Activity Report 2019

Team MARACAS

Models and Algorithms for Reliable Communication Systems

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Networks and Telecommunications

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Team MARACAS

Creation of the Project-Team: 2020 January 01

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A1.5.2. - Communicating systems
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Other Research Topics and Application Domains:

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B6.2.2. - Radio technology
B6.4. - Internet of things
B6.6. - Embedded systems
B8.1. - Smart building/home
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1. Team, Visitors, External Collaborators

Research Scientists

Malcolm Egan [Inria, Researcher, from Sep 2019 - INSA Lyon, Starting Research position until Sep 2019]
Samir Medina Perlaza [Inria, Researcher]

Faculty Members

Jean Marie Gorce [Team leader, INSA Lyon, Professor, HDR]
Claire Goursaud [INSA Lyon, Associate Professor, HDR]
Leonardo Sampaio Cardoso [INSA Lyon, Associate Professor]

Post-Doctoral Fellow

Bayram Akdeniz [Inria, Post-Doctoral Fellow]

PhD Students

Dadja Anade Akpo [INSA Lyon, PhD Student]
Lélio Chetot [Inria, PhD Student]
Diane Duchemin [Inria, PhD Student]
Mathieu Goutay [Nokia, PhD Student, from Mar 2019, granted by CIFRE]
Hassan Kallam [Insavalor, PhD Student]
Nizar Khalfet [Inria, PhD Student, until Nov 2019]
David Kibloff [Inria, PhD Student, until Sep 2019]
Cyrille Morin [Inria, PhD Student]

Technical staff

Pascal Girard [INSA Lyon, Engineer]
Matthieu Imbert [Inria, Engineer]
Olivier Nicolas [INSA Lyon, Engineer, until Nov 2019]
Othmane Oubejja [Inria, Engineer]

Intern and Apprentice

Huy Duy Do [Inria, from Feb 2019 until Jul 2019]

Administrative Assistants

Sophie Karsai [Inria, Administrative Assistant, until Jul 2019]
Anouchka Ronceray [Inria, Administrative Assistant, from Jul 2019]

Visiting Scientists

Michalis Eliodorou [MTN Cyprus, Sep 2019]
Matei Moldoveanu [U. of Sheffield, UK, from Jul 2019 until Sep 2019]

External Collaborators

Nikolai Lebedev [École supérieure de chimie physique électronique de Lyon]
Chantal Muller [INSA Lyon, HDR]

2. Overall Objectives

2.1. Motivation

During the last century, the industry of communications was devoted to improving human connectivity, leading to a seamless worldwide coverage to cope with increasing data rate demands and mobility requirements. The Internet revolution drew on a robust and efficient multi-layer architecture ensuring end-to-end services. In a classical network architecture, the different protocol layers are compartmentalized and cannot easily interact. For instance, source coding is performed at the application layer while channel coding is performed at the physical (PHY) layer. This multi-layer architecture blocked any attempt to exploit low level cooperation mechanisms such as relaying, phy-layer network coding or joint estimation. During the last decade, a major shift, often referred to as *the Internet of Things (IoT)*, was initiated toward a machine-to-machine (M2M) communication paradigm, which is in sharp contrast with classical centralized network architectures. The IoT enables machine-based services exploiting a massive quantity of data virtually spread over a complex, redundant and distributed architecture.

This new paradigm makes the aforementioned classical network architecture based on a centralized approach out-of-date.

The era of *Internet of Everything* deeply modifies the paradigm of communication systems. They have to transmute into reactive and adaptive intelligent systems, under stringent QoS constraints (latency, reliability) where the networking service is intertwined in an information-centric network. The associated challenges are linked to the intimate connections between communication, computation, control and storage. Actors, nodes or agents in a network can be viewed as forming a distributed system of computations—a *computing network* .

2.2. Scientific methodology

It is worth noting that working on these new architectures can be tackled from different perspectives, e.g. data management, protocol design, middleware, algorithmic design... Our main objective in Maracas is to address this problem from a communication theory perspective. Our background in communication theory includes information theory, estimation theory, learning and signal processing. Our strategy relies on three fundamental and complementary research axes:

- Mathematical modeling: information theory is a powerful framework suitable to evaluate the limits of complex systems and relies on probability theory. We will explore new bounds for complex networks (multi-objective optimization, large scale, complex channels,...) in association with other tools (stochastic geometry, queuing theory, learning,...)
- Algorithmic design: a number of theoretical results obtained in communication theory, despite their high potential are still far from a practical use. We will thus work on exploiting new algorithmic techniques. Back and forth efforts between theory and practice is necessary to identify the most promising opportunities. The key elements are related to the exploitation of feedbacks, signaling and decentralized decisions. Machine learning algorithms will be explored.
- Experimentation and cross-layer approach: theoretical results and simulation are not enough to provide proofs of concept. We will continue to put efforts on experimental works either on our own (e.g. FIT/CorteXlab and SILECS) or in collaboration with industries (Nokia, Orange, Thalès,...) and other research groups.

While our expertise is mostly related to the optimization of wireless networks from a communication perspective, the project of Maracas is to broaden our scope in the context of *Computing Networks*, where a challenging issue is to optimize jointly architectures and applications, and to break the classical network/data processing separation. This will drive us to change our initial positioning and to really think in terms of information-centric networks following, e.g. [60], [58], [66].

To summarize, *Computing Networks* can be described as highly distributed and dynamic systems, where information streams consist in a huge number of transient data flows from a huge number of nodes (sensors, routers, actuators, etc...) with computing capabilities at the nodes. These *Computing Networks* are nothing but the invisible nonetheless necessary skeleton of cloud and fog-computing based services.

Our research strategy is to describe these *Computing Networks* as complex large scale systems in an information theory framework, but in association with other tools, such as stochastic geometry, stochastic network calculus, game theory [19] or machine learning.

The multi-user communication capability is a central feature, to be tackled in association with other concepts and to assess a large variety of constraints related to the data (storage, secrecy,...) or related to the network (energy, self-healing,...).

The information theory literature or more generally the communication theory literature is rich of appealing techniques dedicated to efficient multi-user communications: e.g. physical layer network coding, amplify-and-forward, full-duplexing, coded caching at the edge, superposition coding. But despite their promising performance, none of these technologies play a central role in current protocols. The reasons are two-fold : i) these techniques are usually studied in an oversimplified theoretical framework which neglect many practical aspects (feedback, quantization,...), and that is not able to tackle large scale networks and ii) the proposed algorithms are of a high complexity and are not compatible with the classical multi-layer network architecture.

Maracas addresses these questions, leveraging on its past outstanding experience from wireless network design.

The aim of Maracas is to push from theory to practice a fully cross-layer design of *Computing Networks* , based on multi-user communication principles relying mostly on information theory, signal processing, estimation theory, game theory and optimization. We refer to all these tools under the umbrella of *communication theory* .

As such, Maracas project goes much beyond wireless networks. The *Computing Networks* paradigm applies to a wide variety or architectures including wired networks, smart grids, nanotechnology based networks. One Maracas research axis will be devoted to the identification of new research topics or scenarios where our algorithms and mathematical models could be useful.

3. Research Program

3.1. General description

As presented in the first section, *Computing Networks* is a concept generalizing the study of multi-user systems under the communication perspective. This problematic is partly addressed in the aforementioned references. Optimizing *Computing Networks* relies on exploiting simultaneously multi-user communication capabilities, in the one hand, and storage and computing resources in the other hand. Such optimization needs to cope with various constraints such as energy efficiency or energy harvesting, delays, reliability or network load.

The notion of reliability (used in MARACAS acronym) is central when considered in the most general sense : ultimately, the reliability of a *Computing Network* measures its capability to perform its intended role under some confidence interval. Figure 1 represents the most important performance criteria to be considered to achieve reliable communications. These metrics fit with those considered in 5G and beyond technologies [63].

On the theoretical side, multi-user information theory is a keystone element. It is worth noting that classical information theory focuses on the power-bandwith tradeoff usually referred as Energy Efficiency-Spectral Efficiency (EE-SE) tradeoff (green arrow on 1). However, the other constraints can be efficiently introduced by using a non-asymptotic formulation of the fundamental limits [62], [64] and in association with other tools devoted to the analysis of random processes (queuing theory, ...).

Maracas aims at studying *Computing Networks* from a communication point of view, using the foundations of information theory in association with other theoretical tools related to estimation theory and probability theory.

In particular, Maracas combines techniques from communication and information theory with statistical signal processing, control theory, and game theory. Wireless networks is the emblematic application for Maracas, but other scenarios are appealing for us, such as molecular communications, smart grids or smart buildings.

Several teams at Inria are addressing computing networks, but working on this problem with an emphasis on communication aspects is unique within Inria.

The complexity of *Computing Networks* comes first from the high dimensionality of the problem: i) thousands of nodes, each with up to tens setting parameters and ii) tens variable objective functions to be minimized/maximized.

In addition, the necessary decentralization of the decision process, the non stationary behavior of the network itself (mobility, ON/OFF Switching) and of the data flows, and the necessary reduction of costly feedback and signaling (channel estimation, topology discovering, medium access policies...) are additional features that increase the problem complexity.

The original positioning of Maracas holds in his capability to address three complementary challenges :

1. **to develop a sound mathematical framework inspired by information theory.**
2. **to design algorithms, achieving performance close to these limits.**
3. **to test and validate these algorithms on experimental testbeds.**

3.2. Research program

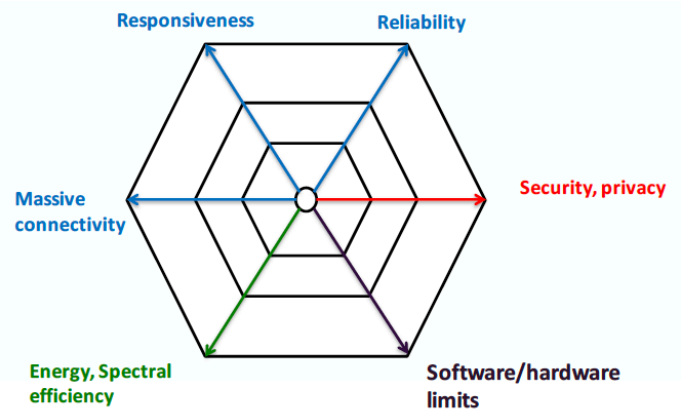

Figure 1. Main metrics for future networks (5G and beyond)

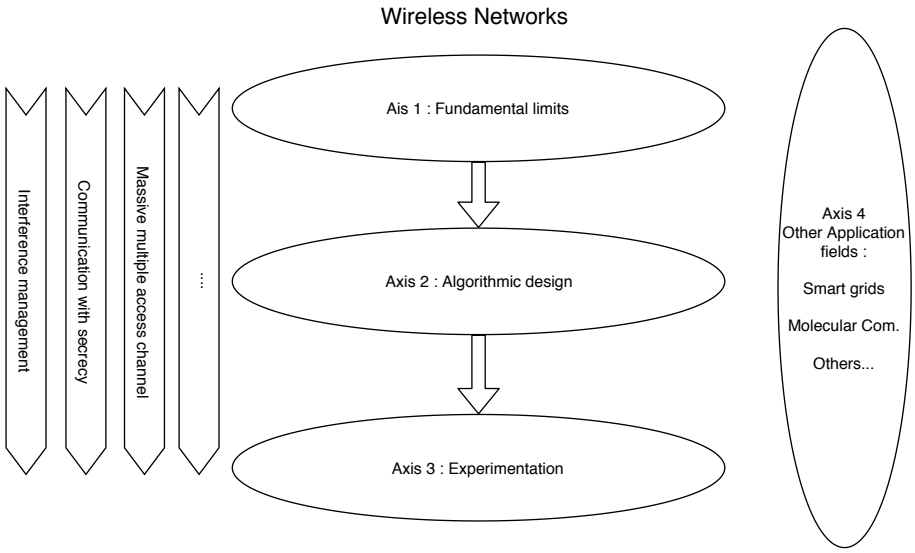

Figure 2. Maracas organization

Our research is organized in 4 research axes:

- **Axis 1 - Fundamental Limits of Reliable Communication Systems**: Information theory is revisited to integrate reliability in the wide sense. The non-asymptotic theory which made progress recently and attracted a lot of interest in the information theory community is a good starting point. But for addressing computing network in a wide sense, it is necessary to go back to the foundation of communication theory and to derive new results, e.g. for non Gaussian channels [8] of for multi-constrained systems [17].

  This also means revisiting the fundamental estimation-detection problem [65] in a general multi-criteria, multi-user framework to derive tractable and meaningful bounds.

  As mentioned in the introduction, *Computing Networks* also relies on a data-centric vision, where transmission, storage and processing are jointly optimized. The strategy of *caching at the edge* [57] proposed for cellular networks shows the high potential of considering simultaneously data and network properties. Maracas is willing to extend his skills on source coding aspects to tackle with a data-oriented modeling of *Computing Networks*.

- **Axis 2 - Algorithms and protocols**: Our second objective is to elaborate new algorithms and protocols able to achieve or at least to approach the aforementioned fundamental limits. While the exploration of fundamental limits is helpful to determine the most promising strategies (e.g. relaying, cooperation, interference alignment) to increase system performance, the transformation of these degrees of freedom into real protocols is a non trivial issue. One reason is the exponentially growing complexity of multi-user communication strategies, with the number of users, due to the necessity of some coordination, feedback and signaling. The general problem is a decentralized and dynamic multi-agents multi-criteria optimization problem and the general formulation is a non-linear and non-convex large scale problem.

  The conventional research direction aims at reducing the complexity by relaxing some constraints or by reducing the number of degrees of freedom. For instance, topology interference management is a seducing model used to reduce feedback needs in decentralized wireless networks leading to original and efficient algorithms [67], [59].

  Another emerging research direction relies on using machine learning techniques [54] as a natural evolution of cognitive radio based approaches. Machine learning in the wide sense is not new in radio networks, but the most important works in the past were devoted to reinforcement learning approaches. The use of deep learning (DL) is much more recent, with two important issues : i) identifying the right problems that really need DL algorithms and ii) providing extensive data sets from simulation and real experiments. Our group started to work on this topic in association with Nokia in the joint research lab. As we are not currently expert in deep learning, our primary objective is to identify the strategic problems and to collaborate in the future with Inria experts in DL, and in the long term to contribute not only to the application of these techniques, but also to improve their design according to the constraints of computing networks.

- **Axis 3 - Experimental validation** : With the rapid evolution of network technologies, and their increasing complexity, experimental validation is necessary for two reasons: to get data, and to validate new algorithms on real systems.

  Maracas activity leverages on the FIT/CorteXlab platform (http://www.cortexlab.fr/), and our strong partnerships with leading industry including Nokia Bell Labs, Orange labs, Sigfox or Sequans. Beyond the platform itself which offers a worldwide unique and remotely accessible testbed , Maracas also develops original experimentations exploiting the reproducibility, the remote accessibility, and the deployment facilities to produce original results at the interface of academic and industrial research [1], [10]. FIT/CorteXlab uses the GNU Radio environment to evaluate new multi-user communication systems.

  Our experimental work is developed in collaboration with other Inria teams especially in the Rhone-Alpes centre but also in the context of the future SILECS project https://www.silecs.net/ which will

implement the convergence between FIT and Grid'5000 infrastructures in France, in cooperation with European partners and infrastructures. SILECS is a unique framework which will allow us to test our algorithms, to generate data, as required to develop a data-centric approach for computing networks.

Last but not least, software radio technologies are leaving the confidentiality of research laboratories and are made available to a wide public market with cheap (few euros) programmable equipment, allowing to setup non standard radio systems. The existence of home-made and non official radio systems with legacy ones could prejudice the deployment of Internet of things. Developing efficient algorithms able to detect, analyse and control the spectrum usage is an important issue. Our research on FIT/CorteXlab will contribute to this know-how.

- **Axis 4 - Other application fields** : Even if the wireless network context is still challenging and provides interesting problems, Maracas targets to broaden its exploratory playground from an application perspective. We are looking for new communication systems, or simply other multi-user decentralized systems, for which the theory developed in the context of wireless networks can be useful. Basically, Maracas might address any problem where multi-agents are trying to optimize their common behavior and where the communication performance is critical (e.g. vehicular communications, multi-robots systems, cyberphysical systems). Following this objective, we already studied the problem of missing data recovery in smart grids [11] and the original paradigm of molecular communications [6].

  Of course, the objective of this axis is not to address random topics but to exploit our scientific background on new problems, in collaboration with other academic teams or industry. This is a winning strategy to develop new partnerships, in collaboration with other Inria teams.

4. Application Domains

4.1. 5G, 6G, and beyond

The fifth generation (5G) broadens the usage of cellular networks but requires new features, typically very high rates, high reliability, ultra low latency, for immersive applications, tactile internet, M2M communications.

From the technical side, new elements such as millimeter waves, massive MIMO, massive access are under evaluation. The initial 5G standard validated in 2019, is finally not really disruptive with respect to the 4G and the clear breakthrough is not there yet. The ideal network architecture for billions of devices in the general context of Internet of Things, is not well established and the debate still exists between several proposals such as NB-IoT, Sigfox, Lora. We are developing a deep understanding of these techniques, in collaboration with major actors (Orange Labs, Nokia Bell Labs, Sequans, Sigfox) and we want to be able to evaluate, to compare and to propose evolutions of these standards with an independent point of view.

This is why we are interested in developing partnerships with major industries, access providers but also with service providers to position our research in a joint optimization of the network infrastructure and the data services, from a theoretical perspective as well as from experimentation.

4.2. Energy sustainability

The energy footprint and from a more general perspective, the sustainability of wireless cellular networks and wireless connectivity is somehow questionable.

We develop our models and analysis with a careful consideration of the energy footprint : sleeping modes, power adaptation, interference reduction, energy gathering, ... many techniques can be optimized to reduce the energetic impact of wireless connectivity. In a *computing networks* approach, considering simultaneously transmission, storage and computation constraints may help to reduce drastically the overall energy footprint.

4.3. Smart building, smart cities, smart environments

Smart environments rely on the deployment of many sensors and actuators allowing to create interactions between the twinned virtual and real worlds. These smart environments (e.g. smart building) are for us an ideal playground to develop new models based on information theory and estimation theory to optimize the network architecture including storage, transmission, computation at the right place.

Our work can be seen as the dark side of cloud/edge computing. In collaboration with other teams expert in distributed computing or middleware (typically at CITIlab, with the team Dynamid of Frédéric Le Mouel) and in the framework of the chaire SPIE/ICS-INSA Lyon, we want to optimize the mechanisms associated to these technologies : in a multi-constrained approach, we want to design new distributed algorithms appropriate for large scale smart environments.

4.4. Machine learning based radio

During the first 6G wireless meeting which was held in Lapland, Finland in March 2019, machine learning (ML) was clearly identified as one of the most promising breakthroughs for future 6G wireless systems expected to be in use around 2030 (https://www.6gsummit.com/). The research community is entirely leveraging the international ML tsunami. We strongly believe that the paradigm of wireless networks is moving toward to a new era. Our view is supported by the fact that artificial Intelligence (AI) in wireless communications is not new at all. The telecommunications industry has been seeking for 20 years to reduce the operational complexity of communication networks in order to simplify constraints and to reduce costs on deployments. This obviously relies on data-driven techniques allowing the network to self-tune its own parameters. Over the successive 3GPP standard releases, more and more sophisticated network control has been introduced. This has supported increasing flexibility and further self-optimization capabilities for radio resource management (RRM) as well as for network parameters optimization.

We target the following key elements :

- Obtaining data from experimental scenarios, at the lowest level (baseband I/Q signals) in multi-user scenarios (based upon FIT/CorteXlab).
- Developing a framework and algorithms for deep learning based radio.
- Developing new reinforcement learning techniques in high dimensional state-action spaces.
- Embedding NN structures on radio devices (FPGA or m-controllers) and in FIT/CorteXlab.
- Evaluating the gap between these algorithms and fundamental limits from information theory.
- Building an application scenario in a smart environment to experiment a fully cross-layer design (e.g. within a smart-building context, how could a set of object could learn their protocols efficiently ?)

4.5. Molecular communications

Many communication mechanisms are based on acoustic or electromagnetic propagation; however, the general theory of communication is much more widely applicable. One recent proposal is molecular communication, where information is encoded in the type, quantity, or time or release of molecules. This perspective has interesting implications for the understanding of biochemical processes and also chemical-based communication where other signaling schemes are not easy to use (e.g., in mines). Our work in this area focuses on two aspects: (i) the fundamental limits of communication (i.e., how much data can be transmitted within a given period of time); and (ii) signal processing strategies which can be implemented by circuits built from chemical reaction-diffusion systems.

A novel perspective introduced within our work is the incorporation of coexistence constraints. That is, we consider molecular communication in a crowded biochemical environment where communication should not impact pre-existing behavior of the environment. This has lead to new connections with communication subject to security constraints as well as the stability theory of stochastic chemical reaction-diffusion systems and systems of partial differential equations which provide deterministic approximations.

5. Highlights of the Year

5.1. Highlights of the Year

Over the last year, the MARACAS team has made a number of significant contributions in the form of journal publications and international conference proceedings, invited lectures in international conferences and schools, as well as contributions in the form of organization of international conferences and editorial roles in international IEEE journals. These include 9 high quality journal publications and over 10 international conference proceedings, spanning many areas of communication and information theory as well as signal processing. In particular, these results contribute to the ongoing development of 5G wireless communication systems and also to emerging areas of communications in the form of the smart grid and molecular communications.

5.1.1. Awards

- Samir Perlaza: Visiting Research Collaborator (Honorific Position), Term 2019 - 2020, at the Department of Electrical Engineering, Princeton University. Annual Renew under evaluation of a Departmental Committee.
- Samir Perlaza: Fellowship of The Finnish Society of Sciences and Letters for visiting the School of Energy Systems at Lappeenranta University of Technology, Finland. April, 2019.
- Bayram Akdeniz: 2nd place in the Molecular MIMO Competition at the IEEE Communication Theory Workshop.
- Cyrille Morin: 1st place in the Machine learning challenge at the 6th Training School on Machine and Deep Learning Techniques for (Beyond) 5G Wireless Communication Systems.

6. New Software and Platforms

6.1. cortexlab-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

6.2. cortexlab-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

6.3. cortexlab-webapp

KEYWORDS: Experimentation - SDR (Software Defined Radio)

FUNCTIONAL DESCRIPTION: User management module, which aims at easing platform usage and improving the metadata that we can associate with each experimenter and experiment. This metadata aims at improving the metrics we can gather about the platform's usage

- Partner: Insa de Lyon
- Contact: Pascal Girard

6.4. CorteXlab-IoT Framework

Framework for PHY-MAC layers Prototyping in Dense IoT Networks using CorteXlab Testbed

KEYWORDS: SDR (Software Defined Radio) - Iot - CorteXlab - GNU Radio

FUNCTIONAL DESCRIPTION: This framework was developed in the project "Enhanced Physical Layer for Cellular IoT" (EPHYL). It provides a customizable and open source design for IoT networks prototyping in a massive multi-user, synchronized and reproducible environment thanks to the hardware and software capabilities of the testbed.

- Author: Othmane Oubejja
- Contact: Othmane Oubejja
- Publication: Framework for PHY-MAC layers Prototyping in Dense IoT Networks using FIT/CorteXlab Testbed
- URL: https://github.com/CorteXlab/gr-ephyl

6.5. Platforms

6.5.1. FIT/CorteXlab

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

New features are under developments, and the platform is used or has been used by several research groups : i) Nokia Bell Labs - Inria common labs for research in machine learning, ii) ANR projects EPHYL and ARBURST for research on massive access for IoT, iii) ERC of prof. Michele Wigger, IMT Paris, for validating distributed coding strategies, iv) Nokia Bell Labs New Jersey for a proof of concept of wireless caching, Greentouch international consortium to develop a prototype of interference alignment.

7. New Results

7.1. Results of axis 1: fundamental limits

We worked in 2019 on the following main research directions:

1. Fundamental limits of IoT networks

Figure 3. FIT/CorteXlab facility

Table 1.

Principal Investigators:	Malcolm Egan, Samir Perlaza, Jean-Marie Gorce
Students:	Dadja Toussaint Anade-Akbo, Lélio Chetot
Funding:	Orange Labs, ANR Arburst
Partners:	Philippe Mary (IETR, Rennes), Laurent Clavier (IRCICA, Lille) JM Kélif (Orange Labs) H. Vincent Poor (Princeton University, NJ, USA)
Publications:	[34], [48], [36], [49], [35]

One of the main figures of merit in an IoT cell is the capability to support a massive access from distributed nodes, but with very small information quantity [12]. This perspective raises fundamental questions relative to the theoretical limits and performance of this kind of very large scale deployments. Fundamental limits are neither well known nor even well formulated. What is the maximal number of IoT nodes we may deploy in a given environment? At which energetic cost? With which transmission reliability or latency? These multiple questions highlight that the problem is not unique and the capacity is not the only (and even not the main) challenge to be addressed. We aim at establishing the fundamental limits of a decentralized system in a bursty regime which includes short packets of information and impulsive interference regime. We are targeting the fundamental limits and their mathematical expression, according to the usual information theory framework capturing the capacity region by establishing converse and achievability theorems.

2. Stability and sensitivity of fundamental limits

Table 2.

Principal Investigator:	Malcolm Egan, Samir Perlaza
Students:	-
Funding:	
Partners:	H. Vincent Poor, Alex Disto, Princeton University Vyacheslav Kungurtsev, Czech Technical University
Publications:	[8],[33]

The analysis of the fundamental limits on communications systems is performed under some assumptions including Gaussian noise, channel input symbols with average power, among others. Nonetheless, despite that these constraints were well suited for describing communications systems in the early 90's, the evolution of these systems make these assumptions vacuous today. Often, noise is better described by α–stable stochastic processes in IoT networks and channel inputs are subject to constraints in the amplitude, energy harvesting etc. From this perspective, our contributions are based on the notion of capacity sensitivity to study the capacity of continuous memoryless point-to-point channels. The capacity sensitivity reflects how the capacity changes with small perturbations in any of the parameters describing the channel, e.g., cost constraints on the input distribution as well as on the noise distribution.

3. Energy self-sustained wireless networks

Table 3.

Principal Investigator:	Samir Perlaza
Students:	Nizar Khalfet
Funding:	H2020 ComMed
Partners:	I. Kikridis (U. of Cyprus)
Publications:	[29], [42], [43], [50]

The main scientific challenge is to set up a theoretical framework for designing and developing fully decentralized energy-self-sustained communications systems. The main motivation stems from the fact that wireless networks deployed in hard-to-reach places, e.g., remote geographical areas, concrete structures, human body or war zones are often limited by the lifetime of their batteries. This contrasts with the fact that hardware is built to last for very long periods. One of the solutions being considered today for solving the energy limitation problem is the use of energy harvesting (EH) techniques. Within this context, our work focuses on the study of wireless communications systems based on EH sources. EH is expected to be the enabler of energy self-sustainability by eliminating the critical dependence on manual battery recharging.

However, a solid answer on whether or not EH is a viable solution can be given only if the corresponding fundamental limits of data transmission based on EH are known. This is mainly because these limits are based on the laws of Physics and thus, determine the barrier between feasible and unfeasible systems. We study the fundamental limits of three strongly correlated problems regarding the energy supply of future wireless networks: (i) Data transmission over centralized and decentralized EH multi-user channels; (ii) Simultaneous energy and information transmission in multi-user channels; and (iii) Energy cooperation. In a near future, we expect to exploit these results to design algorithms and protocols and later to perform a proof of concept on FIT/CorteXlab. We believe that a solid theoretical framework may help to drive the future design and performance evaluation of applications involving EH based wireless communications systems within smart buildings, smart cities.

4. Security and Privacy

Table 4.

Principal Investigator:	Samir Perlaza
Students:	David Kibloff
Funding:	Inria-DGA PhD
Partners:	Guilaume Villemaud (Socrate), Ligong Wang (ETIS, Cergy) Raphael Shaeffer (TU Berlin)
Publications:	[44], [51]

Information theory is also well adapted to study the fundamental limits of privacy and secrecy. Indeed, the wiretap channel and the covert communication [53] models have been shown to be appropriate for privacy preserving communications in wireless communications. With the PhD of David Kibloff defended in October 2019, we explored the following problem. Given a code used to send a message to two receivers through a degraded discrete memoryless broadcast channel (DM-BC), the sender wishes to alter the codewords to achieve the following goals: (i) the original broadcast communication continues to take place, possibly at the expense of a tolerable increase of the decoding error probability; and (ii) an additional covert message can be transmitted to the stronger receiver such that the weaker receiver cannot detect the existence of this message. The main results are: (a) feasibility of covert communications is proven by using a random coding argument for general DM-BCs; and (b) necessary conditions for establishing covert communications are described and an impossibility (converse) result is presented for a particular class of DM-BCs. Together, these results characterize the asymptotic fundamental limits of covert communications for this particular class of DM-BCs within an arbitrarily small gap. Future extensions will concern the Gaussian and other continuous channels, or more complex scenarios where some subsets of nodes are willing to communicate while some external observers cannot even detect the existence of these messages. Covert communication allows to introduce a side constraint that prevent a network to be attacked.

5. Structured Codes for Quantization and Channel Estimation

Table 5.

Principal Investigator:	Malcolm Egan
Publications:	[25]

Finite frames are sequences of vectors in finite dimensional Hilbert spaces that play a key role in signal processing and coding theory. In this work, we study the class of tight unit-norm frames for $\mathbb{C}^d$ that also form regular schemes, which we call tight regular schemes (TRS). Many common frames that arising in vector quantization and channel state estimation, 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 cubature rules for integrals over spheres in $\mathbb{C}^d$—with weights dependent on the Voronoi regions of each frame element. Aided by additional numerical evidence, we conjecture that all TRSs in fact satisfy this property.

7.2. Results of axis 2: algorithms

1. Massive random access in LPWAN

Table 6.

Principal Investigator:	Jean-Marie Gorce, Claire Goursaud
Students:	Diane Duchemin, Lélio Chetot
Funding:	ANR Ephyl, Inria-Nokia common lab
Partners:	Sequans, Supelec Rennes, ISEP, CEA Leti, Nokia
Publications:	[30], [31], [37], [47]

The optimization of IoT access techniques was the objective of the ANR Ephyl collaborative project, where we studied different solutions at the PHY and MAC layers as presented in [47].

The main question Maracas group addressed in this research is the detection of simultaneous random transmissions from distributed nodes. The underlying mechanism is a coded slotted Aloha allowing to avoid hand-skake mechanisms. Each node can transmit randomly and the receiver tries to detect several packets simultaneously. Our objective is to identify a good code family, and to determine the fundamental trade-off in terms of nodes density versus reliability. During this year, we focused on the detection of a small subset of simultaneous active nodes, exploiting optimal detection. We developed a MAP based iterative detector at a multi-antennas receiver in [30]. We also proposed a low complexity detector in [37].

This joint coding-decoding optimization problem will be also investigated from extensive simulations and experimental data (see section 3.4), and represents an interesting problem to evaluate deep learning based approaches.

2. Interference management

Table 7.

Principal Investigator:	Léonardo Cardoso, Jean-Marie Gorce
Students:	Hassan Khalam
Funding:	Fed4PMR (PIA)
Partners:	Thales
Publications:	[41]

Interference management and resource management is a very complex problem in wireless environment (e.g. [55]). The capacity region is known for some specific scenarios and some specific channel conditions. But the optimal performance relies on perfect feedback mechanisms, to get channel state information at the transmitters and to coordinate them. As proposed by Jafar et al, topological interference management (TIM) [56] is a seducing framework to balance performance with feedback complexity. In the context of the Fed4PMR project, we develop new algorithms to allow partial coordination between interfering transmitters [41], relying only on some partial interference information. This approach suits particularly well with the requirements of PMR networks, since their deployments is not optimized. The algorithm relies on an association of degrees of freedom evaluation, graph theory and interference alignment.

Based on this first study, we will explore the suitability of TIM in other application scenarios (especially for the standard IEE802.11ax under preparation). For short, TIM allows to build optimal graph representations of a wireless networks, with reduced coordination needs. TIM can be seen as an approach to optimally quantize a complex interfering graph and to distribute its knowledge in an optimal fashion.

3. Learning in radio systems

Table 8.

Principal Investigator:	Léonardo Cardoso, Malcolm Egan, Jean-Marie Gorce
Student:	Cyrille Morin, Mathieu Goutay
Funding:	ADR Analytics, Inria-Nokia common lab AI chair ANR program (applied)
Partners:	Jakob Hoydis, Nokia Bell Labs
Publications:	[45]

Following the artificial intelligence tsunami, the research community in wireless systems (both industry and academia) is engaged in a strong competition to determine how this revolution could change the paradigm of wireless networks. Following the preliminary studies made by Jakob Hoydis [54], we investigate in this research action, the potential of deep learning in radio communications. The central question is to identify which processing could take advantage from neural networks against classical approaches.

Our joint strategy with Nokia follows: we target the production of a huge set of experimental data with FIT/CorteXlab to facilitate the comparison of different solutions and to train neural networks on real data. We currently investigate three original problems : transmitter identification from its RF signature (Cyrille Morin PhD) [45], self-synchronization procedures based on neural networks (Cyrille Morin PhD) and dirty RF compensation (Mathieu Goutay PhD, patents submitted). Last but not least, we believe that an intelligent radio should be able to learn from its environment and to adapt its behavior. Therefore, in the future, we will explore reinforcement principles associated to neural networks and applied to learning based radio.

This topic is very hot, and most top ranked conference have special sessions on this topic. We believe that our partnership with Nokia, our data sets from FIT/CorteXlab and our experience in estimation theory let us be highly competitive.

7.3. Results of axis 3: experimental assessment

During 2019-2020, our experimental work was mostly devoted to the development of new functions of FIT/CorteXlab, and to the development of experimental evaluations with external partners.

1. Development of a user and administrative graphical interface

Table 9.

Principal Investigator:	Pascal Girard, Matthieu Imbert, Léonardo Cardoso
Funding:	FIT/CorteXlab
Partners:	FIT consortium

The objective is to develop a web-based user-friendly interface for using CorteXlab. Several modules are planned and the first module is the user management module, which aims at easing platform usage and improving the metadata that we can associate with each experimenter and experiment. This metadata aims at improving the metrics we can gather about the platform's usage.

2. Development of a docker-based experiment conducting middleware.

Table 10.

Principal Investigator:	Matthieu Imbert, Léonardo Cardoso
Funding:	FIT/CorteXlab
Partners:	FIT consortium

CorteXlab relies on Minus, an experiment conducting middleware which allows users to submit experimental tasks to the platform, handles the automatic execution of these experiments, and gathers their results. The initial design for Minus relies on a fixed toolchain (mainly composed of GNURadio, hardware drivers, and additional external or in-house software or GNURadio blocks, FPGA tools, etc.). Experimenters are supposed to use this fixed toolchain in a batch-like workflow. It is hard for experimenters to extend the limits of the fixed toolchain (e.g. to use a custom library or software, or a different version of GNURadio), and the development phase of an experiment can be painful due to the batch-like interface. To improve this, we have developed a new experimental workflow based on docker [61] images and containers which allows experimenters to use our in-house provided docker images [52], adapt them if needed, or even create completely custom ones. These images have the benefit that they can be used identically on the experimenters' workstations, on the CorteXlab platform, or another platform, and they can be used interactively if needed, even on CorteXlab. This increases greatly the ease of use of the platform, the reproducibility and share-ability of experiments, and the breadth of its usage.

3. Reference scenario for massive IoT access

Table 11.

Principal Investigator:	Othmane Oubejja, Jean-Marie Gorce Matthieu Imbert, Léonardo Cardoso
Funding:	ANR Ephyl, ANR ARburst
Partners:	CEA Leti, Supelec Rennes, Sequans
Publications:	[46]

In this work we developed an experimental setup for dense IoT access evaluation, as part of the project "Enhanced Physical Layer for Cellular IoT" (EPHYL), using FIT/CorteXlab radio testbed. The aim of this work is to provide a customizable and open source design for IoT networks prototyping in a massive multi-user, synchronized and reproducible environment thanks to the hardware and software capabilities of the testbed. The massive access feature is managed by emulating a base station and several sensors per radio nodes. As shown in Fig.4, two categories of modular network components are used in our design: a base station unit and a multi-sensor emulator unit. These components are separately hosted in dedicated and remotely accessible radio nodes.

The features of this design can be accessed through customizable demos as documentation and resources are available online. As a result, it is possible for any interested user to plug custom algorithms, evaluate diverse communication scenarios and perform necessary physical measurements.

7.4. Results of axis 4: other application fields

1. Smart Grid

Table 12.

Principal Investigators:	Samir Perlaza
Student:	Matei Moldoveanu (visitor)
Partners:	Inaki Esnaola
Publications:	[40]

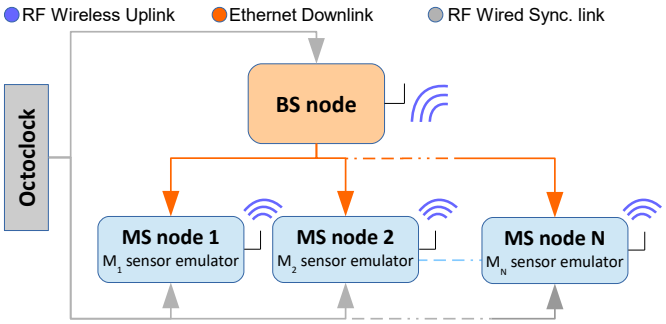

Figure 4. EPHYL IoT network representation

We study the recovery of missing data from multiple smart grid datasets within a matrix completion framework. The datasets contain the electrical magnitudes required for monitoring and control of the electricity distribution system. Each dataset is described by a low rank matrix. Different datasets are correlated as a result of containing measurements of different physical magnitudes generated by the same distribution system. To assess the validity of matrix completion techniques in the recovery of missing data, we characterize the fundamental limits when two correlated datasets are jointly recovered. We then proceed to evaluate the performance of Singular Value Thresholding (SVT) and Bayesian SVT (BSVT) in this setting. We show that BSVT outperforms SVT by simulating the recovery for different correlated datasets. The performance of BSVT displays the tradeoff behaviour described by the fundamental limit, which suggests that BSVT exploits the correlation between the datasets in an efficient manner.

2. Molecular Communications

Table 13.

Principal Investigators:	Malcolm Egan
Postdoc:	Bayram Akdeniz
Funding:	Inria Projet Recherche Exploratoire (PRE)
Partners:	Valeria Loscri (FUN Team, Inria) Marco Di Renzo (CNRS), Bao Tang (University of Graz, Austria) Trung Duong (Queen's University Belfast) Ido Nevat (TUMCREATE, Singapore)
Publications:	[38], [39], [24], [26]

Some of the most ambitious applications of molecular communications are expected to lie in nanomedicine and advanced manufacturing. In these domains, the molecular communication system is surrounded by a range of biochemical processes, some of which may be sensitive to chemical species used for communication. Under these conditions, the biological system and the molecular communication system impact each other. As such, the problem of coexistence arises, where both the reliability of the molecular communication system and the function of the biological system must be ensured. In this paper, we study this problem with a focus on interactions with biological systems equipped with chemosensing mechanisms, which arises in a large class of biological systems. We motivate the problem by considering chemosensing mechanisms arising in bacteria chemo-taxis, a ubiquitous and well-understood class of biological systems. We then propose strategies for a molecular communication system to minimize disruption of biological system equipped with a chemosensing mechanism. This is achieved by exploiting tools from the theory of chemical reaction

networks. To investigate the capabilities of our strategies, we obtain fundamental information theoretic limits by establishing a new connection with the problem of covert communications.

3. Intelligent Transportation

Table 14.

Principal Investigators:	Malcolm Egan
Partners:	Michel Jakob (Czech Technical University in Prague), Nir Oren (University of Aberdeen)
Publications:	[27]

Market mechanisms are now playing a key role in allocating and pricing on-demand transportion services. In practice, most such services use posted-price mechanisms, where both passengers and drivers are offered a journey price which they can accept or reject. However, providers such as Liftago and GrabTaxi have begun to adopt a mechanism whereby auctions are used to price drivers. These latter mechanisms are neither posted-price nor classical double auctions, and can instead be considered a hybrid mechanism. In this work, we develop and study the properties of a novel hybrid on-demand transport mechanism. Due to the need for incorporating statistical knowledge and communication of system state information, communication-theoretic methods can play a useful role.

In particular, as these mechanisms require knowledge of passenger demand, we analyze the data-profit tradeoff as well as how passenger and driver preferences influence mechanism performance. We show that the revenue loss for the provider scales with $\sqrt{n \log n}$ for n passenger requests under a multi-armed bandit learning algorithm with beta distributed preferences. We also investigate the effect of subsidies on both profit and the number of successful journeys allocated by the mechanism, comparing these with a posted-price mechanism, showing improvements in profit with a comparable number of successful requests.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

We have currently the following partnerships

1. Inria-Nokia Bell Labs common lab (600k€) : we are involved in two research actions (Analytics, and Network Information Theory), with the funding of two PhDs and 1 postdoc (to be hired) for Maracas.
2. SPIE-ICS (1Meuros, 2017-2021) : 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. The SPIE-ICS / Insa Lyon chaire on IoT has been setup in 2017 by JM Gorce for the benefit of the CITIlab. JM Gorce was the head of this chair from 2016 to 2019 and is now vice-head (Frédéric Le Mouel is heading the chair since sept 2019). The remaining budget for Maracas corresponds to one postdoc to be hired nad overhead costs.
3. Sigfox : we are collaborating with Sigfox for several years. Maracas explored the performance of UNB networks with an emphasis on robust signal processing techniques (PhD defended on Dec 2018) and a new contract is in preparation for a PhD grant to be started in September, 2020.
4. Orange Labs : our research contract ended in 2018 and we are preparing a new contract.

8.2. Bilateral Grants with Industry

1. PhD grant of Mathieu Goutay (with Nokia Bell Labs, 2019-2022).

9. Partnerships and Cooperations

9.1. Regional Initiatives

- QAMUT *Quantum Algorithms for Multi Users wireless Transmissions* (2019-2021, leader : MARACAS, partners LIP and Institut Camille Jourdan). This project aims to propose new multi-user detection algorithms for wireless transmission systems, based on a quantum architecture.
- *Statistical Hypothesis Testing with Persistent Homology* 2019-2021, leader: MARACAS, partners CRAL. This project aims to develop statistical signal processing methods exploiting persistent homology.

9.2. National Initiatives

9.2.1. ANR

- ANR EPHYL *Enhanced PHY for Cellular Low Power Communication IoT* (2016-2019, 183 keuros, leader : Sequans). This project aims 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.
- ANR ARBURST *Acheivable region of bursty wireless networks* (2016-2020, 195 KEuros, leader : MARACAS). In this project, we propose an original approach complementary to other existing projects, devoted to the study of IoT networks fundamental limits. Instead of proposing one specific technical solution, our objective is to define a unified theoretical framework. 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.
- ANR EquipEx FIT/CorteXlab (2009-2020, 1M€, leader : UPMC). The FIT projet is a national equipex headed by the Lip6 laboratory. As a member of Inria, Maracas is in charge of the development of the Experimental Cognitive Radio platform (CorteXlab) that is used as a testbed 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).

9.2.2. Autres sections...

1. SILECS is a research infrastructure being built to gather the efforts of several testbeds, relying on the success of Grid'5000 and FIT https://www.silecs.net/.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

1. COM-MED, *COMMunication systems with renewable Energy micro-griD*
   - Programm: H2020
   - Duration: October 2016 - October 2019
   - Coordinator: Inria
   - Inria contact: Samir M. Perlaza
   - Summary : 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.
2. WindMill, *Machine Learning for Wireless Communications*
   - Programm: H2020; European Training Network (ETN).
   - Duration: January 2019 - December 2022.
   - Coordinator: Aalborg University, DK
   - Inria contact: Jean-Marie Gorce
   - Summary : With their evolution towards 5G and beyond, wireless communication networks are entering an era of massive connectivity, massive data, and extreme service demands. A promising approach to successfully handle such a magnitude of complexity and data volume is to develop new network management and optimization tools based on machine learning. This is a major shift in the way wireless networks are designed and operated, posing demands for a new type of expertise that requires the combination of engineering, mathematics and computer science disciplines. The ITN project WindMill addresses this need by providing Early Stage Researchers (ESRs) with an expertise integrating wireless communications and machine learning. The project will train 15 ESRs within a consortium of leading international research institutes and companies comprising experts in wireless communications and machine learning. This a very timely project, providing relevant inter-disciplinary training in an area where machine learning represents a meaningful extension of the current methodology used in wireless communication systems. Accordingly, the

project will produce a new generation of experts, extremely competitive on the job market, considering the scale by which machine learning will impact the future and empower the individuals that are versed in it. The project will also nurture the sense of responsibility of the ESRs and the other participants through personal engagement in the training program and by promoting teamwork through collaborative joint projects.

9.3.2. Collaborations in European Programs, Except FP7 & H2020

- Program: PHC Amadeus 2020
- Title: Towards Rigorous Design of Molecular Communication Systems
- Duration: 1/2020 - 12/2021
- Coordinator: Malcolm Egan (MARACAS)
- Other Partners: Institute of Mathematics and Scientific Computing, University of Graz, Austria; CNRS.
- Abstract: The main aim of this project is to bring together experts in molecular communication (Univ. Lyon, Inria, CNRS) and in chemical reaction-diffusion systems (Univ. Graz) to (i) develop novel design of molecular communication systems using up-to-date mathematical results in chemical reaction-diffusion systems, and (ii) strengthen the mathematical theory about chemical reaction networks arising from designation of communication systems.
- Program: COST
- Title: COST Action CA15104, IRACON Inclusive Radio Communications
- Duration: 3/2016 - 3/2020
- Coordinator: Prof. Claude Oestges, University Catholique de Louvain, Belgium.
- Other Partners: many, see website.
- Abstract: This COST Action aims at scientific breakthroughs by introducing novel design and analysis methods for the 5th-generation (5G) and beyond-5G radio communication networks. Challenges include i) modelling the variety of radio channels that can be envisioned for future inclusive radio, ii) capacity, energy, mobility, latency, scalability at the physical layer and iii) network automation, moving nodes, cloud and virtualisation architectures at the network layer, as well as iv) experimental research addressing Over-the-Air testing, Internet of Things, localization and tracking and new radio access technologies. The group of experts supporting this proposal comes from both academia and industry, from a wide spread of countries all over Europe, with the support of some non-COST institutions and R&D associations and standardisation bodies worldwide. The proposers have also long experience on COST Actions in the Radiocommunications field.

9.4. International Initiatives

9.4.1. Inria International Partners

9.4.1.1. Informal 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.
- 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.
- 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.
- UMNG (Universidad Militar de Nueva Granada), Telecommunications Department, Bogota, Colombia. Ongoing collaboration on security for GSM networks using deep learning. Scientific-in-charge at Inria: Leonardo S. Cardoso.
- Department of Power, Electronic and Communication Engineering, University of Novi Sad, Serbia. This collaboration is on GNU radio and signal processing around FIT/CorteXlab with Prof. Dejan Vukobratovic. Scientific-in-charge at Inria: Jean-Marie Gorce.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

9.5.1.1. Internships

1. Huy Duy Do, February-July 2019, Master Thesis MONABIPHOT, ENS Cachan, "Biological Circuits for Detection in Molecular Communication".
2. Antoine Dejonghe, September 2018-July 2020, Telecommunication Department's Research Track, INSA-Lyon, "Techniques for Massive Access in Dense IoT Networks" (Provisional Title)
3. Nuria Vinyes, September 2019-January 2020, Master Thesis, UPC Barcelona, "Simultaneous Information and Energy Transmission: Towards Feasible Systems"
4. Charlotte Hoefler-Hoerle – Undergraduate Student at INSA de Lyon (programme "parcours recherche" de l'INSA de Lyon), Leonardo S. Cardoso and Samir M. Perlaza.
5. INSA de Lyon, D´epartement des T´el´ecommunications. I have advised the following students during their final projects for obtaining the title of Engineer of INSA of Lyon: Samia Bouchareb (2015) and Naslaty Ali Kari (2016), L´elio Chetot (2016), Matias Dwek (2016), and Mamy Niang (2016), Charlotte Hoefler-Hoerle (2019), Adam Ben-Ltaifa (2019), Carl Hatoum (2019).
6. ENS de Lyon, D´epartement d'Informatique. I have advised the following students during their M2-level projects: Lucas Venturini (2019) and Tran Xuan Thang (2019).
7. Matei Catalin Moldoveanu – Master Student at University of Sheffield (Research Intern, Summer 2019).

9.5.2. Visits to International Teams

9.5.2.1. Research Stays Abroad

- Léonardo Cardoso visited Carles Anton, CTTC (Barcelona, Spain), June 2019.

10. Dissemination

10.1. Promoting Scientific Activities

- Interview to Samir M. Perlaza "A view of the Internet of Things", Cognitive Networks Technical Committee Newsletter, IEEE Communications Society, vol. 5, No. 1, May 2019

10.1.1. Scientific Events: Organisation

10.1.1.1. General Chair, Scientific Chair

- Samir Perlaza: Chair of two special sessions: "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. "Data Analytics for Power Systems" hosted at the 2019 IEEE Data Science Workshop, June 2-5, 2019, Minneapolis, MN, USA.
- Samir Perlaza: Chair of three international Workshops: "Mathematical Tools for IoT Networks Modeling (MOTION)" hosted at the IEEE Wireless Communications and Networking Conference (WCNC). April, 15-18 2019, Marrakech, Morocco. "Resource Allocation, Cooperation and Competition in Wireless Networks (RAWNET)", June 19, 2020, Volvos, Greece. Workshop on Information and Decision Making. A satellite event of the IEEE International Symposium on Information Theory (ISIT), Institut Henri Poincaré, Paris, France, July 10, 2019.
- Samir Perlaza: Publication Chair of the International Symposium on Information Theory (ISIT), July, 2018, Paris, France. (Main conference of the IEEE Information Theory Society)

10.1.1.2. Member of the Organizing Committees

- Leonardo S. Cardoso: Organization and Scientific Commitee of the European GNU Radio Days 2019, June, 2019, Besançon, France.

10.1.2. Scientific Events: Selection

10.1.2.1. Member of the Conference Program Committees

1. Leonardo S. Cardoso
   - IEEE International Conference on Communications (ICC). 7-11 June, 2020, Dublin, Ireland. Member of the Technical Program Committee of the Wireless Communications Symposium.
   - IEEE WCNC 2019, 2020
   - EuCNC 2019, 2020
2. Malcolm Egan
   - IEEE Global Communications Conference (GLOBECOM) 2019, 2020
   - IEEE International Conference on Communications (ICC). 7-11 June, 2020, Dublin, Ireland. Member of the Technical Program Committee of the Wireless Communications Symposium.
   - ACM NanoCommunications Conference (NanCom) 2019, 2020
   - International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS) 2019
3. Jean-Marie Gorce
   - APCC 2019, 2020
   - WF-5G 2019, 2020
   - PIMRC 2019
4. Claire GOURSAUD
   - IEEE ICASSP 2019

5. Samir Perlaza
   - IEEE International Conference on Communications (ICC). 7-11 June, 2020, Dublin, Ireland. Member of the Technical Program Committee of the Wireless Communications Symposium.
   - IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2020) 31 August – 3 September, 2020, London, UK. Member of the Technical Program Committee, Track 3: Mobile and Wireless Networks.
   - International Conference on Computing, Networking and Communications (ICNC). 18-21 February, 2019, Honolulu, Hawaii, USA. Member of the Technical Program Committee.
   - IEEE International Conference on Communications (ICC). 20-24 May 2019, Shanghai, China. Member of the Technical Program Committee of the Wireless Communications Symposium.
   - IEEE Global Communications Conference (Globecom). 9-13 December 2018, Abu Dhabi, UAE. Member of the Technical Program Committee of Workshop on Green and Sustainable 5G Wireless Networks.
   - IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2018) 9-12 September 2018, Bologna, Italy. Member of the Technical Program Committee, Track 3: Mobile and Wireless Networks.

10.1.2.2. Reviewer

1. Malcolm Egan
   - IEEE ISIT 2019
2. Samir Perlaza
   - ISIT, ITW, Eusipco, VTC, Rawnet, WiOpt, GameComm, Globecom, Colcom, PIMRC, Crowncom, WCMC, W-GREEN, ICT, IWCMC, ICC, Infocom, among others.

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

1. Malcolm Egan
   - Associate Editor IEEE Communications Letters
   - Guest Editor IEEE Access Special Section on Molecular Communication Networks
2. Jean-Marie Gorce
   - Associate Editor Springer Journal of Wireless Communications and Networking (JWCN)
3. Claire GOURSAUD
   - Associate Editor of European Transactions on Telecommunications (ETT)
   - Associate Editor of Internet Technologies Letters (ITL)
4. Samir Perlaza
   - 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. (One of the main journals of the IEEE Communication Society)
   - Associate Editor of the IET Smart Grid for the term 2018-2021.
   - Guest Editor of the IEEE Internet of Things Journal, Special Issue on Artificial Intelligence Powered Edge Computing for Internet of Things. Publication date: 2020.

10.1.3.2. Reviewer - Reviewing Activities

1. Malcolm Egan

  - IEEE Transactions on Information Theory
  - IEEE Transactions on Signal Processing
  - IEEE Transactions on Wireless Communications
  - IEEE Transactions on Communications
  - IEEE Transactions on NanoBioscience
  - IEEE Transactions on Molecular, Biological, and Multi-Scale Communications
2. Jean-Marie Gorce
  - IEEE Transactions on Wireless Communications
3. Claire Goursaud
  - IEEE Sensors
  - IEEE Transactions on Communications
  - IEEE Wireless Communication Letters
  - IEEE Internet of Things Journal
4. Samir Perlaza
  - IEEE Journal on Selected Areas in Communications, IEEE Journal on Selected Topics in Signal Processing, IEEE Trans. on Wireless Communications, IEEE Trans. on Communications, IEEE Trans on Vehicular Technologies, IEEE Communications Letters, IEEE Trans. on Mobile Computing, EURASIP Journal on Advances in Signal Processing, EURASIP Journal on Wireless Communications and Networking.

10.1.4. Invited Talks

1. Leonardo S. Cardoso
  - "Transmitter Classification with Supervised Deep Learning". Invited talk at CTTC, June 29, 2019, Barcelona, Spain.
  - "Exploring the Radio Spectrum with GNU Radio". Invited tutorial at European GNU Radio Days , June 19, 2019, Besançon, France..
2. Malcolm Egan
  - Invited Lecture, European School on Information Theory, April 15-19, Nice, 2019.
  - Invited Lecture, International Workshop on Mathematical Tools and Technologies for IoT and mMTC Networks Modeling, 15-18 April, Morocco, 2019.
  - Invited Paper, Third International Balkan Conference on Communications and Networking 2019, 10-12 June, North Macedonia, 2019.
3. Jean-Marie Gorce
  - Invited Paper, International Workshop on Mathematical Tools and Technologies for IoT and mMTC Networks Modeling, 15-18 April, Morocco, 2019.
  - Invited Paper, Special Session on Ultra-Reliable Low-Latency Communicationsgo to top at the 20th international workshop on signal processing advances in wireless communications, 2-5 July, France, 2019.
  - Invited talk entitled *Etat de l'art, focus sur la mobilité et prospectives des communications pour l'IoT*; lors de l'atelier IdéO *Quelles infrastructures numériques et quel IoT pour une mobilité intelligente ?* , organisé par les pôles de compétitivité Systematic and Moveo (regional poles), Paris, Jeudi 26 Sept 2019.
4. Samir Perlaza
  - "Transforming Broadcast Codes to Perform Covert Communications". Invited talk at Department of Automatic Control and Systems Engineering, University of Sheffield, November 26, 2019, Sheffield, UK.

- "Transforming Broadcast Codes to Perform Covert Communications". Invited talk at Centre d'Enseignement et de Recherche en Informatique (CERI) Université d'Avignon, November 14, 2019, Avignon, France.
- "Simultaneous Information and Energy Transmission in Decentralized Networks". Invited talk at Inria, Centre de Recherche Sophia Antipolis Méditerranée, September 24, 2019, Sophia Antipolis, France.
- "Simultaneous Information and Energy Transmission Systems". Invited talk at Eurecom, September 26 2019, Sophia Antipolis, France.
- "On Ultra-Reliable and Low Latency Simultaneous Information and Energy Transmission Systems". Invited talk at Lappeenranta University of Technology, Finland. School of Energy Systems. April 08 2019. Lappeenranta, Finland
- "Information-Theoretic Security in the Smart Grid". Invited talk at Lappeenranta University of Technology, Finland. School of Energy Systems. April 07, 2019, Lappeenranta, Finland.
- "Simultaneous Wireless Information and Energy Transmission". Invited talk at Université de Lille. Institut d'électronique de microélectronique et de nanotechnologie (IEMN), October 4, 2018, Lille, France.

10.1.5. Scientific Expertise

- Jean-Marie Gorce
  - Chair of the evaluation committee for ETIS lab (Cergy) for HCERES.
  - Evaluator of research projects for Region Picardie.
  - Jury member of the senior researchers recruitment competition, Inria.

10.1.6. Research Administration

- Jean-Marie Gorce was:
  - Vice-head for research for the Grenoble Rhone-Alpes research centre.
  - Member (representative for Inria) of the Groupe Academique for University of Lyon.
  - Member of the national evaluation committee, Inria.
- Claire Goursaud was:
  - elected as a CNU member in the 61th section for 2019-2024
- Samir Perlaza was:
  - Member of the On-Line Committee of the IEEE Information Theory Society.
  - Membre du Conseil du Laboratoire CITI à l'INSA de Lyon. Term 2015 - 2019.
  - Committé du Prix Paul CASEAU for the 2017 edition of the thesis award.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master : JM Gorce, M Egan, L Chetot Advanced Digital Communications, 40h eq TD, M1, Telecommunications dept, INSA Lyon, France.

Master : JM Gorce, M Egan, D Duchemin Radio Access Networs, 32h eqTD, M1, Telecommunications dept, INSA Lyon, France.

Master : S Perlaza, JM Gorce, Selected Topics in Information Theory, 32h eqTD, M2, Compute sciences dept, ENS Lyon, France.

Master : L Cardoso, C Morin, Software Radio, 32h eqTD, M2, Telecommunications dept, INSA Lyon, France.

Licence : L Cardoso, C Goursaud, Digital Communications, 80h eqTD, L3, Telecommunications dept, INSA Lyon, France.

Licence : L Cardoso, C Goursaud, Research projetcs, 32h eqTD, L3, Telecommunications dept, INSA Lyon, France.

Master : C Goursaud, Communications Systems, 32h eqTD, M1, Telecommunications dept, INSA Lyon, France.

License : L Cardoso, Electromagnetism and Wave Physics, 104 eqTD, L2, First Cycle Dept, INSA Lyon, France.

License : L Cardoso, Mathematics for Engineering, 60h eqTD, L1, First Cycle Dept, INSA Lyon, France.

10.2.2. Supervision

PhD : David Kibloff, Contributions Théoriques sur les Communications Furtives, INSA Lyon, 17 sept 2019, Samir Perlaza and Guillaume Villemaud.

PhD: Trang Mai, Advanced Technologies in Molecular and Wireless Communication Networks: Analysis, Design and Optimization, Queen's University Belfast, 30 Dec 2019, Trung Duong, Malcolm Egan, and Hien Quoc Ngo.

PhD in progress : Dadja Toussaint Anade-Akpo, Non-asymptotic fundamental limits of impulsive radio communications, 01 oct 2017, Philippe Mary and Jean-Marie Gorce.

PhD in progress : Lélio Chetot, From finite blocklength information theory to multi-user M2M communication protocols, 01 oct 2018, Malcolm Egan and Jean-Marie Gorce.

PhD in progress : Diane Duchemin, Distributed coding for dense IoT networks, October 2016, Claire Goursaud and Jean-Marie Gorce

PhD in progress : Mathieu Goutay, Prédistortion digitale profonde, 01 Feb 2019, Jakob Hoydis and Jean-Marie Gorce.

PhD in progress : Hassan Kallam, Topology aided Multi-User Interference Management in Wireless Networks, 01 Feb 2017, Loonardo S. Cardoso and Jean-Marie Gorce.

PhD in progress : José Rugelles, Deep Learning for Security in GSM Based IoT Systems, 01 Jan 2017, Loonardo S. Cardoso and Edward Guillén.

PhD in progress : Nizar Khalfet, Study of stochastique energy sources to power communication system, 07 nov 2016, Samir Perlaza and Jean-Marie Gorce.

PhD in progress : Cyrille Morin, Deep learning for next generation communication systems, 20 Feb 2018, Leonardo S. Cardoso and Jean-Marie Gorce.

PhD in progress : Ce Zheng, Statistical models for IoT interference, Commenced Oct 2018, Malcolm Egan and Laurent Clavier.

Xiuzhen Ye - Academic Period: 2019 - 2022 – University of Sheffield, Department of Automatic Control and Systems Engineering, Sheffield, UK. Taux d'encadrement : Iñaki Esnaola (University of Sheffield, UK) 50%; and Rob Harrisson (University of Sheffield, UK) 25% and Samir Perlaza (external advisor) 25% Publications: Several under preparation. Thesis Title: Data Injection Attacks in Power Systems

Michalis Eliodorous – PhD Student at University of Cyprus (on-going collaboration during during his PhD)

10.2.3. Juries

1. Leonardo Cardoso
   - Examiner; Thesis Jury for Sumit Kumar supervised by Florian Kaltenberger in Institut Eurecom (Telecom Paristech), Sophia Antipolis, 12 March 2019.

- Examiner; Thesis Jury for Nicolas Araújo supervised by Laurent Clavier in the University de Lille, Lille, 11 July 2019.

2. Malcolm Egan
   - Examiner; Thesis Jury for Pierre Escamilla supervised by Michele Wigger and Abdellatif Zaidi in Telecom ParisTech
   - Invited; Thesis Jury for Yasser Mestrah supervised by Laurent Clavier in the University of Reims Champagne-Ardenne and IMT Lille Douai
3. Jean-Marie Gorce
   - Reviewer; Thesis jury for Gourab Ghatak supervised by Antonio De Domenico (CEA) and Marceau Coupechoux, Telecoms Paris, IMT. 24 janv 2019.
   - Chair; Thesis jury for Alexandre Marcastel, supervised by Veronica Belmega ,Panayotis Mertikopoulos and Inbar Fijalkow, ETIS, Cergy. 21 Feb 2019.
   - Reviewer; HdR jury for Veronica Belmega , ETIS, Cergy. 29 March 2019.
   - Reviewer; HdR jury for Thomas Watteyne, Inria, Sorbonne University. 7 May 2019.
   - Examiner; Thesis jury for Abir Ben Hadj Fredj, supervised by Jean-Claude Belfiore and Ghaya Rekaya-Ben Othman, Telecoms Paris, IMT. 28 June 2019.
   - Examiner; Thesis jury for David Kibloff, supervised by Samir Perlaza and Guillaume Villemaud, INSA Lyon. 17 Sept 2019.
   - Reviewer; HdR jury for Marios Kountouris, Telecoms Paris, IMT. 17 Oct 2019.
   - Reviewer; Thesis jury for Selma Zamoum, supervised by Marie-Laure Boucheret and Jérôme Lacan, Université de Toulouse. 28 Nov 2019.
   - Reviewer; Thesis jury for Kaoutar Abdelalim supervised by Karine Amis and Getachew Redieteab, IMT Atlantique. 9 Dec 2019.
   - Reviewer; Thesis jury for Ibrahim Fawaz, supervised by Philippe Ciblat and Mireille Sarkiss, Telecoms Paris, IMT. 9 Dec 2019.
   - Reviewer; Thesis jury for Marc Kacou, supervised by Valery Guillet, Gheorghe Zaharia, and Ghais El Zein, INSA Rennes. 12 Dec 2019.
   - Reviewer; Thesis jury for Xiaojun Xi supervised by Marco Di Renzo, Supelec, Université Paris Saclay. 19 Dec 2019.
   - Examiner; Thesis jury for Jian Song supervised by Marco Di Renzo, Supelec, Université Paris Saclay. 19 Dec 2019.
4. Claire Goursaud
   - Reviewer for Alex The Phuong Nguyen supervised by Frederic Guilloud and Raphaêl Le Bidan, IMT Atlantique
5. Samir Perlaza
   - Miguel Arrieta, Phd Thesis “Universal Privacy Guarantees for Smart Meters” at the Department of Automatic Control and Systems Engineering, University of Sheffield, November 29 2019, Sheffield, UK.
   - Ms. Nihan Cicek, Mphil Thesis "Probabilistic Energy Management Systems in PV-Rich Communities” Electrical & Electronic Engineering, The University of Melbourne, Australia

11. Bibliography

Major publications by the team in recent years

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

[2] S. BELHADJ AMOR, S. PERLAZA, I. KRIKIDIS, H. V. POOR. *Feedback Enhances Simultaneous Wireless Information and Energy Transmission in Multiple Access Channels*, in "IEEE Transactions on Information Theory", August 2017, vol. 63, n^{o} 8, pp. 5244 - 5265 [*DOI :* 10.1109/TIT.2017.2682166], https://hal.inria.fr/hal-01857373

[3] M. DE FREITAS, M. EGAN, L. CLAVIER, A. GOUPIL, G. W. PETERS, N. AZZAOUI. *Capacity Bounds for Additive Symmetric α -Stable Noise Channels*, in "IEEE Transactions on Information Theory", August 2017, vol. 63, n^{o} 8, pp. 5115-5123 [*DOI :* 10.1109/TIT.2017.2676104], https://hal.univ-reims.fr/hal-02088563

[4] 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

[5] M. EGAN, J. DRCHAL, J. MRKOS, M. JAKOB. *Towards Data-Driven On-Demand Transport*, in "EAI Endorsed Transactions on Industrial Networks and Intelligent Systems", June 2018, vol. 5, n^{o} 14, pp. 1-10 [*DOI :* 10.4108/EAI.27-6-2018.154835], https://hal.archives-ouvertes.fr/hal-01839452

[6] M. EGAN, T. Q. DUONG, M. DI RENZO, J.-M. GORCE, I. NEVAT, V. LOSCRI. *Cognitive Molecular Communication*, in "3rd Workshop on Molecular Communications", 2018

[7] M. EGAN, T. C. MAI, T. Q. DUONG, M. DI RENZO. *Coexistence in Molecular Communications*, in "Nano Communication Networks", February 2018, vol. 16, pp. 37-44 [*DOI :* 10.1016/J.NANCOM.2018.02.006], https://hal.archives-ouvertes.fr/hal-01650966

[8] M. EGAN, S. PERLAZA, V. KUNGURTSEV. *Capacity sensitivity in additive non-gaussian noise channels*, in "2017 IEEE International Symposium on Information Theory (ISIT)", IEEE, 2017, pp. 416–420

[9] I. ESNAOLA, S. PERLAZA, H. V. POOR, O. KOSUT. *Maximum Distortion Attacks in Electricity Grids*, in "IEEE Transactions on Smart Grid", 2016, vol. 7, n^{o} 4, pp. 2007-2015 [*DOI :* 10.1109/TSG.2016.2550420], https://hal.archives-ouvertes.fr/hal-01343248

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

[11] C. GENES, I. ESNAOLA, S. PERLAZA, L. F. OCHOA, D. COCA. *Robust Recovery of Missing Data in Electricity Distribution Systems*, in "IEEE Transactions on Smart Grid", 2018

[12] J.-M. GORCE, Y. FADLALLAH, J.-M. KELIF, H. V. POOR, A. GATI. *Fundamental limits of a dense iot cell in the uplink*, in "Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), 2017 15th International Symposium on", IEEE, 2017, pp. 1–6

[13] C. GOURSAUD, J.-M. GORCE. *Dedicated networks for IoT : PHY / MAC state of the art and challenges*, in "EAI endorsed transactions on Internet of Things", October 2015 [*DOI :* 10.4108/EAI.26-10-2015.150597], https://hal.archives-ouvertes.fr/hal-01231221

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télécommunications", March 2016, pp. 453–46, http://link.springer.com/article/10.1007/s12243-016-0500-4 [*DOI :* 10.1007/s12243-016-0500-4], https://hal.archives-ouvertes.fr/hal-01290211

[15] T. C. MAI, M. EGAN, T. Q. DUONG, M. DI RENZO. *Event Detection in Molecular Communication Networks with Anomalous Diffusion*, in "IEEE Communications Letters", February 2017, vol. 21, n° 6, pp. 1249 - 1252 [*DOI :* 10.1109/LCOMM.2017.2669315], https://hal.archives-ouvertes.fr/hal-01671181

[16] Y. MO, M.-T. DO, C. GOURSAUD, J.-M. GORCE. *Up-Link Capacity Derivation for Ultra-Narrow-Band IoT Wireless Networks*, in "International Journal of Wireless Information Networks", June 2017, vol. 24, n° 3, pp. 300-316 [*DOI :* 10.1007/s10776-017-0361-4], https://hal.inria.fr/hal-01610466

[17] S. PERLAZA, A. TAJER, H. V. POOR. *Simultaneous Energy and Information Transmission: A Finite Block-Length Analysis*, in "IEEE International Workshop on Signal Processing Advances in Wireless Communications", 2018

[18] V. QUINTERO, S. PERLAZA, I. ESNAOLA, J.-M. GORCE. *When Does Output Feedback Enlarge the Capacity of the Interference Channel?*, in "IEEE Transactions on Communications", September 2017, vol. 66, n° 2, pp. 615-628, Part of this work was presented at the 11th EAI International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM), Grenoble, France, May 30-Jun 1 2016 [*DOI :* 10.1109/TCOMM.2017.2753252], https://hal.archives-ouvertes.fr/hal-01432525

[19] V. QUINTERO, S. PERLAZA, I. ESNAOLA, J.-M. GORCE. *Approximate Capacity Region of the Two-User Gaussian Interference Channel with Noisy Channel-Output Feedback*, in "IEEE Transactions on Information Theory", July 2018, vol. 64, n° 7, pp. 5326-5358, Part of this work was presented at the IEEE International Workshop on Information Theory (ITW), Cambridge, United Kingdom, September 2016 and IEEE International Workshop on Information Theory (ITW), Jeju Island, Korea, October, 2015. Parts of this work appear in Inria Technical Report Number 0456, 2015, and Inria Research Report Number 8861. [*DOI :* 10.1109/TIT.2018.2827076], https://hal.archives-ouvertes.fr/hal-01397118

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Publications of the year

Articles in International Peer-Reviewed Journals

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[22] F. DINC, B. CEVDET AKDENIZ, A. E. PUSANE, T. TUGCU. *A General Analytical Approximation to Impulse Response of 3-D Microfluidic Channels in Molecular Communication*, in "IEEE Transactions on NanoBioscience", July 2019, vol. 18, n° 3, pp. 396-403 [*DOI :* 10.1109/TNB.2019.2905417], https://hal.inria.fr/hal-02415993

[23] F. DINC, L. THIELE, B. CEVDET AKDENIZ. *The effective geometry Monte Carlo algorithm: Applications to molecular communication*, in "Modern Physics Letters A", August 2019, vol. 383, pp. 2594 - 2603 [*DOI :* 10.1016/J.PHYSLETA.2019.05.029], https://hal.inria.fr/hal-02415980

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Invited Conferences

[30] D. DUCHEMIN, L. CHETOT, J.-M. GORCE, C. GOURSAUD. *Coded random access for massive MTC under statistical channel knowledge*, in "SPAWC 2019 - 20th IEEE International Workshop on Signal Processing Advances in Wireless Communications", Cannes, France, IEEE, July 2019, pp. 1-5 [*DOI :* 10.1109/SPAWC.2019.8815491], https://hal.inria.fr/hal-02153735

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[32] M. EGAN, B. CEVDET AKDENIZ. *On the Limits of Molecular Communication with Coexisting Biological Systems Towards the Internet of Bio-Nano Things*, in "BalkanCom 2019 - Third International Balkan Conference on Communications and Networking", Skopje, Macedonia, June 2019, pp. 1-5, https://hal.inria.fr/hal-02143434

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International Conferences with Proceedings

[34] D. T. ANADE AKPO, J.-M. GORCE, P. MARY. *Nouvelle borne atteignable de la probabilité d'erreur pour des transmissions en paquets courts*, in "GRETSI 2019 - XXVIIème Colloque francophonede traitement du signal et des images", Lille, France, August 2019, pp. 1-4, https://hal.inria.fr/hal-02428615

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