacity is characterized by conditions expressed in terms of integral equations. The new conditions are used to study the structure of the optimal input distribution for three different additive noise cases: vector Gaussian; scalar Cauchy; and scalar exponential.

6.1.1.4. Simultaneous Information and Energy Transmission

Simultaneous information and energy transmission (SIET) is an active research problem and aims at providing energy and information simultaneously from transmitters to receivers. We explore the optimal trade-offs in different settings.

In [34], a non-asymptotic analysis of the fundamental limits of simultaneous energy and information transmission (SEIT) is presented. The notion of information-capacity region, i.e., the largest set of simultaneously achievable information and energy rates, is revisited in a context in which transmissions occur within a finite number of channel uses and strictly positive error decoding probability and energy shortage probability are tolerated. The focus is on the case of one transmitter, one information receiver and one energy harvester communicating through binary symmetric memoryless channels. In this case, the information-capacity region is approximated and the trade-off between information rate and energy rate is thoroughly studied.

In [5], the fundamental limits of simultaneous information and energy transmission (SIET) in the two-user Gaussian interference channel (G-IC) with and without perfect channel-output feedback are approximated by two regions in each case, i.e., an achievable region and a converse region. When the energy transmission rate is normalized by the maximum energy rate the approximation is within a constat gap. In the proof of achievability, the key idea is the use of power-splitting between two signal components: an information-carrying component and a no-information component. The construction of the former is based on random coding arguments, whereas the latter consists in a deterministic sequence known by all transmitters and receivers. The proof of the converse is obtained via cut-set bounds, genie-aided channel models, Fano's inequality and some concentration inequalities considering that channel inputs might have a positive mean. Finally, the energy transmission enhancement due to feedback is quantified and it is shown that feedback can at most double the energy transmission rate at high signal to noise ratios.

6.1.1.5. Modeling Interference in Large-Scale Uplink SCMA

Massive connectivity is a fundamental challenge for IoT, as discussed in the next section from a practical perspective. From a theoretical perspective, we propose to relax the assumption of Gaussian interference.

Fast varying active transmitter sets with very short length transmissions arise in communications for the Internet of Things. As a consequence, the interference is dynamic, leading to non-Gaussian statistics. At the same time, the very high density of devices is motivating non-orthogonal multiple access (NOMA) techniques, such as sparse code multiple access (SCMA). In [2], we study the statistics of the dynamic interference from devices using SCMA. In particular, we show that the interference is $\alpha-$stable with non-trivial dependence structure for large scale networks modeled via Poisson point processes. Moreover, the interference on each frequency band is shown to be sub-Gaussian $\alpha-$stable in the special case of disjoint SCMA codebooks. We investigate the impact of the $\alpha-$stable interference on achievable rates and on the optimal density of devices. Our analysis suggests that ultra dense networks are desirable even with $\alpha-$stable interference.

This contribution is a good introduction of the next section where the performance of IoT access techniques are evaluated.

6.1.1.6. General Massive Machine Type Communications Uplink

Non Orthogonal Multiple Access (NOMA) is expected to play an important role for IoT networks, allowing to reduce signaling overheads and to maximize the capacity of dense networks with multiple packets simultaneous transmission. In the uplink, NOMA can improve significantly the performance of an ALOHA random access if the receiver implements a multiuser detection algorithm. In [11], we compared the performance of a code domain NOMA with a classical ALOHA protocol, through simulations. The code domain NOMA uses random Gaussian codes at the transmitters and exploits compressive sensing at the receiver to maximize users detection and to minimize symbol error rates.

As the number of machine type communications increases at an exponential rate, new solutions have to be found in order to deal with the uplink traffic. At the same time, new types of Base Stations (BS) that use a high number of antennas are being designed, and their beamforming capabilities can help to separate signals that have different angles of arrivals. In [15], we consider a network where a BS serves a high number of nodes that lacks a receive chain, and we analyze the evolution of the outage probability as a function of the number of antennas at the BS. We then study the effect of an angle offset between the main beam and the desired node's direction in order to provide realistic results in a beam-switching scenario.

6.1.1.7. Multiple Base Stations Diversity for UNB Systems

In the framework of the long-term collaboration with Sigfox, the PhD of Yuqi Mo defended mast December, explored the performance of Ultra Narrow Band (UNB) with a focus on sophisticated signal processing techniques such as multi-BS processing or successive interference cancellation (SIC). UNB (Ultra Narrow Band) is one of the technologies dedicated to low-power wide-area communication for IoT, currently exploited by SigFox

In [33], [18], the specificity of UNB is the Aloha-type channel access scheme, asynchronous in both time and frequency domain. This randomness can cause partial spectral interference. In this paper, we take advantage of the spatial diversity of multiple base stations to improve the UNB performance, by using selection combining. In the presence of pathloss and spectral randomness of UNB, the channels are considered correlated. A theoretical analysis of outage probability is demonstrated by considering this correlation, for the case of 2 base stations. This methodology of probability computing can be extended to K BSs. The diversity of multiple receivers is proved to be beneficial in enhancing the performance of UNB networks. This gain is shown to be related to the density of the base stations, as well as the distance between each of them. In [8], we propose to apply signal combining and interference cancellation technologies across multiple base stations in UNB networks, in order to take advantage of their spatial diversity. We evaluate and compare the performance enhancement of each technology, compared to single BS case. These technologies exploiting multi-BS diversity are proved to be significantly beneficial in improving UNB networks' scalability. We can gain until 28 times better performance with one iteration global SIC. We highlight that these results provide us a choice among the technologies according to the improvement needs and the implementation complexity.

6.1.2. Contributions in other application fields

6.1.2.1. 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 [4], 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. In [29], we develop a general framework for the coexistence problem by drawing an analogy to the cognitive radio problem in wireless communication systems. For the particularly promising underlay strategy, we propose a formalization and outline key consequences.

Another key challenge in nanonetworking is to develop a means of coordinating a large number of nanoscale devices. Devices in molecular communication systems—once information molecules are released— are typically viewed as passive, not reacting chemically with the information molecules. While this is an accurate model in diffusion-limited links, it is not the only scenario. In particular, the dynamics of molecular communication systems are more generally governed by reaction-diffusion, where the reaction dynamics can also dominate. This leads to the notion of reaction-limited molecular communication systems, where the concentration profiles of information molecules and other chemical species depends largely on reaction kinetics. In this regime, the system can be approximated by a chemical reaction network. In [14], we exploit this observation to design new protocols for both point-to-point links with feedback and networks for event detection. In particular, using connections between consensus and advection theory and reaction networks lead to simple characterizations of equilibrium concentrations, which yield simple—but accurate— design rules even for networks with a large number of devices.

6.1.2.2. Smart Grids

Smart grids is another application field where information theory and signal processing can be useful. During 2018, we addressed security issues. In [41], random attacks that jointly minimize the amount of information acquired by the operator about the state of the grid and the probability of attack detection are presented. The attacks minimize the information acquired by the operator by minimizing the mutual information between the observations and the state variables describing the grid. Simultaneously, the attacker aims to minimize the probability of attack detection by minimizing the Kullback-Leibler (KL) divergence between the distribution when the attack is present and the distribution under normal operation. The resulting cost function is the weighted sum of the mutual information and the KL divergence mentioned above. The trade-off between the probability of attack detection and the reduction of mutual information is governed by the weighting parameter on the KL divergence term in the cost function. The probability of attack detection is evaluated as a function of the weighting parameter. A sufficient condition on the weighting parameter is given for achieving an arbitrarily small probability of attack detection. The attack performance is numerically assessed on the IEEE 30-Bus and 118-Bus test systems.

6.1.2.3. Privacy and tracking

In a joint work with Privatics team, we presented in [40] the analysis of an Ultrasound-based tracking application. By analyzing several mobile applications along with the network communication and sample of the original audio signal, we were able to reverse engineer the ultrasonic communications and some other elements of the system. Based on those finding we show how arbitrary ultrasonic signal can be generated and how to perform jamming. Finally we analyze a real world deployment and discuss privacy implications.

6.1.2.4. VLC

In a joint work with Agora, we present in [12] our efforts to design a communication system between an ordinary RGB light emitting diode and a smart-phone. This work in progress presents our preliminary findings obtained investigating this poorly known and unusual channel. We give engineering insights on driving an RGB light emitting diode for camera communication and discuss remaining challenges. Finally, we propose possible solutions to cope with these issues that are blockers for a user ready implementation.

6.1.2.5. Intelligent Transport

On-demand transport has been disrupted by Uber and other providers, which are challenging the traditional approach adopted by taxi services. Instead of using fixed passenger pricing and driver payments, there is now the possibility of adaptation to changes in demand and supply. Properly designed, this new approach can lead to desirable tradeoffs between passenger prices, individual driver profits and provider revenue. However, pricing and allocations - known as mechanisms - are challenging problems falling in the intersection of economics and computer science. In [3], we develop a general framework to classify mechanisms in on-demand transport. Moreover, we show that data is key to optimizing each mechanism and analyze a dataset provided by a real-world on-demand transport provider. This analysis provides valuable new insights into efficient pricing and allocation in on-demand transport.

6.2. Flexible Radio Front-End

Activities in this axis could globally be divided in two main topics: low-power wireless sensors (with applications in wearable devices, guided propagation for ventilation systems, and tag-to-tag RFID), and optimization of waveforms (for wake-up radio receivers and wireless power transfer).

6.2.1. Low-Power WSN

Wearable sensors for health monitoring can enable the early detection of various symptoms, and hence rapid remedial actions may be undertaken. In particular, the monitoring of cardiac events by using such wearable sensors can provide real-time and more relevant diagnosis of cardiac arrhythmia than classical solutions. However, such devices usually use batteries, which require regular recharging to ensure long-term measurements. In the framework of a local collaborative project, we therefore designed and evaluated a connected sensor for the ambulatory monitoring of cardiac events, which can be used as an autonomous device without the need of a battery. Even when using off-the-shelf, low-cost integrated circuits, by optimizing both the hardware and software embedded in the device, we were able to reduce the energy consumption of the entire system to below 0.4 mW while measuring and storing the ECG on a non-volatile memory. Moreover, in this project, a power-management circuit able to store energy collected from the radio communication interface is proposed, able to make the connected sensor fully autonomous. Initial results show that this sensor could be suitable for a truly continuous and long-term monitoring of cardiac events [32].

In collaboration with Atlantic, we have done here a preliminary study [37], [23] of wireless transmissions using the ventilation metallic ducts as waveguides. Starting from the waveguide theory, we deeply studied in simulation the actual attenuation encountered by radiowaves in such a specific medium. This kind of wireless link appears to be really efficient, and therefore highly promising to implement Internet of Things (IoT) in old buildings to make them smarter. This study also expresses a very simple empirical model in order to ease dimensioning a wireless network in such conditions and a specific antenna design enabling both good performance and high robustness to the influence of the environment.

The Spie ICS- INSA Lyon chair on IoT has granted us for a PhD thesis on Scatter Radio and RFID tag-to-tag communications. Some seminal results have shown that it is actually possible to create a communication between two RFID tags, just using ambient radiowaves or a dedicated distant radio source, without the need of generating a signal from the tag itself.

6.2.2. Optimization of waveforms for wake-up radio and energy harvesting

First Filter Bank Multi Carrier (FBMC) signals are employed in order to improve the performance of a quasi-passive wake-up radio receiver (WuRx) for which the addressing is performed by the means of a frequency fingerprint. The feasibility of such kind of WuRx was already demonstrated by using orthogonal frequency-division multiplexing (OFDM) signals to form the identifiers. Together with the main advantage of this approach (i.e. no base band processing needed and consequently a reduced energy consumption), one of the drawbacks is their low sensitivity. Through a set of circuit-system co-simulations, it is shown that by their characteristics, especially high Peak to Average Power Ratio (PAPR) and high out of band attenuation, FBMC signals manage to boost the sensitivity and moreover to enhance the robustness of this kind of WuRx. Moreover, we introduced robust wake-up IDs for quasi-passive wake-up receivers in an Internet of Things context[16]. These IDs can address single devices and are based on the Hadamard codes. Further a novel wake-up threshold is implemented to make the device more sensitive and robust against false wake-ups (FWUs). The wake-up procedure is simulated with a tap delay line (TDL) model for a line of sight (LOS) channel and a non line of sight (NLOS) channel. In both scenarios sufficient wake-up distances are reached with low false wake-up probabilitys (FWUPs). Additionally, the system is tested against the influence of an external bandwidth use. Finally, a recommendation for the global system is given.

In [21], we are proposing a way to maximize the DC power collected in the case of a wireless power transfer (WPT) scenario. Three main aspects are taken into account: the RF (radio frequency) source, the propagation channel and the rectifier as the main part of the energy collecting circuit. This problem is formulated as a convex optimization one. Then, as a first step towards solving this problem, a rectifier circuit was simulated by using Keysight's ADS software and, by using a classical model identification strategy i.e. Vector Fitting algorithm, the state-space model of the passive parts of this rectifier were extracted. In order to verify the extracted model, S11 input reflection coefficients and DC output voltages of the original circuit and the state-space model are compared.

6.2.3. UWB for localization

Ultra Wide Band (UWB) is a wireless communication technology that is characterized, in its *impulse radio* scheme [55], by very short duration waveforms called *pulses* (in the order of few nanoseconds), using a wide band and low power spectral density. Among the many advantages offered by this technology is the fact that the arrival time of a pulse can be determined quite precisely, giving the opportunity to measure the distance between two communicating devices by estimating the flight time of the signal.

Although this technology has been known for a long time, it is only recently that cheap UWB chips have been commercialized for civilian applications. As the UWB technology is sensitive to many parameters, the effective performance of localization systems based on UWB may vary a lot compared to what is announced in datasheets. Some accuracy studies have been performed [47], [48] but few of them focus on rapid movement of the transceivers.

Indeed, indoor ranging is in itself dependent on many parameter and very difficult to evaluate objectively, but when the transceivers are moving fast (say as if they were attached to dancer's wrists), more parameters are to be taken into account: transceiver calibration, random errors, presence of obstacle, antenna orientation etc.

In [20], we study experimentally the precision of UWB ranging for rapid movements in an indoor environment, based on the technology proposed by Decawave (DW1000 [45]) whose chips have already been integrated in many commercial devices. We show in particular how to improve the precision of the distance measured by averaging the ranging over successive samples.

6.3. Software Radio Programming Model

6.3.1. Non Uniform Memory Access Analyzer

Non Uniform Memory Access (NUMA) architectures are nowadays common for running High-Performance Computing (HPC) applications. In such architectures, several distinct physical memories are assembled to create a single shared memory. Nevertheless, because there are several physical memories, access times to these memories are not uniform depending on the location of the core performing the memory request and on the location of the target memory. Hence, threads and data placement are crucial to efficiently exploit such architectures. To help in taking decision about this placement, profiling tools are needed. In [36], we propose NUMA MeMory Ana-lyzer (NumaMMA), a new profiling tool for understanding the memory access patterns of HPC applications. NumaMMA combines efficient collection of memory traces using hardware mechanisms with original visualization means allowing to see how memory access patterns evolve over time. The information reported by NumaMMA allows to understand the nature of these access patterns inside each object allocated by the application. We show how NumaMMA can help understanding the memory patterns of several HPC applications in order to optimize them and get speedups up to 28% over the standard non optimized version.

6.3.2. Environments for transiently powered devices

An important research initiative is being followed in Socrate today: 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 memory 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 [50].

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 at the NVMW conference [25] and also to the starting of an Inria Project Lab [39]: 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. A complete description of Sytare has been accepted to IEEE Transaction on Computers [1], special issue on NVRAM.

6.3.3. Dynamic memory allocation for heterogeneous memory systems

In a low power system-on-chip the memory hierarchy is traditionally composed of Static RAM (SRAM) and NOR flash. The main feature of SRAM is a fast access time, while Flash memory is dense, and also non-volatile i.e. it does not require power to retain data. Because of its low writing speed, Flash memory is mostly used in a read-only fashion (e.g. for code) and the amount of SRAM is kept to a minimum in order to lower leakage power.

Emerging memory technologies exhibit different trade-offs and more heterogeneity. Non-Volatile RAM technologies like MRAM (Magnetic RAM) or RRAM (Resistive RAM) open new perspectives on power-management since they can be switched on or off at very little cost. Their characteristics are very dependent on the technology used, but it is now widely known that they will provide a high integration density and fast read access time to persistent data. NVRAM is usually not as fast as SRAM and some technologies have a limited endurance hence are not suited to store frequently modified data. In addition, most NVRAM technologies have asymmetric access times, writes being slower than reads.

In the context of embedded systems, the hardware architecture is evolving towards a model where different memory banks, with different hardware characteristics, are directly exposed to software, as it has been the case for scratchpad memories (SPM). This raises questions including:

- What is the expected performance impact of adding fast memory to a system based on NVRAM? In particular: will the addition of a small amount of fast memory result in significant performance improvement?
- How should one adapt and optimize their software memory management to leverage these new technologies?

In [10], [28], we study these questions in the perpective of dynamic memory allocation. In this first study we show, with extensive profiling how much can be gained with a clever dynamic memory allocation in the context of heterogeneous memory. We limit the study to two different memories, RAM and NVRAM for instance. This gain can go up to 15% of performance, depending of course of the performances of the different memories used. These results will be helpfull to design a clever dynamic allocator for these new architectures and also will help in the design process of new architecture for low power systems that will include NVRAM for normaly-off systems for instance.

6.3.4. Arithmetic for signal processing

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 [7] advocates the construction of LTI architectures that behave as if the computation was performed with infinite accuracy, then converted to the low-precision output format with an error smaller than its least significant bit. This simple specification guarantees the numerical quality of the hardware, even for critical LTI systems. Besides, it is possible to derive the optimal values of all the internal data formats that ensure that the specification is met. This requires a detailed error analysis that captures not only the quantization and rounding errors, but also their infinite accumulation in recursive filters. This generic methodology is detailed for the case of low-precision LTI filters in the Direct Form I implemented in FPGA logic. It is demonstrated by a fully automated and open-source architecture generator tool integrated in FloPoCo, and validated on a range of Infinite Impulse Response filters.

6.3.5. Karatsuba multipliers on modern FPGAs

The Karatsuba method is a well-known technique to reduce the complexity of large multiplications. However it is poorly suited to the rectangular 17x25-bit multipliers embedded in recent Xilinx FPGAs: The traditional Karatsuba approach must under-use them as square 18x18 ones. In [17], the Karatsuba method is extended to efficiently use such rectangular multipliers to build larger multipliers. Rectangular multipliers can be efficiently exploited if their input word sizes have a large greatest common divider. In the Xilinx FPGA case, this can be obtained by using the 17x25 embedded multipliers as 16x24. The obtained architectures are implemented with due detail to architectural features such as the pre-adders and post-adders available in Xilinx DSP blocks. They are synthesized and compared with traditional Karatsuba, but also with (non-Karatsuba) state-of-the-art tiling techniques that make use of the full rectangular multipliers. The proposed technique improves resource consumption and performance for multipliers of numbers larger than 64 bits.

6.3.6. PyGA: a Python to FPGA compiler prototype

In a collaboration with Intel, Yohann Uguen has worked on a compiler of Python to FPGA [22]. Based on the Numba Just-In-Time (JIT) compiler for Python and the Intel FPGA SDK for OpenCL, it allows any Python user to use a FPGA card as an accelerator for Python seamlessly, albeit with limited performance so far.

6.3.7. General computer arithmetic

A second edition of the Handbook for Floating-Point Arithmetic has been published [38].

With colleagues from Aric, we have worked on a critical review [42] of the Posit system, a proposed alternative to the prevalent floating-point format.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

7.1.1. Research Contract with Atlantic 2016-2018

Socrate (Guillaume Villemaud, Florin Hutu, Guillaume Salagnac and Tanguy Risset) are collborating with Atlantic to prototype guided wireless communications in ventilation ducts with low energy consumption. The project will lead to a shift to wireless communications in HVAC ducts.

7.1.2. Research Contract with SigFox 2015-2018

Socrate explored the performance of UNB networks with an emphasis on robust signal processing techniques (PhD defended on Dec 2018).

7.1.3. Research Contract with Orange 2016-2018

Socrate explored in this partnership the theoretical limits of IoT access networks by combining information theory and stochastic geometry.

7.1.4. Research Contract with Nokia 2017-2021

Socrate contributes to two research actions in the Nokia Bell Labs - Inria common lab. The first ADR is on Network Information Theory devoted to to the modeling of IoT networks, and which relies on our academic work in the ANR Arburst. We collaborate with Agora, Infine and Eva teams.

The second ADR is on machine learning for wireless networks. Our contribution is on designing new PHY layer protocols with machine learning, with an experimental assessment of these techniques on FIT/CorteXlab.

7.1.5. Research Contract with Bosch 2018

In collaboration with Aric, Socrate worked with Bosch on the impementation of some elementary functions in an embedded context.

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.

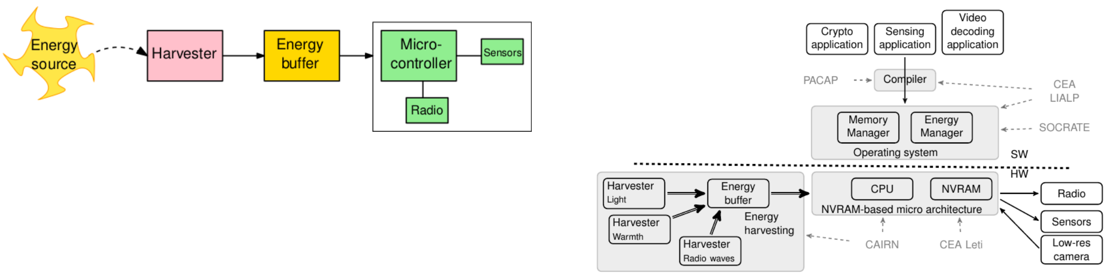

Figure 4. Example of system targeted by the ZEP project on the left, and on the right: the ZEP research program.

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 4, 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 - Imprenum

The objective of this project (INSA-Lyon, École Normale Supérieure de Lyon, CEA LETI) is to promote **accuracy as a first class concern** in all the levels of a computing system:

- at the hardware level, with better support for lower-than-standard and higher-than-standard precisions;
- at the level of run-time support software, in particular answering the memory management challenges entailed by adaptive precision;

- at the lower level of mathematical libraries (kernel level), for instance BLAS for linear algebra, enhancing well established libraries with precision and accuracy control;
- at the higher level of mathematical libraries (solver level, including algebraic linear solvers such as LAPACK, ad hoc steppers for Ordinary Differential Equation, eigenvalues kernels, triangularization problems for computational geometry, etc.) Here, accuracy and precision control of the lower levels should enable higher-level properties such as convergence and stability;
- at the compiler level, enhancing optimising compilers with novel optimisations related to precision and accuracy;
- at the language level, embedding accuracy specification and control in existing languages, and possibly defining domain-specific languages with accuracy-aware semantics for some classes of applications.

8.1.5. ADT CorteXlab

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

8.1.6. 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.

8.1.7. ANR - Arburst

In this project Arburst - "Achievable 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. 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 International Partners

8.3.1.1. 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
- **Queen's University Belfast**, UK. This collaboration is on molecular communication and massive MIMO with Prof. Trung Q. Duong. Scientific-in-charge at Inria: Malcolm Egan
- **Czech Technical University in Prague**, Czech Republic. This collaboration is on optimisation methods related to machine learning with Dr. Vyacheslav Kungurtsev. Scientific-in-charge at Inria: Malcolm Egan
- **TUMCREATE**, Singapore. This collaboration is on signal processing in communications with Dr. Ido Nevat. Scientific-in-charge at Inria: Malcolm Egan
- **telecommunications department of UMNG (Universidad Militar de Nueva Granada), Bogota, Colombia. Ongoing collaboration on security for GSM networks using deep learning. Scientific-in-charge at Inria: Leonardo Sampaio-Cardoso.**

8.4. International Research Visitors

8.4.1. Visits from International Teams

- Prof. Edward Guillen and his joint PhD student with Leonardo Sampaio-Cardoso, José Rugeles, came to Lyon in June 2018 for a 1-month academic stay, to develop work on FIT/CorteXlab for the security for GSM networks using deep learning project

8.4.2. Visits to International Teams

8.4.2.1. Sabbatical programme

Samir M. Perlaza has been on Sabatical year at Princeton University up to septembre 2018.

Malcolm Egan has been a visiting research collaborator in Prof. Poor's group in Princeton University March-April 2018.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

The Socrate team launched two new workshops in relation with FIT/CorteXlab:

- First French GNU Radio days: https://gnuradio-fr-18.sciencesconf.org/. The workshop aimed at the development of radio prototyping why GNU Radio in France and in Europe, by Leonardo Sampaio-Cardoso and Tanguy Risset.
- ISP-IoT : First Winter School on Information Theory and Signal Processing for Internet of Things : https://isp-iot.sciencesconf.org by Jean-Marie Gorce.

Socrate organized *Journée plateformes d'évaluations radio*, 28-03-2018, joint event between the GDR ASR and the GDR ISIS. Co-organized by Leonardo Sampaio-Cardoso and Jean-Marie Gorce with Thalès.

9.1.1.1. Member of the Organizing Committees

- Tanguy Risset, Leonardo Sampaio-Cardoso, Guillaume Villemaud and Jean-Marie Gorce were members of the organizing committee of the first French GNU Radio days.
- Samir M. Perlaza, Claire Goursaud, Leonardo Sampaio-Cardoso were members of the organizing committee of ISP-IOT, the first Winter School on Information Theory and Signal Processing for Internet of Things.
- Seed meeting *Dynamic Modeling and Simulation for Molecular Communication Networks*. Workshop funded by the French Embassy in the UK, London. Co-organized by Malcolm Egan. 17th and 18th September 2018, London UK.

9.1.1.2. Chair of Conference Program Committees

- Jean-Marie Gorce (chair) was co-chair of the ISP-IOT, the first Winter School on Information Theory and Signal Processing for Internet of Things.
- Samir M. Perlaza is chair of the special session on "Energy Harvesting and Wireless Powered Communications" hosted at the 20th IEEE International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), July 2-5, 2019, Cannes, France.
- Samir M. Perlaza is co-chair of the Workshop on "Mathematical Tools for IoT Networks Modeling (MOTION)" hosted at the IEEE Wireless Communications and Networking Conference (WCNC). April, 15-18 2019, Marrakech, Morocco.
- Samir M. Perlaza is Publication Chair of the International Symposium on Information Theory (ISIT), July, 2019, Paris, France.

9.1.1.3. Member of Conference Program Committees

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

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

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

- CROWNCOM2018
- PIMRC 2018
- EUCAP 2018.

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

- 25th IEEE Symposium on Computer Arithmetic (Arith 2018)
- Design Automation and Test in Europe (DATE 2018) (as co-chair of track D11),
- 26th IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM 2018)

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

- IEEE Global Communications Conference (Globecom), 9-13 December 2018, Abu Dhabi, UAE.
- International Conference on Advanced Technologies for Communications (ATC) 2018
- International Conference on Recent Advances on Signal Processing, Telecommunications & Computing (SigTelCom) 2018.

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

- IEEE International Conference on Communications (ICC), 20-24 May 2018, Kansas City, MO, USA.
- IEEE Global Communications Conference (Globecom), 9-13 December 2018, Abu Dhabi, UAE.
- IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), 9-12 September 2018, Bologna, Italy.
- IEEE 5G World Forum 2018 (WF-5G), 9-11 July 2018, Santa Clara, California, USA
- International Conference on Telecommunications(ICT), June, 26-28, 2018, Saint-Malo, France.
- IEEE Wireless Communications and Networking Conference (WCNC). April, 15-18, 2018, Barcelona, Spain.
- IEEE 5G World Forum 2019 (WF-5G), 2019.
- International Conference on Telecommunications(ICT), 2019.

Samir M. Perlaza was a member of the following program committees :

- International Conference on Computing, Networking and Communications (ICNC), 18-21 February, 2019, Honolulu, Hawaii, USA.
- IEEE International Conference on Communications (ICC), 20-24 May 2019, Shanghai, China.
- Workshop on Green and Sustainable 5G Wireless Networks at IEEE Global Communications Conference (Globecom), 9-13 December 2018, Abu Dhabi, UAE.
- IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), 9-12 September 2018, Bologna, Italy.

Claire Goursaud was a member of the following technical program committees:

- IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) 2018
- EAI International Conference on Body Area Networks (BodyNet) 2018

Leonardo Sampaio-Cardoso was a member of the following technical program committees:

- IEEE Wireless Communications and Networking Conference (WCNC) 2019
- IEEE International Conference on Communications (ICC) 2019

9.1.2. Journal

9.1.2.1. Member of the Editorial Boards

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

Malcolm Egan is an associate editor of IEEE Communications Letters and guest editor for IEEE Access special section on Molecular Communication Networks.

Jean-Marie Gorce is an an associate editor of Journal of Wireless Communications and Networking.

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

Samir M. Perlaza is editor of the IEEE Transactions on Communications for the term 2018-2021 in the area of Simultaneous Information and Energy Transmission, Feedback and Applications of Game Theory in Wireless Communications.

Samir M. Perlaza is Associate Editor of the IET Smart Grid for the term 2018-2021.

9.1.3. Scientific Expertise

Guillaume Villemaud served as Research Expert for the European commission for the H2020-MSCA-NIGHT-2018.

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.

Jean-Marie Gorce was the chair of a recruitment committee for a full professor position at Insa.

9.1.4. Invited Talks

Malcolm Egan gave invited talks in the Poor group in Princeton University and Prof. Erkip's group in NYU. With Samir M. Perlaza, he had an invited paper at CISS 2018.

Jean-Marie Gorce gave invited talks at IEMN/Ircica, invited by Prof. Laurent Clavier (June 2018), and at Orange Labs (Sept 2019).

Samir M. Perlaza gave a keynote on “Key Technologies in the IoT: Simultaneous Wireless Information and Energy Transmission” at the First Winter School on Information Theory and Signal Processing for Internet of Things, Villeurbanne, France, November 20, 2018.

Florent de Dinechin gave two talks at the FPGA days organized at LIP, Lyon, june 21, "Introduction to FPGA computing", then "computing just right on FPGAs"

Florent de Dinechin gave a talk at the RiscV days organized at CEA, October 16, Grenoble, "Dark silicon: a computer arithmetic perspective"

Florent de Dinechin gave a talk at the RiscV days organized at CEA, October 16, Grenoble, "Dark silicon: a computer arithmetic perspective"

Florent de Dinechin gave an invited lecture at the Advanced Workshop on FPGA-based Systems-On-Chip for Scientific Instrumentation and Reconfigurable Computing, organized by the International center for Theoretical Physics in Trieste, Italy, November 29, 2018.

Florent de Dinechin gave a talk at the Institute for Systems Programming of the Russian Academy of Science in Moscow, Russia, December 24, 2018.

Guillaume Salagnac and Tanguy Risset gave an invited talk at Spintec (Grenoble, FR), October 23rd, 2018, untitled "Peripheral State Persistence and Interrupt Management For Transiently Powered Systems".

Guillaume Villemaud gave an invited talk in the special session on Wake-up radio at the IEEE ICECS 2018 conference in december 2018

9.1.5. Research Administration

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

Tanguy Risset is Vice-director of the FIL (CNRS Computer Science Research Federation of Lyon/Saint-Etienne).

Florent de Dinechin is director of the Citi-Lab.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Tanguy Risset and Jean-Marie Gorce 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 and Malcolm Egan are an associate professor at the Telecommunications department of Insa Lyon.

Leonardo Sampaio-Cardoso is an associate professor at the FIMI department as well as the Telecommunications Department of Insa Lyon

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 **Gautier Berthou** *Operating system for transiently powered systems*, Inria, (IPL ZEP) since 01/2018.

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 **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 bursty communications*, ANR Arburst grant, since 10/2017.

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

PhD starting **Luc Forget** : *Algèbre linéaire calculant au plus juste*, ANR Imprenum, since 10/2018.

PhD starting **Yanni Zhou** : *Full Duplex and spatial modulation*

PhD starting **Tarik Lassouaoui**: *Tag 2 Tag communication*

PhD starting **Regis Rousseau**: *Wireless Power Transfer*

PhD defended: **Yuqi Mo** *Scaling of Iot Communication issues*, École Doctorale EEA,sept. 2018.

9.2.3. Juries

- Guillaume Salagnac was examiner in the jury of the PhD Nadir Cherify "Assistance au développement de logiciels embarqués contraints en énergie"
- Florin Hutu was examiner int the PhD Jury of Frank Itoua, defended on March 12, 2018 at Limoges University.
- Tanguy Risset was a member of the jury of the following theses:
  - Maxime France-Pillois (U. Grenoble)
  - Perrin Njoyah Ntafam (U. Grenoble)
  - Simon Rokicki (U. Rennes)
- Florent de Dinechin was a reviewer in the jury of Hugues de Lassus Saint-Genis, defended on May 17 2018 at Université de Perpignan Via Domitia.
- Malcolm Egan was a co-supervisor in the jury of Mauro de Freitas, defended at Université de Lille 1.
- Claire Goursaud and Jean-Marie Gorce were co-supervisors in the jury of Yuqi Mo, defended at Insa Lyon.
- Jean-Marie Gorce was :
  - a reviewer of the HdR jury of Guillaume Andrieux (IETR, Nantes U., December 2018).
  - a reviewer of the PhD jury of Philippe Ezran (Supelec Paris Saclay U., January 2018).
  - a reviewer of the PhD jury of Antony Pottier (IMT Atlantique, Nov 2018).
  - a reviewer of the PhD jury of Luca Feltrin (Bologna U., Italy, December 2018).
  - an examiner of the PhD jury of Xavier Leturc (IMT Paris, U. Paris Saclay, December 2018),
- Guillaume Villemaud was a reviewer for the PhD defense of
  - Andreina Liendo (Univ. Grenoble)
  - Mai-Thanh TRAN (Univ. Rennes 1)
  - Manuel Milla Peinado (Univ. Poitiers)
- Claire Goursaud was a member in the jury of Alaa Khreis, defended at l'Université Paris Saclay, prepared at Télécom ParisTech .
- Claire Goursaud was a reviewer in the jury of Remi Bonnefoi, defended at CentraleSupelec

10. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

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[2] M. EGAN, L. CLAVIER, C. ZHENG, M. DE FREITAS, J.-M. GORCE. *Dynamic Interference for Uplink SCMA in Large-Scale Wireless Networks without Coordination*, in "EURASIP Journal on Wireless Communications and Networking", August 2018, vol. 2018, n^o 1, pp. 1-14 [*DOI :* 10.1186/s13638-018-1225-z], https://hal.archives-ouvertes.fr/hal-01871576

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[5] N. KHALFET, S. M. PERLAZA. *Simultaneous Information and Energy Transmission in the Two-User Gaussian Interference Channel*, in "IEEE Journal on Selected Areas in Communications", September 2018, pp. 1-15 [*DOI :* 10.1109/JSAC.2018.2872365], https://hal.archives-ouvertes.fr/hal-01874019

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Invited Conferences

[8] Y. MO, C. GOURSAUD, J.-M. GORCE. *Uplink Multiple Base Stations Diversity for UNB based IoT networks*, in "CAMA 2018 - IEEE International Conference on Antenna Measurement and Applications", Västerås, Sweden, September 2018, pp. 1-4, https://hal.inria.fr/hal-01887640

[9] M. S. WIDMAIER, F. HUTU, G. VILLEMAUD. *Efficiency of Orthogonal Codes for Quasi-passive Wake-Up Radio Receivers using Frequency Footprint IDs*, in "25th IEEE International Conference on Electronics Circuits and Systems", Bordeaux, France, December 2018, https://hal.archives-ouvertes.fr/hal-01973114

International Conferences with Proceedings

[10] T. DELIZY, S. GROS, K. MARQUET, M. MOY, T. RISSET, G. SALAGNAC. *Estimating the Impact of Architectural and Software Design Choices on Dynamic Allocation of Heterogeneous Memories*, in "RSP 2018 - 29th International Symposium on Rapid System Prototyping", Turin, Italy, October 2018, pp. 1-7, https://hal.archives-ouvertes.fr/hal-01891599

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[13] A. DYTSO, M. EGAN, S. PERLAZA, H. V. POOR, S. SHAMAI. *Optimal Inputs for Some Classes of Degraded Wiretap Channels*, in "2018 IEEE Information Theory Workshop (ITW)", Guangzhou, China, November 2018, https://hal.inria.fr/hal-01884159

[14] M. EGAN, T. C. MAI, T. Q. DUONG, M. DI RENZO. *Coordination via Advection Dynamics in Nanonetworks with Molecular Communication*, in "ICC 2018 - IEEE International Conference on Communications", Kansas City, United States, IEEE, May 2018, pp. 1-6 [*DOI :* 10.1109/ICC.2018.8422573], https://hal.archives-ouvertes.fr/hal-01696268

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[17] *Best Paper*
M. KUMM, O. GUSTAFSSON, F. DE DINECHIN, J. KAPPAUF, P. ZIPF. *Karatsuba with Rectangular Multipliers for FPGAs*, in "ARITH 2018 - 25th IEEE International Symposium on Computer Arithmetic", Amherst, United States, IEEE, June 2018, pp. 13-20, Best paper award [*DOI :* 10.1109/ARITH.2018.8464809], https://hal.inria.fr/hal-01773447.

[18] Y. MO, C. GOURSAUD, J.-M. GORCE. *Multiple Base Stations Diversity for UNB Systems: Theoretical Analysis and Performances*, in "ISNCC 2018 - International Symposium on Networks, Computers and Communications", Rome, Italy, June 2018, pp. 1-6, https://hal.inria.fr/hal-01887619

[19] S. POOJARY, R. EL-AZOUZI, E. ALTMAN, A. SUNNY, I. TRIKI, M. HADDAD, T. JIMENEZ, S. VALENTIN, D. TSILIMANTOS. *Analysis of QoE for adaptive video streaming over wireless networks*, in "WiOpt 2018 - 16th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks", Shanghai, China, May 2018, https://hal.inria.fr/hal-01972647

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