



RESEARCH CENTER

FIELD

**Networks, Systems and Services,  
Distributed Computing**

Activity Report 2018

# Section Partnerships and Cooperations

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## Coast Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. *Region Grand Est TV Paint (2017–2019)*

**Participants:** Claudia-Lavinia Ignat, Gérald Oster, Cédric Enclos.

Partners: TVPaint Development, Inria Coast project-team

Website: <https://www.tvpaint.com/>

This is a project in collaboration with TVPaint Development financed by Region Grand Est. It is a follow-up of a project in collaboration with TVPaint Development financed by Region Lorraine from 2016 to 2017. The goal is to contribute to the creation of a collaborative system dedicated to manage the production of animated movies. This system has to manipulate a large amount of data in a safe and secure manner. Based on the previously proposed architecture and prototype, this project intends to design and implement a commercial product. In the framework of this project, we bring our expertise in data management, business process management, distributed systems and collaborative systems.

## 8.2. National Initiatives

### 8.2.1. *OpenPaas NG (2015–2019)*

**Participants:** Claudia-Lavinia Ignat, François Charoy [contact], Gérald Oster, Olivier Perrin, Jean-Philippe Eisenbarth, Phillippe Kalitine, Matthieu Nicolas, Mohammed Riyadh Abdmeziem, Victorien Elvinger, Quentin Laporte Chabasse, Hoai Le Nguyen, Hoang Long Nguyen.

Partners: Linagora, XWiki SAS, Nexedi, Coast project-team (Université de Lorraine, LORIA), DaScim team (LIX).

Website: <http://www.open-paas.org/>

This project is financed by BpiFrance and involves French industrial leaders in open-source software development (Linagora, Nexedi, XWiki) and academic partners in collaborative work (Coast team) and recommender systems (DaScim team, LIX). The goal of the project is to develop next generation of cloud enabled virtual desktop based on an Enterprise Social Network to provide advanced collaborative and recommendation services. Coast team is responsible of the work package dedicated to the design of the peer-to-peer collaborative middleware. In this context, we bring our expertise on data replication for collaborative data in peer-to-peer environments and on trust and access control and identity management in distributed collaborative information systems.

## 8.3. International Initiatives

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

#### 8.3.1.1. *USCoast2*

Title: User Studies on Trustworthy Collaborative Systems

International Partner (Institution - Laboratory - Researcher):

Wright State University (United States) - Department of Psychology, Knoesis - Valerie Shalin

Start year: 2016

See also: <http://usCoast.loria.fr>

The proposed project addresses the perception of trust by users, the appropriateness of a trust-based security approach and the role of trust metrics in the management of distributed work. The main challenge of this project is how to measure trust based on user behaviour and to verify by means of experimental studies with users that the trust-based mechanism is acceptable by users. We plan to apply this trust-based mechanism for two types of applications. The first one is collaborative editing where user trust will be computed based on the quality of user contributions for a document or project. The second type of application is in the management of work over a large group of people in order to conduct efficient, high-yield, high-density real time crowdsourcing activities. Partners of USCoast2 project have complementary expertise. Coast provides expertise in collaborative methods, systems and related technologies. Coast will propose algorithms that track and manipulate trust metrics. Knoesis provides expertise on the analysis of human work-related behaviour, including methods of data collection and data analysis, as well as a theoretical foundation for the evaluation of human performance. Knoesis will analyse trust from a psychological phenomenon point of view.

### **8.3.2. Inria International Partners**

#### *8.3.2.1. Informal International Partners*

As part of our work on elastic business processes execution, we started a collaboration with Professor Cesare Pautasso from the University of Lugano. We developed a benchmarking framework for business process execution in the cloud, including hot migration of process engine in a multi-tenant setting. This collaboration resulted in a framework that allows repeatable evaluation of process execution.

## **8.4. International Research Visitors**

### *8.4.1. Visits of International Scientists*

Weihai Yu, The Arctic University of Norway, is doing his sabbatical year in the period September 1, 2018 - August 31, 2019 in the Coast team. He is working on the formalisation of undo with CRDTs.

### *8.4.2. Visits to International Teams*

#### *8.4.2.1. Research Stays Abroad*

- François Charoy visited Knoesis team at Wright State University, OH from the 15th of June to the 23rd of July (USCoast2). He worked with Valerie Shalin on trust in sharing data during crisis among different organisations.
- François Charoy visited the SOC Team of Boualem Benatallah at UNSW, Sydney, Australia from the 26 of August to the 14th of September. He collaborated with Boualem Benatallah on a new project on Composition of cognitive services at a large scale.

## CTRL-A Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. Grenoble Alpes Cybersecurity Institute Cross-Disciplinary Project of the IDEX

The Grenoble Alpes Cybersecurity Institute aims at undertaking ground-breaking interdisciplinary research in order to address cybersecurity and privacy challenges. Our main technical focus is on low-cost secure elements, critical infrastructures, vulnerability analysis and validation of large systems, including practical resilience across the industry and the society.

In Ctrl-A, it is funding an internship position followed by a PhD position to be provided in September 2019 and supervised by Stephane Mocanu.

## 8.2. National Initiatives

### 8.2.1. ANR HPeC

HPeC is an ANR project on Self-Adaptive, Energy Efficient High Performance Embedded Computing, with a UAV case study (<http://hpec.fr/>). The Coordinator is Lab-STICC / MOCS (Lorient / Brest), and the duration: 42 month from october 2015. Others Partners are: UBO, U. Clermont-Ferrand, InPixal.

In Ctrl-A, it is funding a post-doc position, hired in Grenoble and co-advised with Lorient : Soguy Gueye. The work will be continued with a post-doc hired in Lorient : Erwan Moreac. A PhD based in Brest, Chabha Hireche, is co-advised by Stéphane Mocanu.

### 8.2.2. ANR Sacade

The ANR ASTRID Sacade project is funded by DGA. Stéphane Mocanu is in charge of several workpackages including a demonstrator. An expert engineer position is funded for the implementation of attack/defense scenarios in SCADA.

### 8.2.3. Informal National Partners

We have contacts with colleagues in France, in addition to the cooperation mentioned before, and with whom we are submitting collaboration projects, co-organizing events and workshops, etc. They feature : Avalon Inria team in Lyon (Ch. Perez, L. Lefevre, E. Caron), LIP6 (J. Malenfant), Scales Inria team in Sophia-Antipolis (L. Henrio), LIRRM in Montpellier (A. Gamatié, K. Godary, D. Simon), IRISA/Inria Rennes (J. Buisson, J.L. Pazat, ...), Telecom Paris-Tech (A. Diaconescu, E. Najm), LAAS (Thierry Monteil), LURPA ENS Cachan (J.M. Faure, J.J. Lesage).

### 8.2.4. Informal National Industrial Partners

We have ongoing discussions with several industrial actors in our application domains, some of them in the framework of cooperation contracts, other more informal: Eolas/Business decision (G. Dulac, I. Saffiedine), ST Microelectronics (V. Bertin), Schneider Electric (C. El-Kaed, P. Nappey, M. Pitel).

## 8.3. International Initiatives

### 8.3.1. Inria International Labs

We participate in the jLESC, Joint Laboratory for Extreme Scale Computing, with partners Inria, the University of Illinois, Argonne National Laboratory, Barcelona Supercomputing Center, Jülich Supercomputing Centre and RIKEN AICS.

We participated to the 7th Workshop of the JLESC at Urbana-Champaign in July 2017.

We started a cooperation with Argonne National Labs, on Improving the performance and energy efficiency of HPC applications using autonomic computing techniques.

[https://jlesc.github.io/projects/energy\\_autonomic/](https://jlesc.github.io/projects/energy_autonomic/)

We are also exploring possibilities on the topic of integrating FPGAs in HPC grids, with a participation in a workshop at FPT 18.

<https://collab.cels.anl.gov/display/HPCFPGA/HPC-FPGA>

### **8.3.2. Inria International Partners**

#### *8.3.2.1. Informal International Partners*

We have ongoing relations with international colleagues in the emerging community on our topic of control for computing e.g., in Sweden at Lund (K.E. Arzen, M. Maggio), Mälardalen (A. Papadopoulos) and Linnaeus Universities (D. Weyns, N. Khakpour), in the Netherlands at CWI/leiden University (F. Arbab), in the U.K. at Liverpool U. (N. Berthier), in China at Heifei University (Xin An), in Italy at University Milano (C. Ghezzi, A. Leva), in the USA at Ann Arbor University (S. Lafortune) and UMass (P. Shenoy, E. Cecchet).



## DELYS Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### 7.1.1. ANR

#### 7.1.1.1. ESTATE - (2016–2020)

Members: LIP6 (DELYS, project leader), LaBRI (Univ. de Bordeaux); Verimag (Univ. de Grenoble).

Funding: ESTATE is funded by ANR (PRC) for a total of about 544 000 euros, of which 233 376 euros for DELYS.

Objectives: The core of ESTATE consists in laying the foundations of a new algorithmic framework for enabling Autonomic Computing in distributed and highly dynamic systems and networks. We plan to design a model that includes the minimal algorithmic basis allowing the emergence of dynamic distributed systems with self-\* capabilities, *e.g.*, self-organization, self-healing, self-configuration, self-management, self-optimization, self-adaptiveness, or self-repair. In order to do this, we consider three main research streams:

(*i*) building the theoretical foundations of autonomic computing in dynamic systems, (*ii*) enhancing the safety in some cases by establishing the minimum requirements in terms of amount or type of dynamics to allow some strong safety guarantees, (*iii*) providing additional formal guarantees by proposing a general framework based on the Coq proof assistant to (semi-)automatically construct certified proofs.

The coordinator of ESTATE is Franck Petit.

#### 7.1.1.2. RainbowFS - (2016–2020)

Members: LIP6 (DELYS, project leader), Scality SA, CNRS-LIG, Télécom Sud-Paris, Université Savoie-Mont-Blanc.

Funding: is funded by ANR (PRC) for a total of 919 534 euros, of which 359 554 euros for DELYS.

Objectives: RainbowFS proposes a “just-right” approach to storage and consistency, for developing distributed, cloud-scale applications. Existing approaches shoehorn the application design to some pre-defined consistency model, but no single model is appropriate for all uses. Instead, we propose tools to co-design the application and its consistency protocol. Our approach reconciles the conflicting requirements of availability and performance vs. safety: common-case operations are designed to be asynchronous; synchronisation is used only when strictly necessary to satisfy the application’s integrity invariants. Furthermore, we deconstruct classical consistency models into orthogonal primitives that the developer can compose efficiently, and provide a number of tools for quick, efficient and correct cloud-scale deployment and execution. Using this methodology, we will develop an enterprise-grade, highly-scalable file system, exploring the rainbow of possible semantics, and we demonstrate it in a massive experiment.

The coordinator of RainbowFS is Marc Shapiro.

### 7.1.2. LABEX

#### 7.1.2.1. SMART - (2012–2019)

Members: ISIR (Sorbonne Univ./CNRS), LIP6 (Sorbonne Univ./CNRS), LIB (Sorbonne Univ./INSERM), LJLL (Sorbonne Univ./CNRS), LTCI (Institut Mines-Télécom/CNRS), CHArt-LUTIN (Univ. Paris 8/EPHE), L2E (Sorbonne Univ.), STMS (IRCAM/CNRS).

Funding: Sorbonne Universités, ANR.

Description: The SMART Labex project aims globally to enhancing the quality of life in our digital societies by building the foundational bases for facilitating the inclusion of intelligent artifacts in our daily life for service and assistance. The project addresses underlying scientific questions raised by the development of Human-centered digital systems and artifacts in a comprehensive way. The research program is organized along five axes and DELYS is responsible of the axe “Autonomic Distributed Environments for Mobility.”

The project involves a PhD grant of 100 000 euros over 3 years.

## **7.2. European Initiatives**

### **7.2.1. FP7 & H2020 Projects**

#### *7.2.1.1. LightKone*

Title: Lightweight Computation for Networks at the Edge

Programm: H2020-ICT-2016-2017

Duration: January 2017 - December 2019

Coordinator: Université Catholique de Louvain

Partners:

Université Catholique de Louvain (Belgium)

Technische Universitaet Kaiserslautern (Germany)

INESC TEC - Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciencia (Portugal)

Faculdade de Ciencias E Tecnologiada Universidade Nova de Lisboa (Portugal)

Universitat Politecnica De Catalunya (Spain)

Scality (France)

Gluk Advice B.V. (Netherlands)

Inria contact: Marc Shapiro

The goal of LightKone is to develop a scientifically sound and industrially validated model for doing general-purpose computation on edge networks. An edge network consists of a large set of heterogeneous, loosely coupled computing nodes situated at the logical extreme of a network. Common examples are networks of Internet of Things, mobile devices, personal computers, and points of presence including Mobile Edge Computing. Internet applications are increasingly running on edge networks, to reduce latency, increase scalability, resilience, and security, and permit local decision making. However, today’s state of the art, the gossip and peer-to-peer models, give no solution for defining general-purpose computations on edge networks, i.e., computation with shared mutable state. LightKone will solve this problem by combining two recent advances in distributed computing, namely synchronisation-free programming and hybrid gossip algorithms, both of which are successfully used separately in industry. Together, they are a natural combination for edge computing. We will cover edge networks both with and without data center nodes, and applications focused on collaboration, computation, and both. Project results will be new programming models and algorithms that advance scientific understanding, implemented in new industrial applications and a startup company, and evaluated in large-scale realistic settings.

## **7.3. International Initiatives**

### **7.3.1. Participation in Other International Programs**

#### *7.3.1.1. STIC Amsud*

Title: PaDMetBio - Parallel and Distributed Metaheuristics for Structural Bioinformatics

International Partners (Institution - Laboratory - Researcher):

Universidade Federal do Rio Grande do Sul (Brazil)- Márcio Dorn  
 Universidad Nacional de San Luis (Argentina) - Verónica Gil-Costa  
 Universidad de Santiago de Chile (Chile) - Mario Inostroza-Ponta

Duration: 2017 - 2018

Start year: 2017

Structural bioinformatics deals with problems where the rules that govern the biochemical processes and relations are partially known which makes hard to design efficient computational strategies for these problems. There is a wide range of unanswered questions, which cannot be answered neither by experiments nor by classical modeling and simulation approaches. Specifically, there are several problems that still do not have a computational method that can guarantee a minimum quality of solution. Two of the main challenging problems in Structural Bioinformatics are (1) the three-dimensional (3D) protein structure prediction problem (PSP) and (2) the molecular docking problem for drug design. Predicting the folded structure of a protein only from its amino acid sequence is a challenging problem in mathematical optimization. The challenge arises due to the combinatorial explosion of plausible shapes, where a long amino acid chain ends up in one out of a vast number of 3D conformations. The problem becomes harder when we have proteins with complex topologies, in this case, their predictions may be only possible with significant increases in high-performance computing power. In the case of the molecular docking problem for drug design, we need to predict the preferred orientation of a small drug candidate against a protein molecule. With the increasing availability of molecular biological structures, smarter docking approaches have become necessary. These two problems are classified as NP-Complete or NP-Hard, so there is no current computational approach that can guarantee the best solution for them in a polynomial time. Because of the above, there is the need to build smarter approaches that can deliver good solutions to the problem. In this project, we plan to explore a collaborative work for the design and implementation of population based metaheuristics, like genetic and memetic algorithms. Metaheuristics are one of the most common and powerful techniques used in this case. The main goal of this project is to gather the expertise and current work of researchers in the areas of structural bioinformatics, metaheuristics and parallel and distributed computing, in order to build novel and high quality solutions for these hot research area.

#### 7.3.1.2. *Capes-Cofecub*

Title: CHOOSING - Cooperation on Hybrid cOmputing cLOuds for energy SavING

French Partners: Paris XI (LRI), Regal, LIG, SUPELEC

International Partners (Institution - Laboratory - Researcher):

Universidade de São Paulo - Instituto de Matemática e Estatística - Brazil, Unicamp -  
 Instituto de Computação - Brazil

Duration: 2014–2018

The cloud computing is an important factor for environmentally sustainable development. If, in the one hand, the increasing demand of users drive the creation of large datacenters, in the other hand, cloud computing's "multitenancy" trait allows the reduction of physical hardware and, therefore, the saving of energy. Thus, it is imperative to optimize the energy consumption corresponding to the datacenter's activities. Three elements are crucial on energy consumption of a cloud platform: computation (processing), storage and network infrastructure. Therefore, the aim of this project is to provide different techniques to reduce energy consumption regarding these three elements. Our work mainly focuses on energy saving aspects based on virtualization, i.e., pursuing the idea of the intensive migration of classical storage/processing systems to virtual ones. We will study how different organizations (whose resources are combined as hybrid clouds) can cooperate with each other in order to minimize the energy consumption without the detriment of client requirements or quality of service. Then, we intend to propose efficient algorithmic solutions and design new coordination mechanisms that incentive cloud providers to collaborate.

### 7.3.1.3. Spanish research ministry project

Title: BFT-DYNASTIE - Byzantine Fault Tolerance: Dynamic Adaptive Services for Partitionable Systems

French Partners: Labri, Irisa, LIP6

International Partners (Institution - Laboratory - Researcher):

University of the Basque Country UPV - Spain, EPFL - LSD - Switzerland, Friedrich-Alexander-Universität Erlangen-Nürnberg - Deutschland, University of Sydney - Australia

Duration: 2017–2019

The project BFT-DYNASTIE is aimed at extending the model based on the alternation of periods of stable and unstable behavior to all aspects of fault-tolerant distributed systems, including synchrony models, process and communication channel failure models, system membership, node mobility, and network partitioning. The two main and new challenges of this project are: the consideration of the most general and complex to address failure model, known as Byzantine, arbitrary or malicious, which requires qualified majorities and the use of techniques from the security area; and the operation of the system in partitioned mode, which requires adequate reconciliation mechanisms when two partitions merge.

## MIMOVE Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

“BottleNet: Understanding and Diagnosing End-to-end Communication Bottlenecks of the Internet”, project funded by the French research agency (ANR), from Feb 2016 to Sep 2020.

### 9.1.1. Inria Support

#### 9.1.1.1. Inria IPL CityLab@Inria

**Participants:** Valérie Issarny, Bruno Lefèvre.

- **Name:** CityLab@Inria – *Overcoming the Smart City Challenge – Toward Environmental and Social Sustainability*
- **Period:** [January 2014 – November 2018]
- **Inria teams:** CLIME/ANGE, DICE, FUN, MIMOVE, MYRIADS, SMIS/PETRUS, UR-BANET/AGORA
- **URL:** <http://citylab.inria.fr>

The Inria Project Lab (IPL) CityLab@Inria studies ICT solutions toward smart cities that promote both social and environmental sustainability. A strong emphasis of the Lab is on the undertaking of a multi-disciplinary research program through the integration of relevant scientific and technology studies, from sensing up to analytics and advanced applications, so as to actually enact the foreseen smart city Systems of Systems. Obviously, running experiments is a central concern of the Lab, so that we are able to confront proposed approaches to actual settings.

#### 9.1.1.2. Inria IPL BetterNet

**Participants:** Renata Teixeira, Vassilis Christophides, Francesco Bronzino.

- **Name:** BetterNet – *An observatory to measure and improve Internet service access from user experience*
- **Period:** [2016 – 2019]
- **Inria teams:** Diana, Dionysos, Inria Chile, Madynes, MiMove, Spirals
- **URL:** <https://project.inria.fr/betternet/>

BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Our observatory can be defined as a vantage point, where:

1. tools, models and algorithms/heuristics will be provided to collect data,
2. acquired data will be analyzed, and shared appropriately with scientists, stakeholders and civil society,
3. and new value-added services will be proposed to end-users.

#### 9.1.1.3. Inria ADT MOSQUITO

**Participants:** Renata Teixeira, Francesco Bronzino.

- **Name:** MOSQUITO – *A mobile platform to measure the quality of Internet connectivity*
- **Period:** [November 2016 – October 2018]
- **Partners:** Inria MiMove, Inria SPIRALS.

The ADT MOSQUITO is part of the Inria Project Lab (IPL) initiative BetterNet. This ADT project focuses on the design and the development of a measurement platform for the quality of mobile Internet access by federating the existing mobile platforms identified in the BetterNet IPL. Beyond the priceless value of such a measurement platform for the research community, this ADT also aims to publish live reports on the quality of mobile Internet access through the BetterNet initiative.

## 9.2. European Initiatives

### 9.2.1. FP7 & H2020 Projects

#### 9.2.1.1. H2020 ICT FIESTA-IoT

**Participants:** Valérie Issarny, Nikolaos Georgantas, Rachit Agarwal.

**Name:** FIESTA-IoT – *Federated Interoperable Semantic IoT/cloud Testbeds and Applications*

**URL:** <http://fiesta-iot.eu>

**Type:** Research & Innovation Action (ICT)

**Topic:** FIRE+ (Future Internet Research & Experimentation)

**Period:** [February 2015 - January 2018]

**Partners:** Fraunhofer FOKUS (Germany) [**coordinator**], INSIGHT @ National University of Galway (Ireland) [**co-coordinator**], University of Southampton IT Innovation Centre (UK), Inria MiMove, University of Surrey (UK), Unparallel Innovation Lda (Portugal), Easy Global Market (France), NEC Europe Ltd (UK), University of Cantabria (Spain), Com4innov (France), Athens Information Technology (Greece), SOCIEDAD PARA EL DESARROLLO REGIONAL DE CANTABRIA (Spain), Ayuntamiento de Santander (Spain), Korea Electronics Technology Institute (Korea).

Despite the proliferation of IoT and smart cities testbeds, there is still no easy way to conduct large scale experiments that leverage data and resources from multiple geographically and administratively distributed IoT platforms. Recent advances in IoT semantic interoperability provide a sound basis for implementing novel cloud-based infrastructures that could allow testbed-agnostic access to IoT data and resources. FIESTA will open new horizons in IoT experimentation at a global scale, based on the interconnection and interoperability of diverse IoT testbeds. FIESTA will produce a first-of-a-kind blueprint experimental infrastructure (tools, techniques and best practices) enabling testbed operators to interconnect their facilities in an interoperable way, while at the same time facilitating researchers in deploying integrated experiments, which seamlessly transcend the boundaries of multiple IoT platforms. FIESTA will be validated and evaluated based on the interconnection of four testbeds (in Spain, UK, France and Korea), as well as based on the execution of novel experiments in the areas of mobile crowd-sensing, IoT applications portability, and dynamic intelligent discovery of IoT resources. In order to achieve global outreach and maximum impact, FIESTA will integrate an additional testbed and experiments from Korea, while it will also collaborate with IoT experts from USA. The participation of a Korean partner (based its own funding) will maximize FIESTA's value for EC money. Moreover, the project will take advantage of open calls processes towards attracting third-parties that will engage in the integration of their platforms within FIESTA or in the conduction of added-value experiments. As part of its sustainability strategy, FIESTA will establish a global market confidence programme for IoT interoperability, which will enable innovative platform providers and solution integrators to ensure/certify the openness and interoperability of their developments.

## 9.3. International Initiatives

### 9.3.1. Inria International Labs

**Inria@SiliconValley**

Associate Team involved in the International Lab:

#### 9.3.1.1. MINES

Title: Adaptive Communication Middleware for Resilient Sensing & Actuation IN Emergency Response Scenarios

International Partner:

University of California, Irvine (United States) - Information and Computer Science -  
Nalini Venkatasubramanian

Start year: 2018

See also: <http://mimove-apps.paris.inria.fr/mines/index.html>

Emerging smart-city and smart-community efforts will require a massive deployment of connected entities (Things) to create focused smartspaces. Related applications will enhance citizen quality of life and public safety (e.g., providing safe evacuation routes in fires). However, supporting IoT deployments are heterogeneous and can be volatile and failure-prone as they are often built upon low-powered, mobile and inexpensive devices - the presence of faulty components and intermittent network connectivity, especially in emergency scenarios, tend to deliver inaccurate/delayed information. The MINES associate team addresses the resulting challenge of enabling interoperability and resilience in large-scale IoT systems through the design and development of a dedicated middleware. More specifically, focusing on emergency situations, the MINES middleware will: (i) enable the dynamic composition of IoT systems from any and all available heterogeneous devices; (ii) support the timely and reliable exchange of critical data within and across IoT in the enabled large-scale and dynamic system over heterogeneous networks. Finally, the team will evaluate the proposed solution in the context of emergency response scenario use cases.

#### 9.3.2. Inria Associate Teams Not Involved in an Inria International Lab

##### 9.3.2.1. HOMENET

Title: Home network diagnosis and security

International Partner:

Princeton University (United States) - Computer Science Department - Nick Feamster

Start year: 2017

See also: <https://team.inria.fr/homenet/>

Modern households connect a multitude of networked devices (ranging from laptops and smartphones to a number of Internet of Things devices) via a home network. Most home networks, however, do not have a technically skilled network administrator for managing the network, for example to identify faulty equipment or take steps to secure end hosts such as applying security patches. Home networks represent a particularly challenging environment due to the diversity of devices, applications, and services users may connect. The goal of HOMENET is to assist users in diagnosing and securing their home networks. Our approach is based on developing new algorithms and mechanisms that will run on the home router (or in-collaboration with the router). The router connects the home network to the rest of the Internet; it is hence the ideal place to secure home devices and to distinguish problems that happen in the home from those happening elsewhere. We will address a number of research challenges for example in device discovery and fingerprinting, anomaly detection in the Internet of Things, home network diagnosis (including wireless diagnosis). HOMENET will bring together two leading research teams in the network measurement arena with successful prior collaboration. Moreover, Princeton brings an existing home router platform and expertise in security, wireless, and software-defined networks; and MiMove brings an existing Web-based measurement platform, and expertise in traffic-based profiling and anomaly detection.

##### 9.3.2.2. ACHOR

Title: Adaptive enactment of service choreographies

International Partner:

Universidade Federal de Goiás (Brazil) - Computer Science Department - Fabio Costa

Start year: 2016

See also: <http://www.inf.ufg.br/projects/achor>

Service choreographies are distributed compositions of services (e.g., Web services) that coordinate their execution and interactions without centralized control. Due to this decentralized coordination and the ability to compose third-party services, choreographies have shown great potential as an approach to automate the construction of large-scale, on-demand, distributed applications. Technologies to enable this approach are reaching maturity level, such as modeling languages for choreography specification and engines that operate the deployment of services and enactment of choreographies at Future Internet scales. Nevertheless, a number of problems remain open on the way to fully realize the approach, among them: (i) Deployment of multiple choreographies on top of a collection of shared services (considering service sharing as an effective way to increase the utilization of resources); (ii) Dynamic adaptation of functional and non-functional properties due to runtime changes in the environment and user requirements (adapting the set of services and/or the resources used to run the services in order to add/remove/change functions and maintain QoS properties, respectively); and (iii) Seamless and dynamic integration of mobile services (e.g., smartphone apps, sensors and actuators on handhelds and wearables) and cloud-based services (including the need to consider: mobility of both devices and services, resource constraints of mobile devices, temporary disconnection, interoperability between different interaction paradigms (message-passing, event-based, data-sharing) at the middleware layer, and effect of these paradigms on end-to-end QoS). The overall goal of the project is to design an architecture for adaptive middleware to support service choreographies in large-scale scenarios that involve dynamicity and diversity in terms of application requirements, service interaction protocols, and the use of shared local, mobile and cloud resources.

### **9.3.3. Inria International Partners**

#### *9.3.3.1. Informal International Partners*

- Northeastern University (Prof. David Choffnes): We are working on methods based on active probing to diagnose poor video quality.

## **9.4. International Research Visitors**

### **9.4.1. Visits of International Scientists**

Mark Crovella from Boston University is visiting professor at Inria.

### **9.4.2. Visits to International Teams**

#### *9.4.2.1. Research Stays Abroad*

- Valérie Issarny was visiting scholar at the EECS Department at UC Berkeley till August 2018. She was hosted by CITRIS in the context of which she was carrying out collaborative research in the area of smart cities and acting as scientific coordinator of the Inria@SiliconValley program.
- Renata Teixeira is visiting scholar at the Computer Science department at Stanford University.
- Georgios Bouloukakis is Inria postdoctoral fellow at University of California, Irvine, in the context of the Inria@SiliconValley program.



## MYRIADS Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. INDIC - Cybersecurity Pole of Excellence (2014-2020)

**Participants:** Christine Morin, Louis Rilling, Amir Teshome Wonjiga, Clément Elbaz.

Our study carried out in the framework of a collaboration with DGA-MI aims at defining and enforcing SLA for security monitoring of virtualized information systems. To this aim we study three topics:

- defining relevant SLA terms for security monitoring,
- enforcing and evaluating SLA terms,
- making the SLA terms enforcement mechanisms self-adaptable to cope with the dynamic nature of clouds.

The considered enforcement and evaluation mechanisms should have a minimal impact on performance. The funding from DGA funds the PhD of Anna Giannakou (defended in 2017) and Amir Teshome Wonjiga. Clément Elbaz is partially funded by the Brittany Regional Council in the PEC framework.

## 9.2. National Initiatives

### 9.2.1. ADEME RennesGrid

**Participants:** Anne Blavette, Benjamin Camus, Anne-Cécile Orgerie, Martin Quinson.

The aim of the RennesGrid project is to design and implement a large-scale preindustrial microgrid demonstrator in the territory of Rennes Metropole to organize the shared self-consumption of a group of photovoltaic panels coupled to stationary storage devices. Traditional approaches to power grid management tend to overlook the costs, both energy and economic, of using computers to ensure optimal electricity network management. However, these costs can be significant. It is therefore necessary to take them into account along with the design of IT tools during studies of optimal energy management of smart grids. In addition, telecommunication networks are generally considered to have an ideal functioning, that is to say they can not negatively affect the performance of the electricity network. However, this is not realistic and it is necessary to analyze the impact of phenomena such as congestion, latency, failures related to computer equipment or impact on the batteries of sensors, etc. on strategies for optimal management of the electricity network. In this project, we closely collaborate with Anne Blavette (CR CNRS in electrical engineering, SATIE, Rennes) and co-supervise the post-doc of Benjamin Camus who started in April 2018 on evaluating the impact of the IT infrastructure in the management of smart grids.

### 9.2.2. Inria ADT SaaP (2016-2018)

**Participants:** Toufik Boubehziz, Martin Quinson.

The SaaP technological development action (SimGrid As A Platform) funded by INRIA targets the refactoring of SimGrid to make it ready to use in production and teaching contexts. Our ultimate goal is to sustain the development of the framework by involving 5 to 10 companies that are using it internally. Our target of the teaching context is thus an intermediate goal, as we think that the best solution to ensure the adoption of our tool by the industrial engineers is that they discover the tool during their studies.

The technical actions envisioned for this ADT are the complete re-factoring of the software (to make it easier to script a new model within the tool kernel) and a reorganization of the interfaces (for a better integration in the Java and python language). This work is lead by Toufik Boubehziz in collaboration with the whole SimGrid community, which provide valuable feedback.

### 9.2.3. Inria ADT DiFFuSE (2017-2018)

**Participants:** Nikos Parlavantzas, Christine Morin, Manh Linh Pham.

The DiFFuSE technological development action (Distributed framework for cloud-based epidemic simulations) funded by INRIA focuses on the DiFFuSE framework developed by Myriads in the context of MIHMES (2012-2017). MIHMES was a 5-year collaborative multidisciplinary project funded by ANR under the Investments for the Future Program, and led by BIOEPAR, INRA, ONIRIS. DiFFuSE is a framework that provides design support, reusable code, and tools for building and executing epidemic simulations in the cloud. The main objectives of this ADT were to improve the usability and robustness of DiFFuSE, to provide support to scientists for applying the framework to a new epidemic simulations as well as to provide a thorough evaluation of the framework using two case studies.

### 9.2.4. Inria IPL Discovery (2015-2019)

**Participants:** Ehsan Ahvar, Anne-Cécile Orgerie, Matthieu Simonin, Genc Tato, Cédric Tedeschi.

The Inria IPL Discovery officially started in September 2015. It targets the design, development and deployment of a distributed Cloud infrastructure within the network's backbone. It will be based upon a set of building blocks whose design will take locality as a primary constraint, so as to minimize distant communications and consequently achieve better network traffic, partition management and improved availability.

Its developments are planned to get integrated within the OpenStack framework. Myriads is involved in the design of new overlay networks for such environments so as to support efficient messaging and routing. Myriads is also involved in the energy/cost benefit analysis of distributed edge-cloud architectures.

### 9.2.5. Inria IPL CityLab (2015-2018)

**Participants:** Subarna Chatterjee, Christine Morin.

The Inria Project Lab (IPL) CityLab@Inria (<http://citylab.inria.fr>) studies ICT solutions toward smart cities that promote both social and environmental sustainability. A strong emphasis of the Lab is on the undertaking of a multi-disciplinary research program through the integration of relevant scientific and technology studies, from sensing up to analytics and advanced applications, so as to actually enact the foreseen smart city Systems of Systems. City-scale experiments of the proposed platforms and services are planned in cities in California and France, thereby learning lessons from diverse setups.

Myriads investigates advanced cloud solutions for the Future Internet, which are critical for the processing of urban data. It leverages its experience in cloud computing and Internet of services while expanding its research activities to the design and implementation of cloud services to support crowd-Xing applications and mobile social applications.

In 2017, Christine Morin was involved in the preparation of a SPOC entitled "Technological challenges of participatory smart cities", which is proposed in the framework of the EIT Digital professional school. She prepared seven sequences on cloud-based urban data management. This SPOC is the English version of the MOOC entitled "*Défis technologiques des villes intelligentes participatives*" run on the FUN platform in Spring and Fall 2017.

In 2017, we also conducted a comparative experimental evaluation of data stream processing environments executed on clusters and clouds. We compared the performance and energy consumption of Heron, Storm and Flink frameworks with three data streaming representative applications.

### 9.2.6. Inria IPL Hac Specis (2016-2020)

**Participants:** Anne-Cécile Orgerie, Martin Quinson, The Anh Pham.

The goal of the HAC SPECIS (High-performance Application and Computers: Studying PErformance and Correctness In Simulation) project (<http://hacspecis.gforge.inria.fr/>) is to answer methodological needs of HPC application and runtime developers and to allow to study real HPC systems both from the correctness and performance point of view. To this end, we gather experts from the HPC, formal verification and performance evaluation community.

During his second year of PhD thesis, The Anh Pham proposed a new algorithm to mitigate the state space explosion problem, using event folding structures to efficiently compute how to not explore equivalent execution traces more than once. This work, co-advised by Martin Quinson with Thierry Jérón (team SUMO, formal methods), was important to bridge the gap between the involved communities. The work will be submitted in the near future.

During her first year of PhD thesis, Dorra Boughzala studied the energy consumption of GPU and the simulation tools of the literature related to this aspect. Her work is co-advised by Laurent Lefèvre (Avalon team, Lyon), Martin Quinson and Anne-Cécile Orgerie.

### 9.2.7. COSMIC PRE (2016 - 2018)

**Participants:** Benjamin Camus, Anne-Cécile Orgerie, Martin Quinson.

The distributed nature of Cloud infrastructures involves that their components are spread across wide areas, interconnected through different networks, and powered by diverse energy sources and providers, making overall energy monitoring and optimization challenging. The COSMIC project aims at taking advantage of the opportunity brought by the Smart Grids to exploit renewable energy availability and to optimize energy management in distributed Clouds. This PRE, led by Anne-Cécile Orgerie also involves Fanny Dufossé from Datamove team (Inria Grenoble), Anne Blavette from SATIE laboratory (electrical engineering, Rennes), and Benjamin Camus, who finished a 18 months post-doc in March 2018 in the context of this project. Several paper on this project have been presented this year: ACM SIGSIM PADS 2018 [16], SBAC-PAD 2018 [15], IEEE Cluster 2018 [14], IEEE PES ISGT 2018 [37], and one book chapter [38].

### 9.2.8. SESAME ASTRID project (2016-2019)

**Participants:** Pascal Morillon, Christine Morin, Matthieu Simonin, Cédric Tedeschi, Mehdi Belkhiria.

The Sesame project (<http://www.agence-nationale-recherche.fr/Project-ANR-16-ASTR-0026>) led by IMT Atlantique aims at develop efficient infrastructures and tools for the maritime traffic surveillance. The role of Myriads is to define a robust and scalable infrastructure for the real-time and batch processing of vessel tracking information.

In 2018, we investigated the dynamic, decentralized scaling of stream processing applications. Also, we collaborated with the Inria OBELIX team to scale and deploy a machine learning application they developed to build a model of a *normal* vessel trajectory.

### 9.2.9. PIA ELCI (2015-2018)

**Participant:** Anne-Cécile Orgerie.

The PIA ELCI project deals with software environment for computation-intensive applications. It is led by BULL. In the context of this project, we collaborate with ROMA and Avalon teams from Lyon: we co-supervise a PhD student (Issam Rais) funded by this project on multi-criteria scheduling for large-scale HPC environments. Issam successfully defended his PhD in September 2018. This collaboration has led to two publications in 2017: two journal articles published in IJHPCA [3] and CCPE [11] and two conference papers presented at HPCS [26] and ICA3PP [27].

### 9.2.10. CNRS GDS EcoInfo

**Participant:** Anne-Cécile Orgerie.

The EcoInfo group deals with reducing environmental and societal impacts of Information and Communications Technologies from hardware to software aspects. This group aims at providing critical studies, lifecycle analyses and best practices in order to improve the energy efficiency of printers, servers, data centers, and any ICT equipment in use in public research organizations.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. FogGuru

**Participant:** Guillaume Pierre.

Title: MSCA ITN EID

Program: H2020

Duration: September 2017 - August 2021

Coordinator: Guillaume Pierre

Participants:

University of Rennes 1, France (coordinator)

Technisch Universität Berlin, Germany

Elastisys AB, Sweden

U-Hopper srl, Italy

EIT Digital Rennes, France

Las Naves, Spain

FogGuru is a doctoral training project which aims to train eight talented PhD students with an innovative and inter-sectoral research program to constitute the next generation of European Cloud and Fog computing experts. Besides their scientific and technical education, FogGuru's PhD students will receive extensive training in technological innovation and entrepreneurship as well as soft skills. These combined skills will enable them to fully master the innovation process stemming from fundamental research towards invention and development of innovative products and services, and to real-life deployment, experimentation and engagement with beta-testers.

### 9.3.2. Collaborations in European Programs, Except FP7 & H2020

Program: EIT Digital

Project acronym: DriveTrust

Project title: AI-Powered Driving Evaluation

Duration: January 2019 - December 2019

Coordinator: University of Rennes 1

Other partners:

Eurapco, Switzerland

Achmea, the Netherlands

Imec, Belgium

Abstract: This project aims to develop and commercialize an AI-powered dash cam with short range V2X and LTE communication capabilities. The product uses the newest AI capable hardware for real-time object detection. The device can detect street signs, traffic lights, other cars, and pedestrians. Combined with sensor data from the accelerometer, GPS and weather data from the cloud we use the data to calculate different dimensions of driving profiles. In addition the V2X and object detection capabilities allow us to warn the driver in real-time about dangers on the road.

#### 9.3.2.1. NESUS

**Participant:** Anne-Cécile Orgerie.

Program: ICT COST

Project acronym: NESUS

Project title: Network for Sustainable Ultrascale Computing (ICT COST Action IC1305)

Duration: 2014 - 2018

Coordinator: Prof. Jesus Carretero, University Carlos III of Madrid, Spain, <http://www.nesus.eu>

Other partners: 33 COST countries and 11 non-COST countries

Abstract: Ultrascale systems are envisioned as large-scale complex systems joining parallel and distributed computing systems that will be two to three orders of magnitude larger than today's systems. The EU is already funding large scale computing systems research, but it is not coordinated across researchers, leading to duplications and inefficiencies. The goal of the NESUS Action is to establish an open European research network targeting sustainable solutions for ultrascale computing aiming at cross fertilization among HPC, large scale distributed systems, and big data management. The network will contribute to gluing disparate researchers working across different areas and provide a meeting ground for researchers in these separate areas to exchange ideas, to identify synergies, and to pursue common activities in research topics such as sustainable software solutions (applications and system software stack), data management, energy efficiency, and resilience. Some of the most active research groups of the world in this area are members of this proposal. This Action will increase the value of these groups at the European-level by reducing duplication of efforts and providing a more holistic view to all researchers, it will promote the leadership of Europe, and it will increase their impact on science, economy, and society. Anne-Cécile Orgerie is co-responsible of the focus group on metrics, monitoring, instrumentation and profiling in the Working Group 5 on Energy Efficiency. A joint paper has been accepted in 2018 on this topic at the Elsevier journal on Sustainable Computing [2]. In the context of this COST action, we closely collaborate with Pascal Felber's research group from University of Neuchâtel (Switzerland) on energy efficiency in Clouds and in particular on the design of energy cost models for virtual machines. A joint journal paper has been accepted in 2018 for publication in Sustainable Computing: Informatics and Systems, Elsevier [9].

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

#### **Inria@SiliconValley**

Associate Team involved in the International Lab:

##### 9.4.1.1. DALHIS

Title: Data Analysis on Large Heterogeneous Infrastructures for Science

International Partner (Institution - Laboratory - Researcher):

Lawrence Berkeley National Laboratory (United States) - Data Science and Technology department - Deb Agarwal

Start year: 2016

See also: <https://project.inria.fr/dalhis/>

Data produced by scientific instruments (large facilities like telescopes or field data), large-scale experiments, and high-fidelity simulations are increasing in magnitude and complexity. Existing data analysis methods, tools and infrastructure are often difficult to use and unable to provide the complete data management, collaboration, and curation environment needed to manage these complex, dynamic, and large-scale data analysis environments. The goal of the Inria-LBL DALHIS associate team involving the Myriads (PI) and Avalon Inria project-teams and the Data Science and Technology (DST) department at Lawrence Berkeley National Laboratory (LBL) is to create a collaborative distributed software ecosystem to manage data lifecycle and enable data analytics on distributed data sets and resources. Specifically, our goal is to build a dynamic software stack that is user-friendly, scalable, energy-efficient and fault tolerant. Our research determines appropriate execution environments that allow users to seamlessly execute their end-to-end dynamic data analysis workflows in various resource environments and scales while meeting energy-efficiency,

performance and fault tolerance goals. We engage in deep partnerships with scientific teams (Fluxnet in environmental science and SNFactory and LSST experiences in cosmology) and use a mix of user research with system software R&D to address specific challenges that these communities face. This associate team ended in 2018.

#### **9.4.2. Inria Associate Teams Not Involved in an Inria International Labs**

##### *9.4.2.1. FogCity*

Title: QoS-aware Resource Management for Smart Cities

International Partner (Institution - Laboratory - Researcher):

IITKGP (India) - Department of Computer Science and Engineering - Sudip Misra

Start year: 2018

See also: <https://www.inria.fr/en/associate-team/fogcity>

The FogCity associate team proposal concerns a collaboration between the Myriads project-team and a research team at Indian Institute of Technology Kharagpur led by Dr. Sudip Misra. The proposal focuses on a smart city scenario in which data from static and mobile sensors is routed to appropriate fog data centres based on application QoS requirements. The main goal of the research is to select suitable nodes within the fog data centers to optimize the QoS of the applications in terms of latency. The two teams have complementary expertise in theoretical research (Indian partner) and system research (Inria Myriads project-team) and share a strong research interest in IoT and Fog Computing.

#### **9.4.3. Inria International Partners**

##### *9.4.3.1. Informal International Partners*

We collaborate with Prof. Etienne Riviere from UC Louvain on legacy application edgification. Genc Tato spent six month at UCL.

We collaborate extensively with Prof. Gene Cooperman from Northeastern University, USA. One of his students, Onesphore Ndayishimiye, visited us for a three-month visit. Conversely, Arif Ahmed visited Northeastern University for three months as well. These informal collaborations are the basis of a proposal for a joint Inria team.

We collaborate with Dr. Djawida Dib (Tlemcen University, Algeria) on energy-efficient and fault-tolerant resource management in containerized clouds. Christine Morin and Nikos Parlavantzas are co-advising Yasmina Bouizem, who is enrolled in both Tlemcen University and University of Rennes 1.

We collaborate with Prof. Hector Duran-Limon (University of Guadalajara, Mexico) on cloud resource management. Nikos Parlavantzas co-advised Carlos Ruiz Diaz, a PhD student enrolled in the University of Guadalajara, who defended his thesis in January 2018.

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

#### *9.5.1.1. Internships*

- Onesphore Ndayishimiye (PhD student from Northeastern University) spend three months in the Myriads team.
- Lorenzo Civolani (master student from Bologna University) spent three months in the Myriads team.

### **9.5.2. Visits to International Teams**

#### *9.5.2.1. Research Stays Abroad*

- Amir Teshome Wonjiga did a 3-month research internship in the Data Science and Technology department of the Lawrence Berkeley National Laboratory from January to March 2018. He worked with Sean Peisert, staff scientist, on the follow-up of his previous internship in 2017 about ensuring data integrity in the workflow of high performance applications.
- Arif Ahmed spent three months from September to December 2018 at Northeastern University. He worked with Gene Cooperman, Professor, on combining Docker cache sharing (developed in the Myriads team) with checkpoint-restart (developed at Northeastern University) to speed up the starting time of Docker containers.

## SPIRALS Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. Région Hauts-de-France

#### 9.1.1.1. CIRRUS

**Participants:** Yahya Al-Dhuraibi, Stéphanie Challita, Guillaume Fieni, Alexandre Garnier, Christophe Gourdin, Philippe Merle [correspondant], Romain Rouvoy, Lionel Seinturier, Faiez Zalila.

CIRRUS is a 3-year (2017–20) joint team with the Scalair cloud operator and architect company funded by the Hauts-de-France region. The CIRRUS joint team is developing novel solutions in the domains of the on demand configuration of heterogeneous cloud resources, the management of cloud elasticity for all deployed services (SaaS, PaaS, IaaS) in order to guarantee quality of service and user quality of experience, and the taming of financial costs of cloud infrastructures.

#### 9.1.1.2. Alloy@Scale

**Participants:** Philippe Merle [correspondant], Romain Rouvoy, Lionel Seinturier, Zakaria Ournani.

Alloy@Scale is a 12-month project funded in the context of CPER Data program. Alloy@Scale aims at overcoming the limits of the formal verification of large software systems specified with the Alloy formal specification language. For that, the program combines the Grid'5000 infrastructure and the Docker container technology.

### 9.1.2. Inria Lille - Nord Europe

#### 9.1.2.1. ADT LibRepair

**Participants:** Benjamin Danglot, Martin Monperrus, Lionel Seinturier [correspondant], Simon Urli.

ADT LibRepair (2016–18) is a technology development initiative supported by the Inria Lille - Nord Europe Center that aims at supporting the development of an integrated library of automated software repair algorithms and techniques. This ADT builds on our results about with the Astor, Nopol and NpeFix that have been obtained in the context of the defended PhD theses of Matias Martinez [57] and Benoit Cornu [46].

#### 9.1.2.2. ADT FingerKit

**Participants:** Antoine Canda, Walter Rudametkin Ivey [correspondant], Antoine Vastel.

ADT FingerKit (2018–20) is a technology development initiative supported by the Inria Lille - Nord Europe Center that focuses on the design and development of a new and enhanced version of the **AmIUnique** platform. AmIUnique is a data collection and analysis platform to better understand, analyze and vulgarize the uses and threats of browser fingerprinting. This initiative led by Inria is a key asset to better understand novel techniques that threatens the user privacy on Internet. This ADT builds on our first results with the ongoing PhD thesis of Antoine Vastel.

#### 9.1.2.3. ADT e-Lens

**Participants:** Arthur d'Azémar, Guillaume Fieni, Romain Rouvoy [correspondant].

ADT e-Lens (2018–20) is a technology development initiative supported by the Inria Lille - Nord Europe Center that aims at extending the **PowerAPI** energy monitoring library that we develop in the team since 2011. The extension deals with the integration of new power models (for GPU, disk, network interface), the implementation of a self-optimization algorithm, the port of the platform to embedded systems running with Raspberry Pi, ROS and Android, and the implementation of an active learning algorithm for power models. This ADT builds on our results with the defended PhD theses of Adel Nouredine [59] and Maxime Colmant [45], and with the ongoing PhD thesis of Guillaume Fieni.



## 9.2. National Initiatives

### 9.2.1. ANR

#### 9.2.1.1. ANR BottleNet

**Participants:** Romain Rouvoy [correspondant], Walter Rudametkin Ivey, Lionel Seinturier.

BottleNet is a 48-month project (2015–19) funded by ANR. The objective of BottleNet is to deliver methods, algorithms, and software systems to measure Internet *Quality of Experience* (QoE) and diagnose the root cause of poor Internet QoE. Our goal calls for tools that run directly at users’ devices. We plan to collect network and application performance metrics directly at users’ devices and correlate it with user perception to model Internet QoE, and to correlate measurements across users and devices to diagnose poor Internet QoE. This data-driven approach is essential to address the challenging problem of modeling user perception and of diagnosing sources of bottlenecks in complex Internet services. BottleNet will lead to new solutions to assist users, network and service operators as well as regulators in understanding Internet QoE and the sources of performance bottleneck.

#### 9.2.1.2. ANR SATAS

**Participants:** Philippe Merle [correspondant], Romain Rouvoy, Lionel Seinturier.

SATAS is a 48-month project (2015–19) funded by ANR. SATAS aims to advance the state of the art in massively parallel SAT solving with a particular eye to the applications driving progress in the field. The final goal of the project is to be able to provide a “pay as you go” interface to SAT solving services, with a particular focus on their power consumption. This project will extend the reach of SAT solving technologies, daily used in many critical and industrial applications, to new application areas, which were previously considered too hard, and lower the cost of deploying massively parallel SAT solvers on the cloud.

#### 9.2.1.3. ANR Headwork

**Participants:** Pierre Bourhis [correspondant], Marion Tommasi.

Headwork is a 48-month project (2016–21) funded by ANR. The main objective of Headwork is to develop data-centric workflows for programming crowd sourcing systems in flexible declarative manner. The problem of crowd sourcing systems is to fill a database with knowledge gathered by thousands or more human participants. A particular focus is to be put on the aspects of data uncertainty and for the representation of user expertise. This project is coordinated by D. Gross-Amblard from the Druid Team (Rennes 1). Other partners include the Dahu team (Inria Saclay), Sumo (Inria Bretagne), and Links (Inria Lille) with J. Nierhen and M. Sakho.

#### 9.2.1.4. ANR Delta

**Participant:** Pierre Bourhis [correspondant].

Delta is a 48-month project (2016–21) funded by ANR. The project focuses on the study of logic, transducers and automata. In particular, it aims at extending classical framework to handle input/output, quantities and data. This project is coordinated by M. Zeitoun from LaBRI. Other partners include LIF (Marseille), IRIF (Paris-Diderot), and D. Gallois from the Inria Lille Links team.

### 9.2.2. Competitivity Clusters

#### 9.2.2.1. FUI StoreConnect

**Participants:** Aurélien Bourdon, Julien Duribreux, Romain Rouvoy, Lionel Seinturier [correspondant], Antoine Veullier.

StoreConnect is a 36-month project (2016–19) funded by FUI and labelled by the PICOM (**Pôle des Industries du COMmerce**) competitivity cluster. The partners are Tevolys, UbuDu (leader), Smile, STIME, Leroy Merlin, Insiteo, Inria Spirals, **Inria Fun**, **Inria Stars**. The goal of the project is to define a modular multi-sensors middleware platform for indoor geolocation.

### 9.2.3. Inria National Initiatives

#### 9.2.3.1. Inria IPL BetterNet

**Participants:** Lakhdar Meftah, Romain Rouvoy [correspondant], Romain Sommerard, Antoine Veuille.

BetterNet (2016–19) aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Our observatory can be defined as a vantage point, where: (1) tools, models and algorithms/heuristics will be provided to collect data, (2) acquired data will be analyzed, and shared appropriately with scientists, stakeholders and civil society, and (3) new value-added services will be proposed to end-users. IPL BetterNet is led by Isabelle Chrisment (Inria Madynes), with the participation of the [Diana](#), [Dionysos](#), [Inria Chile](#), [Muse](#), and Spirals Inria project-teams, as well as the ARCEP French agency and the ip-label company.

### 9.2.4. CNRS Momentum

#### 9.2.4.1. Manage Your Data Without Information Leakage

**Participants:** Pierre Bourhis [correspondant], Louis Jachiet.

“Gérer vos données sans fuite d’information” is a 3-year (2018–20) project granted in the context of the CNRS-Momentum call for projects. Data manipulated by modern applications are stored in large databases. To protect these pieces of data, security policies limit a user’s access to what she is allowed to see. However, by using the semantics of the data, a user can deduce information that she was not supposed to have access to. The goal of this project is to establish methods and tools for understanding and detecting such data leaks.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

Program: H2020 ICT-10-2016.

Project acronym: STAMP.

Project title: Software Testing Amplification.

Duration: 36 months (2016–19).

Coordinator: Inria.

Other partners: ActiveEon (France), Atos (Spain), Engineering (Italy), OW2 (France), SINTEF (Norway), TellU (Norway), TU Delft (The Netherlands), XWiki (France).

Abstract: By leveraging advanced research in automatic test generation, STAMP aims at pushing automation in DevOps one step further through innovative methods of test amplification. It will reuse existing assets (test cases, API descriptions, dependency models), in order to generate more test cases and test configurations each time the application is updated. Acting at all steps of development cycle, STAMP techniques aim at reducing the number and cost of regression bugs at unit level, configuration level and production stage.

**Participants:** Benjamin Danglot, Martin Monperrus [correspondant].

Program: H2020 JU Shift2Rail.

Project acronym: X2Rail-1.

Project title: Start-up activities for Advanced Signalling and Automation System.

Duration: 36 months (2016–19).

Coordinator: Siemens.

Other partners: 19 partners, among others Bombardier, Siemens, Thales, IRT Railenium.

Abstract: Our contribution to the project is focused on adaptive communication middleware for cyber-physical railway systems.

**Participants:** Lionel Seinturier [correspondant].

Program: EIT Digital.

Project acronym: MCS.

Project title: Multi-Cloud Studio.

Duration: 12 months (2018).

Coordinator: Inria.

Other partners: Santer Reply (Italy) and Scalair (France).

Abstract: The goal of this EIT Digital activity is to create the Xscalibur start-up and develop its first Multi-Cloud Studio product. This product is a model-driven graphical interface to design, deploy and administrate multi-cloud systems based on Amazon Web Service, OpenStack, and VMware.

**Participants:** Jamal Boudjaj, Rida Darmal, Julien Decaudin, Bénédicte Delcourt, Christophe Gourdin, Philippe Merle [correspondant].

Program: EIT Digital.

Project acronym: Bankable.

Project title: Bankable, Deliver the best mobile banking services and customer experience

Duration: 12 months (2018).

Coordinator: Alfstore.

Other partners: Inria, Cefriel

Abstract: BANKABLE helps consumer banks continuously deliver the best mobile banking experience. The platform will anonymously analyze data gathered from mobile sensors, user context and interactions. Enriched by online customers' feedbacks, the bank will find deeper insights & drive real-time actions.

**Participants:** Romain Rouvroy [correspondant].

### ***9.3.2. Collaborations in European Programs, Except FP7 & H2020***

Program: EUREKA Celtic-Plus.

Project acronym: SENDATE.

Project title: SEcure Networking for a DATa Center Cloud in Europe.

Duration: 36 months (2016–19).

Coordinator: Nokia.

Other partners: 50+ partners in Finland, France, Germany, Norway, and Sweden. Selected partners involved: Nokia, Orange.

Abstract: The project addresses the convergence of telecommunication networks and IT in the context of distributed data centers. We are involved in the TANDEM subproject that targets the infrastructure of such a distributed system. More specifically, we are studying new approaches in terms of software engineering and component-based solutions for enabling this convergence of network and IT.

**Participants:** Lionel Seinturier [correspondant].

## **9.4. International Initiatives**

### ***9.4.1. Inria Associate Teams Not Involved in an Inria International Labs***

#### ***9.4.1.1. SOMCA***

Title: Self-Optimization of Service Oriented Architectures for Mobile and Cloud Applications

International Partner (Institution - Laboratory - Researcher):

Université du Québec À Montréal (Canada) - LATECE - Naouel MOHA

Start year: 2017

See also: <http://sofa.uqam.ca/somca.php>

The long-term goal of this research program is to propose a novel and innovative methodology embodied in an software platform, to support the runtime detection and correction of anti-patterns in large-scale service-oriented distributed systems in order to continuously optimize their quality of service. One originality of this program lies in the dynamic nature of the service-oriented environments and the application on emerging frameworks for embedded and distributed systems (e.g., Android/iOS for mobile devices, PaaS/SaaS for Cloud environments), and in particular mobile systems interacting with remote services hosted on the Cloud.

### **9.4.2. Participation in Other International Programs**

#### *9.4.2.1. PHC Zenon Cyprus - Project RRI-MobDev*

**Participants:** Sarra Habchi, Lakhdar Meftah, Mohammad Naseri, Romain Rouvoy [correspondant], Walter Rudametkin Ivey, Romain Sommerard, Antoine Vastel.

RRI-MobDev (*Responsible Research and Innovation for Mobile Application Development*) is a 2-year (2017–2018) bilateral collaboration with UCLan Cyprus, an overseas campus of the University of Central Lancashire. Mobile applications are part of a complex ecosystem involving various stakeholders (developers, users, app stores, etc.) exposed to various threats, including not only malware, but also potential information leaks through the continuous interactions with remote servers. This project aims to study and alleviate this problem by intervening both with the users and the developers of mobile apps, with an aim of enabling a cleaner, safer and more responsible mobile app ecosystem.

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

Rajkumar Buyya, Redmond Barry Distinguished Professor and Director of the Cloud Computing and Distributed Systems (CLOUDS) Laboratory at the University of Melbourne, visited us in February 2018.

#### *9.5.1.1. Internships*

Mohammad Naseri, MSc. Student in Computer Science from Saarland University, Germany, visited us for 3 months, from November 2017 to January 2018.

Chaima Chakhaba, MSc. Student in Computer Science from ESI Alger, Algeria, visited us for 9 months, from December 2017 to August 2018.

### **9.5.2. Visits to International Teams**

#### *9.5.2.1. Research Stays Abroad*

Thomas Durieux, PhD Student, spent 3 months from April to June 2018 in KTH, Sweden.

## WHISPER Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

- City of Paris, 2016-2019, 100 000 euros. As part of the “Émergence - young team” program the city of Paris is supporting part of our work on domain-specific languages and trustworthy domain-specific compilers.

## 9.2. National Initiatives

### 9.2.1. ANR

**ITrans** - awarded in 2016, duration 2017 - 2020

Members: LIP6 (Whisper), David Lo (Singapore Management University)

Coordinator: Julia Lawall

Whisper members: Julia Lawall, Gilles Muller, Lucas Serrano, Van-Anh Nguyen

Funding: ANR PRCI, 287,820 euros.

Objectives:

Large, real-world software must continually change, to keep up with evolving requirements, fix bugs, and improve performance, maintainability, and security. This rate of change can pose difficulties for clients, whose code cannot always evolve at the same rate. This project will target the problems of *forward porting*, where one software component has to catch up to a code base with which it needs to interact, and *back porting*, in which it is desired to use a more modern component in a context where it is necessary to continue to use a legacy code base, focusing on the context of Linux device drivers. In this project, we will take a *history-guided source-code transformation-based* approach, which automatically traverses the history of the changes made to a software system, to find where changes in the code to be ported are required, gathers examples of the required changes, and generates change rules to incrementally back port or forward port the code. Our approach will be a success if it is able to automatically back and forward port a large number of drivers for the Linux operating system to various earlier and later versions of the Linux kernel with high accuracy while requiring minimal developer effort. This objective is not achievable by existing techniques.

**VeriAmos** - awarded in 2018, duration 2018 - 2021

Members: Inria (Antique, Whisper), UGA (Erods)

Coordinator: Xavier Rival

Whisper members: Julia Lawall, Gilles Muller

Funding: ANR, 121,739 euros.

Objectives:

General-purpose Operating Systems, such as Linux, are increasingly used to support high-level functionalities in the safety-critical embedded systems industry with usage in automotive, medical and cyber-physical systems. However, it is well known that general purpose OSes suffer from bugs. In the embedded systems context, bugs may have critical consequences, even affecting human life. Recently, some major advances have been done in verifying OS kernels, mostly employing interactive theorem-proving techniques. These works rely on the formalization of the programming language semantics, and of the implementation of a software component, but require significant human intervention to supply the main proof arguments. The VeriAmos project will attack this problem by building on recent advances in the design of domain-specific languages and static

analyzers for systems code. We will investigate whether the restricted expressiveness and the higher level of abstraction provided by the use of a DSL will make it possible to design static analyzers that can statically and fully automatically verify important classes of semantic properties on OS code, while retaining adequate performance of the OS service. As a specific use-case, the project will target I/O scheduling components.

## 9.3. International Initiatives

### 9.3.1. Inria International Labs

- EPFL-Inria Lab Our work on scheduling [13] and on the Ipanema DSL [48] is done as part of the EPFL-Inria Lab. Our direct partners, Willy Zwaenepoel and Baptiste Lepers, have moved to the University of Sydney in September 2018. Therefore we have migrated our cooperation.

### 9.3.2. Inria International Partners

#### 9.3.2.1. Informal International Partners

- We collaborate with David Lo and Lingxiao Jiang of Singapore Management University, who are experts in software mining, clone detection, and information retrieval techniques. Our work with Lo and/or Jiang has led to 8 joint publications since 2013 [58], [69], [71], [74], [75], [76], [79], [77], at conferences including ASE and ICSME. The ITrans ANR is a joint project with them.
- We collaborate with David Lo and James Hoang of Singapore Management University and with Sasha Levin of Microsoft on the use of machine learning to identify stable-relevant patches in the Linux kernel. Preliminary results from this collaboration have been presented with Sasha Levin at the Open Source Summit North America, the Open Source Summit Europe, and the Linux Plumbers Conference kernel summit track.
- Our previous collaboration with EPFL has been transferred to the University of Sydney due to the moves of Willy Zwaenepoel and Baptiste Lepers.
- We collaborate with Christoph Reichenbach of the University of Lund and Krishna Narasimhan of Itemis (Germany) on program transformation and the design of tools for code clone management [11].
- We collaborate with Jia-Ju Bai of Tsinghua University on bug finding in Linux kernel code, particularly focusing on issues requiring interprocedural analysis [12].
- As part of the LIP6 Invited Professor program, we have initiated a collaboration between Karine Heydemann (ALSOC team – LIP6, France) and Patrick Schaumont (Virginia Tech, US) on the development of fault-resistant and side-channel attack resistant compilation techniques.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

- Patrick Schaumont of Virginia Tech visited LIP6 in July and November 2018, as part of the LIP6 Invited Professor program.
- David Lo and Lingxiao Jiang of Singapore Management University visited the Whisper team for two weeks in October 2018 as part of the ANR ITrans project.
- Michele Martone of the Leibniz Supercomputing Centre in Munich Germany made two visits of one week each to the Whisper team in August and December to work on applying Coccinelle to high performance computing code.

#### 9.4.1.1. Internships

- Jonathan Carroll of Oberlin College spent January 2018 working on using machine learning to identify stable-relevant patches for the Linux kernel.
- David Bergvelt of the University of Illinois at Urbana-Champaign spent May-August 2018 working on applying Verifiable C, developed at Princeton, to verification of process schedulers.

## WIDE Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. *Web of Browser's (Brittany Region and Labex CominLabs 2019-2020)*

**Participant:** François Taïani.

Browsers are de facto the most widely deployed execution environments in the world. Initially simple HTML readers, they now run complex applications interacting with humans and web services. The recent introduction of WebRTC has further extended the capability of browsers by introducing support for browser-to-browser communication. This turns browsers into a decentralized execution environment where interactions between human and web services are enabled without third party.

The Web of browsers is a vision where the web is serverless, ephemeral and massively decentralized. Web where pages are hosted by networks of browsers connected through WebRTC. The objective of the project is to build and experiment the Web of Browsers.

## 8.2. National Initiatives

### 8.2.1. *Labex CominLab Descent (2013-2018)*

**Participants:** Davide Frey, Michel Raynal, François Taïani.

This project (2013-2018), which also involves researchers from Nantes (LS2N, former LINA), aims to provide fundamental programming blocks to support the construction of federations of plug computers (e.g. Raspberry pi). The project's overarching vision is that everyone should be able create cheap nano-clusters of domestic servers, host data and services and federate these resources with their friends, colleagues, and families.

### 8.2.2. *ANR Project PAMELA (2016-2020)*

**Participants:** Davide Frey, George Giakkoupis, François Taïani.

PAMELA is a collaborative ANR project involving Inria/IRISA, Inria Lille (MAGNET team), UMPC, Mediego and Snips. The project aims at developing machine learning theories and algorithms in order to learn local and personalized models from data distributed over networked infrastructures. This project seeks to provide fundamental answers to modern information systems built by interconnecting many personal devices holding private user data in the search of personalized suggestions and recommendations. A significant asset of the project is the quality of its industrial partners, Snips and Mediego, who bring in their expertise in privacy protection and distributed computing as well as use cases and datasets.

### 8.2.3. *ANR Project OBrowser (2016-2020)*

**Participants:** David Bromberg, Davide Frey, François Taïani.

OBrowser is a collaborative ANR project involving Inria, the University of Nantes, the University of South Brittany, and Orange. The project emerges from the vision of designing and deploying distributed applications on millions of machines using web-enabled technologies without relying on a cloud or a central authority. OBrowser proposes to build collaborative applications through a decentralized execution environment composed of users' browsers that autonomously manages issues such as communication, naming, heterogeneity, and scalability.

### 8.2.4. *ANR Project DESCARTES (2016-2020)*

**Participants:** George Giakkoupis, Michel Raynal, François Taïani.



DESCARTES is a collaborative ANR project involving Inria/IRISA, Labri (U. Bordeaux), IRIF (U. Paris Diderot), Inria Paris (GANG Team), Vérimag (Grenoble), LIF (Marseilles), and LS2N (former LINA, Nantes). The DESCARTES project aims at bridging the lack of a generic theoretical framework in order to unify the large body of fundamental knowledge on distributed computation that has been acquired over the last 40 years. In particular, the project's objective is to develop a systematic model of distributed computation that organizes the functionalities of a distributed computing system into reusable modular constructs assembled via well-defined mechanisms that maintain sound theoretical guarantees on the resulting system.

### **8.2.5. ANR-ERC Tremplin Project NDFUSION (2016-2018)**

**Participant:** George Giakkoupis.

NDFUSION is an 18-month ANR project awarded to George Giakkoupis to support his preparation for his upcoming ERC grant application.

The idea of intervening in a network diffusion process to enhance or retard its spread has been studied in various contexts, e.g., to increase the spread or speed of diffusion by choosing an appropriate set of seed nodes, or achieve the opposite effect either by choosing a small set of nodes to remove, or by seeding a competing diffusion (e.g., to limit the spread of misinformation in a social network).

### **8.2.6. Labex CominLab PROFILE (2016-2019)**

**Participants:** David Bromberg, Davide Frey, François Taïani.

The PROFILE (2016-2019) project brings together experts from law, computer science (the Inria teams DIVERSE and ASAP/WIDE, the IRISA team DRUID) and sociology to address the challenges raised by online profiling, following a multidisciplinary approach. More precisely, the project will pursue two complementary and mutually informed lines of research: first, the project will investigate, design, and introduce a new right of opposition into privacy Law to better regulate profiling and to modify the behavior of commercial companies. Second, the project aims to provide users with the technical means they need to detect stealthy profiling techniques, and to control the extent of the digital traces they routinely produce.

## **8.3. International Initiatives**

### **8.3.1. Inria Associate Teams Not Involved in an Inria International Lab**

#### **8.3.1.1. LiDiCo**

Title: Aux limites du calcul réparti

International Partner (Institution - Laboratory - Researcher):

UNAM (Mexico) - Instituto de Matematicas - Sergio Rajsbaum

Start year: 2017

See also: <https://sites.google.com/site/lidicoequipeassocie/>

Today distributed applications are pervasive, some very successful (e.g., Internet, P2P, social networks, cloud computing), and benefit everyone, but the design and the implementation of many of them still rely on ad-hoc techniques instead of on a solid theory. The next generation of distributed applications and services will be more and more complex and demands research efforts in establishing sound theoretical foundations to be able to master their design, their properties and their implementation. This proposal is a step in this inescapable direction.

## **8.4. International Research Visitors**

### **8.4.1. Visits of International Scientists**

Fábio Moreira Costa (Institute of Informatics, Federal University of Goiás, Goiânia, GO, Brazil); 17–28 September, 5–11 November, and 3–14 December 2018.



Paulo Ferreira (INESC ID Lisboa, Portugal); Associate Professor, in Sabbatical, 5 February–17 March 2018.

Hayk Saribekyan (University of Cambridge, UK); 2–12 April 2018

Sergio Rajsbaum (Instituto de Matematicas, Universidad Nacional Autonoma de Mexico, UNAM); 20 April 2018.

Thomas Sauerwald (University of Cambridge, UK); 2–12 April 2018.

## **8.4.2. Visits to International Teams**

### *8.4.2.1. Research Stays Abroad*

Quentin Dufour visited Etienne Rivière, Université de Louvain La Neuve UCL, 5–30 November 2018.

David Bromberg visited University of Sao Paulo, Brazil, 8–24 July 2018.

Michel Raynal visited Jiannong Cao, HK Politechnic University, 17 November–22 December 2018.

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## ALPINES Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

**GIS**, Géosciences franciliennes: scientific collaboration network between ten public institutions from the Paris (Ile-de-France) region, focused on natural resources and environment. The project-team Alpines is a member.

## 9.2. National Initiatives

### 9.2.1. ANR

#### 9.2.1.1. B3DCMB

ANR Decembre 2017 - Novembre 2021 This project is in the area of data analysis of cosmological data sets as collected by contemporary and forthcoming observatories. This is one of the most dynamic areas of modern cosmology. Our special target are data sets of Cosmic Microwave Background (CMB) anisotropies, measurements of which have been one of the most fruitful of cosmological probes. CMB photons are remnants of the very early evolution of the Universe and carry information about its physical state at the time when the Universe was much younger, hotter and denser, and simpler to model mathematically. The CMB has been, and continue to be, a unique source of information for modern cosmology and fundamental physics. The main objective of this project is to empower the CMB data analysis with novel high performance tools and algorithms superior to those available today and which are capable of overcoming the existing performance gap. Partners: AstroParticules et Cosmologie Paris 7 (PI R. Stompor), ENSAE Paris Saclay.

#### 9.2.1.2. ANR Cine-Para

October 2015 - September 2019, Laura Grigori is Principal Coordinator for Inria Paris. Funding for Inria Paris is 145 Keuros. The funding for Inria is to combine Krylov subspace methods with parallel in time methods. Partners: University Pierre and Marie Curie, J. L. Lions Laboratory (PI Y. Maday), CEA, Paris Dauphine University, Paris 13 University.

#### 9.2.1.3. Non-local DD

ANR appel à projet générique October 2015 - September 2020

This project in scientific computing aims at developing new domain decomposition methods for massively parallel simulation of electromagnetic waves in harmonic regime. The specificity of the approach that we propose lies in the use of integral operators not only for solutions local to each subdomain, but for coupling subdomains as well. The novelty of this project consists, on the one hand, in exploiting multi-trace formalism for domain decomposition and, on the other hand, considering optimized Schwarz methods relying on Robin type transmission conditions involving quasi-local integral operators.

#### 9.2.1.4. Soil $\mu$ -3D

ANR appel à projet générique October 2015 - September 2020

In spite of decades of work on the modeling of greenhouse gas emission such as CO<sub>2</sub> and N<sub>2</sub>O and on the feedback effects of temperature and water content on soil carbon and nitrogen transformations, there is no agreement on how these processes should be described, and models are widely conflicting in their predictions. Models need improvements to obtain more accurate and robust predictions, especially in the context of climate change, which will affect soil moisture regime.

The goal of this new project is now to go further using the models developed in MEPSOM to upscale heterogeneities identified at the scale of microbial habitats and to produce macroscopic factors for biogeochemical models running at the field scale.

To achieve this aim, it will be necessary to work at different scales: the micro-scale of pores ( $\mu\text{m}$ ) where the microbial habitats are localized, the meso-scale of cores at which laboratory measurements on  $\text{CO}_2$  and  $\text{N}_2\text{O}$  fluxes can be performed, and the macro-scale of the soil profile at which outputs are expected to predict greenhouse gas emission. The aims of the project are to (i) develop new descriptors of the micro-scale 3D soil architecture that explain the fluxes measured at the macro-scale, (ii) Improve the performance of our 3D pore scale models to simulate both micro-and meso- scales at the same time. Upscaling methods like “homogenization” would help to simulate centimeter samples which cannot be achieved now. The reduction of the computational time used to solve the diffusion equations and increase the number of computational units, (iii) develop new macro-functions describing the soil micro-heterogeneity and integrate these features into the field scale models.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. NLAFFET (197)

Title: Parallel Numerical Linear Algebra for Future Extreme-Scale Systems

Programm: H2020

Duration: November 2015 - April 2019

Coordinator: UMEÅ Universitet

Partners:

Science and Technology Facilities Council (United Kingdom)

Computer Science Department, UmeåUniversitet (Sweden)

Mathematics Department, The University of Manchester (United Kingdom)

Inria, Alpines group

Inria contact: Laura Grigori

The NLAFFET proposal is a direct response to the demands for new mathematical and algorithmic approaches for applications on extreme scale systems, as identified in the FETHPC work programme and call. This project will enable a radical improvement in the performance and scalability of a wide range of real-world applications relying on linear algebra software, by developing novel architecture-aware algorithms and software libraries, and the supporting runtime capabilities to achieve scalable performance and resilience on heterogeneous architectures. The focus is on a critical set of fundamental linear algebra operations including direct and iterative solvers for dense and sparse linear systems of equations and eigenvalue problems. Achieving this requires a co-design effort due to the characteristics and overwhelming complexity and immense scale of such systems. Recognized experts in algorithm design and theory, parallelism, and auto-tuning will work together to explore and negotiate the necessary tradeoffs. The main research objectives are: (i) development of novel algorithms that expose as much parallelism as possible, exploit heterogeneity, avoid communication bottlenecks, respond to escalating fault rates, and help meet emerging power constraints; (ii) exploration of advanced scheduling strategies and runtime systems focusing on the extreme scale and strong scalability in multi/many-core and hybrid environments; (iii) design and evaluation of novel strategies and software support for both offline and online auto-tuning. The validation and dissemination of results will be done by integrating new software solutions into challenging scientific applications in materials science, power systems, study of energy solutions, and data analysis in astrophysics. The deliverables also include a sustainable set of methods and tools for cross-cutting issues such as scheduling, auto-tuning, and algorithm-based fault tolerance packaged into open-source library modules.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Informal International Partners

- J. Demmel, UC Berkeley, USA
- R. Hipmair, ETH Zurich
- M. Grote, Université de Bâle, Suisse
- F. Assous, Israel

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

- Visit to Xavier Claeys of Jan Zapletal from IT4Innovation of University of Ostrava, Czech Republic from 4th to 30th of March 2018. The main topic of the visit was discussions around HPC implementation of multi-trace formulations in the BEM code of IT4Innovation.
- Visit to Laura Grigori of Agnieszka Miedlar, University of Kansas, from Jun 2018 until Jul 2018.
- Visit to Laura Grigori of Qiang Niu, Xi'an Jiaotong Liverpool University, from May 2018 until Jul 2018.
- Visit to Frédéric Nataf of Lawrence Mitchell from University of Durham (UK) from December 17th to 22nd. The main topic of the visit was to finalize the interface of the finite element software Firedrake to our library geneo4PETSc.
- Visit to Frédéric Hecht of T. Chacon of Differential equations and numerical analysis at University of Seville Rectorate from April 23th to May 4th.
- Visit to Frédéric Hecht of P. Degond of Department of Mathematics at Imperial College London from Juin 6th to 10th.

#### 9.5.1.1. Internships

- Visit to Xavier Claeys of Michal Kravchenko from IT4Innovation of University of Ostrava, Czech Republic from 1st of October to 28th of December 2018. The main subject of the visit was effective implementation of multi-trace formulations in the BEM code of IT4Innovation.

### 9.5.2. Visits to International Teams

#### 9.5.2.1. Research Stays Abroad

- Visit of Xavier Claeys to Ralf Hiptmair at ETH Zuerich from the 19th of August to 25th of August 2018. The main subject of the visit was discussion on boundary integral equations adapted to low frequency electromagnetics.
- Visit of Xavier Claeys to Paul Escapil-Inchauspe at Pontificia Universidad Catholica at Santiago Chile for further collaboration around analysis of local multi-trace formulation for electromagnetics.
- Visit of Laura Grigori to the group of Professor J. Demmel, UC Berkeley, for 6 weeks in July and August 2018.

## AVALON Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. CPER

**Participants:** Thierry Gautier, Laurent Lefèvre, Christian Perez.

The LECO experimental platform is a new medium size scientific instrument deployed in Grenoble in 2018. It was funded by the CPER 2015-2020 LECO++ to investigate research related to BigData and HPC.

## 9.2. National Initiatives

### 9.2.1. PIA

#### 9.2.1.1. PIA ELCI, *Environnement Logiciel pour le Calcul Intensif, 2014-2018*

**Participants:** Mathilde Boutigny, Thierry Gautier, Laurent Lefèvre, Christian Perez, Issam Raïs, Jérôme Richard, Philippe Virouleau.

The ELCI PIA project is coordinated by BULL with several partners: CEA, Inria, SAFRAB, UVSQ.

This project aims to improve the support for numerical simulations and High Performance Computing (HPC) by providing a new generation software stack to control supercomputers, to improve numerical solvers, and pre- and post computing software, as well as programming and execution environment. It also aims to validate the relevance of these developments by demonstrating their capacity to deliver better scalability, resilience, modularity, abstraction, and interaction on some application use-cases. AVALON is involved in WP1 and WP3 ELCI Work Packages through the PhD of Issam Raïs and the postdoc of H el ene Coullon. Laurent Lef evre is the Inria representative in the ELCI technical committee.

### 9.2.2. MRSEI

#### 9.2.2.1. *Fennec, FastEr NaNo-Characterisation, 24 months, 2018-2021*

**Participants:** Eddy Caron, Christian Perez.

The goal of the ANR-MRSEI FENNEC project is to support the submission of a project to the European call DT-NMBP-08-2019 entitled "Real-time nano-characterisation technologies (RIA)".

### 9.2.3. Inria Large Scale Initiative

#### 9.2.3.1. *DISCOVERY, DIStributed and COoperative management of Virtual EnviRonments autonomously, 4 years, 2015-2019*

**Participants:** Maverick Chardet, Jad Darrous, Christian Perez.

To accommodate the ever-increasing demand for Utility Computing (UC) resources, while taking into account both energy and economical issues, the current trend consists in building larger and larger Data Centers in a few strategic locations. Although such an approach enables UC providers to cope with the actual demand while continuing to operate UC resources through centralized software system, it is far from delivering sustainable and efficient UC infrastructures for future needs.

The DISCOVERY initiative aims at exploring a new way of operating Utility Computing (UC) resources by leveraging any facilities available through the Internet in order to deliver widely distributed platforms that can better match the geographical dispersal of users as well as the ever increasing demand. Critical to the emergence of such locality-based UC (LUC) platforms is the availability of appropriate operating mechanisms. The main objective of DISCOVERY is to design, implement, demonstrate and promote the LUC Operating System (OS), a unified system in charge of turning a complex, extremely large-scale and widely distributed infrastructure into a collection of abstracted computing resources which is efficient, reliable, secure and at the same time friendly to operate and use.

To achieve this, the consortium is composed of experts in research areas such as large-scale infrastructure management systems, network and P2P algorithms. Moreover two key network operators, namely Orange and RENATER, are involved in the project.

By deploying and using such a LUC Operating System on backbones, our ultimate vision is to make possible to host/operate a large part of the Internet by its internal structure itself: A scalable set of resources delivered by any computing facilities forming the Internet, starting from the larger hubs operated by ISPs, government and academic institutions, to any idle resources that may be provided by end-users.

#### 9.2.3.2. HAC SPECIS, High-performance Application and Computers, Studying Performance and Correctness In Simulation, 4 years, 2016-2020

**Participants:** Dorra Boughzala, Idriss Daoudi, Thierry Gautier, Laurent Lefèvre, Frédéric Suter.

Over the last decades, both hardware and software of modern computers have become increasingly complex. Multi-core architectures comprising several accelerators (GPUs or the Intel Xeon Phi) and interconnected by high-speed networks have become mainstream in HPC. Obtaining the maximum performance of such heterogeneous machines requires to break the traditional uniform programming paradigm. To scale, application developers have to make their code as adaptive as possible and to release synchronizations as much as possible. They also have to resort to sophisticated and dynamic data management, load balancing, and scheduling strategies. This evolution has several consequences:

First, this increasing complexity and the release of synchronizations are even more error-prone than before. The resulting bugs may almost never occur at small scale but systematically occur at large scale and in a non deterministic way, which makes them particularly difficult to identify and eliminate.

Second, the dozen of software stacks and their interactions have become so complex that predicting the performance (in terms of time, resource usage, and energy) of the system as a whole is extremely difficult. Understanding and configuring such systems therefore becomes a key challenge.

These two challenges related to correctness and performance can be answered by gathering the skills from experts of formal verification, performance evaluation and high performance computing. The goal of the HAC SPECIS Inria Project Laboratory is to answer the methodological needs raised by the recent evolution of HPC architectures by allowing application and runtime developers to study such systems both from the correctness and performance point of view.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. POP

**Participant:** Frédéric Suter.

Program: H2020 Center of Excellence

Project acronym: POP

Project title: Performance Optimisation and Productivity

Duration: 2015-2018

Coordinator: Barcelona Supercomputing Centre (BSC)

Other partners: High Performance Computing Center Stuttgart of the University of Stuttgart (HLRS), Jülich Supercomputing Centre (JSC), Numerical Algorithm Group (NAG), Rheinisch-Westfälische Technische Hochschule Aachen (RWTH), TERATEC (TERATEC).

Abstract: The Center of Excellence for Performance Optimisation and Productivity provides performance optimisation and productivity services for academic and industrial codes. European's leading experts from the High Performance Computing field will help application developers getting a precise understanding of application and system behaviour. This project is supported by the European Commission under H2020 Grant Agreement No. 676553.

Established codes, but especially codes never undergone any analysis or performance tuning, may profit from the expertise of the POP services which use latest state-of-the-art tools to detect and locate bottlenecks in applications, suggest possible code improvements, and may even help by Proof-of-Concept experiments and mock-up test for customer codes on their own platforms.

### 9.3.2. Collaborations in European Programs, Except FP7 & H2020

#### 9.3.2.1. COST IC1305 : Nesus

**Participants:** Marcos Dias de Assunção, Laurent Lefèvre.

Program: COST

Project acronym: IC1305

Project title: Network for Sustainable Ultrascale Computing (NESUS)

Duration: 2014-2018

Coordinator: Jesus Carretero (Univ. Madrid)

Abstract: Ultrascale systems are envisioned as large-scale complex systems joining parallel and distributed computing systems that will be two to three orders of magnitude larger than today's systems. The EU is already funding large scale computing systems research, but it is not coordinated across researchers, leading to duplications and inefficiencies. The goal of the NESUS Action is to establish an open European research network targeting sustainable solutions for ultrascale computing aiming at cross fertilization among HPC, large scale distributed systems, and big data management. The network will contribute to glue disparate researchers working across different areas and provide a meeting ground for researchers in these separate areas to exchange ideas, to identify synergies, and to pursue common activities in research topics such as sustainable software solutions (applications and system software stack), data management, energy efficiency, and resilience. In Nesus, Laurent Lefèvre is co-chairing the Working on Energy Efficiency (WG5).

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

#### 9.4.1.1. Joint Laboratory for Extreme Scale Computing (JLESC) (2014-2018)

**Participants:** Thierry Gautier, Christian Perez, Jérôme Richard.

Partners: NCSA (US), ANL (US), Inria (FR), Jülich Supercomputing Centre (DE), BSC (SP), Riken (JP).

The purpose of the Joint Laboratory for Extreme Scale Computing (JLESC) is to be an international, virtual organization whose goal is to enhance the ability of member organizations and investigators to make the bridge between Petascale and Extreme computing. The founding partners of the JLESC are Inria and UIUC. Further members are ANL, BSC, JSC and RIKEN-AICS.

JLESC involves computer scientists, engineers and scientists from other disciplines as well as from industry, to ensure that the research facilitated by the Laboratory addresses science and engineering's most critical needs and takes advantage of the continuing evolution of computing technologies.

#### 9.4.1.2. Associate Team DALHIS – Data Analysis on Large-scale Heterogeneous Infrastructures for Science (2013-2018)

**Participant:** Frédéric Suter.

Partners: EPC Myriads (Rennes, Bretagne Atlantique), AVALON (Grenoble, Rhône-Alpes), Data Science and Technology Department (LBNL,USA).

The goal of the Inria-LBL collaboration is to create a collaborative distributed software ecosystem to manage data lifecycle and enable data analytics on distributed data sets and resources. Specifically, our goal is to build a dynamic software stack that is user-friendly, scalable, energy-efficient and fault tolerant. We plan to approach the problem from two dimensions: (i) Research to determine appropriate execution environments that allow users to seamlessly execute their end-to-end dynamic data analysis workflows in various resource environments and scales while meeting energy-efficiency, performance and fault tolerance goals; (ii) Engagement in deep partnerships with scientific teams and use a mix of user research with system software R&D to address specific challenges that these communities face, and inform future research directions from acquired experience.

#### **9.4.2. Inria Associate Teams Not Involved in an Inria International Labs**

##### *9.4.2.1. Associate Team SUSTAM – Sustainable Ultra Scale compuTing, dAta and energy Management (2017-2020)*

**Participants:** Eddy Caron, Hadrien Croubois, Marcos Dias de Assunção, Alexandre Da Silva Veith, Jean-Patrick Gelas, Olivier Glück, Laurent Lefèvre, Valentin Lorentz, Christian Perez, Issam Raïs.

International Partners: Rutgers University (United States) - RDI2 - Manish Parashar

The SUSTAM associate team will focus on the joint design of a multi-criteria orchestration framework dealing with resources, data and energy management in a sustainable way. The SUSTAM associated team will enable a long-term collaboration between the Inria AVALON team and the Rutgers Discovery Informatics Institute (RDI2) from Rutgers University (USA). The SUSTAM associated team is led by Laurent Lefèvre.

#### **9.4.3. Participation in Other International Programs**

##### *9.4.3.1. Joint Project CNRS/University of Melbourne – Algorithms for Placement and Reconfiguration of Data Stream Processing Applications (2017-2018)*

**Participants:** Marcos Dias de Assunção, Alexandre Da Silva Veith, Laurent Lefèvre.

Partner: Clouds Lab (The University of Melbourne, Australia).

Much of the “big data” produced today is created as continuous data streams that are most valuable when processed quickly. Several data stream processing frameworks have been designed for running on clusters of homogeneous computers. Under most frameworks, an application is a Direct Acyclic Graph (DAG) whose vertices are operators that execute transformations over the incoming data and edges that define how the data flows between operators. While cloud computing is a key infrastructure for deploying such frameworks, more modern solutions leverage the edges of the Internet (e.g. edge computing) to offload some of the processing from the cloud and hence reduce the end-to-end latency. The placement and reconfiguration of stream processing DAGs onto highly distributed and heterogeneous infrastructure are, however, challenging endeavours. This project aims to investigate algorithms for the placement and dynamic reconfiguration of stream processing components considering multiple criteria.

## **9.5. International Research Visitors**

### **9.5.1. Research Stays Abroad**

**Participant:** Olivier Glück.

Olivier Glück has been invited professor by Concordia University (Faculty of Engineering & Computer Science, Department of Computer Science & Software Engineering). He has conducted researches with Dr. Brigitte Jaumard, Professor & Research Chair, Tier 1, on the Optimization of Communication Networks. He has worked on the following Virtual Machine (VM) migration optimization problem: find a scheduling of VM migration that minimizes the makespan *i.e.*, total duration of the migration assuming that the current VM placement and the target one are given. He has proposed a new sequence-based optimization model with a Mixed Integer Linear Program (MILP), which not only guarantees the finding of the best VM migration scheduling but also the migration of the largest possible number of VMs in the case of deadlocks. He also worked on the design of heuristic algorithms for VM migration and a generator of real VM migration instances to evaluate the models and heuristics proposed. He has also worked on the task offloading problem in edge computing.



## **DATAMOVE Project-Team**

# **8. Partnerships and Cooperations**

## **8.1. National Initiatives**

### **8.1.1. ANR**

- **ANR grant GRECO (2017-2020)**. Resource manager for cloud of things. Coordinator: Quarnot Computing. Partners: Quarnot Computing, Grenoble-INP, Inria.
- **ANR grant Energumen (2018-2022)**. Resource management: malleable jobs for a better use of the resources along with energy optimization. Coordinator: Denis Trystram. Partners: Grenoble-INP, IRIT, Sorbonne Université.

### **8.1.2. Competitvity Clusters**

- **PIA Avido (2015-2018)**. In situ analysis and visualization for large scale numerical simulation. Coordinator: EDF SA. Partners: EDF R&D, Total SA, Kitware SAS , Université Pierre et Marie CURIE, Inria (DataMove).
- **FUI OverMind (2015-2018)**. Task planification and asset management for the cartoon productions. Coordinator: Teamto Studio. Partners: Teamto Studio, Folimage Studio, Ecole de Gobelins, Inria (DataMove).
- **FUI IDIOM (2018-2020)**. Monitoring and optimization of I/Os. Coordinator DDN Storage. Partners: DDN Storage, Criteo, Quarnot, QuasarDB, CEA, Université de Bretagne Occidentale, Telecom SudParis, Inria (DataMove).

### **8.1.3. Inria**

- Inria PRE COSMIC (exploratory research project), 2017-2019. Photovoltaic Energy Management for Distributed Cloud Platforms. Myriads, DataMove.
- Inria IPL HPC-BigData, 2018-2021). Convergence between HPC, Big Data and AI. Coordinator: Bruno Raffin. Partners: the Inria teams Zenith, Kerdata, Datamove, Tadaam, SequeL, Parietal, Tau, and the external partners ATOS, ANL, IBPC, ESI-Group. See <https://project.inria.fr/hpcbigdata/>

## **8.2. European Initiatives**

### **8.2.1. Collaborations in European Programs, Except FP7 & H2020**

Program: SKŁODOWSKA-CURIE ACTIONS - Individual Fellowship

Project acronym: DAMA

Project title: Extreme-Scale Data Management

Duration: November 2018 - October 2020

Coordinator: Bruno Raffin

Fellowship Recipient: Francieli Zanon Boito.

Abstract: This project is concerned with the I/O challenges that arise from the convergence between these two different paradigms. It is clear data analytics tools cannot simply replace their typical storage solutions for the HPC I/O stack, centered on the abstraction of files and powered by a parallel file system, because their workload is not well suited for that and would observe poor performance. Moreover, the separated storage infrastructure breaks the data affinity idea in which they are built upon. Finally, even among traditional HPC applications there is a need to minimize data movement, as it imposes high latency and increases energy consumption.

## 8.3. International Initiatives

### 8.3.1. Inria International Labs

#### 8.3.1.1. JLESC

Title: Joint Laboratory for Extreme-Scale-Computing.

International Partners:

University of Illinois at Urbana Champaign (USA)

Argonne National Laboratory (USA),

Barcelona Supercomputing Center (Spain),

Jülich Supercomputing Centre (Germany)

Riken Advanced Institute for Computational Science (Japan)

Start year: 2009

See also: <https://jlesc.github.io/>

The purpose of the Joint Laboratory for Extreme Scale Computing is to be an international, virtual organization whose goal is to enhance the ability of member organizations and investigators to make the bridge between Petascale and Extreme computing. The JLESC organizes a workshop every 6 months DataMove participates to. DataMove developed several collaborations related to in situ processing with Tom Peterka group (ANL) , the Argo exascale operating system with Swann Perarnau (ANL).

### 8.3.2. Participation in Other International Programs

#### 8.3.2.1. LICIA

Title: International Laboratory in High Performance and Ubiquitous Computing

International Partner (Institution - Laboratory - Researcher):

UFRGS (Brazil)

Duration: 2011 - 2018

See also: <http://licia-lab.org/>

The LICIA is an Internacional Laboratory and High Performance and Ubiquitous Computing born in 2011 from the common desire of members of Informatics Institute of the Federal University of Rio Grande do Sul and of Laboratoire d'Informatique de Grenoble to enhance and develop their scientific partnership that started by the end of the 1970. LICIA is an Internacional Associated Lab of the CNRS, a public french research institution. It has support from several brazilian and french research funding agencies, such as CNRS, Inria, ANR, European Union (from the french side) and CAPES, CNPq, FAPERGS (from the Brazilian side). DataMove is deeply involved in the animation of LICIA. Bruno Raffin is LICIA associate director.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

Professor visit: Alba Cristina Magalhaes Alves De Melo, Professor at University of Brasilia, visited the Datamove for one month in 2018.

PhD in progress: Danilo Carastan Dos Santos, Dynamic Scheduling of Tasks in High Performance Platforms with Machine Learning (Sao Paulo, Brasil). 1 year "sandwich" visit. Local adviser: Denis Trystram

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## HIEPACS Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. HPC Scalable Ecosystem

**Participants:** Emmanuel Agullo, Olivier Coulaud, Aurélien Esnard, Mathieu Faverge, Luc Giraud, Abdou Guermouche, Pierre Ramet.

**Grant:** Regional council

**Dates:** 2018 – 2020

**Partners:** EPIs **REALOPT**, **STORM** from Inria Bordeaux Sud-Ouest, CEA-CESTA and l'Institut pluridisciplinaire de recherche sur l'environnement et les matériaux (IPREM) .

**Overview:**

Numerical simulation is today integrated in all cycles of scientific design and studies, whether academic or industrial, to predict or understand the behavior of complex phenomena often coupled or multi-physical. The quality of the prediction requires having precise and adapted models, but also to have computation algorithms efficiently implemented on computers with architectures in permanent evolution. Given the ever increasing size and sophistication of simulations implemented, the use of parallel computing on computers with up to several hundred thousand computing cores and consuming / generating massive volumes of data becomes unavoidable; this domain corresponds to what is now called High Performance Computing (HPC). On the other hand, the digitization of many processes and the proliferation of connected objects of all kinds generate ever-increasing volumes of data that contain multiple valuable information; these can only be highlighted through sophisticated treatments; we are talking about Big Data. The intrinsic complexity of these digital treatments requires a holistic approach with collaborations of multidisciplinary teams capable of mastering all the scientific skills required for each component of this chain of expertise.

To have a real impact on scientific progress and advances, these skills must include the efficient management of the massive number of compute nodes using programming paradigms with a high level of expressiveness, exploiting high-performance communications layers, effective management for intensive I / O, efficient scheduling mechanisms on platforms with a large number of computing units and massive I / O volumes, innovative and powerful numerical methods for analyzing volumes of data produced and efficient algorithms that can be integrated into applications representing recognized scientific challenges with high societal and economic impacts. The project we propose aims to consider each of these links in a consistent, coherent and consolidated way.

For this purpose, we propose to develop a unified Execution Support (SE) for large-scale numerical simulation and the processing of large volumes of data. We identified four Application Challenges (DA) identified by the Nouvelle-Aquitaine region that we propose to carry over this unified support. We will finally develop four Methodological Challenges (CM) to evaluate the impact of the project. This project will make a significant contribution to the emerging synergy on the convergence between two yet relatively distinct domains, namely High Performance Computing (HPC) and the processing, management of large masses of data (Big Data); this project is therefore clearly part of the emerging field of High Performance Data Analytics (HPDA).

## 8.2. National Initiatives

### 8.2.1. ANR

#### 8.2.1.1. SASHIMI: Sparse Direct Solver using Hierarchical Matrices

**Participants:** Mathieu Faverge, Pierre Ramet, Aurelien Esnard.

**Grant:** ANR-18-CE46-0006

**Dates:** 2018 – 2022

**Overview:** Nowadays, the number of computational cores in supercomputers has grown largely to a few millions. However, the amount of memory available has not followed this trend, and the memory per core ratio is decreasing quickly with the advent of accelerators. To face this problem, the SaSHiMi project wants to tackle the memory consumption of linear solver libraries used by many major simulation applications by using low-rank compression techniques. In particular, the direct solvers which offer the most robust solution to strategy but suffer from their memory cost. The project will especially investigate the super-nodal approaches for which low-rank compression techniques have been less studied despite the attraction of their large parallelism and their lower memory cost than for the multi-frontal approaches. The results will be integrated in the PaStiX solver that supports distributed and heterogeneous architectures.

#### 8.2.1.2. *DEDALES: Algebraic and geometric domain decomposition for subsurface/groundwater flows*

**Participants:** Emmanuel Agullo, Mathieu Faverge, Luc Giraud, Louis Poirel.

**Grant:** ANR-14-CE23-0005

**Dates:** 2014 – 2018

**Partners:** Inria EPI POMDAPI (leader); Université Paris 13 - Laboratoire Analyse, Géométrie et Applications; Maison de la Simulation; Andra.

**Overview:** Project **DEDALES** aims at developing high performance software for the simulation of two phase flow in porous media. The project will specifically target parallel computers where each node is itself composed of a large number of processing cores, such as are found in new generation many-core architectures. The project will be driven by an application to radioactive waste deep geological disposal. Its main feature is phenomenological complexity: water-gas flow in highly heterogeneous medium, with widely varying space and time scales. The assessment of large scale model is of major importance and issue for this application, and realistic geological models have several million grid cells. Few, if at all, software codes provide the necessary physical features with massively parallel simulation capabilities. The aim of the **DEDALES** project is to study, and experiment with, new approaches to develop effective simulation tools with the capability to take advantage of modern computer architectures and their hierarchical structure. To achieve this goal, we will explore two complementary software approaches that both match the hierarchical hardware architecture: on the one hand, we will integrate a hybrid parallel linear solver into an existing flow and transport code, and on the other hand, we will explore a two level approach with the outer level using (space time) domain decomposition, parallelized with a distributed memory approach, and the inner level as a subdomain solver that will exploit thread level parallelism. Linear solvers have always been, and will continue to be, at the center of simulation codes. However, parallelizing implicit methods on unstructured meshes, such as are required to accurately represent the fine geological details of the heterogeneous media considered, is notoriously difficult. It has also been suggested that time level parallelism could be a useful avenue to provide an extra degree of parallelism, so as to exploit the very large number of computing elements that will be part of these next generation computers. Project **DEDALES** will show that space-time DD methods can provide this extra level, and can usefully be combined with parallel linear solvers at the subdomain level. For all tasks, realistic test cases will be used to show the validity and the parallel scalability of the chosen approach. The most demanding models will be at the frontier of what is currently feasible for the size of models.

### 8.2.2. *FUI*

#### 8.2.2.1. *ICARUS: Intensive Calculation for AeRo and automotive engines Unsteady Simulations*

**Participants:** Cyril Bordage, Aurelien Esnard.

**Grant:** FUI-22

**Dates:** 2016-2019

**Partners:** SAFRAN, SIEMENS, IFPEN, ONERA, DISTENE, CENAERO, GDTECH, Inria, CORIA, CER-FACS.

**Overview:** Large Eddy Simulation (LES) is an increasingly attractive unsteady modelling approach for modelling reactive turbulent flows due to the constant development of massively parallel supercomputers. It can provide open and robust design tools that allow access to new concepts (technological breakthroughs) or a global consideration of a structure (currently processed locally). The mastery of this method is therefore a major competitive lever for industry. However, it is currently constrained by its access and implementation costs in an industrial context. The ICARUS project aims to significantly reduce them (costs and deadlines) by bringing together major industrial and research players to work on the entire high-fidelity LES computing process by:

- increasing the performance of existing reference tools (for 3D codes: AVBP, Yales2, ARGO) both in the field of code coupling and code/machine matching;
- developing methodologies and networking tools for the LES;
- adapting the ergonomics of these tools to the industrial world: interfaces, data management, code interoperability and integrated chains;
- validating this work on existing demonstrators, representative of the aeronautics and automotive industries.

## 8.3. European Initiatives

### 8.3.1. FP7 & H2020 Projects

#### 8.3.1.1. EoCoE

Title: Energy oriented Centre of Excellence for computer applications

Programm: H2020

Duration: October 2015 - October 2018

Coordinator: CEA

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Commissariat A L Energie Atomique et Aux Energies Alternatives (France)

Centre Europeen de Recherche et de Formation Avancee en Calcul Scientifique (France)

Consiglio Nazionale Delle Ricerche (Italy)

The Cyprus Institute (Cyprus)

Agenzia Nazionale Per le Nuove Tecnologie, l'energia E Lo Sviluppo Economico Sostenibile (Italy)

Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)

Instytut Chemii Bioorganicznej Polskiej Akademii Nauk (Poland)

Forschungszentrum Julich (Germany)

Max Planck Gesellschaft Zur Foerderung Der Wissenschaften E.V. (Germany)

University of Bath (United Kingdom)

Universite Libre de Bruxelles (Belgium)

Universita Degli Studi di Trento (Italy)

Inria contact: Michel Kern

The aim of the present proposal is to establish an Energy Oriented Centre of Excellence for computing applications, (EoCoE). EoCoE (pronounce “Echo”) will use the prodigious potential offered by the ever-growing computing infrastructure to foster and accelerate the European transition to a reliable and low carbon energy supply. To achieve this goal, we believe that the present revolution in hardware technology calls for a similar paradigm change in the way application codes are designed. EoCoE will assist the energy transition via targeted support to four renewable energy pillars: Meteo, Materials, Water and Fusion, each with a heavy reliance on numerical modelling. These four pillars will be anchored within a strong transversal multidisciplinary basis providing high-end expertise in applied mathematics and HPC. EoCoE is structured around a central Franco-German hub coordinating a pan-European network, gathering a total of 8 countries and 23 teams. Its partners are strongly engaged in both the HPC and energy fields; a prerequisite for the long-term sustainability of EoCoE and also ensuring that it is deeply integrated in the overall European strategy for HPC. The primary goal of EoCoE is to create a new, long lasting and sustainable community around computational energy science. At the same time, EoCoE is committed to deliver high-impact results within the first three years. It will resolve current bottlenecks in application codes, leading to new modelling capabilities and scientific advances among the four user communities; it will develop cutting-edge mathematical and numerical methods, and tools to foster the usage of Exascale computing. Dedicated services for laboratories and industries will be established to leverage this expertise and to foster an ecosystem around HPC for energy. EoCoE will give birth to new collaborations and working methods and will encourage widely spread best practices.

#### 8.3.1.2. PRACE 5IP

Title: PRACE Fifth Implementation Phase (PRACE-5IP) project

Duration: January 2017 - April 2019

Partners: see the following [url](#)

Inria contact: Stéphane Lanteri

The mission of PRACE (Partnership for Advanced Computing in Europe) is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. PRACE seeks to realise this mission by offering world class computing and data management resources and services through a peer review process. PRACE also seeks to strengthen the European users of HPC in industry through various initiatives. PRACE has a strong interest in improving energy efficiency of computing systems and reducing their environmental impact.

The objectives of **PRACE-5IP** are to build on and seamlessly continue the successes of PRACE and start new innovative and collaborative activities proposed by the consortium. These include:

- assisting the transition to PRACE2 including an analysis of TransNational Access;
- strengthening the internationally recognised PRACE brand;
- continuing and extend advanced training which so far provided more than 18 800 person-training days;
- preparing strategies and best practices towards Exascale computing;
- coordinating and enhancing the operation of the multi-tier HPC systems and services;
- supporting users to exploit massively parallel systems and novel architectures.

## 8.4. International Initiatives

### 8.4.1. Inria International Labs

In the framework of the Joint Laboratory for Extreme Scale Computing (JLESC) within a collaboration between Inria and Argonne national laboratory an new joint project studies how lossy compression can be monitored by Krylov solvers to significantly reduce the memory footprint when solving very-large sparse

linear systems. The resulting solvers will alleviate the I/O penalty paid when running large calculations using either check-point mechanisms to address resiliency or out-of-core techniques to solve huge problems. For the solution of large linear systems of the form  $Ax = b$  where  $A \in \mathbb{R}^{n \times n}$ ,  $x$  and  $b \in \mathbb{R}^n$ , Krylov subspace methods are among the most commonly used iterative solvers; they are further extended to cope with extreme scale computing as one can integrate features such as communication hidden in their variants referred to as pipelined Krylov solvers [7]. On the one hand, the Krylov subspace methods such as GMRES allow some inexactness when computing the orthonormal search basis; more precisely theoretical results [24], [25] show that the matrix-vector product involved in the construction of the new search directions can be more and more inexact when the convergence towards the solution takes place. An inexact scheme of that form writes into a generalized Arnoldi equality

$$[(A + E_1)v_1, \dots, (A + E_k)v_k] = [v_1, \dots, v_k, v_{k+1}]\overline{H}_k, \quad (1)$$

where the theory gives a bound on  $\|E_k\|$  that depends on the residual norm  $\|b - Ax_k\|$  at step  $k$ , where  $x_k$  is the  $k^{\text{th}}$  iterate. Such a result has a major interest in applications where the matrix is not formed explicitly, e.g., in the fast multipole (FMM) or domain decomposition (DDM) methods context, where this allows one to drastically reduce the computational effort.

On the other hand, novel agnostic lossy data compression techniques are studied to reduce the I/O footprint of large applications that have to store snapshots of the calculation, for a posteriori analysis, because they implement out-of-core calculation or for checkpointing data for resilience. Those lossy compression techniques allow for precise control on the error introduced by the compressor to ensure that the stored data are still meaningful for the considered application. In the context of the Krylov method, the basis  $V_{k+1} = [v_1, \dots, v_k, v_{k+1}]$  represents the most demanding data in terms of memory footprint, so that, in a fault-tolerant or out-of-core context, storing it in a lossy form would allow for a tremendous saving.

The objective of this work, developed within the post-doc of N. Schenkels, is to dynamically control the compression error of  $V_{k+1}$  to comply with the inexact Krylov theory. The main difficulty is to translate the known theoretical inexactness on  $E_k$  into a suited lossy compression mechanism for  $v_k$  with loss  $\|\delta v_k\|$ .

## KERDATA Project-Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### 7.1.1. ANR

#### 7.1.1.1. OverFlow (2015–2019)

**Participants:** Alexandru Costan, Pedro Silva, Paul Le Noac’h.

Project Acronym: OverFlow.

Project Title: Workflow Data Management as a Service for Multisite Applications.

Coordinator: Alexandru Costan.

Duration: Octobre 2015–October 2019.

Other Partners: None (Young Researcher Project).

External collaborators: **Kate Keahey** (University of Chicago and Argonne National Laboratory), **Bogdan Nicolae** (Argonne National Lab).

Abstract: This JCJC project led by Alexandru Costan investigates approaches to data management enabling an efficient execution of geographically distributed workflows running on multi-site clouds.

In 2018, we focused on the challenges of executing workflows on hybrid environments combining the Cloud and the Edge. First, processing live data sources at the Edge can offer a potential solution that deals with the explosion of data sizes, as the data is filtered and aggregated locally, before it gets a chance to accumulate. Then, partial results instead of full data are sent to the Cloud for stream processing. In this context, we designed Planner, a middleware for uniform and transparent stream processing across Edge and Cloud. Planner automatically selects which parts of the execution graph will be executed at the Edge in order to minimize the network cost. We also focused on understanding the conditions that enable the usage of Edge or Cloud to improve the performance or reduce costs of an application.

### 7.1.2. Other National Projects

#### 7.1.2.1. HPC-Big Data Inria Project Lab (IPL)

**Participants:** Gabriel Antoniu, Alexandru Costan, Pedro Silva.

Project Acronym: HPC-BigData

Project Title: The HPC-BigData Inria Project Lab

Coordinator: Bruno Raffin.

Duration: 2018–2022.

Abstract: The goal of this HPC-BigData IPL is to gather teams from the HPC, Big Data and Machine Learning (ML) areas to work at the intersection between these domains. Research is organized along three main axes: high performance analytics for scientific computing applications, high performance analytics for big data applications, infrastructure and resource management. Gabriel Antoniu is a member of the Advisory Board and leader of the Frameworks work package.

#### 7.1.2.2. ADT Damaris

**Participants:** Hadi Salimi, Gabriel Antoniu, Luc Bougé.

Project Acronym: ADT Damaris

Project Title: Technology development action for the Damaris environment.

Coordinator: Alexandru Costan.

Duration: 2016–2018.

Abstract: This action aims to support the development of the Damaris software. Inria’s *Technological Development Office (D2T, Direction du Développement Technologique)* provided 2 years of funding support for a senior engineer.



Hadi Salimi has been funded through this project to document, test and extend the **Damaris** software and make it a safely distributable product.

In 2018, the main goal was to enforce the support Damaris provides for HDF5 storage.

#### 7.1.2.3. Grid'5000

We are members of Grid'5000 community and run experiments on the Grid'5000 platform on a daily basis.

## 7.2. European Initiatives

### 7.2.1. FP7 and H2020 Projects

#### 7.2.1.1. BigStorage

Title: BigStorage: Storage-based Convergence between HPC and Cloud to handle Big Data.

Programme: H2020 ETN.

Duration: January 2015–December 2018.

Coordinator: Universidad Politecnica de Madrid (UPM).

Partners:

- Barcelona Supercomputing Center — Centro Nacional de Supercomputacion (Spain)
- CA Technologies Development Spain (Spain)
- CEA — Commissariat à l'énergie atomique et aux énergies alternatives (France)
- Deutsches Klimarechenzentrum (Germany)
- Foundation for Research and Technology Hellas (Greece)
- Fujitsu Technology Solutions (Germany)
- Johannes Gutenberg Universitaet Mainz (Germany)
- Universidad Politecnica de Madrid (Spain)
- Seagate Systems UK (United Kingdom)

Inria contact: **Gabriel Antoniu** and **Adrien Lèbre**.

URL: <http://www.bigstorage-project.eu/>.

Description: BigStorage is a European Training Network (ETN) whose main goal is to train future *data scientists*. It aims at enabling them and us to apply holistic and interdisciplinary approaches to take advantage of a data-overwhelmed world. This world requires *HPC* and *Cloud* infrastructures with a redefinition of *storage* architectures underpinning them — focusing on meeting highly ambitious performance and *energy* usage objectives. The KerData team has hosted 2 *Early Stage Researchers* in this framework and has co-advised an extra PhD student.

### 7.2.2. Collaborations with Major European Organizations

#### 7.2.2.1. BDVA and ETP4HPC

Gabriel Antoniu and Alexandru Costan are serving as Inria representatives in the working groups dedicated to *HPC-Big Data* convergence within the **Big Data Value Association** (BDVA) and the **European Technology Platform in the area of High-Performance Computing** (ETP4HPC). They are contributing to the definition of the respective Strategic Research Agendas of BDVA and ETP4HPC. A special focus this year of their contributions was the **Joint BDVA-ETP4HPC report on technology convergence**.

## 7.3. International Initiatives

### 7.3.1. Inria International Labs

#### 7.3.1.1. JLESC: Joint Laboratory for Extreme Scale Computing

The **Joint Laboratory on Extreme-Scale Computing** is jointly run by Inria, UIUC, ANL, BSC, JSC and RIKEN/AICS. It has been created in 2014 as a follow-up of the Inria-UIUC JLPC, the *Joint Laboratory for Petascale Computing*.

The KerData team is collaborating with teams from ANL and UIUC within this lab since 2009 on several topics in the areas of I/O, storage and in situ processing and cloud computing. This collaboration has been initially formalized as the *Data@Exascale* Associate Team with ANL and UIUC (2013–2015) followed by *Data@Exascale 2* Associate Team with ANL (2016–2018). Our activities in this framework are described here: <http://www.irisa.fr/kerdata/data-at-exascale/>

Since 2015, Gabriel Antoniu serves as a topic leader for Inria for the *I/O, Storage and In Situ Processing* topic. Ongoing lab research directions and projects he is co-supervising in this area are described here: <https://jlesc.github.io/projects/> in the *I/O, Storage and In-Situ Processing* section.

Since 2017, Gabriel Antoniu is serving as *Vice-Executive Director* of JLESC for Inria.

#### 7.3.1.2. Associate Team involved in the JLESC International Lab: Data@Exascale 2

Title: Convergent Data Storage and Processing Approaches for Exascale Computing and Big Data Analytics

Partner: Argonne National Laboratory (United States), Department of Mathematics, Symbolic Computation Group, Robert Ross

Web site: <http://www.irisa.fr/kerdata/data-at-exascale/>

Start year: 2016

In the past few years, countries including United States, the European Union, Japan and China have set up aggressive plans to get closer to what appears to be the next goal in terms of high-performance computing (HPC): Exascale computing, a target which is now considered reachable by the next-generation supercomputers in 2020–2023. While these government-led initiatives have naturally focused on the big challenges of exascale for the development of new hardware and software architectures, the quite recent emergence of the Big Data phenomenon introduces what could be called a tectonic shift that is impacting the entire research landscape for exascale computing. As data generation capabilities in most science domains are now growing substantially faster than computational capabilities, causing these domains to become data-intensive, new challenges appeared in terms of volumes and velocity for data to be stored, processed and analyzed on the future exascale machines.

To face the challenges generated by the exponential data growth (a general phenomenon in many fields), a certain progress has already been made in the recent years in the rapidly-developing, industry-led field of cloud-based Big Data analytics, where advanced tools emerged, relying on machine-learning techniques and predictive analytics. Unfortunately, these advances cannot be immediately applied to exascale computing: the tools and cultures of the two worlds, HPC (High-Performance Computing) and BDA (Big Data Analytics) have developed in a divergent fashion (in terms of major focus and technical approaches), to the detriment of both. The two worlds share however multiple similar challenges and unification now appears as essential in order to address the future challenges of major application domains that can benefit from both.

The scientific program of the *Data@Exascale 2* Associate Team is defined from this new, highly-strategic perspective and builds on the idea that the design of innovative approaches to data I/O, storage and processing allowing Big Data analytics techniques and the newest HPC architectures to leverage each other clearly appears as a key catalyst factor for the convergence process.

Activities in 2018 are described on the web site of the Associate Team.

### 7.3.2. Inria International Partners

#### 7.3.2.1. DataCloud@Work

Title: DataCloud@Work.

International Partner:

- Polytechnic University of Bucharest (Romania), Computer Science Department, Nicolae Tapus and Valentin Cristea.

Duration: 5 years.

Start year: 2013. The status of IIP was established right after the end of our former *DataCloud@work* Associate Team (2010–2012).

URL: [https://www.irisa.fr/kerdata/doku.php?id=cloud\\_at\\_work:start](https://www.irisa.fr/kerdata/doku.php?id=cloud_at_work:start).

Description: Our research topics address the area of distributed data management for cloud services, focusing on autonomic storage. The goal is explore how to build an efficient, secure and reliable storage IaaS for data-intensive distributed applications running in cloud environments by enabling an autonomic behavior.

#### 7.3.2.2. Informal International Partners

Instituto Politécnico Nacional, IPN, Ciudad de México: We continued our informal collaboration in the area of stream processing.

### 7.3.3. Participation in Other International Programs

#### 7.3.3.1. International Initiatives

##### 7.3.3.1.1. BDEC: Big Data and Extreme Computing

Since 2015, Gabriel Antoniu has been invited to participate to the yearly workshops of the international **Big Data and Extreme-scale Computing** (BDEC) working group focused on the convergence of Extreme Computing (the latest incarnation of High-Performance Computing - HPC) and Big Data. BDEC is organized as an yearly series of invitation-based international workshops.

In 2018 Gabriel Antoniu was invited again to contribute to the first workshop of the BDEC2 series, where he presented a **white paper on HPC-Big Data convergence at the level of data processing**.

## 7.4. International Research Visitors

### 7.4.1. Visits of International Scientists

**Rob Ross:** Argonne National Laboratory, USA

**Ryan Stutsman:** University of Utah, USA

**Tilmann Rabl:** TU Berlin/DFKI/Berlin Big Data Center, Germany

**Nicolae Tapus:** Politehnica University of Bucharest

### 7.4.2. Internships

Laurent Prosperi (M1, ENS Cachan) has done a 4-month internship within the team, working with Alexandru Costan and Pedro Silva on hybrid Edge/Cloud stream processing. This work lead to the Planner middleware [26], presented at the WORKS workshop at the IEEE/ACM SC18 conference.

### 7.4.3. Visits to International Teams

#### 7.4.3.1. Research Stays Abroad

Nathanaël Cherièrè has done a 3-month internship at Argonne National Lab, to work on optimizing data migration for efficient distributed storage system rescaling under the supervision of Robert Ross. See Section 5.1 for details.

Yacine Taleb has done a 1-month internship at the University of Utah to work on RDMA replication for in-memory storage systems under the supervision of Ryan Stutsman. See Section 5.1 for details.

Yacine Taleb has done a 3-month internship at Barcelona Supercomputing Center, to work on in-memory storage for Big Data analytics under the supervision of Toni Cortés. See Section 5.1 for details.

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## POLARIS Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. IDEX UGA

Nicolas Gast received a grant from the IDEX UGA that funds a two-years post-doctoral researcher (Takai Kennouche) for two years (2018 and 2019) to work on the smart-grid project that focus on distributed optimization in electrical distribution networks.

Patrick Loiseau and Panayotis Mertikopoulos received a grant from the IDEX UGA that partly funds a PhD student (Benjamin Roussillon) to work on game theoretic models for adversarial classification.

## 9.2. National Initiatives

### 9.2.1. Inria Project Labs

Arnaud Legrand is the leader of the HAC SPECIS project. The goal of the HAC SPECIS (High-performance Application and Computers: Studying PERFORMANCE and Correctness In Simulation) project is to answer methodological needs of HPC application and runtime developers and to allow to study real HPC systems both from the correctness and performance point of view. To this end, we gather experts from the HPC, formal verification and performance evaluation community. Inria Teams: AVALON, POLARIS, MYRIADS, SUMO, HIEPACS, STORM, MEXICO, VERIDIS.

### 9.2.2. DGA Grants

Patrick Loiseau and Panayotis Mertikopoulos received a grant from DGA that complements the funding of PhD student (Benjamin Roussillon) to work on game theoretic models for adversarial classification.

### 9.2.3. PGMO Projects

PGMO projects are supported by the Jacques Hadamard Mathematical Foundation (FMJH). Our project (HEAVY.NET) is focused on congested networks and their asymptotic properties.

### 9.2.4. PEPS

Panayotis Mertikopoulos est co-PI of a PEPS I3A project: MixedGAN ("Mixed-strategy generative adversarial networks") (PI: R. Laraki, U. Dauphine).

### 9.2.5. Fondation Blaise Pascal

Project IAM (Informatique à la Main) funded by fondation Blaise Pascal (Jean-Marc Vincent).

### 9.2.6. ANR

- *ORACLESS (2016–2021)*  
ORACLESS is an ANR starting grant (JCJC) coordinated by Panayotis Mertikopoulos. The goal of the project is to develop highly adaptive resource allocation methods for wireless communication networks that are provably capable of adapting to unpredictable changes in the network. In particular, the project will focus on the application of online optimization and online learning methodologies to multi-antenna systems and cognitive radio networks.
- *CONNECTED (2016–2019)*  
CONNECTED is an ANR Tremplin-ERC (T-ERC) grant coordinated by Patrick Loiseau. The goal of the project is to work on several game-theoretic models involving learning agents and data revealed by strategic agents in response to the learning algorithms, so as to derive better learning algorithms for such special data.

## 9.3. International Initiatives

### 9.3.1. Inria International Labs

The POLARIS team is involved in the JLESC (Joint Laboratory for Extreme-Scale Computing) with University of Illinois Urbana Champaign, Argonne Nat. Lab and BSC.

### 9.3.2. Participation in Other International Programs

- *LICIA*: The CNRS, Inria, the Universities of Grenoble, Grenoble INP, and Universidade Federal do Rio Grande do Sul have created the LICIA (*Laboratoire International de Calcul intensif et d'Informatique Ambiante*). LICIA's main research themes are high performance computing, language processing, information representation, interfaces and visualization as well as distributed systems. Jean-Marc Vincent is the director of the laboratory on the French side and visited Porto Alegre for three weeks in November 2018.

More information can be found at <http://www.inf.ufrgs.br/licia/>.

- *GENE*: Stochastic dynamics of large games and networks. This is a joint project (2018 - 2019) with Universidad de Buenos Aires, Argentina (Matthieu Jonckheere), Universidad de la Republica Uruguay (Federico La Rocca), CNRS (Balakrishna Prabhu) and Universidad ORT Uruguay (Andrés Ferragut).

Through the creation and consolidation of strong research and formation exchanges between Argentina, France and Uruguay, the GENE project will contribute to the fields of performance evaluation and control of communication networks, using tools of game theory, probability theory and control theory. Some of the challenges this project will address are: (1) Mean-field games and their application to load balancing and resource allocations, (2) Scaling limits for centralized and decentralized load balancing strategies and implementation of practical policies for web servers farms, (3) Information diffusion and communication protocols in large and distributed wireless networks.

- *LEARN*: Learning algorithms for games and applications (2016-2018). POLARIS is a member of the Franco-Chilean collaboration network LEARN with CONICYT (the Chilean national research agency), formed under the ECOS-Sud framework. The main research themes of this network is the application of continuous optimization and game-theoretic learning methods to traffic routing and congestion control in data networks. Panayotis Mertikopoulos was an invited researcher at the University of Chile in October 2016.

More information can be found at <http://www.conicyt.cl/pci/2016/02/11/programa-ecos-conicyt-adjudica-proyectos-para-el-ano-2016>.

## 9.4. International Research Visitors

### 9.4.1. Visits to International Teams

#### 9.4.1.1. Research Stays Abroad

Panayotis Mertikopoulos was a visiting scientist at UC Berkeley / Simons Institute for the Theory of Computing (Feb.-March 2018) and a visiting scientist at U Athens / STSM in the framework of the EU COST Action GAMENET (Apr. - May 2018).

Jean-Marc Vincent is the director of Licia (Laboratoire de Calcul Intensif et d'Informatique Ambiante) and stayed 20 days at Porto Alegre to teaching and nurture research collaborations.

## ROMA Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. PhD grant laboratoire d'excellence MILYON-Mumps consortium

The doctoral program from Labex MILYON dedicated to applied research in collaboration with industrial partners funded 50% of a 3-year PhD grant (the other 50% being funded by the MUMPS consortium) to work on improvements of the solution phase of the MUMPS solver. The PhD aimed at answering industrial needs in application domains where the cost of the solution phase of sparse direct solvers is critical. The PhD was defended on December 10, 2018 [2].

## 9.2. National Initiatives

### 9.2.1. ANR

ANR Project SOLHAR (2013-2018), 4,5 years. The ANR Project SOLHAR was launched in November 2013, for a duration of 48 months. It gathers five academic partners (the HiePACS, Cepage, ROMA and Runtime Inria project-teams, and CNRS-IRIT) and two industrial partners (CEA/CESTA and EADS-IW). This project aims at studying and designing algorithms and parallel programming models for implementing direct methods for the solution of sparse linear systems on emerging computers equipped with accelerators.

The proposed research is organized along three distinct research thrusts. The first objective deals with linear algebra kernels suitable for heterogeneous computing platforms. The second one focuses on runtime systems to provide efficient and robust implementation of dense linear algebra algorithms. The third one is concerned with scheduling this particular application on a heterogeneous and dynamic environment.

## 9.3. International Initiatives

### 9.3.1. Inria International Labs

#### 9.3.1.1. JLESC — Joint Laboratory on Extreme Scale Computing

The University of Illinois at Urbana-Champaign, Inria, the French national computer science institute, Argonne National Laboratory, Barcelona Supercomputing Center, Jülich Supercomputing Centre and the Riken Advanced Institute for Computational Science formed the Joint Laboratory on Extreme Scale Computing, a follow-up of the Inria-Illinois Joint Laboratory for Petascale Computing. The Joint Laboratory is based at Illinois and includes researchers from Inria, and the National Center for Supercomputing Applications, ANL, BSC and JSC. It focuses on software challenges found in extreme scale high-performance computers.

Research areas include:

- Scientific applications (big compute and big data) that are the drivers of the research in the other topics of the joint-laboratory.
- Modeling and optimizing numerical libraries, which are at the heart of many scientific applications.
- Novel programming models and runtime systems, which allow scientific applications to be updated or reimaged to take full advantage of extreme-scale supercomputers.
- Resilience and Fault-tolerance research, which reduces the negative impact when processors, disk drives, or memory fail in supercomputers that have tens or hundreds of thousands of those components.
- I/O and visualization, which are important part of parallel execution for numerical simulations and data analytics
- HPC Clouds, that may execute a portion of the HPC workload in the near future.

Several members of the ROMA team are involved in the JLESC joint lab through their research on scheduling and resilience. Yves Robert is the Inria executive director of JLESC.

### **9.3.2. Inria Associate Teams Not Involved in an Inria International Labs**

#### *9.3.2.1. Keystone*

Title: Scheduling algorithms for sparse linear algebra at extreme scale

International Partner (Vanderbilt University - Department of Electrical Engineering and Computer Science - Padma Raghavan):

Start year: 2016

See also: <http://graal.ens-lyon.fr/~abenoit/Keystone>

The Keystone project aims at investigating sparse matrix and graph problems on NUMA multicores and/or CPU-GPU hybrid models. The goal is to improve the performance of the algorithms, while accounting for failures and trying to minimize the energy consumption. The long-term objective is to design robust sparse-linear kernels for computing at extreme scale. In order to optimize the performance of these kernels, we plan to take particular care of locality and data reuse. Finally, there are several real-life applications relying on these kernels, and the Keystone project is assessing the performance and robustness of the scheduling algorithms in applicative contexts.

### **9.3.3. Inria International Partners**

#### *9.3.3.1. Declared Inria International Partners*

- Anne Benoit, Frederic Vivien and Yves Robert have a regular collaboration with Henri Casanova from Hawaii University (USA). This is a follow-on of the Inria Associate team that ended in 2014.

### **9.3.4. Cooperation with ECNU**

ENS Lyon has launched a partnership with ECNU, the East China Normal University in Shanghai, China. This partnership includes both teaching and research cooperation.

As for teaching, the PROSFER program includes a joint Master of Computer Science between ENS Rennes, ENS Lyon and ECNU. In addition, PhD students from ECNU are selected to conduct a PhD in one of these ENS. Yves Robert is responsible for this cooperation. He has already given two classes at ECNU, on Algorithm Design and Complexity, and on Parallel Algorithms, together with Patrice Quinton (from ENS Rennes).

As for research, the JORISS program funds collaborative research projects between ENS Lyon and ECNU. Anne Benoit and Minsong Chen are leading a JORISS project on scheduling and resilience in cloud computing. Frédéric Vivien and Jing Liu (ECNU) are leading a JORISS project on resilience for real-time applications. In the context of this collaboration two students from ECNU, Li Han and Changjiang Gou, have joined Roma for their PhD.

## **9.4. International Research Visitors**

### **9.4.1. Visits to International Teams**

#### *9.4.1.1. Research Stays Abroad*

- Yves Robert has been appointed as a visiting scientist by the ICL laboratory (headed by Jack Dongarra) at the University of Tennessee Knoxville since 2011. He collaborates with several ICL researchers on high-performance linear algebra and resilience methods at scale.
- Anne Benoit and Bora Uçar visited the School of Computational Science and Engineering Georgia Institute of Technology, Atlanta, GA, USA. During their stay August 2017–June 2018, they worked with the research group of Prof. Umit V. Çatalyürek.



## STORM Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

HPC Cloud Computing

**Participants:** Olivier Aumage, Nathalie Furmento, Samuel Thibault.

Other participants : David Auber, Olivier Beaumont, Lionel Eyraud-Dubois, Gérald Point

Abstract: The goal of this project is to gather teams from the HPC and Big Data communities to work at the intersection between these domains. We will focus on how StarPU can be adapted to achieve good performances on Big Data platforms.

## 8.2. National Initiatives

ELCI The ELCI PIA project (Software Environment for HPC) aims to develop a new generation of software stack for supercomputers, numerical solvers, runtime and programming development environments for HPC simulation. The ELCI project also aims to validate this software stack by showing its capacity to offer improved scalability, resilience, security, modularity and abstraction on real applications. The coordinator is Bull, and the different partners are CEA, Inria, SAFRAN, CERFACS, CNRS CORIA, CENAERO, ONERA, UVSQ, Kitware and AlgoTech.

### 8.2.1. ANR

ANR SOLHAR (<http://solhar.gforge.inria.fr/doku.php?id=start>).

ANR MONU 2013 Program, 2013 - 2018 (36 months extended )

Identification: ANR-13-MONU-0007

Coordinator: Inria Bordeaux/LaBRI

Other partners: CNRS-IRIT, Inria-LIP Lyon, CEA/CESTA, EADS-IW

Abstract: This project aims at studying and designing algorithms and parallel programming models for implementing direct methods for the solution of sparse linear systems on emerging computers equipped with accelerators. The ultimate aim of this project is to achieve the implementation of a software package providing a solver based on direct methods for sparse linear systems of equations. Several attempts have been made to accomplish the porting of these methods on such architectures; the proposed approaches are mostly based on a simple offloading of some computational tasks (the coarsest grained ones) to the accelerators and rely on fine hand-tuning of the code and accurate performance modeling to achieve efficiency. This project proposes an innovative approach which relies on the efficiency and portability of runtime systems, such as the StarPU tool developed in the runtime team (Bordeaux). Although the SOLHAR project will focus on heterogeneous computers equipped with GPUs due to their wide availability and affordable cost, the research accomplished on algorithms, methods and programming models will be readily applicable to other accelerator devices such as ClearSpeed boards or Cell processors.

ANR EXACARD

AAPG ANR 2018 (42 months)

Coordinator: Yves Coudière (Carmen) Inria Bordeaux



Abstract: Cardiac arrhythmia affect millions of patients and cause 300,000 deaths each year in Europe. Most of these arrhythmia are due to interaction between structural and electrophysiological changes in the heart muscle. A true understanding of these phenomena requires numerical simulations at a much finer resolution, and larger scale, than currently possible. Next-generation, heterogeneous, high-performance computing (HPC) systems provide the power for this. But the large scale of the computations pushes the limits of current runtime optimization systems, and together with task-based parallelism, prompts for the development of dedicated numerical methods and HPC runtime optimizations. With a consortium including specialists of these domains and cardiac modeling, we will investigate new task-based optimization techniques and numerical methods to utilize these systems for cardiac simulations at an unprecedented scale, and pave the way for future use cases.

### 8.2.2. ADT - Inria Technological Development Actions

ADT SwLoc (<http://swloc.gforge.inria.fr/>)

**Participants:** Raymond Namyst, Pierre-André Wacrenier, Andra Hugo, Brice Goglin, Corentin Salingue.

Inria ADT Campaign 2017, 10/2017 - 9/2019 (24 months)

Coordinator: Raymond Namyst

Abstract: The Inria action ADT SwLoc is aiming at developing a library allowing dynamic flexible partitioning of computing resources in order to execute parallel regions concurrently inside the same processes.

ADT Gordon

**Participants:** Denis Barthou, Nathalie Furmento, Samuel Thibault, Pierre-André Wacrenier.

Inria ADT Campaign 2018, 11/2018 - 11/2020 (24 months)

Coordinator: Emmanuel Jeannot (Tadaam)

Other partners: HiePACS, PLEIADE, Tadaam (Inria Bordeaux)

Abstract: Teams HiePACS, Storm and Tadaam develop each a brick of an HPC software stack, namely solver, runtime, and communication library. The goal of the Gordon project is to consolidate the HPC stack, to improve interfaces between each brick, and to target a better scalability. The bioinformatics application involved in the project has been selected so as to stress the underlying systems.

ADT AFF3CT Matlab

**Participants:** Denis Barthou, Olivier Aumage, Adrien Cassagne.

Inria ADT Campaign 2018, 12/2018 - 12/2019 (12 months)

Coordinator: Denis Barthou

Other partners: C.Jego and C.Leroux (IMS lab, U.Bordeaux)

Abstract: AFF3CT is a toolchain for designing, validation and experimentation of new Error Correcting codes. This toolchain is written in C++, and this constitutes a difficulty for many industrial users, who are mostly electronicians. The goal of this ADT is to widen the number of possible users by designing a Matlab and Python interface for AFF3CT, in collaboration with existing users, and proposing a parallel framework in OpenMP.

### 8.2.3. IPL - Inria Project Lab

HAC-SPECIS (High-performance Application and Computers, Studying PErformance and Correctness In Simulation)

**Participants:** Samuel Thibault, Luka Stanistic, Emmanuelle Saillard, Olivier Aumage, Idriss Daoudi.

Inria IPL 2016 - 2020 (48 months)

Coordinator: Arnaud Legrand (team Polaris, Inria Rhône Alpes)

Since June 2016, the team is participating to the HAC-SPECIS <http://hacspecis.gforge.inria.fr/> Inria Project Lab (IPL). This national initiative aims at answering methodological needs of HPC application and runtime developers and allowing to study real HPC systems both from the correctness and performance point of view. To this end, it gathers experts from the HPC, formal verification and performance evaluation community.

HPC-BigData (High Performance Computing and Big Data)

**Participant:** Samuel Thibault.

Inria IPL 2018 - 2022 (48 months)

Coordinator: Bruno Raffin (team DataMove, Inria Rhône Alpes)

Since June 2018, the team is participating to the HPC-BigData <https://project.inria.fr/hpcbigdata/> Inria Project Lab (IPL). The goal of this HPC-BigData IPL is to gather teams from the HPC, Big Data and Machine Learning (ML) areas to work at the intersection between these domains. Research is organized along three main axes: high performance analytics for scientific computing applications, high performance analytics for big data applications, infrastructure and resource management.

## 8.3. European Initiatives

### 8.3.1. H2020 Projects

INTERTWinE

- Title: Programming Model INTERoperability ToWards Exascale
- Program: H2020
- Duration: October 2015 - October 2018
- Coordinator: EPCC
- Inria contact: Olivier Aumage
- Partners:
  - \* Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)
  - \* Deutsches Zentrum für Luft - und Raumfahrt Ev (Germany)
  - \* Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)
  - \* Institut National de Recherche en Informatique et en Automatique (France)
  - \* Kungliga Tekniska Hoegskolan (Sweden)
  - \* T-Systems Solutions for Research (Germany)
  - \* The University of Edinburgh (United Kingdom)
  - \* Universitat Jaume I de Castellon (Spain)
  - \* The University of Manchester (United Kingdom)

This project addresses the problem of programming model design and implementation for the Exascale. The first Exascale computers will be very highly parallel systems, consisting of a hierarchy of architectural levels. To program such systems effectively and portably, programming APIs with efficient and robust implementations must be ready in the appropriate timescale. A single, “silver bullet” API which addresses all the architectural levels does not exist and seems very unlikely to emerge soon enough. We must therefore expect that using combinations of different APIs at different system levels will be the only practical solution in the short to medium term. Although there remains room for improvement in individual programming models and their implementations, the main challenges lie in interoperability between APIs. It is this interoperability,

both at the specification level and at the implementation level, which this project seeks to address and to further the state of the art. INTERTWinE brings together the principal European organisations driving the evolution of programming models and their implementations. The project will focus on seven key programming APIs: MPI, GASPI, OpenMP, OmpSs, StarPU, QUARK and PaRSEC, each of which has a project partner with extensive experience in API design and implementation. Interoperability requirements, and evaluation of implementations will be driven by a set of kernels and applications, each of which has a project partner with a major role in their development. The project will implement a co-design cycle, by feeding back advances in API design and implementation into the applications and kernels, thereby driving new requirements and hence further advances.

#### Exa2PRO

- Title: Enhancing Programmability and boosting Performance Portability for Exascale Computing systems
- Program: H2020-FETHPC
- Duration: May 2018 - April 2021
- Coordinator: ICCS
- Inria contact: Samuel Thibault
- Partners:
  - \* Institute of Communications and Computer Systems (ICCS) (Greece)
  - \* Linköping University (LIU) (Sweden)
  - \* Centre for Research and Technology Hellas (CERTH) (Greece)
  - \* Institut National de Recherche en Informatique et en Automatique (Inria) (France)
  - \* Maxeler Technologies Limited (MAX) (UK)
  - \* Forschungszentrum Jülich (JUELICH) (Germany)
  - \* Centre National de la Recherche Scientifique (CNRS) (France)

The vision of EXA2PRO is to develop a programming environment that will enable the productive deployment of highly parallel applications in exascale computing systems. EXA2PRO programming environment will integrate tools that will address significant exascale challenges. It will support a wide range of scientific applications, provide tools for improving source code quality, enable efficient exploitation of exascale systems' heterogeneity and integrate tools for data and memory management optimization. Additionally, it will provide various fault-tolerance mechanisms, both user-exposed and at runtime system level and performance monitoring features. EXA2PRO will be evaluated using 4 use cases from 4 different domains, which will be deployed in JUELICH supercomputing center. The use cases will leverage the EXA2PRO tool-chain and we expect:

- Increased applications performance based on EXA2PRO optimization tools (data and memory management)
- Efficient exploitation of heterogeneity by the applications that will allow the evaluation of more complex problems.
- Identification of trade-offs between design qualities (source code maintainability/reusability) and run-time constraints (performance/energy consumption).
- Evaluation of various fault-tolerance mechanisms for applications with different characteristics.

EXA2PRO outcome is expected to have major impact in a) the scientific and industrial community that focuses on application deployment in supercomputing centers: EXA2PRO environment will allow efficient application deployment with reduced effort. b) on application developers of exascale application: EXA2PRO will provide tools for improving source code maintainability/ reusability, which will allow application evaluation with reduced developers' effort. c) on the scientific community and the industry relevant to the EXA2PRO use cases. At least two of the EXA2PRO use cases will have significant impact to the CO2 capture and to the Supercapacitors industry.

### 8.3.2. Collaborations in European Programs, Except FP7 & H2020

#### PRACE-5IP

- Title: PRACE 5th Implementation Phase
- Program: PRACE
- Duration: 2017 - 2019
- Coordinator: PRACE
- Inria contact for team STORM: Olivier Aumage
- Abstract: The objectives of PRACE-5IP are to build on and seamlessly continue the successes of PRACE and start new innovative and collaborative activities proposed by the consortium. These include:
  - \* assisting the transition to PRACE2 including analysis of TransNational Access;
  - \* strengthening the internationally recognised PRACE brand;
  - \* continuing and extend advanced training which so far provided more than 18 800 persontraining days;
  - \* preparing strategies and best practices towards Exascale computing;
  - \* coordinating and enhancing the operation of the multi-tier HPC systems and services;
  - \* supporting users to exploit massively parallel systems and novel architectures.

A high level Service Catalogue is provided. The proven project structure will be used to achieve each of the objectives in 6 dedicated work packages. The activities are designed to increase Europe's research and innovation potential especially through:

- \* seamless and efficient Tier-0 services and a pan-European HPC ecosystem including national capabilities;
- \* promoting take-up by industry and new communities and special offers to SMEs;
- \* implementing a new flexible business model for PRACE 2;
- \* proposing strategies for deployment of leadership systems;
- \* collaborating with the ETP4HPC, CoEs and other European and international organisations on future architectures, training, application support and policies.

## 8.4. International Research Visitors

- Costin Iancu, LBNL (USA), from Oct. 8 to Oct. 12, 2018

### 8.4.1. Internships

- Dana Akhmetova, KTH (Sweden), PhD Internship, from Feb. 18, 2018 to Mar. 24, 2018, within the context of H2020 INTERTWinE.

## TADAAM Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. CRA HPC Scalable Ecosystem, 2018-2021

2018 - 2021 (36 months)

Coordinator: Emmanuel AGULLO

Other partners: INRA, Institut Pprime, UPPA, Airbus, CEA, CATIE

Abstract: The goal is to design a unified runtime-system for numerical simulation at large-scale and with a large amount of data. We aim at contributing significantly to the convergence between HPC and BigData. TADAAM is involved in scheduling data access and managing communication efficiently on large-scale system.

## 9.2. National Initiatives

### 9.2.1. PIA ELCI, Environnement Logiciel pour le Calcul Intensif, 2014-2018

The ELCI PIA project is coordinated by BULL with several partners: CEA, Inria, SAFRAN, UVSQ.

This project aims to improve the support for numerical simulations and High Performance Computing (HPC) by providing a new generation software stack to control supercomputers, to improve numerical solvers, and pre- and post computing software, as well as programming and execution environment. It also aims at validating the relevance of these developments by demonstrating their capacity to deliver better scalability, resilience, modularity, abstraction, and interaction on some application use-cases. TADAAM is involved in WP1 and WP2 ELCI Work Packages. Emmanuel JEANNOT is the Inria representative in the ELCI steering committee.

### 9.2.2. ANR

ANR SATAS SAT as a Service (<http://www.agence-nationale-recherche.fr/Project-ANR-15-CE40-0017>).

AP générique 2015, 01/2016 - 12/2019 (48 months)

Coordinator: Laurent Simon (LaBRI)

Other partners: CRIL (Univ. Artois), Inria Lille (Spirals)

Abstract: The SATAS project aims to advance the state of the art in massively parallel SAT solving. The final goal of the project is to provide a “pay as you go” interface to SAT solving services and will extend the reach of SAT solving technologies, daily used in many critical and industrial applications, to new application areas, which were previously considered too hard, and lower the cost of deploying massively parallel SAT solvers on the cloud.

ANR DASH Data-Aware Scheduling at Higher scale (<https://project.inria.fr/dash/>).

AP générique JCJC 2017, 03/2018 - 02/2022 (48 months)

Coordinator: Guillaume AUPY (Tadaam)

Abstract: This project focuses on the efficient execution of I/O for High-Performance applications. The idea is to take into account some knowledge on the behavior of the different I/O steps to compute efficient schedules, and to update them dynamically with the online information.

### 9.2.3. ADT - Inria Technological Development Actions

ADT Gordon

10/2018 - 09/2020 (24 months)

Coordinator: Emmanuel JEANNOT

Other partners: Storm, HiePACS, PLEIADE (Inria Bordeaux)

Abstract: Teams HiePACS, Storm and Tadaam develop each a brick of an HPC software stack, namely solver, runtime, and communication library. The goal of the Gordon project is to consolidate the HPC stack, to improve interfaces between each brick, and to target a better scalability. The bioinformatics application involved in the project has been selected so as to stress the underlying systems.

### 9.2.4. IPL - Inria Project Lab

High-Performance computing and BigData

**Participants:** Guillaume Aupy, Emmanuel Jeannot, Julien Herrmann and Nicolas Vidal.

HPC and Big Data evolved with their own infrastructures (supercomputers versus clouds), applications (scientific simulations versus data analytics) and software tools (MPI and OpenMP versus Map/Reduce or Deep Learning frameworks). But Big Data analytics is becoming more compute-intensive (thanks to deep learning), while data handling is becoming a major concern for scientific computing. The goal of this HPC-BigData IPL is to gather teams from the HPC, Big Data and Machine Learning (ML) areas to work at the intersection between these domains. Research is organized along three main axes: high performance analytics for scientific computing applications, high performance analytics for big data applications, infrastructure and resource management

## 9.3. European Initiatives

### 9.3.1. Collaborations in European Programs, Except FP7 & H2020

NESUS: Network for Ultrascale Computing (<http://www.nesus.eu>)

Program: COST

Project acronym: NESUS

Project title: Network for Ultrascale Computing

Duration: April 2014 - April 2018

Coordinator: University Carlos III de Madrid

Other partners: more than 35 countries

Abstract: Ultrascale systems are envisioned as large-scale complex systems joining parallel and distributed computing systems that will be two to three orders of magnitude larger than today's systems. The EU is already funding large scale computing systems research, but it is not coordinated across researchers, leading to duplications and inefficiencies. The goal of the NESUS Action is to establish an open European research network targeting sustainable solutions for ultrascale computing aiming at cross fertilization among HPC, large scale distributed systems, and big data management. The network will contribute to glue disparate researchers working across different areas and provide a meeting ground for researchers in these separate areas to exchange ideas, to identify synergies, and to pursue common activities in research topics such as sustainable software solutions (applications and system software stack), data management, energy efficiency, and resilience. Some of the most active research groups of the world in this area are members of this proposal. This Action will increase the value of these groups at the European-level by reducing duplication of efforts and providing a more holistic view to all researchers, it will promote the leadership of Europe, and it will increase their impact on science, economy, and society. Emmanuel JEANNOT is the vice-chair of this Action.

### **9.3.2. Collaborations with Major European Organizations**

Partner 1: INESC-ID, Lisbon, (Portugal)

Subject 1: Application modeling for hierarchical memory system

Partner 2: University Carlos III de Madrid, (Spain)

Subject 2: I/O Scheduling

## **9.4. International Initiatives**

### **9.4.1. Inria International Labs**

Joint-Lab on Extreme Scale Computing (JLESC):

Coordinators: Franck Cappello (general) and Yves Robert (Inria coordinator).

Other partners: Argonne National Lab, University of Urbana Champaign (NCSA), Tokyo Riken, Jülich Supercomputing Center, Barcelona Supercomputing Center (BSC).

Abstract: The purpose of the Joint Laboratory for Extreme Scale Computing (JLESC) is to be an international, virtual organization whose goal is to enhance the ability of member organizations and investigators to make the bridge between Petascale and Extreme computing. The founding partners of the JLESC are Inria and UIUC. Further members are ANL, BSC, JSC and RIKEN-AICS.

### **9.4.2. Inria International Partners**

#### **9.4.2.1. Informal International Partners**

Partner 1: Argonne National Lab

Subject 1: Binomial Checkpointing Strategies for Machine Learning (recipient of a FACCTS grant, 2018-2020)

Partner 2: Vanderbilt University

Subject 2: Scheduling for Neurosciences

Partner 3: ICL at University of Tennessee

Subject 3: on instrumenting MPI applications and modeling platforms (works on HWLOC take place in the context of the OPEN MPI consortium) and MPI and process placement

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

- Sri Hari Krishna Narayanan (Argonne National Lab), April 2018
- Sri Hari Krishna Narayanan (Argonne National Lab), Jan Hückelheim and Navjot Kukreja (Imperial College), June 2018
- Jesus Carretero, David E. Singh (Univ. Carlos III, Madrid), Dean Chester (Univ. of Warwick), Raymond Nou (BSC), October 2018
- Paul Hovland (Argonne National Lab) and Navjot Kukreja (Imperial College), December 2018

### **9.5.2. Visits to International Teams**

#### **9.5.2.1. Research Stays Abroad**

Valentin HONORÉ visited Ana Gainaru, Padma Raghavan, and Hongyang Sun at Vanderbilt University (USA) for three months in the context of the project “Scheduling for Neurosciences”.

## **DIVERSE Project-Team**

# **8. Partnerships and Cooperations**

## **8.1. Regional Initiatives**

### **8.1.1. PEC – Pôle d’Excellence Cyber**

- Coordinator: Université de Rennes 1
- Dates: 2016-2019
- Abstract: Formal and Executable Specification of domain-specific language families

## **8.2. National Initiatives**

### **8.2.1. ANR**

#### **8.2.1.1. SOPRANO**

- Coordinator: CEA
- CEA, University of Paris-Sud, Inria Rennes, OcamlPro, Adacore
- Dates: 2014-2018
- Abstract: Today most major verification approaches rely on automatic external solvers. However these solvers do not fill the current and future needs for verification: lack of satisfying model generation, lack of reasoning on difficult theories (e.g. floating-point arithmetic), lack of extensibility for specific or new needs. The SOPRANO project aims at solving these problems and prepare the next generation of verification-oriented solvers by gathering experts from academia and industry. We will design a new framework for the cooperation of solvers, focused on model generation and borrowing principles from SMT (current standard) and CP (well-known in optimisation). These ideas will be implemented in an open-source platform, with regular evaluations from the industrial partners.

#### **8.2.1.2. VaryVary ANR JCJC**

- Coordinator: Mathieu Acher
- DiverSE, Inria/IRISA Rennes
- Dates: 2017-2021
- Abstract: Most modern software systems (operating systems like Linux, Web browsers like Firefox or Chrome, video encoders like x264 or ffmpeg, servers, mobile applications, etc.) are subject to variation or come in many variants. Hundreds of configuration options, features, or plugins can be combined, each potentially with distinct functionality and effects on execution time, memory footprint, etc. Among configurations, some of them are chosen and do not compile, crash at runtime, do not pass a test suite, or do not reach a certain performance quality (e.g., energy consumption, security). In this JCJC ANR project, we follow a thought-provocative and unexplored direction: We consider that the variability boundary of a software system can be specialized and should vary when needs be. The goal of this project is to provide theories, methods and techniques to make vary variability. Specifically, we consider machine learning and software engineering techniques for narrowing the space of possible configurations to a good approximation of those satisfying the needs of users. Based on an oracle (e.g., a runtime test) that tells us whether a given configuration meets the requirements (e.g. speed or memory footprint), we leverage machine learning to retrofit the acquired constraints into a variability that can be used to automatically specialize the configurable system. Based on a relative small number of configuration samples, we expect to reach high accuracy for many different kinds of oracles and subject systems. Our preliminary experiments suggest that



varying variability can be practically useful and effective. However, much more work is needed to investigate sampling, testing, and learning techniques within a variety of cases and application scenarios. We plan to further collect large experimental data and apply our techniques on popular, open-source, configurable software (like Linux, Firefox, ffmpeg, VLC, Apache or JHipster) and generators for media content (like videos, models for 3D printing, or technical papers written in LaTeX).

## **8.2.2. Competitivity Clusters**

### *8.2.2.1. Occiware*

- Coordinator: Open Wide
- Open Wide, ActiveEon SA, CSRT - Cloud Systèmes Réseaux et Télécoms, Institut Mines-Télécom/Télécom SudParis, Inria, Linagora, Obeo, OW2 Consortium, Pôle Numérique, Université Joseph Fourier,
- Dates: 2014-2018
- Abstract: The Occiware project aims to establish a formal and equipped framework for the management of all cloud resource based on the OCCI standard.

## **8.2.3. Cominlabs**

### *8.2.3.1. PROFILE*

- Coordinator: Université de Rennes 1
- Partners: Inria, Université de Rennes 2
- Dates: 2016-2019
- Abstract: The PROFILE project brings together experts from law, computer science and sociology to address the challenges raised by online profiling, following a multidisciplinary approach. More precisely, the project will pursue two complementary and mutually informed lines of research: (i) Investigate, design, and introduce a new right of opposition into the legal framework of data protection to better regulate profiling and to modify the behavior of commercial companies towards being more respectful of the privacy of their users; (ii) Provide users with the technical means they need to detect stealthy profiling techniques as well as to control the extent of the digital traces they routinely produce. As a case study, we focus on browser fingerprinting, a new profiling technique for targeted advertisement. The project will develop a generic framework to reason on the data collected by profiling algorithms, to uncover their inner workings, and make them more accountable to users. PROFILE will also propose an innovative protection to mitigate browser fingerprinting, based on the collaborative reconfiguration of browsers.

## **8.3. European Initiatives**

### **8.3.1. FP7 & H2020 Projects**

#### *8.3.1.1. H2020 ICT-10-2016 STAMP*

- Coordinator: Inria Rennes
- Other partners: ATOS, ActiveEon, OW2, TellU, Engineering, XWiki, TU Delft, SINTEF
- Dates: 2016-2019
- Abstract: Leveraging advanced research in automatic test generation, STAMP aims at pushing automation in DevOps one step further through innovative methods of test amplification. It will reuse existing assets (test cases, API descriptions, dependency models), in order to generate more test cases and test configurations each time the application is updated. Acting at all steps of development cycle, STAMP techniques aim at reducing the number and cost of regression bugs at unit level, configuration level and production stage.

STAMP will raise confidence and foster adoption of DevOps by the European IT industry. The project gathers three academic partners with strong software testing expertise, five software companies (in: e-Health, Content Management, Smart Cities and Public Administration), and an open source consortium. This industry-near research addresses concrete, business-oriented objectives. All solutions are open source and developed as microservices to facilitate exploitation, with a target at TRL 6.

### **8.3.2. Collaborations in European Programs, Except FP7 & H2020**

- Coordinator: UR1
- Other partners: Airbreizh - Surveillance of Brittany air quality association, branch of the French national air surveillance network, AmpliSIM - SME specialized in pollution numerical simulation, CNRS / IDRIS - Institute for Development and Resources in Intensive Scientific Computing, GENCI - Supercomputing centres association, Keolis - Public transport operator for Rennes Metropole, Neovia – SME specialized in HPC and project management, Rennes Métropole – Local authority in charge of the Service Public Métropolitain de la Donnée (SPMD), Ryax Technologies – SME providing Data Analytics workflows’ automation and seamless orchestration on hybrid distributed infrastructures UCit – SME providing HPC as a Service
- Dates: 2018-2020
- Abstract: The AQMO project is co-financed by the European Union through its CEF programme. It addresses the air quality challenge, thanks to the development of a smart city pilot in the area of Rennes Metropole. The project will provide an end-to-end urban platform that extends current practices in air quality measurements. The AQMO platform will provide citizens, local authorities, scientific organizations and private companies with new data and innovative services based on computing simulation.
- Program: EIT Digital
- Project acronym: UAV-Retina
- Project title: Unmanned Aerial Vehicles - Retina
- Duration: from 2018-10 to 2019-12
- Coordinator: UR1
- Other partners: Bright Cape (company from the Netherlands), FBK (Trento University, Italy), JCP Connect (company from France), Tellus Environment (company from France), Fire Department of Ille et Vilaine (France), Fire Department of Trento (Italy)
- Abstract: The UAV-Retina objectives aims at the creation of a startup company for a flexible autonomous drone platform for search and rescue, using advanced unmanned vehicles and data analytics. The markets for the company will be Improved Explosive Devices detection, support for firefighting operations, and support for avalanche search and rescue operations.

### **8.3.3. Collaborations with Major European Organizations**

- SINTEF, ICT (Norway): Model-driven systems development for the construction of distributed, heterogeneous applications. We collaborate since 2008 and are currently in two FP7 projects together.
- Université du Luxembourg, (Luxembourg): Models runtime for dynamic adaptation and multi-objective elasticity in cloud management; model-driven development.
- KTH, the Royal Institute of Technology (Sweden): continuous software testing, perturbation and diversification.

## **8.4. International Initiatives**

### **8.4.1. Inria International Labs**

IIL CWI-Inria

Associate Team involved in the International Lab:

#### 8.4.1.1. *ALE*

- Title: Agile Language Engineering
- International Partner (Institution - Laboratory - Researcher):
  - CWI (Netherlands) Tijs van der Storm
- Start year: 2017
- See also: <http://gemoc.org/ale/>
- Software engineering faces new challenges with the advent of modern software-intensive systems such as complex critical embedded systems, cyber-physical systems and the Internet of things. Application domains range from robotics, transportation systems, defense to home automation, smart cities, and energy management, among others. Software is more and more pervasive, integrated into large and distributed systems, and dynamically adaptable in response to a complex and open environment. As a major consequence, the engineering of such systems involves multiple stakeholders, each with some form of domain-specific knowledge, and with an increasingly use of software as an integration layer.

Hence more and more organizations are adopting Domain Specific Languages (DSLs) to allow domain experts to express solutions directly in terms of relevant domain concepts. This new trend raises new challenges about designing DSLs, evolving a set of DSLs and coordinating the use of multiple DSLs for both DSL designers and DSL users.

ALE will contribute to the field of Software Language Engineering, aiming to provide more agility to both language designers and language users. The main objective is twofold. First, we aim to help language designers to leverage previous DSL implementation efforts by reusing and combining existing language modules. Second, we aim to provide more flexibility to language users by ensuring interoperability between different DSLs and offering live feedback about how the model or program behaves while it is being edited (aka. live programming/modeling).

### 8.4.2. *Inria International Partners*

#### 8.4.2.1. *Informal International Partners*

- Université de Montréal (Canada)
- McGill University (Canada)
- University of Alabama (USA)
- TU Wien (Austria)
- Michigan State University (MSU)
- Aachen University (Germany)
- KTH (Sweden)

### 8.4.3. *Participation in Other International Programs*

The GEMOC studio has been sustained through the creation of a Research Consortium at the Eclipse Foundation.

#### 8.4.3.1. *International initiative GEMOC*

The GEMOC initiative (cf. <http://www.gemoc.org>) is an open and international initiative launched in 2013 that coordinates research partners worldwide to develop breakthrough software language engineering (SLE) approaches for global software engineering through the use of multiple domain-specific languages. GEMOC members aim to provide effective SLE solutions to problems associated with the design and implementation of collaborative, interoperable and composable modeling languages.

The GEMOC initiative aims to provide a framework that facilitates collaborative work on the challenges of using of multiple domain-specific languages in software development projects. The framework consists of mechanisms for coordinating the work of members, and for disseminating research results and other related information on GEMOC activities. The framework also provides the required infrastructure for sharing artifacts produced by members, including publications, case studies, and tools.

The governance of the GEMOC initiative is ensured by the Advisory Board. The role of the Advisory Board is to coordinate the GEMOC work and to ensure proper dissemination of work products and information about GEMOC events (e.g., meetings, workshops).

Benoit Combemale is the co-founder and currently acts as principal coordinator of the GEMOC initiative. Benoit Combemale and Jean-Marc Jézéquel are part of the Advisory Board, and 9 DIVERSE members are part of the GEMOC initiative.

## **8.5. International Research Visitors**

### **8.5.1. Visits of International Scientists**

- Yves Le Traon, Professor at the University of Luxembourg, visited the team in June and July 2018.
- François Fouquet, Junior Researcher at the SnT (Lux), visited the team in March 2018.
- Jordi Cabot, Research Professor at Internet Interdisciplinary Institute, the Research center of the Open University of Catalonia (UOC), SOM Research Lab leader, visited the team in December 2018.
- Erwan Bousse, postdoctoral researcher at TU Wien, Austria, visited the team from January until Aug 2018
- Marcel Heinz, research assistant and PhD student at University of Koblenz-Landau visited the team in Jul 2018

#### **8.5.1.1. Internships**

- Enzo Menegaldo, from Jun 2018 until Sep 2018
- Yannick Namour from Apr 2018 until Aug 2018
- Koko Armando Nguepi Kenfack Until Jan 2018
- Anthony Orain from Jun 2018 until Jul 2018
- Max Aguirre, from Jun 2018 until Jul 2018
- Gwendal Didot, from May 2018 until Aug 2018
- Arnaud Gohier, from Apr 2018 until Aug 2018
- Alexis Lemasle, from May 2018 until Aug 2018
- Hugo Martin, from Feb 2018 until Aug 2018

### **8.5.2. Visits to International Teams**

- Fabien Coulon visited CWI for 1 week in June 2018 in the context of the Associated Team ALE.
- Manuel Leduc visited CWI for 1 week in December 2018 in the context of the Associated Team ALE.
- Benoit Combemale made several short visits at CWI in the context of the Associated Team ALE, and visited TU Eindhoven in November 2018.
- Olivier Barais and Amine Benelallam made several short visits at KTH in the context of a collaboration with Prof Monperrus and Prof Baudry.

## **EASE Team**

# **8. Partnerships and Cooperations**

## **8.1. National Initiatives**

### **8.1.1. Collaborations**

We have a long-term collaboration with the CAOR lab at Mines ParisTech. We developed an open source IPv6 communication stack for ITS applications. We also participate together in standardisation at IETF, ETSI ITS and ISO TC204 to develop a comprehensive set of standards. A start-up named YoGoKo has been launched in June 2014 to exploit the outcomes of this collaboration.

## **8.2. European Initiatives**

### **8.2.1. Collaborations in European Programs, Except FP7 & H2020**

#### **Project: SCOOP@F part 2**

Partners: MEDE, Renault, PSA, IMT Atlantique

Starting: Jan 2016; Ending : Dec 2019

Coordinator: JM. Bonnin

Abstract: SCOOP@F is a Cooperative ITS pilot deployment project that intends to connect approximately 3000 vehicles with 2000 kilometers of roads. It consists of 5 specific sites with different types of roads: Ile-de-France, "East Corridor" between Paris and Strasbourg, Brittany, Bordeaux and Isère. SCOOP@F is composed of SCOOP@F Part 1 from 2014 to 2015 and SCOOP@F Part 2 from 2016 to 2019. Its main objective is to improve the safety of road transport and of road operating staff during road works or maintenance. The project includes the validations of Cooperative ITS services in open roads, cross border tests with other EU Member States (Spain, Portugal and Austria) and development of a hybrid communication solution (3G-4G/ITS G5). We are involved in the project to study the security and privacy properties of the hybrid architecture that allow to use non dedicated communication networks (WiFi, 5G) as well as the vehicular dedicated communication technologies (G5). The second phase of SCOOP will end up in 2019. As a partner of the InDiD consortium, we proposed a follow up for this project to the EC for the period 2020-2023.

#### **Project: SCHIEF**

Partners: TUM (Technical University of Munchen), IMT Atlantique, Eurecom

Starting: Sept 2016; Ending : Dec 2018

Coordinator: JM. Bonnin

Abstract: In SCHEIF, we create a pilot for an enabler platform for the industrial Internet of Things. We envision a three-layered architecture with Sensors and actuators on the lowest layer. This layer includes industrial robots. On top of this hardware layer we envision site-local processing of data. Such a processing is beneficial since it allows keeping latency boundaries on the one hand and being in full control of all data on the other hand. The latency is relevant for enabling diverse time-critical operations as they often happen in industrial production environments. The local processing is relevant for protecting data. A privacy-conform processing is required to protect company secrets and to protect the privacy of workers. The third layer comprises data processing in the cloud. We envision mostly local data processing. However, offloading computing tasks to public or private clouds will be relevant for compute-intense tasks and those tasks that require coordination between production sites. The main scenario of SCHEIF is an industrial production site where mobile robots and human workers coexist. The focus is providing the data required to manage and optimize the production process always at the most suitable quality. The suitability of data relies on the requirements of the data producers and consumers. A planned demo scenario is a provoked system crash that leads to reprioritization of data streams to mitigate from the failure.

## **8.3. International Initiatives**

### ***8.3.1. Informal International Partners***

Two years ago we initiate a collaboration with Valerie Gay and Christopher Lawrence (UTS / Australia) on adapting smart spaces for eHealth applications. We continue the collaboration and Jean-Marie Bonnin visited UTS last August. As a result a first position paper has been published in OZCHI 2017, the 29th Australian Conference on Human-Computer Interaction held in Brisbane 28th November -1st December, and a second paper this year at ICOST 2018 (July 2018, Singapore) [4]. Christopher Lawrence visited us in April 2018 and gave an invited talk. Jean-Marie Bonnin visited UTS last August and participated in the deployment of the MyMob Mobile App in several indigenous communities.

## **8.4. International Research Visitors**

### ***8.4.1. Visits of International Scientists***

- Christopher Lawrence, Associate Professor, University of Technology Sydney, visited the team in April 2018
- Marc-Oliver Pahl, Research Associate, Technischen Universitat Munchen (TUM), visited the team in July 2018

## FOCUS Project-Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

- ELICA (Expanding Logical Ideas for Complexity Analysis) is an ANR project that started on October 2014 and that finished on September 2018. ELICA focused on methodologies for the static analysis of programs and their resource consumption. The project's aim was to further improve on logical methodologies for complexity analysis (type systems, rewriting, etc.). More specifically, one would like to have more powerful techniques with less false negatives, being able at the same time to deal with nonstandard programming paradigms (concurrent, probabilistic, etc.). Main persons involved: Avanzini, Dal Lago, Martini.
- REPAS (Reliable and Privacy-Aware Software Systems via Bisimulation Metrics) is an ANR Project that started on October 2016 and that will finish on October 2020. The project aims at investigating quantitative notions and tools for proving program correctness and protecting privacy. In particular, the focus will be put on bisimulation metrics, which are the natural extension of bisimulation to quantitative systems. As a key application, we will develop a mechanism to protect the privacy of users when their location traces are collected. Main persons involved: Dal Lago, Gavazzo, Sangiorgi.
- COCAHOLA (Cost models for Complexity Analyses of Higher-Order Languages) is an ANR Project that started on October 2016 and that will finish on October 2019. The project aims at developing complexity analyses of higher-order computations. The focus is not on analyzing fixed programs, but whole programming languages. The aim is the identification of adequate units of measurement for time and space, i.e. what are called *reasonable* cost models. Main persons involved: Dal Lago, Martini.

## 7.2. European Initiatives

### 7.2.1. FP7 & H2020 Projects

- BEHAPI (Behavioural Application Program Interfaces) is an European Project H2020-MSCA-RISE-2017, running in the period March 2018 - February 2022. The topic of the project is behavioural types, as a suite of technologies that formalise the intended usage of API interfaces. Indeed, currently APIs are typically flat structures, i.e. sets of service/method signatures specifying the expected service parameters and the kind of results one should expect in return. However, correct API usage also requires the individual services to be invoked in a specific order. Despite its importance, the latter information is either often omitted, or stated informally via textual descriptions. The expected benefits of behavioural types include guarantees such as service compliance, deadlock freedom, dynamic adaptation in the presence of failure, load balancing etc. The proposed project aims to bring the existing prototype tools based on these technologies to mainstream programming languages and development frameworks used in industry.

### 7.2.2. Collaborations in European Programs, Except FP7 & H2020

- ICT COST Action IC1405 (Reversible computation - extending horizons of computing). Initiated at the end of April 2015 and with a 4-year duration, this COST Action studies reversible computation and its potential applications, which include circuits, low-power computing, simulation, biological modeling, reliability and debugging. Reversible computation is an emerging paradigm that extends the standard forwards-only mode of computation with the ability to execute in reverse, so that computation can run backwards as naturally as it can go forwards.

Main persons involved: Lanese (vice-chair of the action).

- ICT COST Action IC1402 ARVI (Runtime Verification beyond Monitoring). Initiated in December 2014 and with a 4-year duration, this COST Action studies runtime verification, a computing analysis paradigm based on observing a system at runtime to check its expected behaviour.

Main persons involved: Bravetti, Lanese.

### **7.2.3. Collaborations with Major European Organizations**

We list here the cooperations and contacts with other groups, without repeating those already listed in previous sections.

- ENS Lyon (on concurrency models and resource control). Contact person(s) in Focus: Dal Lago, Martini, Sangiorgi. Some visit exchanges during the year, in both directions. A joint PhD (Adrien Durier).
- University of Innsbruck (on termination and complexity analysis of probabilistic programs). Contact person(s) in Focus: Avanzini. Some short visits during the year.
- University of Southern Denmark (on service-oriented computing). Contact person(s) in Focus: Gabbrielli, Lanese, Zavattaro.
- Universitat Politècnica de Valencia, Spain (on reversibility for Erlang). Contact person(s) in Focus: Lanese. Some visit exchanges during the year, in both directions.
- Laboratoire d'Informatique, Université Paris Nord, Villetaneuse (on implicit computational complexity). Contact person(s) in Focus: Dal Lago, Martini.
- Institut de Mathématiques de Luminy, Marseille (on lambda-calculi, linear logic and semantics). Contact person(s) in Focus: Dal Lago, Martini.
- Team PPS, IRIF Lab, University of Paris-Diderot Paris 7 (on logics for processes, resource control). Contact person(s) in Focus: Dal Lago, Martini, Sangiorgi. Some short visits in both directions during the year.
- IRILL Lab, Paris (on models for the representation of dependencies in distributed package based software distributions). Contact person(s) in Focus: Gabbrielli, Zavattaro. Some short visits in both directions during the year.
- IMDEA Software, Madrid (G. Barthe) (on implicit computational complexity for cryptography). Contact person(s) in Focus: Dal Lago. Some visits during the year.
- Facultad de Informatica, Universidad Complutense de Madrid (on web services). Contact person(s) in Focus: Bravetti. Bravetti is an external collaborator in the project "Desarrollo y Análisis formal de sistemas complejos en contextos DistribuidOS: fundamentos, herramientas y aplicaciones (DARDOS)" (Development and formal analysis of complex systems in distributed contexts: foundations, tools and applications) January 2016 - December 2018, funded by the Spanish Ministerio de Economía y Competitividad.

## **7.3. International Initiatives**

### **7.3.1. Inria Associate Teams Not Involved in an Inria International Labs**

#### **7.3.1.1. CRECOGI**

Title: Concurrent, Resourceful and Effectful Computation by Geometry of Interaction

International Partner (Institution - Laboratory - Researcher):

Kyoto (Japan) - Research Institute for Mathematical Sciences - Naohiko Hoshino

Start year: 2018

See also: <http://crecogi.cs.unibo.it>



The field of denotational semantics has successfully produced useful compositional reasoning principles for program correctness, such as program logics, fixed-point induction, logical relations, etc. The limit of denotational semantics was however that it applies only to high-level languages and to extensional properties. The situation has changed after the introduction of game semantics and the geometry of interaction (GoI), in which the meaning of programs is formalized in terms of movements of tokens, through which programs "talk to" or "play against" each other, thus having an operational flavour which renders them suitable as target language for compilers. The majority of the literature on GoI and games only considers sequential functional languages. Moreover, computational effects (e.g. state or I/O) are rarely taken into account, meaning that they are far from being applicable to an industrial scenario. This project's objective is to develop a semantic framework for concurrent, resourceful, and effectful computation, with particular emphasis on probabilistic and quantum effects. This is justified by the greater and greater interest which is spreading around these two computation paradigms, motivated by applications to AI and by the efficiency quantum parallelism induces.

### **7.3.2. Participation in Other International Programs**

Focus has taken part in the creation of the Microservices Community (<http://microservices.sdu.dk/>), an international community interested in the software paradigm of Microservices. Main aims of the community are: i) sharing knowledge and fostering collaborations about microservices among research institutions, private companies, universities, and public organisations (like municipalities); ii) discussing open issues and solutions from different points of view, to create foundations for both innovation and basic research.

U. Dal Lago is "Partner Investigator" in the project "Verification and analysis of quantum programs", whose Chief Investigator is Prof Yuan Feng, University of Technology Sydney. The project is funded by the Australian Research Council.

#### **7.3.2.1. AYAME**

##### **CRECOGI**

Title: Concurrent, Resourceful and Effectful Computation by Geometry of Interaction

International Partner (Institution - Laboratory - Researcher):

JSPS (Japan) - Kyoto University /Research Institute for Mathematical Sciences - Naohiko Hoshino

Duration: 2015 - 2020 The description of the project can be found in Section 7.3.1.1 .

## **7.4. International Research Visitors**

### **7.4.1. Visits of International Scientists**

The following researchers have visited Focus for short periods; we list them together with the title of the talk they have given during their stay, or the topic discussed during their stay.

- Filippo Bonchi (ENS Lyon and University of Pisa) "Sound up-to techniques and complete abstract domain".
- Luis Fernando Llana Díaz (Universidad Complutense de Madrid) "Probabilistic software product lines".
- Claudia Faggian (Université Paris-Diderot – Paris 7) : "Probabilistic Lambda Calculus – beyond deterministic evaluation"
- Nao Hirokawa (Japan Advanced Institute of Science and Technology): "Transformations for Lazy Evaluation and Theorem Proving".
- Guilhem Jaber (University of Nantes): "Game semantics for higher-order functions with state".
- Thomas Leventis (Institut de Mathématiques de Marseille): "Taylor Expansion of lambda terms and differential linear logic."
- Gabriel Scherer (Inria Parsifal). "Keep (re)playing until you get all the successes".
- Emilio Tuosto (University of Leicester): "On pomsets as models of asynchronous message-passing languages".
- Akihisa Yamada (NII Tokyo): "Mathematics for Complexity in Isabelle/HOL".

#### **7.4.2. Visits to International Teams**

- Francesco Gavazzo visited the Faculty of Mathematics and Physics (University of Ljubljana) hosted by Alex Simpson, from 02/10/2017 to 31/01/2018.
- U. Dal Lago has spent overall a few weeks in Japan (University of Kyoto and University of Tokyo), collaborations with Naohiko Hoshino and Naoki Kobayashi.

##### *7.4.2.1. Sabbatical programme*

Simone Martini is Fellow at the Collegium - Lyon Institute for Advanced Studies, since September 2018 and until June 2019 <https://collegium.universite-lyon.fr>.

## **INDES Project-Team**

# **7. Partnerships and Cooperations**

## **7.1. Inria internal funding**

### **7.1.1. IPL SPAI**

SPAI (Security Program Analyses for the IoT) is an IPL (Inria Project Lab), with a duration of 4 years, started on April 2018. Members of the Antique, Celtique, Indes, Kairos, and Privatics Inria teams are involved in the SPAI IPL.

SPAI is concerned with the design of program analyses for a multitier language for the Internet of Things (IoT). The programming abstractions will allow us to reason about IoT systems from microcontrollers to the cloud. Relying on the Inria multitier language Hop.js semantics and the current Coq formalizations of JavaScript semantics, we plan to certify these analyses in order to guarantee the impossibility of security properties violations and implement security properties' enforcements by compilation.

Tamara Rezk coordinates this project.

### **7.1.2. ADT FingerKit**

In the context of the Inria ADT call, we are involved in a *FingerKit: a Cloud Platform to Study Browser Fingerprints at Large*, lead by Walter Rudametkin from the Spirals project-team. The funding for a two year engineering position for the 2018-2020 period was obtained and an engineer is hired in Spirals project-team. Nataliia Bielova from INDES team is part of this project.

## **7.2. National Initiatives**

### **7.2.1. ANR AJACS**

The AJACS project (Analyses of JavaScript Applications: Certification & Security) is funded by the ANR for 42 months, starting December 2014. The goal of the AJACS project is to provide strong security and privacy guarantees on the client side for web application scripts. The Indes members Tamara Rezk and Nataliia Bielova are involved in the tasks WP2 Certified Analyses and WP3 Security of JavaScript Applications. The partners of this project include Inria teams Celtique (coordinator), Toccata, and Prosecco.

### **7.2.2. ANR CISC**

The CISC project (Certified IoT Secure Compilation) is funded by the ANR for 42 months, starting in April 2018. The goal of the CISC project is to provide strong security and privacy guarantees for IoT applications by means of a language to orchestrate IoT applications from the microcontroller to the cloud. Tamara Rezk coordinates this project, and Manuel Serrano, Ilaria Castellani and Nataliia Bielova participate in the project. The partners of this project are Inria teams Celtique, Indes and Privatics, and Collège de France.

### **7.2.3. ANR PrivaWeb**

The PrivaWeb project (Privacy Protection and ePrivacy Compliance for Web Users) is funded by the ANR JCJC program for 42 months, starting in December 2018. PrivaWeb aims at developing new methods for detection of new Web tracking technologies and new tools to integrate in existing Web applications that seamlessly protect privacy of users. Nataliia Bielova coordinates this project.

### **7.2.4. FUI UCF**

The 3 years long UCF project aims at developing a reactive Web platforms for delivering multimedia contents. The partners of the project are the startups Alterway, OCamlPro, and XWiki, and the academic research laboratories of University Pierre et Marie Curie, and Denis Diderot. Manuel Serrano participates in this project.

## **7.3. European Initiatives**

### **7.3.1. Collaborations in European Programs, Except FP7 & H2020**

#### *7.3.1.1. ICT Cost Action IC1405 on Reversible Computation*

Program: ICT COST Action IC1405

Project title: Reversible computation - extending horizons of computing

Duration: November 2014 - April 2019

Coordinator: Irek Ulidowski, University of Leicester

Other partners: several research groups, belonging to 23 European countries.

Abstract: Reversible computation is an emerging paradigm that extends the standard mode of computation with the ability to execute in reverse. It aims to deliver novel computing devices and software, and to enhance traditional systems. The potential benefits include the design of reversible logic gates and circuits - leading to low-power computing and innovative hardware for green ICT, new conceptual frameworks and language abstractions, and software tools for reliable and recovery-oriented distributed systems. This is the first European network of excellence aimed at coordinating research on reversible computation.

#### *7.3.1.2. Bilateral PICS project SuCCeSS*

Program: CNRS Bilateral PICS project

Project acronym: SuCCeSS

Project title: Security, Adaptability and time in Communication Centric Software Systems

Duration: June 2016 - June 2019

Coordinator: Cinzia Di Giusto, I3S, Sophia Antipolis

Partners: I3S, Inria, University of Groningen

Abstract: The project SuCCeSS is a CNRS-funded "Projet coopératif" (PICS 07313), involving two French teams in Sophia Antipolis (the MDSC team at the laboratory I3S, acting as coordinator, and the INDES team) and one Dutch team at the University of Groningen. The project started in June 2016 and is due to end in June 2019. The objective of the project is to study formal models for reliable distributed communication-centric software systems. The project focusses on analysis and validation techniques based on behavioural types, aimed at enforcing various properties (safety, liveness, security) of structured communications.

## **7.4. International Initiatives**

### **7.4.1. Inria International Partners**

#### *7.4.1.1. Informal International Partners*

- We are initiating a new collaboration with Prof. Robby Findler and his group from Northwestern University of Chicago. We are studying reactive synchronous programming languages and their applications.
- We are pursuing our collaboration on session types with Prof. Mariangiola Dezani Ciancaglini from the University of Torino and Prof. Paola Giannini from the University of Piemonte Orientale. We also continue to collaborate with Dr. Jorge Pérez and his PhD student Mauricio Cano, from the University of Groningen, on the integration of session types with synchronous reactive programming.
- We are initiating a new collaboration with Professor of Law, Frederik Zuiderveen Borgesius from the Radboud University Nijmegen and Amsterdam Law School (double affiliation). We are studying General Data Protection Regulation (GDPR) and ePrivacy Regulation and their application to Web tracking technologies.

- We have been collaborating with Prof. Alejandro Russo from Chalmers University of Technology and Prof. Cormac Flanagan from University of California Santa Cruz, that resulted in a joint publication at WWW conference [15].
- We have been collaborating with Prof. Benoit Baudry from KTH Royal Institute of Technology, Sweden on the survey of browser fingerprinting technologies.

## **7.4.2. Participation in Other International Programs**

### *7.4.2.1. International Initiatives*

#### **DAJA**

Title: Detection strategies based on Software Metrics for Multitier JavaScript

International Partners (Institution - Laboratory - Researcher):

Universidad de Chile (Chile), DDC Alexandre Bergel

Universidad Nacional del Centro de la Provincia de Buenos Aires (Argentina) - ISISTAN  
Research Insitute - Santiago Vidal

Duration: 2018 - 2019

Start year: 2018

See also: <https://daja-sticamsud.github.io/>

JavaScript is the most popular object scripting programming language. It is extensively used conceived only for scripting, it is frequently used in large applications. The rapid adoption of JavaScript has outpaced the Software Engineering community to propose solutions to ensure a satisfactory code quality production. This situation has favored the production of poor quality JavaScript applications: we have found across JavaScript applications a large presence of dead-code (i.e., source code portion that is never used) and code duplications. These symptoms are known to lead to maintenance and performance degradation. Moreover, we have previously analyzed potential security threats to JavaScript applications produced by bad coding practices.

The DAJA project will provide methodologies, techniques, and tools to ease the maintenance of software applications written in JavaScript while improving its security.

## **7.5. International Research Visitors**

### *7.5.1. Visits of International Scientists*

- We are collaborating with Prof. Marc Feeley from University of Montréal. For the second consecutive year, M. Feeley has visited us for studying implementation of dynamic languages.
- As part of our ongoing collaboration on session types, Prof. Paola Giannini from the University of Piemonte Orientale visited our team for two weeks, funded by the COST Action on Reversibility.
- Our team, together with Cinzia Di Giusto's team at I3S, hosted Mauricio Cano, a PhD student from the University of Groningen, for a 2-month visit. This was part of our collaboration with the University of Groningen within the project PICS SuCCeSS. The visit was funded for the most part by Academy 1 of Université Côte d'Azur.

#### *7.5.1.1. Internships*

- Tamara Rezk supervised the intern Sadry Fievet for 6 months
- Tamara Rezk supervised - as "tuteur" - the internship of El Mehdi Regragui for 6 months
- Bertrand Petit and Manuel Serrano supervised the internship of Thibaud Ardoin who studied and implemented the Skini distributed sequencer.

## **PHOENIX-POST Team**

# **7. Partnerships and Cooperations**

## **7.1. International Initiatives**

- Idex cooperation programme UB-UUW-Canada — Category B - Emerging Cooperation (2017-2018), managed by M. Fernandes and H. Sauzéon.
- Idex cooperation programme UB-UUW-Canada — Category A - Research projects - Priority topics (Aging) – (2017-2018), managed by M. Fernandes and H. Sauzéon.

## **RMOD Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. Regional Initiatives**

### **9.1.1. CAR IMT Douai**

Participants: Pablo Tesone, Guillermo Polito, Marcus Denker, Stéphane Ducasse with: L. Fabresse and N. Bouraqadi (IMT Douai)  
From 2009, ongoing.

We have signed a convention with the CAR team led by Noury Bouraqadi of IMT Douai. In this context we co-supervised three PhD students (Mariano Martinez-Peck, Nick Papoylias and Guillermo Polito). The team is also an important contributor and supporting organization of the Pharo project.

Currently, Pablo Tesone is doing a PhD co-supervised by RMOD and Pr. L. Fabresse and N. Bouraqadi. We are collaborating in the Context of CPER Data since 2018.

### **9.1.2. CPER DATA**

Participants: Marcus Denker, Stéphane Ducasse, Alex Oliveira with: L. Fabresse and N. Bouraqadi (IMT Douai)  
From 2018, ongoing.

Funding to work one year on the PharoThings Platform. We are creating content for a website and a Demo in collaboration with IMT Douai.

## **9.2. National Initiatives**

### **9.2.1. CEA List**

Participants: Jason Lecerf, Stéphane Ducasse with T. Goubier (CEA List)  
From 2016, ongoing.

Jason Lecerf started a shared PhD Oct 2016: *Reuse of code artifacts for embedded systems through refactoring.*

## **9.3. European Initiatives**

### **9.3.1. Collaborations in European Programs, Except FP7 & H2020**

#### **Namur University, Belgium**

Participants: Anne Etien, Nicolas Anquetil, Olivier Auverlot, Stéphane Ducasse.

From Sept 2016 to Dec. 2018.

Lille Nord Europe European Associated Team with the PreCISE research center of Pr. A. Cleve from Namur University (Belgium).

This project aims to study the co-evolution between database structure and programs and to propose recommendations to perform required changes on cascade. These programs are either internal to the schema as functions or triggers or external as applications written in Java or Php built on top of the DB. Our intuition is that software engineering techniques can be efficient for such issues. This project also aims to unify the abstract representation of the DB and its relationships with the internal or external program.

#### **VUB Brussels, Belgium**

Participants: Guillermo Polito, Stéphane Ducasse.

From 2016, ongoing.

Student: Matteo Marra, collaboration with Eliza Gonzalez Boix. Guillermo Polito co-supervised Matteo Marra's master thesis.

#### **University of Prague**

Participants: Stéphane Ducasse.

From 2015, ongoing.

We are working with Dr. Robert Pergl from the University of Prague. Stéphane Ducasse gave a lecture at the University of Prague in 2018.

## **9.4. International Initiatives**

### **9.4.1. Inria International Partners**

#### *9.4.1.1. Informal International Partners*

##### **Uqbar Argentina**

Participants: Pablo Tesone, Esteban Lorenzano, Guillermo Polito, Stéphane Ducasse.

From 2015, ongoing.

We are working with the Uqbar team from different Argentinian universities. We hired three of the people: Nicolas Passerini (engineer), Esteban Lorenzano (engineer) and Pablo Tesone (PhD).

##### **Pharo in Research:**

Participants: Pablo Tesone, Esteban Lorenzano, Guillermo Polito, Marcus Denker, Stéphane Ducasse.

From 2009, ongoing.

We are building an ecosystem around Pharo with international research groups, universities and companies. Several research groups (such as Software Composition Group – Bern, and Pleaid – Santiago) are using Pharo. Many universities are teaching OOP using Pharo and its books. Several companies worldwide are deploying business solutions using Pharo.

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

- Abdelghani Alidra [University of Skikda Algeria, from Nov 2018]
- Andy Amoordon [Utocat, from Oct 2018]
- Jan Bliznicenko [University of Prague, Mar 2018]
- Abdelhakim Bouremel [University of Skikda Algeria, May 2018]
- Thomas Dupriez [Ecole Normale Supérieure Paris, Sep 2018]
- Christopher Fuhrman [Ecole de technologie supérieure de montreal, from Oct 2018]
- Tomohiro Oda [Key Technology Laboratory, Japan, from Aug 2018 until Sep 2018]
- Giuseppe Antonio Pierro [University of Cagliari, from Aug 2018]
- Ronie Salgado Faila [University of Chile at Santiago, Chile, from Aug 2018 until Sep 2018]
- Serge Demeyer [Universiteit Antwerpen, Belgium, from Jun 2018 until Jul 2018]

#### *9.5.1.1. Internships*

- Lionel Akue [Inria, from Jul 2018 until Sep 2018]
- Asbathou Bialou Sama [Inria, from Apr 2018 until Aug 2018]
- Quentin Ducasse [Inria, from Jun 2018 until Aug 2018]
- Thomas Dupriez [Ecole Normale Supérieure Cachan, until Feb 2018]
- Yoan Geran [Ecole Normale Supérieure Paris, from Jun 2018 until Jul 2018]
- Pierre Tsapliayeu [Univ de Lille, from Apr 2018 until Aug 2018]
- Eleonore Wald [Univ de Lille, from Apr 2018 until Jul 2018]
- Oleksandr Zaitsev [Inria, from Oct 2018]
- Myroslava Romaniuk [Inria, from Jul 2018 until Sep 2018]

### **9.5.2. Visits to International Teams**

- Marcus Denker: VUB Brussels in spring and fall 2018 (Lecture).



## STACK Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. CoMe4ACloud

**Participant:** Thomas Ledoux [coordinator].

The project, started in October 2016, was completed in March 2018. CoMe4ACloud was an Atlanstic 2020 funded project and supported a one year post-doc position. The project was led by STACK research team and involved also AtlanModels and TASC, all of them from the LS2N and situated at IMT Atlantique.

The high-level objective of the CoMe4ACloud (Constraints and Model Engineering for Autonomic Clouds) project was to provide an end-to-end solution for autonomic Cloud services. To that end, we relied on techniques of Constraint Programming so as a decision-making tool and Model-driven Engineering to ease the automatic generation of the so-called autonomic managers as well as their synchronization with the managed system (i.e., the Cloud layers).

This year, we have focus on the dissemination of the results. We got the best paper award of CLOSER 2018 (the 8th International Conference on Cloud Computing and Services Science) [12] and published in the journal FGCS [3]. We also gave a pitch in the annual Atlanstic 2020 meeting in November.

See <https://come4acloud.github.io> for more information.

### 9.1.2. Oncoshare

**Participant:** Mario Südholt [coordinator].

The ONCOSHARE project (ONCOlogy big data SHARING for Research) will demonstrate, through a multi-disciplinary cooperation within the Western CANCEROPOLE network, the feasibility and the added value of a Cancer Patient Centered Information Common for in-silico research. The STACK team will work on challenges to the security and the privacy of user data in this context.

This project is financed by three French regions from 2018-2021.

### 9.1.3. SyMeTRIC

**Participant:** Jean-Marc Menaud [coordinator].

SyMeTRIC is a regional federated project in Systems Medicine funded by the Pays de la Loire french region. Systems Medicine approaches can be compared to Systems Biology. They aim at integrating several information sources to design and validate bio-models and biomarkers to anticipate and enhance patients follow-up (diagnosis, treatment response prediction, prognosis).

This project is ending in 2018.

### 9.1.4. SysMics

**Participants:** Jean-Marc Menaud, Mario Südholt [coordinator].

The SysMics project aims at federating the NExT scientific community toward a common objective: anticipate the emergence of systems medicine by co-developing 3 approaches in population-scale genomics: genotyping by sequencing, cell-by-cell profiling and microbiome analysis. STACK investigates new means for secure and privacy-aware computations in the context of personalized medicine, notably genetic analyses.

This project is financed by the Nantes excellency initiative in Medecine and Informatics (NExT) from 2018-22.

## 9.2. National Initiatives

### 9.2.1. *CominLabs laboratory of excellence*

#### 9.2.1.1. *PrivGen*

**Participants:** Fatima-Zahra Boujdad, Mario Südholt [coordinator].

PrivGen (“Privacy-preserving sharing and processing of genetic data”) is a three-year project that has been started in Oct. 2016 and is conducted by three partners: a team of computer scientists from the LATIM Inserm institute in Brest mainly working on data watermarking techniques, a team of geneticists from an Inserm institute in Rennes working on the gathering and interpretation of genetic data, and the STACK team. The project provides funding of 330 KEUR altogether with an STACK share of 120 KEUR.

The project considers challenges related to the outsourcing of genetic data that is in the Cloud by different stakeholders (researchers, organizations, providers, etc.). It tackles several limitations of current security solutions in the cloud, notably the lack of support for different security and privacy properties at once and computations executed at different sites that are executed on behalf of multiple stakeholders.

The partners are working on three main challenges:

- Mechanisms for a continuous digital content protection
- Composition of security and privacy-protection mechanisms
- Distributed processing and sharing of genetic data

The Ascola team is mainly involved in providing solutions for the second and third challenges.

#### 9.2.1.2. *SeDuCe++*

**Participants:** Jonathan Pastor, Jean-Marc Menaud [coordinator].

SeDuCe++ is an extended version of the SeDuCe project. Funded by the LS2N (CNRS), an allocated budget of 10KEuros for one year, it aims at studying the energy footprint of extreme edge infrastructure.

### 9.2.2. *ANR*

#### 9.2.2.1. *GRECO (ANR)*

**Participants:** Adrien Lebre [Contact point], Alexandre Van Kempen.

The GRECO project (Resource manager for cloud of Things) is an ANR project (ANR-16-CE25-0016) running for 42 months (starting in January 2017 with an allocated budget of 522KEuros, 90KEuro for ASCOLA).

The consortium is composed of 4 partners: Qarnot Computing (coordinator) and 3 academic research group (DATAMOVE and AMA from the LIG in Grenoble and ASCOLA from Inria Rennes Bretagne Atlantique).

The goal of the GRECO project (<https://anr-greco.net>) is to design a manager for cloud of things. The manager should act at the IaaS, PaaS and SaaS layer of the cloud. One of the principal challenges will consist in handling the execution context of the environment in which the cloud of things operates. Indeed, unlike classical resource managers, connected devices imply to consider new types of networks, execution supports, sensors and new constraints like human interactions. The great mobility and variability of these contexts complexify the modelling of the quality of service. To face this challenge, we intend to innovate in designing scheduling and data management systems that will use machine learning techniques to automatically adapt their behaviour to the execution context. Adaptation here requires a modelling of the recurrent cloud of things usages, the modelling of the dynamics of physical cloud architecture.

#### 9.2.2.2. *KerStream (ANR)*

**Participant:** Shadi Ibrahim [Coordinator].

The KerStream project (Big Data Processing: Beyond Hadoop!) is an ANR JCJC (Young Researcher) project (ANR-16-CE25-0014-1) running for 48 months (starting in January 2017 with an allocated budget of 238KEuros).

The goal of the KerStream project is to address the limitations of Hadoop when running Big Data stream applications on large-scale clouds and do a step beyond Hadoop by proposing a new approach, called KerStream, for scalable and resilient Big Data stream processing on clouds. The KerStream project can be seen as the first step towards developing the first French middleware that handles Stream Data processing at Scale.

### 9.2.3. FSN

#### 9.2.3.1. Hydda (FSN)

**Participants:** Helene Coullon, Jean-Marc Menaud [coordinator].

The HYDDA project aims to develop a software solution allowing the deployment of Big Data applications (with hybrid design (HPC/CLoud)) on heterogeneous platforms (cluster, Grid, private Cloud) and orchestrators (Task scheduler like Slurm, Virtual orchestrator (like Nova for OpenStack or Swarm for Docker). The main questions we are investigating are :

- How to propose an easy-to-use service to host (from deployment to elimination) application components that are both typed Cloud and HPC?
- How propose a service that unifies the HPCaaS (HPC as a service) and the Infrastructure as a Service (IaaS) in order to offer resources on demand and to take into account the specificities of scientific applications?
- How optimize resources usage of these platforms (CPU, RAM, Disk, Energy, etc.) in order to propose solutions at the least cost?

### 9.2.4. CPER

#### 9.2.4.1. SeDuCe

**Participants:** Adrien Lebre, Jean-Marc Menaud [coordinator], Jonathan Pastor.

The SeDuCe project (Sustainable Data Centers: Bring Sun, Wind and Cloud Back Together), aims to design an experimental infrastructure dedicated to the study of data centers with low energy footprint. This innovative data center will be the first experimental data center in the world for studying the energy impact of cloud computing and the contribution of renewable energy (solar panels, wind turbines) from the scientific, technological and economic viewpoints. This project is integrated in the national context of grid computing (Grid'5000), and the Constellation project, which will be an inter-node (Pays de la Loire, Brittany).

### 9.2.5. Inria Project Labs

#### 9.2.5.1. DISCOVERY

**Participants:** Helene Coullon, Marie Delavergne, Shadi Ibrahim, Adrien Lebre [coordinator], Dimitri Pertin [Until May 2018], Ronan Alexandre Rcherreau, Matthieu Simonin, Alexandre Van Kempen.

To accommodate the ever-increasing demand for Utility Computing (UC) resources, while taking into account both energy and economical issues, the current trend consists in building larger and larger Data Centers in a few strategic locations. Although such an approach enables UC providers to cope with the actual demand while continuing to operate UC resources through centralized software system, it is far from delivering sustainable and efficient UC infrastructures for future needs.

The DISCOVERY initiative<sup>0</sup> aims at exploring a new way of operating Utility Computing (UC) resources by leveraging any facilities available through the Internet in order to deliver widely distributed platforms that can better match the geographical dispersal of users as well as the ever increasing demand. Critical to the emergence of such locality-based UC (also referred as Fog/Edge Computing) platforms is the availability of appropriate operating mechanisms. The main objective of DISCOVERY is to design, implement, demonstrate and promote a new kind of Cloud Operating System (OS) that will enable the management of such a large-scale and widely distributed infrastructure in a unified and friendly manner.

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<sup>0</sup><http://beyondtheclouds.github.io>

The consortium is composed of experts in the following research areas: large-scale infrastructure management systems, networking and P2P algorithms. Moreover, two key network operators, namely Orange and RENATER, are involved in the project.

By deploying and using a Fog/Edge OS on backbones, our ultimate vision is to enable large parts of the Internet to be hosted and operated by its internal structure itself: a scalable set of resources delivered by any computing facilities forming the Internet, starting from the larger hubs operated by ISPs, governments and academic institutions, to any idle resources that may be provided by end users.

STACK leads the DISCOVERY IPL and contributes mainly around two axes: VM life cycle management and deployment/reconfiguration concerns.

## 9.2.6. *InriaHub*

### 9.2.6.1. *MERCURY*

**Participants:** Ronan-Alexandre Cherrueau, Adrien Lebre [coordinator], Matthieu Simonin.

STACK, in particular within the framework of the DISCOVERY initiative has been working on the massively distributed use case since 2013. With the development of several proof-of-concepts around OpenStack, the team has had the opportunity to start an InriaHub action. Named MERCURY, the goal of this action is twofold: (i) support the research development made within the context of DISCOVERY and (ii) favor the transfer toward the OpenStack community.

Further information available at: <http://beyondtheClouds.github.io>.

### 9.2.6.2. *APOLLO/SOYUZ*

**Participants:** Ronan-Alexandre Cherrueau, Adrien Lebre [coordinator], Matthieu Simonin.

The Apollo/Soyuz is the second InriaHub action attached the DISCOVERY IPL. While MERCURY aims mainly at supporting development efforts within the DISCOVERY IPL, the APOLLO/SOYUZ is focusing on the animation and the dissemination of the DISCOVERY activities within the different open-source ecosystem (*i.e.*, OpenStack, OPNFV, etc.). One additional engineer will join the current team in January 2019.

Further information available at: <http://beyondtheClouds.github.io>.

## 9.2.7. *Fond d'amorçage IMT Industrie du Futur 2017*

### 9.2.7.1. *aLIFE*

**Participants:** Hélène Coullon [coordinator], Jacques Noyé.

We have organized, in partnership with colleagues from IMT Atlantique, the aLIFE workshop between industry and academia, which took place in Nantes during two days on 30-31 January.

The objective was to share experience and success stories, as well as open challenges related to the contribution of software-related research to Factories of the Future, in French *Apport de l'industrie du Logiciel à l'Industrie du Futur Européenne (aLIFE)*. 86 people registered to the workshop, organized around plenary sessions and discussion panels, with speakers from Airbus, Baldwin Partners, Comau (Italy), Dassault Systèmes, e.I.m. Leblanc, La Poste, Naval Group, Predict, Fraunhofer (Germany), KTH (Sweden), Polytechnique Montréal (Canada), and TUM (Germany).

## 9.2.8. *Connect Talent*

### 9.2.8.1. *Apollo (Connect Talent)*

**Participant:** Shadi Ibrahim [Coordinator].

The Apollo project (Fast, efficient and privacy-aware Workflow executions in massively distributed Data-centers) is an individual research project “Connect Talent” running for 36 months (starting in November 2017 with an allocated budget of 201KEuros).

The goal of the Apollo project is to investigate novel scheduling policies and mechanisms for fast, efficient and privacy-aware data-intensive workflow executions in massively distributed data-centers.

### 9.2.9. *Etoiles Montantes*

#### 9.2.9.1. *VeRDi*

**Participant:** H el ene Coullon [Coordinator].

VeRDi is an acronym for Verified Reconfiguration Driven by execution. The VeRDi project is funded by the French region Pays De La Loire where Nantes is located. The project starts in November 2018 and ends on December 2020 with an allocated budget of 172800 .

It aims at addressing distributed software reconfiguration in an efficient and verified way. The aim of the VeRDi project is to build an argued disruptive view of the problem. To do so we want to validate the work already performed on the deployment in the team and extend it to reconfiguration.

## 9.3. European Initiatives

### 9.3.1. *H2020 Projects*

#### 9.3.1.1. *BigStorage*

Title: BigStorage: Storage-based Convergence between HPC and Cloud to handle Big Data

Programm: H2020

Duration: January 2015 - December 2018

Coordinator: Universidad politecnica de Madrid

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Ca Technologies Development Spain (Spain)

Commissariat A L Energie Atomique et Aux Energies Alternatives (France)

Deutsches Klimarechenzentrum (Germany)

Foundation for Research and Technology Hellas (Greece)

Fujitsu Technology Solutions (Germany)

Johannes Gutenberg Universitaet Mainz (Germany)

Universidad Politecnica de Madrid (Spain)

Seagate Systems Uk (United Kingdom)

Inria contact: G. Antoniu & A. Lebre

The consortium of this European Training Network (ETN) 'BigStorage: Storage-based Convergence between HPC and Cloud to handle Big Data' will train future data scientists in order to enable them and us to apply holistic and interdisciplinary approaches for taking advantage of a data-overwhelmed world, which requires HPC and Cloud infrastructures with a redefinition of storage architectures underpinning them - focusing on meeting highly ambitious performance and energy usage objectives. There has been an explosion of digital data, which is changing our knowledge about the world. This huge data collection, which cannot be managed by current data management systems, is known as Big Data. Techniques to address it are gradually combining with what has been traditionally known as High Performance Computing. Therefore, this ETN will focus on the convergence of Big Data, HPC, and Cloud data storage, its management and analysis. To gain value from Big Data it must be addressed from many different angles: (i) applications, which can exploit this data, (ii) middleware, operating in the cloud and HPC environments, and (iii) infrastructure, which provides the Storage, and Computing capable of handling it. Big Data can only be effectively exploited if techniques and algorithms are available, which help to understand its content, so that it can be processed by decision-making models. This is the main goal of Data Science. We claim that this ETN project will be the ideal means to educate new researchers on the different facets of Data Science (across storage hardware and software architectures, large-scale distributed systems, data management services, data analysis, machine learning, decision making). Such a multifaceted expertise is mandatory to enable researchers to propose appropriate answers to applications requirements, while leveraging advanced data storage solutions unifying cloud and HPC storage facilities.'

## **9.4. International Initiatives**

### **9.4.1. Inria International Partners**

#### *9.4.1.1. Informal International Partners*

Huazhong university of Science and Technology (HUST): We collaborate on resource management and task scheduling for stream data applications in the cloud.

National University of Singapore (NUS): We collaborate on mitigating stragglers for Big Data applications in clouds and optimizing graph processing in geo-distributed data-centers.

ShenZhen University: We collaborate on data management in HPC systems, mitigating stragglers for Big Data applications in clouds and optimizing graph processing in geo-distributed data-centers.

## **9.5. International Research Visitors**

### **9.5.1. Visits to International Teams**

#### *9.5.1.1. Research Stays Abroad*

HUST, China: From October 20 to November 5, S. Ibrahim visited the Services Computing Technology and System Lab at Huazhong university of Science and Technology.

Flagstaff, Northern Arizona University, USA: From September 10 to September 16, H. Coullon visited the School of Informatics, Computing and Cyber Systems, Northern Arizona University, Flagstaff, USA.

## AGORA Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

- FIL Grant, 2018  
 Participants: Hervé Rivano  
 The partners of this project, supported by the *Fédération d'Informatique de Lyon*, are: CITI, LIP.  
 The goal is to use crowd-sensing applications with data collection of Wi-Fi networks which are available in the neighborhood in order *i*) to build a map of the wireless network in terms of performance for the application and *ii*) to optimize the wireless network configuration.
- Labex IMU UrPolSens, 10/2015-10/2018  
 Participants: Walid Bechkit, Amjed Belkhiri, Ahmed Boubrima, Hervé Rivano  
 The partners in this project are Ifsttar, LMFA, EVS, TUBA, and Air Rhone-Alpes, with Inria Agora leading the project.  
 UrPolSens deals with the monitoring of air pollution using low-cost sensors interconnected by a wireless networks. Although they are less accurate than the high-end sensors used today, low-cost autonomous air quality sensors allow to achieve a denser spatial granularity and, hopefully, a better monitoring of air pollution. The main objectives of this project are to improve the modeling of air pollution dispersion; propose efficient models to optimize the deployment the sensors while considering the pollution dispersion and the impact of urban environment on communications; deploy a small-scale network for pollution monitoring as a proof of concept; compare the measured and estimated levels of exposure; study the spatial disparities in exposure between urban areas.
- Labex IMU 3M' Air 2018-2021  
 Participants: Walid Beckhit, Ahmed Boubrima, Manoel Dahan, Mohamed Anis Fekih, Ichrak Mokhtari, Hervé Rivano.  
 The partners in this project are: EVS, LMFA, Métropole de Lyon, Ville de Lyon , Atmo AURA, Météo France, Lyon Météo. Inria Agora is the leader of this project.  
 The 3M' Air project explore the potential of participatory sensing to improve local knowledge of air quality and urban heat islands. The main aim of this project is therefore to equip citizens with low-cost mobile sensors and then ensure an efficient real-time data collection and analysis. This allows to obtain a finer spatiotemporal granularity of measurements with lighter installation and operational costs while involving citizens.
- ARC6 Robot fleet mobility under communication constraints, 10/2016-09/2019.  
 Participant : Fabrice Valois.  
 This work is a joint project with the Inria Chroma research group. Considering a fleet of drones moving in a 3D area, looking for a given target, we focus on how to maintain the wireless connectivity of the network of drones while the drones patrol autonomously. The other partners in this project are University of Grenoble and Viameca.
- Labex IMU Veival, 10/2017-10/2019  
 Participant: Hervé Rivano.  
 The partners in this project are: EVS, LIRIS, LLSETI and CITI, with LAET leading the project.  
 The goal of this pluridisciplinary project is to study, understand and model the behavior of cyclists in an urban environment with a methodology combining quantitative measurements of mobility traces and image analysis with qualitative informations from reactivation interviews. In particular the input of Agora is to provide crowdsourcing tools for gathering mobility data that are optimized for the practice of urban cycling.

## 9.2. National Initiatives

### 9.2.1. ANR

- ANR CANCAN 2019 - 2022 (accepted in 2018, kickoff in February 2019)  
Participants: Solohaja Rabenjamina, Razvan Stanica.  
The partners in this project are: CEDRIC, Inria, Orange Labs, with Thalès Communications & Security leading the project.  
The ANR CANCAN (Content and context based adaptation in mobile networks) targets the following objectives: *i*) collecting novel measurement datasets that describe mobile network data traffic at unprecedented spatial and temporal accuracy levels, and for different mobile services separately. The datasets will be gathered in an operational nationwide network, *ii*) evaluating existing analytics for classification, prediction and anomaly detection within real-world high-detail per-service mobile network data, and tailoring them to the specifications of the management of resources at different network levels, and *iii*) demonstrating the integration of data analytics within next-generation cognitive network architectures in several practical case studies.
- ANR MAESTRO 5G 2019 - 2022 (accepted in 2018, kickoff in February 2019)  
Participants: Hervé Rivano, Razvan Stanica.  
The partners in this project are: CEDRIC, Inria, L2S, LIA, Nokia Bell Labs, TSP, with Orange Labs leading the project.  
The ANR MAESTRO 5G (Management of slices in the radio access of 5G networks) is expected to provide: *i*) a resource allocation framework for slices, integrating heterogeneous QoS requirements and spanning on multiple resources including radio, backhauling/fronthauling and processing resources in the RAN, *ii*) a complete slice management architecture including provisioning and re-optimization modules and their integration with NFV and SDN strata, *iii*) a business layer for slicing in 5G, *iv*) a demonstrator showing the practical feasibility as well as integration of the major functions and mechanisms proposed by the project, on a 5G Cloud RAN platform. The enhanced platform is expected to support the different 5G services.
- ANR CoWorkWorlds 01/2018 - 12/2020.  
Participants: Solohaja Rabenjamina, Razvan Stanica.  
The ANR CoWorkWorlds (Sustainability and spatiality in co-workers' mobility practices) project is lead by ENTPE. Its focus is on the study of co-working environments, and more precisely on the mobility behaviour of users of such spaces. Our role in the project is to collect and analyse mobility data from a set of users, using the PrivaMov smartphone application.

### 9.2.2. DGA

- DGA CLOTHO 10/2016-10/2018.  
Participants: Junaid Khan, Romain Pujol, Razvan Stanica, Fabrice Valois  
The partners in the DGA CLOTHO project are Traqueur and Sigfox. The objective of the project is to reduce the energy consumption of the device tracking functionality, by taking profit of short-range communications between the tracked objects.

### 9.2.3. PIA

- PIA ADAGE 07/2016-06/2018.  
Participants: Elli Zavou, Razvan Stanica  
The partners in the PIA ADAGE project are Orange, LAAS-CNRS and Inria Privatics. The objective of the ADAGE project is to design and evaluate anonymization algorithms for the specific case of mobile traffic data. Our role in the project is focused on evaluating whether the anonymized data is still usable for adaptive networking mechanisms.

### 9.2.4. Pôle ResCom



- Ongoing participation (since 2006)  
Communication networks, working groups of GDR ASR/RSD, CNRS (<http://rescom.inrialpes.fr>).  
Hervé Rivano is member of the scientific committee of ResCom.

### 9.2.5. EquipEx

- SenseCity  
We have coordinated the participation of several Inria teams to the SenseCity EquipEx. Within the SenseCity project, several small reproduction of 1/3rd scale city surroundings will be built under a climatically controlled environment. Micro and nano sensors will be deployed to experiment on smart cities scenarios, with a particular focus on pollution detection and intelligent transport services. Agora will have the opportunity to tests some of its capillary networking solutions in a very realistic but controlled urban environment. A proof of concept test site has been built in 2015. We have deployed an experiment on low cost sensor network for vehicle detection and one on atmospheric pollution sensor calibration. The operational site is build, the information system is being finalized and the equipment will be inaugurated in April 2018.

### 9.2.6. Inria Project lab

- CityLab  
Agora is involved in the CityLab Inria Project Lab lead by Valérie Issarny. Within this project, Hervé Rivano co-advises, with Nathalie Mitton (FUN team, Inria Lille-Nord-Europe), the PhD thesis of Abdoul Aziz Mbacke on “Data gathering in sensor and passive RFID with energy harvesting for urban infrastructure monitoring”.

## 9.3. European Initiatives

### 9.3.1. Collaborations in European Programs, Except FP7 & H2020

Program: Interreg Med

Project acronym: ESMARTCITY

Project title: Enabling Smarter City in the MED Area through Networking

Duration: 02/2018 - 07/2020

Coordinator: Abruzzo Region, Italy

Other partners: ARIC and RWG (Greece), APEGR (Spain), RAIS (Bosnia and Herzegovina), ENA (Portugal), MCM and PoliMi (Italy), Capergies (France)

Abstract: The project has its primary objective in improving the innovation capacity of MED cities by creating innovation ecosystems, which involve actors of the quadruple helix (Citizens, Businesses Operators, Research, Universities and Public Authorities) , and in applying the Smart City concept, which utilizes digital and energy saving technologies to allow better services for the citizen with less impact on the environment, producing furthermore new employability and living scenarios. To achieve this goal, the project envisages the pilot testing of the Smart City concept to provide specific services to citizens in the field of intelligent urban districts, energy efficiency of buildings and smarter public lighting.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Informal International Partners

- **University of Waterloo, ON, Canada.** Joint publications and visits to/from the group of Prof. Catherine Rosenberg.
- **Nimbus Centre, Cork, Ireland.** Collaboration around LoRa experiments with Dr. Ramona Marfievici.

- **CNR-IEIIT, Turin, Italy.** Joint publications and projects with Dr. Marco Fiore.
- **Trento University, Italy.** Collaboration around routing for IoT networks with the group of Prof. Gian Pietro Picco.
- **University of Edinburgh, UK.** Joint publications and visits to/from the group of Dr. Paul Patras.

#### ***9.4.2. Participation in Other International Programs***

##### *9.4.2.1. PHC Campus France*

- **University of Cluj-Napoca, Romania.** PHC DRONEM (2017-2019) on Monitoring using connected fleet of drones, a collaboration with the group of Prof. Gabriela Czibula.

### **9.5. International Research Visitors**

#### ***9.5.1. Visits of International Scientists***

- Abdelmalik Bachir, Professor, Biskra University, Algeria: invited professor at INSA Lyon (July, 2018)
- Josep Paradells Aspas, Professor, Universitat Politecnica de Catalunya, Barcelona, Spain: invited professor at INSA Lyon (October 2018)
- Rui Li, PhD student, University of Edinburgh, Scotland, UK: visiting PhD student (March, 2018)

##### *9.5.1.1. Research Stays Abroad*

- Ahmed Boubrima visited the group of Prof. Azzedine Boukerche, University of Ottawa, Canada.
- Mihai Popescu visited the group of Prof. Gabriela Czibula, at University of Cluj-Napoca, Romania (3 periods of 1 month duration: April, June and November 2018).

## COATI Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. COSIT, 2018-2019

**Participants:** Mohammed Amine Ait Ouahmed, Ali Al Zoobi, David Coudert, Nicolas Nisse.

Program: Innovation project, Centre de reference “Smart City” of IDEX UCA<sup>JEDI</sup>.

Project acronym: COSIT

Project title: Convergent Service for Intermodal Transportation

Duration: February 2018 - January 2019

Coordinator: David Coudert

Other partners: UMR ESPACE (France) and SME Instant-System

Abstract: On-demand transportation is a highly flexible mode of transportation that aims at optimizing transit operator service by reducing operational cost while increasing the number of passengers per vehicles, and to increase customer satisfaction. We are considering a service where a fleet of vehicles (minibuses with a limited number of seats) is used to answer user requests. Vehicle trajectories need to be recalculated dynamically as new queries arrive. It is a complementary offer to existing public transport services (bus, tram, metro, etc.) and intermediate in terms of cost and quality of service between public transport and individual transport ( taxi, VTC).

In the COSIT project, we studied different aspects of the problem including static and dynamic algorithms for the assignment of users to vehicles, the study of user flows in the city, and the prediction of users queries. We will developed a graphical interface to visualize the evolution of vehicle itineraries as the demands of users arrive.

### 8.1.2. SNIF, 2018-2021

**Participants:** David Coudert, Frédéric Giroire, Nicolas Nisse, Stéphane Pérennes.

Program: Innovation project of IDEX UCA<sup>JEDI</sup>.

Project acronym: SNIF

Project title: Scientific Networks and IDEX Funding

Duration: September 2018 - August 2021

Coordinator: Patrick Musso

Other partners: GREDEG, SKEMA, I3S (SigNet) and Inria (COATI), all from UCA.

Abstract: Scientific collaboration networks play a crucial role in modern science. This simple idea underlies a variety of initiatives aiming to promote scientific collaborations between different research teams, universities, countries and disciplines. The recent French IDEX experience is one of them. By fostering competition between universities and granting few of them with a relatively small amount of additional resources (as compare to their global budget), public authorities aim to encourage them to deeply reshape the way academic activities are organized in order to significantly increase the quality of their research, educational programs and innovative activities. The development of new collaboration networks is one of the factors at the heart of this global reorganization. Promoting new international and/or interdisciplinary collaborations is supposed to increase researchers’ productivity and industry partnerships. This project aims to question the validity of this line of thought.

## 8.2. National Initiatives

### 8.2.1. ANR-17-CE22-0016 MultiMod, 2018-2021

**Participants:** Mohammed Amine Ait Ouahmed, Ali Al Zoobi, David Coudert, Nicolas Nisse, Michel Syska.

Program: ANR

Project acronym: MultiMod

Project title: Scalable routing in Multi Modal transportation networks

Duration: January 2018 - December 2021

Coordinator: David Coudert

Other partners: Inria Paris, EP GANG; team CeP, I3S laboratory; SME Instant-System; SME Benomad

Abstract: The MultiMod project addresses key algorithmic challenges to enable the fast computation of personalized itineraries in large-scale multi-modal public transportation (PT) networks (bus, tram, metro, bicycle, etc.) combined with dynamic car-pooling. We will use real-time data to propose itineraries with close to real travel-time, and handle user-constraints to propose personalized itineraries. Our main challenge is to overcome the scalability of existing solutions in terms of query processing time and data-structures space requirements, while including unplanned transportation means (car-pooling), real-time data, and personalized user constraints. The combination of car-pooling and PT network will open-up areas with low PT coverage enable faster itineraries and so foster the adoption of car-pooling. We envision that the outcome of this project will dramatically enhanced the mobility and daily life of citizens in urban areas.

Web: <https://project.inria.fr/multimod/>

### 8.2.2. PEPS POCODIS

Program PEPS

Project Acronym: POCODIS

Project Title: PONDérations et COLORations DISTinguantes de graphes

Duration: Février-Décembre 2018

Coordinator: Julien Bensmail

Others Partners: None

Abstract: This project is about two conjectures on *proper* weightings of a graph, namely the 1-2-3 conjecture and a conjecture about locally irregular decompositions. A weighting is proper whenever the coloring obtained by taking as color for a vertex  $v$  the sum of the weight in the neighbourhood of  $v$  is a proper coloring, more concisely adjacent vertices have different sums. The main objective of the project is to address several open questions around (i.e. motivated by) these conjectures since we believe that this could lead to significant progress toward the solution of the two main conjectures. To that aim we will make use of several recent and innovative tools and technique in the field, such as the probabilistic method and the polynomial method. In order to use and understand these techniques to their best we shall strengthen several international collaborations with experts from the field.

### 8.2.3. PICS DISCO

Program: PICS

Project acronym: DISCO

Project title: DIsjoint Structures and Coverings in Oriented graphs

Duration: January 2018 -December 2020.

Coordinator: Stéphane Bessy (LIRMM)

Other partners: organisme, labo (pays) CNRS LIRMM (Montpellier), Syddansk universitet (Odense, Danemark)

Abstract: Directed graphs (digraphs) are much less understood than undirected graphs. Many, seemingly very simple questions remain unsolved for digraphs while the analogous problem for undirected graphs is trivial. At the same time digraphs is a very important modelling tool for practical applications and so a better understanding of their structure is important. The purpose of DISCO is to advance knowledge on fundamental problems on digraphs, including splitting a digraph into smaller pieces with given properties, problems regarding disjoint paths and trees, finding small certificates for given properties, such as strong spanning subdigraphs with few arcs. The later is important for speeding up certain algorithms.

Through a concerted effort we expect to obtain important results which will lead to a better understanding of fundamental questions about the structure of digraphs. The participants will meet regularly both in France and in Denmark to work on carefully selected problems.

### 8.2.4. GDR Actions

#### 8.2.4.1. GDR RSD, ongoing (since 2006)

Members of COATI are involved in the working group RESCOM (*Réseaux de communications*) of GDR RSD, CNRS (<http://rescom.asr.cnrs.fr/>). In particular, David Coudert is co-chair of this working group since 2017 and has organized its annual summer school, RESCOM'18. Christelle Caillouet was co-chair of the programme committee of the annual conference AlgoTel'18.

We are also involved in the working group "Energy" of GDR RSD. In particular, Frédéric Giroire is co-chair of this working group.

#### 8.2.4.2. GDR IM, ongoing (since 2006)

Members of COATI are involved in the working group "Graphes" of GDR IM, CNRS. (<http://gtgraphes.labri.fr/>). In particular, Frédéric Havet is member of the steering committee.

#### 8.2.4.3. GDR MADICS, ongoing (since 2017)

Members of COATI are involved in the working group GRAMINEES (GRaph data Mining in Natural, Ecological and Environmental Sciences) of GDR MADICS (Masses de Données, Informations et Connaissances en Sciences). (<http://www.madics.fr/actions/actions-en-cours/graminees/>).

The annual summer school RESCOM'18 of GDR RSD has been co-organized with GDR MADICS.

## 8.3. International Initiatives

### 8.3.1. IFCAM Program, Applications of Graph homomorphisms

Program: IFCAM 2018-2020 (<http://math.iisc.ac.in/~ifcam/>)

Project acronym: –

Project title: Applications of graph homomorphisms on graph database

Duration: Janvier 2018 - Décembre 2020

Coordinator: Reza Naserasr (for France) - Sagnik Sen (for India)

Other partners: complete list of participants on the [project website](#).

Abstract: In this project, we are going to study the graph homomorphism problems from a very general point of view. Apart from studying the usual graph homomorphism on undirected graphs, we will study it for different types of graphs such as, signed graphs, oriented graphs, edge-colored graphs, colored mixed graphs etc. We will apply the theories and techniques associated with graph homomorphism to solve practical problems. Our main application oriented work is studying graph homomorphism in the context of graph database, a type of database now a days used even by popular social medias. Graph homomorphism is equivalent to the query evaluation problem in graph

database, and thus have exciting intersection with the theory. In our group we have experts of graph homomorphisms as well as graph database making this project a potential case for Indo-French interdisciplinary collaboration. We want to organize a workshop by the end of this project. We also consider a few other application oriented topics as auxiliary research tracks inside this project.

### 8.3.2. Inria International Labs

#### Inria Chile

Associate Team involved in the International Lab:

##### 8.3.2.1. ALDYNET

Title: distributed ALgorithms for DYnamic NETworks

International Partner (Institution - Laboratory - Researcher):

Universidad Adolfo Ibañez (Chile) - Facultad de Ingeniería y Ciencias - Karol SUCHAN

Start year: 2016

See also: <https://team.inria.fr/coati/projects/aldynet/>

This associated team would be the natural continuation of the fruitful EA AIDyNet (2013-2015, <https://team.inria.fr/coati/projects/aldynet/>)

The main goal of this Associate Team is to design and implement practical algorithms for computing graph structural properties. We will then use these algorithms on a concrete case of study which concerns the transportation network of the Santiago agglomeration. We are both interested in theoretical results concerning the feasibility of computing graph properties, and by their practical implementation (using **Sagemath**) for our application and their diffusion in the scientific community. There are three main objectives:

- 1) Design efficient algorithms to compute important graph properties (hyperbolicity, treelength, centrality, treewidth...) in real networks. We are not only interested by the worst-case time-complexity of these algorithms but by their performance in practice.
- 2) Implement and document our algorithms using the open-source framework SageMath. One advantage of using SageMath is that it has interfaces with other graph libraries (igraph, Boost...) and with Linear Programming solver (GLPK, Cplex...). Moreover, the success of SageMath (which has accumulated thousands of users over the last 10 years) will participate to the diffusion of our algorithms.
- 3) Apply our algorithms on the Santiago transportation network that have been collected by our Chilean partner during the last year of AIDyNet (2013-2015). Based on the results, propose tools for decision support in designing bus routes, timetables, etc. More precisely, we have collected information about the use of public transport (data of smart cards for automatic fare collection - BIP-, bus routes and bus schedules, etc.), urban infrastructure information, schools' addresses, and approximate locations where students live. We have started to clean and consolidate these data. We will then develop decision support tools, for example, for improving quality education accessibility.

### 8.3.3. Inria International Partners

#### 8.3.3.1. Informal International Partners

Apart from formal collaboration COATI members maintain strong connections with the following international teams, with regular visits of both sides.

Universidade Federal do Ceará (Fortaleza, Brazil), ParGO team;

Universidade Estadual do Ceará (Fortaleza, Brazil), Prof. Leonardo Sampaio;

Univ. of Southern Denmark (Odense, Denmark), Prof. Jørgen Bang-Jensen;

RWTH Aachen Univ., Lehrstuhl II für Mathematik (Aachen, Germany), Prof. Arie M.C.A. Koster;

Concordia Univ. (Montréal, Québec, Canada), Prof. Brigitte Jaumard.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

- Jørgen Bang-Jensen  
University of Southern Denmark, Odense, Denmark. June 2018.
- Romuald Elie  
Paris-Est University. February 3 - March 2 2018.
- Gwenael Joret  
Université Libre de Bruxelles, Belgique. March 2018.
- Takako Kodate  
Tokyo's Woman's Christian University. December 15 2017 till March 31 2018.
- Kasper Szabo Lyngsie  
Technical University of Denmark, Lyngby, Denmark. June 27 - July 8.
- Joseph Peters  
Simon Fraser University, Vancouver, BC, Canada. October 1 2017 till March 31 2018.
- Tahiry Razafindralambo  
Université de la Réunion. July 8-28 2018.
- Leonardo Sampaio Rocha  
University Federal de Ceara, Fortaleza, Brazil. July 1 2018 till June 30 2019.
- Karol Suchan  
Universidad Adolfo Ibañez, Santiago, Chile. September 9-23 2018.
- Robert E. Tarjan  
Princeton University, Princetown, NJ, USA. July 2018.
- Min-Li (Joseph) Yu  
University of the Fraser Valley, Abbotsford, BC, Canada. March 1 till April 15 2018.

### 8.4.2. Visits to International Teams

#### 8.4.2.1. Research Stays Abroad

- Julien Bensmail :  
Northwestern Polytechnical University, Xi'an, China. 22 Avril-13 Mai.  
LaBRI, Bordeaux, France. 23 Mai-12 Juin.  
Technical University of Denmark, Lyngby, Denmark. 22 Août-2 Septembre.  
AGH University, Krakow, Poland. 24 Novembre-2 Décembre.
- David Coudert :  
Universidad Adolfo Ibañez, Santiago, Chile, December 1-14, 2018.
- Frédéric Havet :  
University of Southern Denmark, Odense, Denmark. April 2018.  
Ecole Normale Supérieure de Lyon, France, January and September 2018.
- Nicolas Nisse :  
Xidian University, Xi'an, China, September 1-15, 2018  
Univ. Adolfo Ibañez, Santiago, Chile, December 1-15, 2018

## DANTE Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. *IDEX Lyon ACADEMICS*

**Participants:** Paulo Gonçalves, Dominique Barbe, Gaetan Frusque.

See Section 5.1.1 for an executive summary of this project. The project brings together a **consortium of 4 teams from Laboratories of Université de Lyon (UdL)** and will form a working group with complementary expertise in machine learning (deep learning, statistical learning, data mining), in data science (complex data analysis, adaptive and/or data-driven methods, network science) and in the studies of climate modeling and of computational social science. It comprises:

- Laboratoire Informatique du Parallélisme (LIP): P. Gonçalves (PI), M. Karsai (PI for Comp. Social Sc.)
- Laboratoire de Physique (LP): P. Borgnat (Coordinator), F. Bouchet (PI for Climate)
- Laboratoire Hubert Curien (LabHC), Université Jean Monnet: M. Sebban (PI)
- Laboratoire d'InfoRmatique en Images et Systèmes d'information (LIRIS): C. Robardet (PI)

The **impacts** of the project will stem from the efficiency of our proposed methods to learn from complex and dynamic data, and if so, **future applications** will naturally follow in many areas: social science and study of social interactions, climate and environmental science but also in technological networks, neuroscience with the study of brain networks and more generally in any domain where effective dynamical models of complex situations are to be learned from data. All these situations go beyond the current classical applicative frameworks of ML (time measurements, 2D images, or texts) and compel us to work out a major scientific breakthrough.

### 9.1.2. *ISI Torino / Dante*

**Participant:** Márton Karsai [correspondant].

Duration of the project: **October 2016 - October 2020.**

This project involves M. Karsai and L. Gauvin (ISI Torino) and funded by the IXXI Complex System Institute. The purpose of this project is to investigate the presence and the importance of higher-order correlations in dynamical networks. As the first attempt to address this problem we applied autoencoder, a recent representation using deep neural networks, on modelled and small-scale real temporal networks. However, since the results were trivial on the modelled network and not convincing on the real one we decided to take a different approach during the second phase of the project. We involved an ISI PhD student Maddalena Toricelli, to work out a method for temporal network embedding. Our idea is to extend the node2vec representation of static networks for time-varying structures, by using a local random walk to explore the structural-temporal neighbourhood of a node. Based on such local information we can effectively propose an embedding, which captures the temporal and structural properties of nodes in a temporal network.

## 9.2. National Initiatives

### 9.2.1. *Equipex FIT (Futur Internet of Things)*

**Participant:** Éric Fleury [correspondant].



FIT was one of 52 winning projects in the Equipex research grant program. It will set up a competitive and innovative experimental facility that brings France to the forefront of Future Internet research. FIT benefits from 5.8 million euro grant from the French government Running from 22.02.11 – 31.12.2019. The main ambition is to create a first-class facility to promote experimentally driven research and to facilitate the emergence of the Internet of the future.

### 9.2.2. ANR GRAPHSIP (*Graph Signal Processing*)

**Participants:** Paulo Gonçalves [correspondant], Éric Fleury, Thomas Begin, Mikhail Tsitsvero.

Duration of the project: **October 2014 - October 2018.**

An increasing number of application areas require the processing of massive datasets. These data can often be represented by graphs in order to encode complex interactions. When data vectors are associated with graph vertices, a so-called graph signal is obtained. The processing of such graph signals includes several open challenges because of the nature of the involved information. Indeed graph theory and signal and image processing methodologies do not combine readily. In particular, such a combination requires new developments, allowing classical signal processing methods to work on irregular grids and non Euclidean spaces. Considering the significant success of classical signal processing tools, it appears essential to generalise their use to graph signals. The GRAPHSIP project aims at developing a set of advanced methods and algorithms for the processing of graph signals: multi-scale transforms and solutions of variational problems on graphs. The major outcomes of this project are expected to lead to significant breakthroughs for graph data processing. The project will also focus on two novel applications on instances of graph signals: brain networks and 3D colour point clouds. They will exemplify and illustrate the proposed methodological advances on emerging applications.

### 9.2.3. ANR SoSweet

**Participants:** Jean Pierre Chevrot, Éric Fleury, Márton Karsai [correspondant], Jean-Philippe Magué [PI].

Duration of the project: **November 2015 - November 2019.**

The SoSweet project focuses on the synchronic variation and the diachronic evolution of the variety of French used on Twitter. The recent rise of novel digital services opens up new areas of expression which support new linguistic behaviours. In particular, social medias such as Twitter provide channels of communication through which speakers/writers use their language in ways that differ from standard written and oral forms. The result is the emergence of new varieties of languages. The main goal of SoSweet is to provide a detailed account of the links between linguistic variation and social structure in Twitter, both synchronically and diachronically. Through this specific example, and aware of its bias, we aim at providing a more detailed understanding of the dynamic links between individuals, social structure and language variation and change.

### 9.2.4. ANR DylNet

**Participants:** Márton Karsai [correspondant], Jean Pierre Chevrot, Jean-Philippe Magué, Éric Fleury.

Duration of the project: **September 2016 - September 2020.**

The DylNet project aims to observe and to characterise the relationships between childhood sociability and oral-language learning at kindergarten. With a view to this, it takes a multidisciplinary approach combining work on language acquisition, sociolinguistics, and network science. It will be implemented by following all the children ( $\approx 220$ ) and teaching staff in one kindergarten over a 3-year period. The use of wireless proximity sensors will enable collection of social contacts throughout the study. The data on sociability will be linked to the results of language tests and recordings of verbal interactions used to follow the children's progress on both a psycholinguistic level (lexicon, syntax, pragmatics) and a sociolinguistic level (features showing belonging to a social group). The aim is to better understand the mechanisms of adaptation and integration at work when young children first come into contact with the school context.

### 9.2.5. Inria PRE LIAISON

**Participants:** Márton Karsai [correspondant], Éric Fleury.

Duration of the project: **November 2017 - December 2019.**

This project implements unsupervised deep learning approaches to infer correlations/patterns that exist between dynamic linguistic variables, the mesoscopic and dynamic structure of the social network, and their socio-economic attributes. This interdisciplinary project is positioned at the crossroads of Natural Language Processing (NLP), Network Science, Data Science and Machine Learning.

More precisely, we develop a joint feature-network embedding, named AN2VEC (Attributed Network to Vector), which ultimately aims at disentangling the information shared by the structure of a network and the features of its nodes. Building on the recent developments of Graph Convolutional Networks (GCN), we use a multitask GCN Variational Autoencoder where different dimensions of the generated embeddings can be dedicated to encoding feature information, network structure, or shared feature-network information separately. This method thus defines a range of models whose performance in embedding a given data set varies depending with the allocation of dimensions. By exploring the behaviour of these models on synthetic data sets having different levels of feature-network correlation, we show (i) that embeddings relying on shared information perform better than the corresponding reference with unshared information, and (ii) that this performance gap increases with the correlation between network and feature structure, thus confirming that our embedding is able to capture joint information of structure and features.

### 9.2.6. Inria & HCERES

**Participants:** Éric Guichard [correspondant], Éric Fleury.

Bilateral project on the evolution of the Multi/inter-disciplinary of SHS.

An increasing number of researchers in SHS has the desire to develop new researches with computer scientists or mathematicians because they want to apply new methodologies (according to various or numerous data) or to develop older ones, which can now be easily implemented online. Some also develop a reflexion on their discipline, with the idea that epistemological questions are revitalized by the internet. This reality invite them to discuss with philosophers or with other SHS scientists who have the same intuition (eg: cartography, visualisation).

The project is hence to measure these new forms or inter-multi-disciplinarity. The main source will be the publications of all academics of French SHS laboratories, to find out who writes a paper with somebody of a different discipline and/or laboratories. All data are anonymized,

### 9.2.7. Inria IPL BetterNet

**Participant:** Éric Guichard.

An Observatory to Measure and Improve Internet Service Access from User Experience<sup>0</sup>.

BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks with a particular focus on geography and cartography.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. EMBERS

- Title: Enabling a Mobility Back-End as a Robust Service
- Programm: H2020
- Duration: December 2015 - November 2018
- Coordinator: UPMC

<sup>0</sup><https://www.inria.fr/en/research/research-teams/inria-project-labs>

- Partners:
  - Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)
  - Technische Universitat Berlin (Germany)
  - Universite Pierre et Marie Curie - Paris 6 (France)
  - Ubiwhere Lda (Portugal)
- Inria contact: Eric Fleury
- EMBERS will bring to market a back-end for smart city mobility that is developed by a European small enterprise based upon its smart parking and smart traffic management products that two municipalities in Portugal currently deploy. The Mobility Back-end as a Service (MBaaS) replaces such all-in-one systems, in which a municipality purchases the full set of components from a single vendor. Instead, the city manager can purchase best-of-breed devices and apps developed by third parties, with the only constraint being that they interoperate with the back-end via a free, open, smart city mobility API. This domain-specific API lowers barriers to entry for app and device developers, making it easier for innovative SMEs to enter the market. Furthermore, the API is offered via a variety of generic interfaces, including oneM2M, ETSI M2M, OMA LWM2M, and FIWARE NGSI. EMBERS thus clears the way for developers and to municipalities that have adopted any one of these potential emerging machine-to-machine (M2M) communication standards. Beyond its primary goal of bringing the MBaaS to market, EMBERS will stimulate development of an entire ecosystem around the MBaaS smart city mobility API. Separating out the back-end from the other components will, however, require rigorous testing. EMBERS will experiment with the system on two testbeds that are part of the FIRE OneLab facility: the FUSECO Playground, for M2M communications, and FIT IoT-LAB, for wireless sensor devices. EMBERS will host a hackathon and an app challenge to bring in third party developers. The project will also include three demonstrators by third parties via an open call. These activities will contribute back to FIRE by demonstrating successful experimentation by SMEs developing close-to-market products. The project will also conduct real world pilots in two or more cities as a final step in bringing the MBaaS to market.

### 9.3.1.2. ARMOUR

Title: Large-Scale Experiments of IoT Security & Trust (Project n°688237)

Programm: H2020

Duration: 2015 Dec to 2018

Coordinator: UPMC

Partners:

Synelixis Lyseis Pliroforikis Automatismou & Tilepikoinonion Monoprosopi EPE (Greece)

Smartesting Solutions & Services (France)

Unparallel Innovation, Lda (Portugal)

Easy Global Market (France)

ODIN Solutions (Spain)

Universite Pierre et Marie Curie - Paris 6 (France)

Inria contact: Eric Fleury

ARMOUR will provide duly tested, benchmarked and certified Security & Trust solutions for large-scale IoT using upgraded FIRE large-scale IoT/Cloud testbeds properly-equipped for Security & Trust experimentations. ARMOUR takes the top large-scale FIT IoT-LAB testbed a FIRE OpenLAB / FIT IoT LAB facility and enhances it as to enable experimentally-driven research on a key research dimension: large-scale IoT Security & Trust. Presently, no proper installations exist to experiment IoT Security & Trust on large-scale conditions; ARMOUR will develop and install such capability.

## 9.4. International Initiatives

### 9.4.1. Participation in International Programs

#### 9.4.1.1. PHC Peridot

**Participants:** Mohammed Amer, Thomas Begin, Anthony Busson, Isabelle Guérin Lassous.

Framework for Control and Monitoring of Wireless Mesh Networks (WMN) using Software-Defined Networking (SDN). The main objective of this project is propose mechanisms and modifications in the SDN architecture, specifically in the OpenFlow, which allow SDN mechanisms to operate over WMN considering the dynamic network topology that WMN may experience and some other relevant characteristics. The project will involve devising mechanisms for controlling mesh switches through controllers in a wireless environment, which will require developing novel and WMN-specific rules, actions and commands. The project will involve proposing mechanism that consider dynamic environment of WMN along with providing redundancy in the network. Besides, there is a requirement to have an adaptive measurement API for WMN. This is the second objective of our research project. The proposed measurement API will enable the network operators to monitor network traffic over WMN which may be content-specific or host-specific. This is a joint project between DANTE and M. A. Jinnah University, Islamabad. It started in June 2015 and will end in June 2018.

### 9.4.2. International Initiatives

#### 9.4.2.1. MOTif - Mobile phone sensing of human dynamics in techno-social environment

- Program: Stic AmSud
- Duration: January 2018 - December 2019
- Coordinator: Inria DANTE (Márton Karsai)
- Partners:
  - Universidad de Buenos Aires (Argentina)
  - Grandata (USA-Argentina)
  - Universidade Federal de Minas Gerais (Brazil)
  - LNCC (Brazil)

This project brings together two Inria teams - INFINE (Saclay) - DANTE (Lyon) and multiple Latin-American partners to work together with the IT company Grandata.

Scope of the project: Information and Communication Technology (ICT) is becoming increasingly social, as demonstrated by the multitude of emerging technologies and technology platforms that facilitate social interactions, taking place as communication via telephone, text message, email, online social networks etc. At the same time, our social activities are increasingly embedded in the ICT environments that enable and enhance our ability to transact, share experiences, and maintain social relationships. One of the best ways to explore these developments is through the mining and analysis of data, which are collected through mobile phones and allow us to investigate how individuals act when embedded in a technology-enabled environment. Unlimited access to a wide range of mobile applications and services may change our way to gain information, to communicate, or even to behave in different contextual places like home, work, or anywhere else. Thus understanding individual activity patterns and the source of decisions behind them is moreover important for the design of future services and to estimate the demand on the infrastructure. The MOTIF project builds on the analysis and modeling of geo-localized temporally detailed but fully anonymised mobile phone call networks. These datasets allow us to address the two scientific objectives about spatiotemporal patterns of service usage of anonymised individuals to learn when, where, and what people are doing; and about the fine-grained sociodemographic structure of society and its effect on the the individual social behaviour. In other words our goal in general is to understand how individuals behave in a dynamic techno-social environment.

## **9.5. International Research Visitors**

### ***9.5.1. Visits of International Scientists***

- Don Towsley, University of Massachusetts, Amherst, USA (march 15 - june 15, 2018).
- Alexandre Brandwajn, University of California Santa Cruz, USA (march 2018)

### ***9.5.2. Visits to International Teams***

#### ***9.5.2.1. Research Stays Abroad***

- Philippe Nain visited the University of Massachusetts at Amherst (Sep. 1, 2018 - Jan. 31, 2019). He taught a graduate course on Performance Evaluation of Computer and Communication Systems and collaborated with Prof. D. Towsley and some of his students/collaborators on several research projects.
- Christophe Crespelle is on leave with a Marie Skłodowska-Curie Grant from EU. He is currently at the University of Bergen (Norway) until the beginning of 2020.
- Christophe Crespelle visited the Institute of Mathematics of the Vietnam Academy of Science and Technology, Hanoi, Vietnam (Nov. 6 - Dec. 6, 2018).

## DIANA Project-Team

# 8. Partnerships and Cooperations

## 8.1. Inria internal funding

### 8.1.1. ADT ACQUA

**Participants:** Chadi Barakat.

In the context of the Inria ADT call, we have a funding for a two year engineering position on the ACQUA project for the 2015-2017 period. Thierry Spetebroot is hired on this position. In 2017, this ADT got extended by six months beyond the two years period to therefore end on March 2018.

### 8.1.2. IPL BetterNet

**Participants:** Chadi Barakat.

The DIANA team is part of the Inria Project Lab BetterNet (<http://project.inria.fr/betternet/>). Within this lab, Inria has funded two PhD students in 2017 co-supervised by Chadi Barakat from the DIANA project-team. The first PhD student is Thibaut Ehlinger hosted within the DIANA team and co-supervised by Vassilis Christophides from the MiMove team in Paris. The second PhD student is Imane Taibi hosted by the Dionysos team in Rennes and co-supervised by Gerardo Rubino and Yassine Hadjadj-Aoul. Both PhDs started on the 1st of November 2017. Further in 2018, Inria funded a PostDoc position to supervise the experiments planned within the IPL and develop the data analysis part. This PostDoc position is occupied by Giulio Grassi who is co-supervised by Chadi Barakat from the DIANA project-team and Renata Teixeira from the MiMove project-team. Giulio Grassi started on October 1st, 2018 and is currently located in Paris.

## 8.2. Regional Initiatives

### 8.2.1. ElectroSmart

**Participants:** Arnaud Legout, Mondri Ravi, David Migliacci, Abdelhakim Akodadi, Yanis Boussad.

The ElectroSmart project benefits from the following fundings:

- a 39 months engineering position from the UCN@Sophia Labex for the 2016-2019 period (Ravi Mondri is hired on this position)
- 30KEuros from Academy 1 of UCAJedi
- a two years engineering position from an Inria ADT for 2017/2019 (Abdelhakim Akodadi)
- a 18 months business developer from Inria ATT for June 2017-June 2019 (David Migliacci)
- a 3 years 2017/2020 Ph.D. thesis from Academy 1 of UCAJedi (Yanis Boussad)

### 8.2.2. D2D Indoor

**Participants:** Chadi Barakat, Zeineb Guizani.

This project is joint with the NFCOM startup in Nice, specialized in the development of new services for mobile phones. The project aims at leveraging mobile to mobile communications for offloading the cellular infrastructure, and will target a solution based on algorithms previously developed in the DIANA project-team (BitHoc and HBSD). The project got a funding for one year engineer from the Labex. Zeineb Guizani has been working on this project since July 2018.

## 8.3. National Initiatives

### 8.3.1. ANR

- **ANR JCJC DET4ALL** (2019-2021): Modern factories and industrial system massively rely on cyber physical systems with digital communications (e.g., to allow collaborative robots, for data analytics...). However, industrial networks are still mostly managed and conceived as collections of independent communicating units instead of one unified piece of software.

The reason why the shift of paradigm did not occur yet to industrial digital communication networks is because industrial processes generally impose strong determinism and real-time constraints. As a result, industrial networks have a propensity of being physically segregated to contain potential malfunctions and simplify conception.

With the DET4ALL project, we will apply the concept of network programmability to the world of industrial communicating systems. To that aim, we will construct and prove the essential building blocks that will allow to virtualise industrial networks:

- algorithms to automatically provision the various components constituting industrial networks;
- Domain Specific Languages (DSLs) to specify real-time communication schemes;
- mechanisms to update on-the-fly the production infrastructures without service degradation.

The impact of the DET4ALL project goes beyond technological advances; it will also bring a new vision on what production tools can become, namely agile systems in perpetual evolution.

- **ANR FIT** (2011-2019): FIT (Future Internet of Things) aims at developing an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It will provide this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project will give French Internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the Future Internet. FIT is one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's Equipements of Excellence (Equipex) research grant programme. The project will benefit from a 5.8 million euro grant from the French government. Other partners are UPMC, IT, Strasbourg University and CNRS. The project was extended for one year and will end in december 2019. See also <http://fit-equipex.fr/>.
- **ANR BottleNet** (2016-2019): BottleNet aims to deliver methods, algorithms, and software systems to measure Internet Quality of Experience (QoE) and diagnose the root cause of poor Internet QoE. This goal calls for tools that run directly at users' devices. The plan is to collect network and application performance metrics directly at users' devices and correlate it with user perception to model Internet QoE, and to correlate measurements across users and devices to diagnose poor Internet QoE. This data-driven approach is essential to address the challenging problem of modeling user perception and of diagnosing sources of bottlenecks in complex Internet services. ANR BottleNet will lead to new solutions to assist users, network and service operators as well as regulators in understanding Internet QoE and the sources of performance bottleneck.

## 8.4. European Initiatives

### 8.4.1. FP7 & H2020 Projects

- Program: FP7 FIRE programme
- Project acronym: Fed4Fire+
- Project title: Federation for FIRE Plus

- Duration: January 2017 - December 2021
- Coordinator: iMinds (Belgium)
- Other partners: 20 european partners including IMEC (Belgium), UPMC (Fr), Fraunhofer (Germany), TUB (Germany), etc.
- Web site: <http://www.fed4fire.eu/>
- Abstract: The Fed4FIRE+ project has the objective to run and further improve Fed4FIRE as best-in-town federation of experimentation facilities for the Future Internet Research and Experimentation initiative. Federating a heterogeneous set of facilities covering technologies ranging from wireless, wired, cloud services and open flow, and making them accessible through common frameworks and tools suddenly opens new possibilities, supporting a broad range of experimenter communities covering a wide variety of Internet infrastructures, services and applications. Fed4FIRE+ will continuously upgrade and improve the facilities and include technical innovations, focused towards increased user satisfaction (user-friendly tools, privacy-oriented data management, testbed SLA and reputation, experiment reproducibility, service-level experiment orchestration, federation ontologies, etc.). It will open this federation to the whole FIRE community and beyond, for experimentation by industry and research organisations, through the organization of Open Calls and Open Access mechanisms. The project will also establish a flexible, demand-driven framework which allows test facilities to join during the course of its lifetime by defining a set of entry requirements for new facilities to join and to comply with the federation. FIRE Experimental Facilities generate an ever increasing amount of research data that provides the foundation for new knowledge and insight into the behaviour of FI systems. Fed4FIRE+ will participate in the Pilot on Open Research Data in Horizon 2020 to offer open access to its scientific results, to the relevant scientific data and to data generated throughout the project's lifetime. Fed4FIRE+ will finally build on the existing community of experimenters, testbeds and tool developers and bring them together regularly (two times a year) in engineering conferences to have maximal interaction between the different stakeholders involved.

## 8.5. International Initiatives

### 8.5.1. Inria Associate Teams Involved in an Inria International Lab

#### 8.5.1.1. DrIVE

Title: DrIVE: Distributed Intelligent Vehicular Environment - Enabling ITS through programmable networks

Inria International Lab: **Inria@SiliconValley**

International Partner (Institution - Laboratory - Researcher):

Ericsson Research, Indaiatuba-SP, BRAZIL (Brazil) Mateus Augusto Silva Santos

Start year: 2018

See also: <https://team.inria.fr/diana/drive-associated-team/>

Abstract: Transportation systems are part of our society's critical infrastructure and are expected to experience transformative changes as the Internet revolution unfolds. The automotive industry is a notable example: it has been undergoing disruptive transformations as vehicles transition from traditional unassisted driving to fully automated driving, and eventually to the self-driving model. Communication technology advancements such as support for vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication have been one of the key enablers of next generation transportation services, also known as Intelligent Transport Systems (ITS). However, ITS services and applications pose significant challenges to the underlying communication and network infrastructure due to their stringent low latency, reliability, scalability, and geographic decentralization requirements. The DrIVE associated team proposal aims at addressing such challenges by: (1) developing a programmable network control plane that will dynamically adjust to current environment conditions and network characteristics to support ITS' scalability, quality of service (QoS), and decentralization requirements, and (2) applying the proposed distributed network control plane framework to ITS applications, such as road hazard warning, autonomous- and self-driving vehicles, and passenger-centric services (e.g., infotainment and video streaming).



## 8.5.2. Inria Associate Teams Not Involved in an Inria International Labs

### 8.5.2.1. UHD-on-5G

Title: Ultra High Definition video streaming on future 5G networks

International Partner (Institution - Laboratory - Researcher):

National Institute of Information and Communications Technology (NICT) (Japan) -  
Hitoshi Asaeda

Start year: 2016

See also: <https://team.inria.fr/diana/uhd-on-5g/>

The aim of this collaboration is to design and develop efficient mechanisms for streaming UHD video on 5G networks and to evaluate them in a realistic and reproducible way by using novel experimental testbeds.

Our approach leverages and extends when necessary ICN and SDN technologies to allow very high quality video streaming at large scale. We also plan to use Virtual Network Functions (VNF) in order to place easily and dynamically different functions (e.g. transcoding, caching) at strategic locations within the network. Specifically, the placement of these functions will be decided by SDN controllers to optimize the quality of experience (QoE) of users. Moreover, we plan to integrate ICN functionalities (e.g., name-based forwarding and multipath transport using in-network caching) with SDN/NFV to provide better QoE and mobility services support to users than traditional IP architectures. Monitoring mechanisms such as the Contrace tool we developed in the SIMULBED associated team will be helpful to provide an accurate view of the network at the SDN controllers side. In addition, we will build a large-scale testbed to evaluate our solutions through reproducible experimentations based on two testbeds: the ICN wired CUTEi testbed developed by NICT and the wireless R2lab testbed developed by Inria.

## 8.6. International Research Visitors

### 8.6.1. Visits of International Scientists

Katia Obraczka is Professor of Computer Engineering and Graduate Director at Department of Computer Engineering, UC Santa Cruz where she leads the Internetworking Research Group (i-NRG). She has visited us for four weeks in July 2018. The Labex UCN@Sophia has supported two one-month visits at the DIANA project-team, in July 2017 and during summer 2018 to work in particular on the decentralization of the SDN control plane applied to Intelligent Transport Systems (ITS). These two visits were very fruitful as they resulted in common publications [18], [17] and contributed to the start of the DrIVE Associated team.

### 8.6.2. Internships

Yevhenii Semenko and Alberto Zironelli

Date: from from Apr 2018 until Sep 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Damien Saucez

Subject: Privacy preserving taxi service with blockain

Laila Daanoun

Date: from Apr 2018 until Aug 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Damien Saucez

Subject: The Network of the Future in Industry 4.0: Solving the Reachability problem

Gayatri Sivadoss

Date: from Apr 2018 until Aug 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Mohamed Naoufal Mahfoudi, Thierry Turletti and Walid Dabbous

Subject: LoRa: Characterization and Range Extension in campus environment

Ohtmane Bensouda Korachi

Date: from Apr 2018 until Aug 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Mohamed Naoufal Mahfoudi, Thierry Turletti and Walid Dabbous

Subject: Geolocation for LoRa Low Power Wide Area Network

Othmane Belmoukadam

Date: from Mar 2018 until Aug 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Chadi Barakat

Subject: ACQUA - A data-driven approach for network and Quality of Experience monitoring

Yonathan Bleyfuesz

Date: from Feb 2018 to Aug 2018

Institution: International Master programme M1, University of Nice Sophia Antipolis

Supervisor: Thierry Parmentelat

Subject: Using neri-ng to evaluate MANET routing protocols.

Indukala Naladala

Date: from May 2018 until Jul 2018

Institution: National Institute of Technology Karnataka, Surathkal, India

Supervisor: Thierry Turletti and Walid Dabbous

Subject: Integration of R2LAB with ns-3

Janati Idrissi

Date: from Mar 2018 until Aug 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Arnaud Legout

Subject: Étude de la précision de la localisation dans ElectroSmart sous Android.

### **8.6.3. Visits to International Teams**

Thierry Turletti visited NICT in Tokyo Japan in the context of the UHD-on-5G associated team in october 2018.

Thierry Turletti also visited UNICAMP in Campinas Bresil in the context of the UHD-on-5G associated team in october 2018.

## DIONYSOS Project-Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

- Yann Busnel is a member of the ONCOSHARe project (ONCOlogy bigdata SHARing for Research) funded by Brittany and Pays de la Loire regions, with 280.000 k€ for 24 months.
- Bruno Sericola continues to work on the analysis of fluid queues with Fabrice Guillemin from Orange Labs in Lannion, France.

### 9.2. National Initiatives

#### ANR

- Yassine Hadjadj-Aoul is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Sofiène Jelassi is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Yann Busnel is a member of the three following projects: SocioPlug granted by the ANR (ANR-13-INFR-0003), INSHARE granted by the ANR (ANR-15-CE19-0024) and BigClin granted by the LabEx CominLabs (ANR-10-LABX-07-01).

#### IPL (Inria Project Lab) BetterNet

Yassine Hadjadj-Aoul, Gerardo Rubino and Bruno Tuffin are members of the IPL (Inria Project Lab) BetterNet: An Observatory to Measure and Improve Internet Service Access from User Experience, 2016-2020.

BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Our observatory can be defined as a vantage point, where: 1) tools, models and algorithms/heuristics will be provided to collect data, 2) acquired data will be analyzed, and shared appropriately with scientists, stakeholders and civil society, and 3) new value-added services will be proposed to end-users.

### 9.3. European Initiatives

- Bruno Sericola continues to work on the analysis of fluid queues with Marie-Ange Remiche from the university of Namur in Belgium.

#### 9.3.1. FP7 & H2020 Projects

##### 9.3.1.1. FINTEROP

Program: H2020-ICT-12-2015

Project acronym: F-Interop

Project title: FIRE+ online interoperability and performance test tools to support emerging technologies from research to standardization and market launch

Duration: November 2015 – October 2018

Coordinator: UPMC-LIP6

Other partners: 9 partners including F. Sismondi and C. Viho (Dionysos), and T. Watteyne (Eva)

Abstract: The goal of F-Interop is to extend FIRE+ with online interoperability and performance test tools supporting emerging IoT-related technologies from research to standardization and to market launch for the benefit of researchers, product development by SME, and standardization processes.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Informal International Partners

We maintain a strong line of collaborations with the Technical University Federico Santa María (UTFSM), Valparaíso, Chile. Over the years, this has taken different forms (associated team Manap, Stic AmSud project “AMMA”, Stic AmSud project “DAT”). In 2018, we finished a joint PhD work (co-tutelle PhD of Nicolás Jara), and a new joint PhD will start in 2019 (PhD of Jonathan Olavarría). The first one was on optical network analysis and design; the second one’s topic is on modeling evaluation techniques, with focus on Stochastic Activity Networks.

#### 9.4.2. Participation in Other International Programs

**ECOS-Sud project MASC: Mathematical Algorithms for Semantic Cognition.** MASC is a three-year project (code U17E03) with the Faculty of Sciences of the university of the Republic, in Uruguay, on the application of mathematical modeling tools to a better understanding of a cognitive disease called semantic dementia. This involves Prof. Eduardo Mizraji and Jorge Graneri, a PhD student whose co-advisors are Prof. Mizraji and G. Rubino from Dionysos, plus Pablo Rodríguez Bocca, from the Engineering Faculty of the university of the Republic. Our contribution to this project is around the use of mathematical models of neural structures.

## 9.5. International Research Visitors

- Pierre L’Ecuyer holds an Inria International Chair, Nov. 2013- Oct. 2018.
- Three colleagues from the University of the Republic, Uruguay, visited us in 2018. First, Jorge Graneri, in the context of the starting ECOS project MASC (July–August), then Professor Gustavo Guerberoff to work on mathematical problems related to reliability network models (October–November), and then Professor Pablo Rodríguez Bocca, to work also on the previously entioned ECOS project.

### 9.5.1. Visits to International Teams

#### 9.5.1.1. Research Stays Abroad

- Yassine Hadjadj-Aoul was able to benefit from a one-month scientific stay at the Metropolitan University of Manchester (MMU), in June 2018. This stay was part of the “Research and knowledge Exchange Funding” program run by the MMU.

## DYOGENE Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. *Laboratory of Information, Networking and Communication Sciences (LINCS)*

Dyogene participates in LINCS <https://www.lincs.fr/>, a research centre co-founded by Inria, Institut Mines-Télécom, UPMC and Alcatel-Lucent Bell Labs (currently Nokia Bell Labs) dedicated to research and innovation in the domains of future information and communication networks, systems and services. S. Meyn [University of Florida] was invited professor by LINCS and ENS from July to December 2018.

### 8.1.2. *PGMO*

Dyogene participates to the PGMO (Gaspard Monge Program for Optimization, operations research, and their interactions with data science) via the project a 2 year project “Distributed control of flexible loads” funded through the ICODE/IROE call. This is a collaborative project between University Paris-Sud (PI: Gilles Stoltz) and Inria (PI: Ana Busic). Post-doc Cheng Wan was financed by this project from Feb-Nov 2018.

## 8.2. National Initiatives

### 8.2.1. *GdR GeoSto*

Members of Dyogene participate in Research Group GeoSto (Groupement de recherche, GdR 3477) <http://gdr-geostoch.math.cnrs.fr/> on Stochastic Geometry led by and David Coupier [Université de Valenciennes].

This is a collaboration framework for all French research teams working in the domain of spatial stochastic modeling, both on theory development and in applications. This year DYOGENE has co-organized yearly conference of the GdR *Stochastic Geometry Days 2018* 14–18 mai 2018 Paris (France); <https://geosto-2018.sciencesconf.org/>.

### 8.2.2. *GdR RO*

Members of Dyogene participate in GdR-RO (Recherche Opérationnelle; GdR CNRS 3002), <http://gdrro.lip6.fr/>, working group COSMOS (Stochastic optimization and control, modeling and simulation), lead by A. Busic and E. Hyon (LIP 6); <http://gdrro.lip6.fr/?q=node/78>

### 8.2.3. *ANR JCJC PARI*

Probabilistic Approach for Renewable Energy Integration: Virtual Storage from Flexible Loads. The project started in January 2017. PI — A. Bušić. This project is motivated by current and projected needs of a power grid with significant renewable energy integration. Renewable energy sources such as wind and solar have a high degree of unpredictability and time variation, which makes balancing demand and supply challenging. There is an increased need for ancillary services to smooth the volatility of renewable power. In the absence of large, expensive batteries, we may have to increase our inventory of responsive fossil-fuel generators, negating the environmental benefits of renewable energy. The proposed approach addresses this challenge by harnessing the inherent flexibility in demand of many types of loads. The objective of the project is to develop decentralized control for automated demand dispatch, that can be used by grid operators as ancillary service to regulate demand-supply balance at low cost. We call the resource obtained from these techniques virtual energy storage (VES). Our goal is to create the necessary ancillary services for the grid that are environmentally friendly, that have low cost and that do not impact the quality of service (QoS) for the consumers. Besides respecting the needs of the loads, the aim of the project is to design local control solutions that require minimal communications from the loads to the centralized entity. This is possible through a systems architecture that includes the following elements: i) local control at each load based on local measurements combined with a grid-level signal; ii) frequency decomposition of the regulation signal based on QoS and physical constraints for each class of loads.

## 8.3. International Initiatives

### 8.3.1. Inria International Partners

#### 8.3.1.1. IFCAM Project “Geometric statistics of stationary point processes”

B. Błaszczyszyn and Yogeshwaran D. from Indian Statistical Institute (ISI), Bangalore, have got in 2018 the approval from Indo-French Centre for Applied Mathematics (IFCAM), for their joint project on “Geometric statistics of stationary point processes” for the period 2018–2021. B. Błaszczyszyn was visiting ISI Bangalore for two weeks in November–December 2018.

#### 8.3.1.2. Informal International Partners

- University of Florida: collaborations with Prof Sean Meyn (ECE), Associate Prof Prabir Barooah (MAE), and the PhD students: A. Devraj (ECE), A. Coffman (MAE), N. Cammardella (ECE), J. Mathias (ECE).

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

- D. Yogeshwaran [Indian Statistical Institute, Bangalore, India]
- S. Meyn [University of Florida, USA] was invited Prof at ENS and LINCS, July - December 2018

#### 8.4.1.1. Internships

- Master Probabilités et Modèles aléatoires UPMC, Walid Ghanem, *Hydrodynamic limit of a network with moving servers*, 04-07/2018, encadrant Christine Fricker.
- Master MASH (Mathématiques appliquées aux sciences humaines) ENS-Paris Dauphine University, *Using customer oriented policies based on probabilistic methods to enhance the Bike Sharing System Velib'*, 08-011/2018, encadrants Christine Fricker et Laurent Massoulié.
- Akshay Goel [Kyushu University, Fukuoka, Japan] Mars 2018,
- Tokuyama Kiichi [Tokyo Tech, Tokyo, Japan], April 2018,

### 8.4.2. Visits to International Teams

#### 8.4.2.1. Research Stays Abroad

- B. Błaszczyszyn was visiting Yogeshwaran D. at the Indian Statistical Institute Bangalore for two weeks in November–December 2018 (IFCAM project).
- A. Basic was a long-term participant (March-Mai 2018) of the Real-Time Decision Making program, Simons Institute, UC Berkeley, USA; <https://simons.berkeley.edu/programs/realtime2018>

## EVA Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

- The GeoBot FUI project (<https://geobot.fr/>) is one of the most innovative, challenging and fun projects around wireless localization in the world today. It applies true innovation to a real-world problem, with a clear target application (and customer) in mind. The GeoBot partners are building a small robot (think of a matchbox-sized RC car) that will be inserted into a gas pipe, and move around it to map the location of the different underground pipes. Such mapping is necessary to prevent gas-related accidents, for example during construction. At the end of the project, this solution will be commercialized and used to map the network of gas pipe in France, before being used in worldwide. Each partner is in charge of a different aspect of the problem: robotics, analysis of the inertial data, visualization, etc. Inria is in charge of the wireless part. We will be equipping the robot with a wireless chip(set) in order to (1) communicate with the robot as it moves about in the pipes while standing on the surface, and (2) discover the relative location of the robot w.r.t. a person on the surface. Inria is evaluating different wireless technologies, benchmarking around ranging accuracy and capabilities to communicate. We start from off-the-shelf kits from different vendors and build a custom board, benchmark it, and integrate it with the other partners of the project.

### 9.1.2. Other collaborations

- EVA has a collaboration with Orange Labs. **Thomas Watteyne** supervises the PhD of Mina Rady, which happens under a CIFRE agreement with Orange Labs.
- EVA has a collaboration with Vedecom. **Paul Muhlethaler** supervises Fouzi Boukhalfa's PhD funded by Vedecom. This PhD aims at studying low latency and high reliability vehicle-to-vehicle communication to improve roads safety.
- EVA has an ongoing collaboration with SODEAL company, which exploits the Cap d'Agde marina, as part of the SmartMarina project.

## 9.2. European Initiatives

### 9.2.1. FP7 & H2020 Projects

The H2020 following projects are ongoing:

- H2020 SPARTA, Jan 2019 – December 2020.
- H2020 F-Interop, <http://f-interop.eu/>, Nov 2015 – Oct 2018.
- H2020 ARMOUR, <https://www.armour-project.eu/>, Feb 2016 – Jan 2018.

### 9.2.2. Collaborations with Major European Organizations

Inria-EVA has collaboration in 2018 with ETSI (the European Telecommunications Standards Institute) to organize the F-Interop 6TiSCH 2 Interop Event on 2-4 February 2018 in Paris.

## 9.3. International Initiatives

### 9.3.1. Inria Associate Teams Not Involved in an Inria International Labs

#### 9.3.1.1. REALMS

- Title: Real-Time Real-World Monitoring Systems
- International Partner (Institution - Laboratory - Researcher):
  - University of California Berkeley (United States) - Civil and Environmental Engineering - Steven Glaser
  - University of Michigan (United States) - Civil and Environmental Engineering - Branko Kerkez
- Start year: 2015
- See also: <http://glaser.berkeley.edu> et <http://www-personal.umich.edu/~bkerkez/>
- The Internet of Things revolution prompted the development of new products and standards; The IEEE 802.15.4e (2012) standard introduced the Time Synchronized Channel Hopping (TSCH) which can provide end-to-end reliability of 99.999 % and an energy autonomy of many years. This exceptional performance prompted the IETF to create the 6TiSCH working group to standardize the integration of TSCH networks in the Internet. While the first experimental data have highlighted the great robustness of these networks, there is no data of a real network, accessible in real time, on a large scale and over a long period. Such data is needed to better model network performance and produce better products and standards. Teams of Professors Glaser and Kerkez are successfully deploying such networks to study mountain hydrology, monitor water quality and manage rainwater in urban environments. A model is missing to assist in the deployment and operation of these networks, as well as to monitor an operational network.

#### 9.3.1.2. DIVERSITY

- Title: Measuring and Exploiting Diversity in Low-Power Wireless Networks
- International Partner (Institution - Laboratory - Researcher):
  - University of Southern California (United States) - Autonomous Networks Research Group (ANRG) - Bhaskar Krishnamachari
- Start year: 2016
- The goal of the DIVERSITY associate team is to develop the networking technology for tomorrow's Smart Factory. The two teams comes with a perfectly complementary background on standardization and experimentation (Inria-EVA) and scheduling techniques (USC-ANRG). The key topic addressed by the joint team will be networking solutions for the Industrial Internet of Things (IIoT), with a particular focus on reliability and determinism.

### 9.3.2. Inria International Partners

#### 9.3.2.1. Declared Inria International Partners

Inria-EVA has a long-standing Memorandum of Understanding with the OpenMote company (<http://www.openmote.com/>), which runs until 2020. OpenMote emerged as a spin-off of the OpenWSN project, co-lead by **Thomas Watteyne** and Prof. Xavier Vilajosana, Professor at the Open University of Catalonia and Chief Technical Officer at OpenMote.

The collaboration has been ongoing since 2012 and at the time of writing has resulted in:

- Joint academic publications, including 7 journal articles, 1 letter, 1 book chapter, 5 conference papers, 2 tutorials and invited talks.
- Joint standardization activities, in particular in the IETF 6TiSCH working group, co-chaired by **Thomas Watteyne** and for which Prof. Xavier Vilajosana is a key contributor. This activity has resulted in the joint participation in 12 IETF face-to-face meetings, joint participation in over 100 audioconferences, co-authorship of 3 Internet-Drafts and joint organization of 2 interop events.
- Joint software development, as both institutions closely collaborate in the maintenance, development, promotion and research along the OpenWSN project, including the development of the protocol stack, the integration of novel hardware technologies, the support to the community and the participation in standardization activities and interoperability events.



This MOU is NOT a commitment of funds by any part.

#### 9.3.2.2. Informal International Partners

The Inria-EVA collaborates extensively with Prof. Pister's group at UC Berkeley on the OpenWSN and Smart Dust projects. This activity translated into several members of the Pister team visiting Inria-EVA and vice-versa in 2018.

#### 9.3.2.3. International Initiatives

Inria-EVA participates in the IoT Benchmarks Initiative (<https://www.iotbench.ethz.ch/>)

Inria-EVA will be participating in 2019 in the WirelessWine SticAm-Sud project.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

1. **Prof. Xavi Vilajosana (UOC/OpenMote)** (26-30 November 2018) working on OpenMote B bring-up with Tengfei Chang and **Thomas Watteyne**
2. **Brian Gregory Kilberg (UC Berkeley)** (11-18 September 2018) working on OpenWSN/ROS integration with **Thomas Watteyne** and Tengfei Chang
3. **Prof. Xavi Vilajosana (UOC/OpenMote)** (24-28 June 2018) working on F-Interop 6TiSCH with **Thomas Watteyne** and Tengfei Chang
4. **Pablo Modernell (UOC)** (28 May – 1 June 2018) working on F-Interop with Tengfei Chang and **Thomas Watteyne**
5. **Malisa Vucinic (U Montenegro)** (9 -16 March 2018) working on 6TiSCH Security with **Thomas Watteyne**
6. **Lance Doherty (Analog Devices)** (8-9 February 2018) working on SmartMesh IP with **Thomas Watteyne**
7. **Malisa Vucinic (U Montenegro)** (29 January-16 February 2018) working on 6TiSCH Security with **Thomas Watteyne**

### 9.4.2. Internships

1. **Felipe Moran**, MSc intern from ENSTA ParisTech (1 September 2017 – 31 August 2018), EDF fellow, Research Topic: mote feeding habits, SmartMesh IP, Advisor: Thomas Watteyne
2. **Fabian Rincon Vija**, MSc intern from ENSTA ParisTech (14 May – 31 August 2018), Research Topic: Extension of F-Interop to IEEE 802.15.4 sub-GHz, Advisor: Thomas Watteyne
3. **Marcelo Augusto Ferreira**, MSc intern from ENSTA ParisTech (1 May – 31 August 2018), Research Topic: Measuring Energy Consumption in F-Interop, Advisor: Thomas Watteyne
4. **Imene Ben Haddada**, Using Support Vector Machine for Positioning Services in Vehicle Ad-hoc NETWORKS (ENSI- Tunisia), March-July 2018.
5. **Khalifa Hadded**, Generation of positioning data in Vehicle Ad-hoc NETWORKS (ENSI- Tunisia), March-July 2018.
6. **Zied Soua**, Formation d'un réseau TSCH et ordonnancement de ses communications dans le cadre de l'IoT industriel, (INSAT- Tunisia), February-July 2018.

### 9.4.3. Visits to International Teams

#### 9.4.3.1. Research Stays Abroad

- **Thomas Watteyne** spent the month of August 2017 at UC Berkeley, working with Prof. Glaser on the SnowHow project, and with Prof. Pister on Smart Dust and OpenWSN.
- Tengfei Chang spent the month of July 2017 in California working with Prof. Pister working on Smart Dust UC Berkeley, and Prof. Krishnamachari working on testbed deployment at the University of Southern California.

## FUN Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. StoreConnect

**Participants:** Nathalie Mitton, Valeria Loscri [correspondant], Antonio Costanzo, Ibrahim Amadou.

Title: StoreConnect

Type: FUI

Duration: September 2016 - October 2018

Coordinator: NEOSENSYS

Others partners: Inria FUN, SPIRALS and STARS, TeVolys, Ubudu, Smile, STIME, Leroy Merlin

The aim of StoreConnect is to provide French large retailers with efficient and powerful tools in the in-store customer interaction. This project has yielded to several publications in 2018: [39], [38], [24], [40].

### 9.1.2. PIPA

**Participants:** Nathalie Mitton [correspondant], Farouk Mezghani.

Title: Partager de l'Info PARTout à bas coût

Type: Chercheur citoyen

Duration: Dec 2015 - Aug 2018

Coordinator: Inria FUN

Others partners: SpotTrotter

PIPA project aims to provide an innovative low cost solution to share information in places where communication infrastructure are lacking, insufficient or not adapted, going beyond technical, economical or political limitations. This project has yield to several publications in 2018: [31], [19], [30].

## 9.2. National Initiatives

### 9.2.1. Inria Project Lab

#### 9.2.1.1. CityLab@Inria

**Participants:** Valeria Loscri, Abdoul Aziz Mbacke, Nathalie Mitton [correspondant].

- Title: CityLab@Inria
- Type: IPL
- Duration: 2015 - 2019
- Coordinator: Valerie Issarny
- CityLab@Inria studies ICT solutions toward smart cities that promote both social and environmental sustainability. A strong emphasis of the Lab is on the undertaking of a multi-disciplinary research program through the integration of relevant scientific and technology studies, from sensing up to analytics and advanced applications, so as to actually enact the foreseen smart city Systems of Systems. Obviously, running urban-scale experiments is a central concern of the Lab, so that we are able to confront proposed approaches to actual settings. The Lab's research leverages relevant effort within Inria project-teams that is further revisited as well as integrated to meet the challenges of smart cities. Research themes span: energy-efficient wireless communication protocols, urban-scale social and physical sensing, privacy by design, cloud-based urban data management, data assimilation, visual analysis, and urban system software engineering. In addition, CityLab Inria research builds upon collaborative effort at the International level, and especially collaboration in the context of the Inria SiliconValley program. This project has yield to the set up of a full course on Smart Cities via a MOOC [48] and a set of publications [18], [29], [28], [37], [11].

## 9.2.2. ADT

### 9.2.2.1. Catimex

**Participants:** Matthieu Berthome, Nathalie Mitton [correspondant], Julien Vandaele.

Duration: September 2017 -June 2019

Coordinator: Inria FUN

The purpose of this project is to foster research transfer in IoT from ADT members to their industrial partners by widening experimental features and PoC realization. It is lead in closed partnership with Inria Chile and Université of Strasbourg.

## 9.2.3. Equipements d'Excellence

### 9.2.3.1. FIT

**Participants:** Nathalie Mitton [correspondant], Julien Vandaele, Matthieu Berthome.

Title: Future Internet of Things

Type: EquipEx

Duration: March 2010 - December 2019

Coordinator: UPMC

See also: <http://fit-equipex.fr/>

Abstract: FIT (Future Internet of Things) aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It will provide this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project will give French Internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the Future Internet. FIT is one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Equipements d'Excellence" (Equipex) research grant program. Coordinated by Professor Serge Fdida of UPMC Sorbonne Universités and running over a nine-year period, the project will benefit from a 5.8 million euro grant from the French government.

## 9.3. European Initiatives

### 9.3.1. H2020 Projects

#### 9.3.1.1. VESSEDIA

**Participants:** Rehan Malak, Nathalie Mitton, Allan Blanchard [correspondant].

- Title: VERIFICATION ENGINEERING OF SAFETY AND SECURITY CRITICAL DYNAMIC INDUSTRIAL APPLICATIONS
- Program: H2020
- Duration: January 2017 - Dec. 2019
- TECHNIKON FORSCHUNGS UND PLANUNGSGESELLSCHAFT MBH (TEC)

The VESSEDIA project will bring safety and security to many new software applications and devices. In the fast evolving world we live in, the Internet has brought many benefits to individuals, organizations and industries. With the capabilities offered now (such as IPv6) to connect billions of devices and therefore humans together, the Internet brings new threats to the software developers and VESSEDIA will allow connected applications to be safe and secure. VESSEDIA proposes to enhance and scale up modern software analysis tools, namely the mostly open-source Frama-C Analysis platform, to allow developers to benefit rapidly from them when developing connected applications. At the forefront of connected applications is the IoT, whose growth is exponential and whose security risks are real (for instance in hacked smart phones). VESSEDIA will take this domain as a target for demonstrating the benefits of using our tools on connected applications. VESSEDIA will tackle this challenge by 1) developing a methodology that allows to adopt and use source code analysis tools efficiently and produce similar benefits than already achieved for highly-critical applications (i.e. an exhaustive analysis and extraction of faults), 2) enhancing the Frama-C toolbox to enable efficient and fast implementation, 3) demonstrating the new toolbox capabilities on typical IoT (Internet of Things) applications including an IoT Operating System (Contiki), 4) developing a standardization plan for generalizing the use of the toolbox, 5) contributing to the Common Criteria certification process, and 6) defining a label “Verified in Europe” for validating software products with European technologies such as Frama-C. This project yields to set of publications in 2018: [23], [47], [27].

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

#### 9.4.1.1. Agrinet

**Participants:** Abdoul Aziz Mbacke, Brandon Foubert, Valeria Loscri, Anjalalaina Jean Cristanel Razafimandimby, Nathalie Mitton [correspondant].

#### **Agrinet**

Title: Agrinet

International Partner (Institution - Laboratory - Researcher):

Type: LIRIMA Associate team

Duration: 2017-2020

See also: <https://team.inria.fr/agrinet/>

The current drought and limited water resources in many parts of Southern Africa and beyond, already have a significant impact on agriculture and hence, food production. Sustainable food security depends upon proper plant and crop management respectful of soils and natural resources, such as water. This includes very important South African farming areas, such as the Western Cape and Northern Cape. In France, agriculture is also hugely important. Not just nationally, but also in Europe. The system proposed can be applied to a variety of crops. The economic- and social consequences are profound and any contribution towards more efficient farming within increasingly onerous natural constraints, should be a priority. To address these constraints, we propose to develop a flexible, rapidly deployable, biological/agricultural data acquisition platform and associated machine learning algorithms to create advanced agricultural monitoring and management techniques, to improve crop management and use of natural resources. The project also addresses an industry with very high socioeconomic impact.

Publications issued from that project in 2018 are: [25], [45], [35].

### 9.4.2. Inria International Partners

#### 9.4.2.1. Declared Inria International Partners

Università Mediterranea di Reggio Calabria (UNIC) (Italy) Objective of this collaboration is the design of an innovative architecture that enables autonomic and decentralized fruition of the services offered by the network of smart objects in many heterogeneous and dynamic environments, in a way that is independent of the network topology, reliable and flexible. The result is an 'ecosystem' of objects, self-organized and self-sustained, capable of making data and services available to the users wherever and whenever required, thus supporting the fruition of an 'augmented' reality thanks to a new environmental and social awareness.

#### 9.4.2.2. Informal International Partners

##### **Southern University, China**

The purpose of this collaboration is to study the green (or energy-efficient) communication problem in vehicular ad hoc networks (VANETs) and the application of vehicular network communication in green transportation. In this framework, Nathalie Mitton visited the Nanjing University. It gave birth to joint project submission, joint conference organization and joint publications.

##### **Arun Sen from Arizona State University, USA**

The purpose of this collaboration is to study the joint scheduling and trajectory of RFID readers in a mobile environment. In this framework, Arun Sen visited the FUN team for 6 months in 2015 and in July 2016. It gave birth to joint project submission, joint conference submission and joint publications, among them in 2018 [14].

##### **Anna-Maria Vegni from Roma Tre University, Italy**

The purpose of this collaboration is to study alternative communication paradigms and investigate their limitations and different effects on performances. In this framework, joint publications have been obtained, among them in 2018 [17], [21], [26], [36], [43], [45].

### 9.4.3. Participation in Other International Programs

#### 9.4.3.1. CROMO

**Participants:** Valeria Loscri, Joao Batista Pinto Neto, Nathalie Mitton [correspondant].

Title: Crowd Data In the mobile cloud

Duration: January 2015 - December 2019

CroMo (Crowd Data In the mobile cloud) is a submission to the CAPES-COFECUB project call lead by Inria from the French side and University of Rio de Janeiro from Brazilian Side. Other partner institutions are Université Pierre et Marie Curie and Université de la Rochelle.

Mobile cloud computing is an emerging paradigm to improve the quality of mobile applications by transferring part of the computational tasks to the resource-rich cloud. The multitude data sources combined with the known difficulties of wireless communications represent an important issue for mobile cloud computing. Therefore, the additional computational power added by the cloud has to deal with the constraints of the wireless medium. One could imagine a situation where different sensors collect data and require intensive computation. This data must be transmitted at high rates before becoming stale. In this case, the network becomes the main bottleneck, not the processing power or storage size. To circumvent this issue, different strategies can be envisioned. As usual alternatives, wireless data rates must be increased or the amount of data sent to the cloud must be reduced. CROMO tackles challenges from all these three components of the mobile clouds (data generation, collect and processing) to then integrate them as a whole enhanced mobile cloud with improved network performances in terms of delay, energy consumption, availability, and reliability. In this context, joint exchanges and crossed visits have been done (Aziz went to Rio, Dianne went to Lille). The project yield to several publications such as [22].

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

Several researchers have visited our group in 2018, mainly from our partner universities but not only:

- Gentian, Jakllari, ENSEEITH, France, January 2018
- Georgios Papadopoulos, IMT Atlantique, France, January 2018
- Bruno Quoitin, University of Mons, Belgium, January and March 2018
- Sebastien Bindel, Université de Haute Alsace, France, June 2018
- Karen Miranda Campos, Metropolitan Autonomous University Lerma Campus, Mexico, October 2018
- Zied Chtourou, University of Sfax, Tunisia, October 2018
- Fabrice Théoleyre, University of Strasbourg, October 2018
- Fabrice Valois, INSA Lyon, October 2018
- Miguel Elias Campista, Federal University of Rio de Janeiro (UFRJ), Brazil, December 2018
- Pranvera Kortoci, Aalto University, from Mar 2018 until Apr 2018
- Noura Mares Univ. Sfax, from Apr 2018 until Jul 2018
- Morgan O Kennedy, Stellenbosch University, from Jul 2018 until Sep 2018

#### 9.5.1.1. Research Stays Abroad

- Jad Nassar visited Metropolitan Autonomous University Cuajimalpa Campus, Mexico in January-February 2018

## GANG Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. *Laboratory of Information, Networking and Communication Sciences (LINCS)*

Gang is participating to the LINCS, a research centre co-founded by Inria, Institut Mines-Télécom, UPMC and Alcatel-Lucent Bell Labs, dedicated to research and innovation in the domains of future information and communication networks, systems and services. Gang contributes to work on online social networks, content centric networking and forwarding information verification.

## 9.2. National Initiatives

### 9.2.1. *ANR DESCARTES*

**Participants:** Carole Delporte-Gallet, Hugues Fauconnier, Pierre Fraigniaud, Adrian Kosowski, Laurent Viennot.

Cyril Gavoille (U. Bordeaux) leads this project that grants 1 Post-Doc. H. Fauconnier is the local coordinator (This project began in October 2016).

Despite the practical interests of reusable frameworks for implementing specific distributed services, many of these frameworks still lack solid theoretical bases, and only provide partial solutions for a narrow range of services. We argue that this is mainly due to the lack of a generic framework that is able to unify the large body of fundamental knowledge on distributed computation that has been acquired over the last 40 years. The DESCARTES project aims at bridging this gap, by developing a systematic model of distributed computation that organizes the functionalities of a distributed computing system into reusable modular constructs assembled via well-defined mechanisms that maintain sound theoretical guarantees on the resulting system. DESCARTES arises from the strong belief that distributed computing is now mature enough to resolve the tension between the social needs for distributed computing systems, and the lack of a fundamentally sound and systematic way to realize these systems.

### 9.2.2. *ANR MultiMod*

**Participants:** Adrian Kosowski, Laurent Viennot.

David Coudert (Sophia Antipolis) leads this project. L. Viennot coordinates locally. The project began in 2018. The MultiMod project aims at enhancing the mobility of citizens in urban areas by providing them, through a unique interface enabling to express their preferences, the most convenient transportation means to reach their destinations. Indeed, the increasing involvement of actors and authorities in the deployment of more responsible and cost-effective logistics and the progress made in the field of digital technology have made possible to create synergies in the creation of innovative services for improving the mobility in cities. However, users are faced with a number of solutions that coexist at different scales, providing complementary information for the mobility of users, but that make very complex to find the most convenient itinerary at a given time for a specific user. In this context, MultiMod aims at improving the mobility of citizens in urban areas by proposing contextualized services, linking users, to facilitate multimodal transport by combining, with flexibility, all available modes (planned/dynamic carpooling, public transport (PT), car-sharing, bicycle, etc.).

We consider the use of carpooling in metropolitan areas, and so for short journeys. Such usage enables itineraries that are not possible with PT, allows for opening up areas with low PT coverage by bringing users near PT (last miles), and for faster travel-time when existing PT itineraries are too complex or with too low frequency (e.g., one bus per hour). In this context, the application must help the driver and the passenger as much as possible. In particular, the application must propose the meeting-point, indicate the driver the detour duration, and indicate the passenger how to reach this meeting-point using PT. Here, the time taken by drivers and passengers to agree becomes a critical issue and so the application must provide all needed information to quickly take a decision (i.e., in one click).

In addition, the era of Smart City gathers many emerging concepts, driven by innovative technological players, which enables the exploitation of real-time data (e.g., delay of a bus, traffic jam) made available by the various actors (e.g., communities in the framework of Open Data projects, users via their mobile terminals, traffic supervision authorities). In the MultiMod project, we will use these rich sources of data to propose itineraries that are feasible at query-time. Our findings will enable the design of a mobility companion able not only to guide the user along her journey, including when and how to change of transportation mean, but also to propose itinerary changes when the current one exceeds a threshold delay. The main originality of this project is thus to address the problem of computing itineraries in large-scale networks combining PT, carpooling and real-time data, and to satisfy the preferences of users. We envision that the outcome of this project will significantly improve the daily life of citizens.

The targeted metropolitan area for validating our solutions is Ile-de-France. Indeed, Instant-System is currently developing the new application “Vianavigo lab” which will replace the current “Vianavigo” application for the PT network of Ile-de-France. Our findings will therefore be tested at scale and eventually be integrated and deployed in production servers and mobile applications. The smaller networks of Bordeaux and Nice will be used to perform preliminary evaluations since Instant System already operates applications in these cities (Boogi Nice, Boogi Bordeaux). An important remark is that new features and algorithms can contractually be deployed in production every 4 months, thus enabling Instant System to measure and challenge the results of the MultiMod project in continue. This is a chance for the project to maximize its impact.

### 9.2.3. ANR FREDDA

**Participants:** Carole Delporte-Gallet, Hugues Fauconnier, Pierre Fraigniaud.

Arnaud Sangnier (IRIF, Univ Paris Diderot) leads this project that grants 1 PhD. (This project began in October 2017).

Distributed algorithms are nowadays omnipresent in most systems and applications. It is of utmost importance to develop algorithmic solutions that are both robust and flexible, to be used in large scale applications. Currently, distributed algorithms are developed under precise assumptions on their execution context: synchronicity, bounds on the number of failures, etc. The robustness of distributed algorithms is a challenging problem that has not been much considered until now, and there is no systematic way to guarantee or verify the behavior of an algorithm beyond the context for which it has been designed. We propose to develop automated formal method techniques to verify the robustness of distributed algorithms and to support the development of robust applications. Our methods are of two kinds: statically through classical verification, and dynamically, by synthesizing distributed monitors, that check either correctness or the validity of the context hypotheses at runtime.

### 9.2.4. ANR Distancia

**Participants:** Pierre Charbit, Michel Habib, Laurent Viennot.

Victor Chepoi (Univ. Marseille) leads this project. P. Charbit coordinates locally. The project began in early-2018.

The theme of the project is Metric Graph Theory, and we are concerned both on theoretical foundations and applications. Such applications can be found in real world networks. For example, the hub labelling problem in road networks can be directly applied to car navigation applications. Understanding key structural properties of large-scale data networks is crucial for analyzing and optimizing their performance, as well as



improving their reliability and security. In prior empirical and theoretical studies researchers have mainly focused on features such as small world phenomenon, power law degree distribution, navigability, and high clustering coefficients. Although those features are interesting and important, the impact of intrinsic geometric and topological features of large-scale data networks on performance, reliability and security is of much greater importance. Recently, there has been a surge of empirical works measuring and analyzing geometric characteristics of real-world networks, namely the Gromov hyperbolicity (called also the negative curvature) of the network. It has been shown that a number of data networks, including Internet application networks, web networks, collaboration networks, social networks, and others, have small hyperbolicity.

Metric graph theory was also indispensable in solving some open questions in concurrency and learning theory in computer science and geometric group theory in mathematics. Median graphs are exactly the 1-skeletons of CAT(0) cube complexes (which have been characterized by Gromov in a local-to-global combinatorial way). They play a vital role in geometric group theory (for example, in the recent solution of the famous Virtual Haken Conjecture). Median graphs are also the domains of event structures of Winskel, one of the basic abstract models of concurrency. This correspondence is very useful in dealing with questions on event structures.

Many classical algorithmic problems concern distances: shortest path, center and diameter, Voronoi diagrams, TSP, clustering, etc. Algorithmic and combinatorial problems related to distances also occur in data analysis. Low-distortion embeddings into  $l_1$ -spaces (theorem of Bourgain and its algorithmical use by Linial et al.) were the founding tools in metric methods. Recently, several approximation algorithms for NP-hard problems were designed using metric methods. Other important algorithmic graph problems related to distances concern the construction of sparse subgraphs approximating inter-node distances and the converse, augmentation problems with distance constraints. Finally, in the distributed setting, an important problem is that of designing compact data structures allowing very fast computation of inter- node distances or routing along shortest or almost shortest paths. Besides computer science and mathematics, applications of structures involving distances can be found in archeology, computational biology, statistics, data analysis, etc. The problem of characterizing isometric subgraphs of hypercubes has its origin in communication theory and linguistics. . To take into account the recombination effect in genetic data, the mathematicians Bandelt and Dress developed in 1991 the theory of canonical decompositions of finite metric spaces. Together with geneticists, Bandelt successfully used it over the years to reconstruct phylogenies, in the evolutionary analysis of mtDNA data in human genetics. One important step in their method is to build a reduced median network that spans the data but still contains all most parsimonious trees. As mentioned above, the median graphs occurring there constitute a central notion in metric graph theory.

With this project, we aim to participate at the elaboration of this new domain of Metric Graph Theory, which requires experts and knowledge in combinatorics (graphs, matroids), geometry, and algorithms. This expertise is distributed over the members of the consortium and a part of the success of our project it will be to share these knowledges among all the members of the consortium. This way we will create a strong group in France on graphs and metrics.

### **9.2.5. ANR HOSIGRA**

**Participants:** Pierre Charbit, Michel Habib.

This project starting in early-2018, led by Reza Naserasr, explores the connection between minors and colorings, exploiting the notion of signed graphs. With the four colour theorem playing a central role in development of Graph Theory, the notions of minor and coloring have been branded as two of the most distinguished concepts in this field. The geometric notion of planarity has given birth to the theory of minors among others, and coloring have proven to have an algebraic nature through its extension to the theory of graph homomorphisms. Great many projects have been completed on both subjects, but what remains mostly a mystery is the correlation of the two subjects. The four color theorem itself, in slightly stronger form, claims that if a complete graph on five vertices cannot be formed by minor operation from a given graph, then the graph can be homomorphically mapped into the complete graph on four vertices (thus a 4-coloring). Commonly regarded as the most challenging conjecture on graph theory, the Hadwiger conjecture claims that

five and four in this theorem can be replaced with  $n$  and  $n - 1$  respectively for any value of  $n$ . The correlation of these two concepts has been difficult to study, mainly for the following reason: While the coloring or homomorphism problems roots back into intersections of odd-cycles, the minor operation is irrelevant of the parity of cycles. To overcome this barrier, the notion of signed graphs has been used implicitly since 1970s when coloring results on graphs with no odd- $K_4$  is proved, following which a stronger form of the Hadwiger conjecture, known as Odd Hadwiger conjecture, was proposed by P. Seymour and B. Gerards, independently. Being a natural subclass of Matroids and a superclass of graphs, the notion of minor of signed graphs is well studied and many results from graph minor are either already extended to signed graphs or it is considered by experts of the subject. Observing the importance, and guided by some earlier works, in particular that of B. Guenin, we then started the study of algebraic concepts (coloring and homomorphisms) for signed graphs. Several results have been obtained in the past decade, and this project aims at exploring more of this topic.

### 9.3. European Initiatives

#### 9.3.1. FP7 & H2020 Projects

Amos Korman has an ERC Consolidator Grant entitled “Distributed Biological Algorithms (DBA)”, started in May 2015. This project proposes a new application for computational reasoning. More specifically, the purpose of this interdisciplinary project is to demonstrate the usefulness of an algorithmic perspective in studies of complex biological systems. We focus on the domain of collective behavior, and demonstrate the benefits of using techniques from the field of theoretical distributed computing in order to establish algorithmic insights regarding the behavior of biological ensembles. The project includes three related tasks, for which we have already obtained promising preliminary results. Each task contains a purely theoretical algorithmic component as well as one which integrates theoretical algorithmic studies with experiments. Most experiments are strategically designed by the PI based on computational insights, and are physically conducted by experimental biologists that have been carefully chosen by the PI. In turn, experimental outcomes will be theoretically analyzed via an algorithmic perspective. By this integration, we aim at deciphering how a biological individual (such as an ant) “thinks”, without having direct access to the neurological process within its brain, and how such limited individuals assemble into ensembles that appear to be far greater than the sum of their parts. The ultimate vision behind this project is to enable the formation of a new scientific field, called algorithmic biology, that bases biological studies on theoretical algorithmic insights.

#### 9.3.2. LIA Struco

Pierre Charbit is director of the LIA STRUCO, which is an Associated International Laboratory of CNRS between IÚUK, Prague, and IRIF, Paris. The director on the Czech side is Pr. Jaroslav Nešetřil. The primary theme of the laboratory is graph theory, more specifically: sparsity of graphs (nowhere dense classes of graphs, bounded expansion classes of graphs), extremal graph theory, graph coloring, Ramsey theory, universality and morphism duality, graph and matroid algorithms and model checking.

STRUCO focuses on high-level study of fundamental combinatorial objects, with a particular emphasis on comprehending and disseminating the state-of-the-art theories and techniques developed. The obtained insights shall be applied to obtain new results on existing problems as well as to identify directions and questions for future work.

One of the main goals of STRUCO is to provide a sustainable and reliable structure to help Czech and French researchers cooperate on long-term projects, disseminate the results to students of both countries and create links between these students more systematically. The chosen themes of the project indeed cover timely and difficult questions, for which a stable and significant cooperation structure is needed. By gathering an important number of excellent researchers and students, the LEA will create the required environment for making advances, which shall be achieved not only by short-term exchanges of researchers, but also by a strong involvement of Ph. D students in the learning of state-of-the-art techniques and in the international collaborations.

STRUCO is a natural place to federate and organize these many isolated collaborations between our two countries. Thus, the project would ensure long-term cooperations and allow young researchers (especially PhD students) to maintain the fruitful exchanges between the two countries in the future years, in a structured and federated way.

## 9.4. International Initiatives

### 9.4.1. Inria Associate Teams Not Involved in an Inria International Labs

Carole Delporte-Gallet and Hugues Fauconnier are members of the Inria-MEXICO Equipe Associée LiDiCo (At the Limits of Distributed Computability, <https://sites.google.com/site/lidicoequipeassociee/>).

### 9.4.2. Inria International Partners

#### 9.4.2.1. Informal International Partners

Ofer Feinerman (Physics department of complex systems, Weizmann Institute of Science, Rehovot, Israel), is a team member in Amos Korman's ERC project DBA. This collaboration has been formally established by signing a contract between the CNRS and the Weizmann Institute of Science, as part of the ERC project.

Rachid Guerraoui (School of Computer and Communication Sciences, EPFL, Switzerland) maintains an active research collaboration with Gang team members (Carole Delporte, Hugues Fauconnier).

Sergio Rajsbaum (UNAM, Mexico) is a regular collaborator of the team, also involved formally in a joint French-Mexican research project (see next subsection).

Boaz Patt-Shamir (Tel Aviv University, Israel) is a regular collaborator of the team, also involved formally in a joint French-Israeli research project (see next subsection).

Lalla Moutadib, PhD student at University of Toronto, directed by Alan Borodin and Derek Corneil but also informally by Michel Habib. 2 visits in 2018 in our group. She got her PhD in september 2018. See <https://tspace.library.utoronto.ca/handle/1807/92081>.

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

- Sergio Rajsbaum ( UNAM Mexico) - April 1 to June 30.
- Giuliano Losa ( UCLA USA)- May 17 to May 30.

### 9.5.2. Visits to International Teams

- Carole Delporte and Hugues Fauconnier have visited Sergio Rajsbaum at UNAM Mexico - September 2 to September 14.

## INFINE-POST Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### 7.1.1. Equipex FIT:

**Participants:** Cedric Adjih, Emmanuel Baccelli, Alexandre Abadie [SED - Inria], Ichrak Amdouni [Ecole Nationale d'Ingénieurs de Sousse & CRISTAL].

**Partners:** Inria (Lille, Sophia-Antipolis, Grenoble), INSA, UPMC, Institut Telecom Paris, Institut Télécom Evry, LSIIT Strasbourg.

FIT (Future Internet of Things) aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It provides this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project gives french internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the future internet. FIT was one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Équipements d'Excellence" (Equipex) research grant program, in 2011.

One component of the FIT platform is the sets of IoT-LAB testbeds (see [the IoT-LAB web site](#)). These were motivated by the observation that the world is moving towards an "Internet of Things", in which most communication over networks will be between objects rather than people.

The Infine team is more specifically managing the FIT IoT-LAB site formerly at Rocquencourt, which recently moved to Saclay (on-going re-deployment), and is participating in the deployment of an additional IoT-lab testbed in Berlin (at Freie Universitaet Berlin).

### 7.1.2. ANR

The team has submitted three PRC ANR projects: two projects for the CE25, i.e., on "Réseaux de communication multi-usages, infrastructures de hautes performances, sciences et technologies logicielles" and one for the CE35, i.e., on "Révolution numérique : rapports au savoir et à la culture".

## 7.2. European Initiatives

### 7.2.1. H2020 Projects

#### 7.2.2. AGILE (H2020 project)

**Participants:** Emmanuel Baccelli, Cedric Adjih.

Program: H2020 ICT-30-2015 Topic: Internet of Things and Platforms for Connected Smart Objects

Project acronym: AGILE

Project title: Adoptive Gateways for dIverse muLtiiple Environments

Duration: 2015-2018

Coordinator: Emmanuel Baccelli

Other partners: Canonical (UK), Eclipse IoT Foundation (IE), Mobistar (BE), Libelium (ES), Startupbootcamp IoT (SP), CREATE-NET (IT), iMinds (BE), Atos (SP), Rulemotion (UK), Jolocom (DE), Passau University (DE), Sky-Watch (DN), BioAssist (GR), Graz Technical University (AT), Eurotech (IT), IoTango (US).

Abstract: The AGILE project is a 3-year H2020 project started in January 2016, which will deliver an integrated framework of open source tools and platforms that interoperate for enabling the delivery of adaptive, self-configurable and secure IoT elements (both software and hardware) that can be utilized in a variety of scenarios. Such tools target actors with heterogeneous skills, including entrepreneurs, researchers, and individuals, aiming to enable the realization of IoT applications respecting user privacy and data ownership.

## 7.3. International Initiatives

### 7.3.1. Inria Associate Teams Not Involved in an Inria International Labs

#### 7.3.1.1. EMBRACE

Title: Leveraging Human Behavior and Uncertainty in 5G Networks to Build Robust Resource Allocation and Services Orchestration Models

International Partners (Institution - Laboratory - Researcher):

UTFPR (Brazil) - Departamento Acadêmico de Informática (DAINF) Curso de Pós-Graduação em Engenharia Elétrica e Informática Industrial (CPGEI) - Anelise Munaretto

UFG (Brazil) - Institute of Computational Mathematics and Scientific / Engineering Computing - Kleber Vieira Cardoso

UFMG (Brazil) - Dpt of Statistics - Antonio A. F. Loureiro

Start year: 2017

See also: <https://team.inria.fr/embrace/>

Abstract: EMBRACE propose une architecture novatrice pour gérer des ressources et des services opérationnels hétérogènes. EMBRACE se concentre sur les défis scientifiques liés des ensembles de données collectées dans le monde réel et décrivant le comportement du réseau des utilisateurs. En particulier, EMBRACE exploite la modélisation du comportement humain en termes de mobilité, de demande de contenu, d'intérêts communs et des interactions entre-utilisateurs. En construisant des modèles d'allocation des ressources tenant compte de l'utilisateur, EMBRACE a pour objectif de diminuer l'incertitude et mieux cerner les profils humains dans les réseaux 5G. La communication D2D sera également utilisée comme service opérationnel pour gérer la croissance du trafic mobile en libérant des ressources des réseaux cellulaires, sans augmenter les coûts. La nouveauté de l'architecture réside dans les algorithmes conçus qui exploiteront les caractérisations tirés de l'analyse du comportement des utilisateurs, l'hétérogénéité du réseau, et de l'incertitude. L'évaluation par simulation et l'émulation sera également l'un des thèmes clés. Enfin, les équipes concernées (Inria Infine, UFMG, UFG, UTFPR) ont un long historique de coopération sur ces thèmes.

### 7.3.2. Inria International Partners

#### 7.3.2.1. Declared Inria International Partners

1. Renewed IOTPUSH collaboration with Freie Universitaet Berlin around the long-term stay of Emmanuel Baccelli in Berlin, on research topics about the Internet of Things, RIOT and Information-Centric Networking.

#### 7.3.2.2. Informal International Partners

1. On-going collaboration with Freie Universitaet Berlin and Hamburg University of Applied Science around RIOT.
2. Informal collaborations with UIUC and UMass.
3. Informal collaborations with ENSI Tunis and Sesame Tunis.
4. On-going strong collaboration with Sapienza University of Rome, Italy.
5. On-going strong collaboration with CNR Torino, Italy.

6. On-going collaboration with University of Porto, Portugal.
7. On-going collaboration with ENSAE/CNRS, France.
8. On-going collaboration with University of Edinburgh, UK.
9. On-going collaboration with Boston University, US.

### 7.3.3. Participation in Other International Programs

#### 7.3.3.1. Indo-French project

The Inria teams Infine and Eva are part of the "D2D Communication for LTE Advanced Cellular Network" , a project funded by the Indo-French Centre for the Promotion of Advanced Research (CEFIPRA). With industrial partners, and also with Indian partners, this project is focusing on the evolution of cellular networks towards 5G: this includes exploration of device-to-device (D2D) communication, and more generally IoT communication in a cellular context. Research directions include efficient access for IoT devices (massive numbers of devices with low volume communication); combination of random access protocols/error coding/physical layer ; efficient neighbor discovery, ....

#### 7.3.3.2. STIC AmSud MOTIf 2017

**Participant:** Aline Carneiro Viana.

Program: STIC AmSud

Project title: Mobile phone sensing of human dynamics in techno-social environment

Duration: 2017-2019

Coordinators: Marton Karsai (ENS/Inria) and Jussara M. Almeida (UFMG) and Alejo Salles (Univ. of Buenos Aires)

Abstract: Information and Communication Technology (ICT) is becoming increasingly social, as demonstrated by the multitude of emerging technologies and technology platforms that facilitate social interactions, taking place as communication via telephone, text message, email, online social networks etc. At the same time, our social activities are increasingly embedded in the ICT environments that enable and enhance our ability to transact, share experiences, and maintain social relationships. One of the best ways to explore these developments is through the mining and analysis of data, which are collected through mobile phones and allow us to investigate how individuals act when embedded in a technology-enabled environment. The MOTIf project builds on the analysis and modeling of geo-localized temporally detailed but fully anonymised mobile phone call networks. These datasets allow us to address the two scientific objectives about spatiotemporal patterns of service usage of anonymised individuals to learn when, where, and what people are doing; and about the fine-grained sociodemographic structure of society and its effect on the the individual social behaviour. In other words our goal in general is to understand how individuals behave in a dynamic techno-social environment.

## 7.4. International Research Visitors

### 7.4.1. Visits of International Scientists

**Prof. Antonio F. Loureiro** is a Visiting Researcher at Infine for 3 months, under the *DigiCosme Visiting Professor* funding. He worked with Aline C. Viana and the internship Joao Batista Borges on the inference of motifs from daily human mobility. He is also the Brazilian coordinator of the EMBRACE Inria associate team. He will give a series of lectures on "What can a mobility trace tell us?".

#### 7.4.1.1. Internships

**Joao Batista Borges** visited us for 2 weeks on October 2018 and will return on January 2019. The visits enter in the context of EMBRACE associated team. He work with Aline C. Viana and Antonio Loureiro on the extraction of motifs of mobility patterns of individuals that, when merged together, describe their daily motion and can be used to enhance mobility prediction.

**Diego Madariaga Roman** did an internship of 3 months at our team (Sep-Nov 2018). He work with Aline C. Viana, Marco Fiore and Panagiota Katsikouli on adaptive sampling frequency of human mobility.

**Lucas Santos** did an internship of 5 months at our team (May-Nov 2018), in the context of EMBRACE associated team. He work with Aline C. Viana and Pedro Olmo on the investigation of causalities in habits of human visits.

## **7.4.2. Visits to International Teams**

### *7.4.2.1. Research Stays Abroad*

**Emmanuel Baccelli** is Visiting Professor at Freie Universitaet (FU) Berlin, within the context of the formal collaboration IOTPUSH with this university on research topics about the Internet of Things, RIOT and Information-Centric Networking.

## Neo Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

MYDATA (Sept. 2018 - Nov. 2020) This is a research project in cooperation with two other labs (LJAD and GREDEG) from Univ. Côte d'Azur to study how to achieve privacy through obfuscation. The project is funded by IDEX UCA<sup>JEDI</sup> Academy 1 on "Networks, Information and Digital society."

## 9.2. National Initiatives

### 9.2.1. PIA ANSWER

**Participants:** Konstantin Avrachenkov, Abhishek Bose.

Project Acronym: ANSWER

Project Title: Advanced aNd Secured Web Experience and seaRch

Coordinator: QWANT

Duration: 15 November 2017 – 31 December 2020

Others Partners: Inria Project-Teams WIMMICS, INDES, COFFEE

Abstract: ANSWER is a joint project between QWANT and Inria, funded by the French Government's initiative PIA "Programme d'Investissement d'Avenir".

The aim of the ANSWER project is to develop the new version of the search engine <http://www.qwant.com> by introducing radical innovations in terms of search criteria as well as indexed content and security. This initiative is a part of the Big Data Big Digital Challenges field, since a Web search engine deals with large volumes of heterogeneous and dynamic data.

Of the five characteristics of big data, the ANSWER project will focus more particularly on the aspects of Velocity in terms of near real-time processing of results, and Variety for the integration of new indicators (emotions, sociality, etc.) and meta-data. The Volume, Value and Veracity aspects will necessarily be addressed jointly with these first ones and will also be the subject of locks, especially on the topics of crawling and indexing.

This registration of the search engine in the Big Data domain will only be reinforced by developments in the Web such as the Web of data, and generally by the current trend to integrate the Web of increasingly diverse, rich and complex resources.

## 9.3. European Initiatives

### 9.3.1. Collaborations in European Programs, Except FP7 & H2020

**Participant:** Konstantin Avrachenkov.

Program: EU COST

Project acronym: COSTNET

Project title: European Cooperation for Statistics of Network Data Science

Duration: May 2016 - April 2020

Coordinator: Ernst Wit (NL), Gesine Reinert (UK)

Other partners: see [http://www.cost.eu/COST\\_Actions/ca/CA15109](http://www.cost.eu/COST_Actions/ca/CA15109)

Abstract: A major challenge in many modern economic, epidemiological, ecological and biological questions is to understand the randomness in the network structure of the entities they study: for example, the SARS epidemic showed how preventing epidemics relies on a keen understanding of random interactions in social networks, whereas progress in curing complex diseases is aided by a robust data-driven network approach to biology.



Although analysis of data on networks goes back to at least the 1930s, the importance of statistical network modelling for many areas of substantial science has only been recognized in the past decade. The USA is at the forefront of institutionalizing this field of science through various interdisciplinary projects and networks. Also in Europe there are excellent statistical network scientists, but until now cross-disciplinary collaboration has been slow.

This Action aims to facilitate interaction and collaboration between diverse groups of statistical network modellers, establishing a large and vibrant interconnected and inclusive community of network scientists. The aim of this interdisciplinary Action is two-fold. On the scientific level, the aim is to critically assess commonalities and opportunities for cross-fertilization of statistical network models in various applications, with a particular attention to scalability in the face of Big Data. On a meta-level, the aim is to create a broad community which includes researchers across the whole of Europe and at every stage in their scientific career and to facilitate contact with stakeholders.

## 9.4. International Initiatives

### 9.4.1. Inria Associate Teams Not Involved in an Inria International Labs

#### 9.4.1.1. MALENA

Title: Machine Learning for Network Analytics

International Partner (Institution - Laboratory - Researcher):

Indian Institute of Technology Bombay (India) - Electrical Communication Engineering - Vivek Borkar

Start year: 2017

See also: <http://www-sop.inria.fr/members/Konstantin.Avratchenkov/MALENA.html>

In the past couple of decades network science has seen an explosive growth, enough to be identified as a discipline of its own, overlapping with engineering, physics, biology, economics and social sciences. Much effort has gone into modelling, performance measures, classification of emergent features and phenomena, etc, particularly in natural and social sciences. The algorithmic side, all important to engineers, has been recognised as a thrust area (e.g., two recent Nevanlinna Prize (J. Kleinberg 2006 and D. Spielman 2010) went to prominent researchers in the area of network analytics). Still, in our opinion the area is yet to mature and has a lot of uncharted territory. This is because networks provide a highly varied landscape, each flavour demanding different considerations (e.g., sparse vs dense graphs, Erdős-Rényi vs planted partition graphs, standard graphs vs hypergraphs, etc). Even adopting existing methodologies to these novel situations is often a nontrivial exercise, not to mention many problems that cry out for entirely new algorithmic paradigms. It is in this context that we propose this project of developing algorithmic tools, drawing not only upon established as well as novel methodologies in machine learning and big data analytics, but going well beyond, e.g., into statistical physics tools.

#### 9.4.1.2. THANES

Title: Theory and Application of Network Science

International Partner (Institution - Laboratory - Researcher):

Universidade Federal do Rio de Janeiro (Brazil) - Department of Computer and Systems Engineering (PESC/COPPE) - Daniel Ratton Figueiredo, Edmundo De Souza e Silva

Universidade Federal do Rio de Janeiro (Brazil) - Math institute - Giulio Iacobelli

Purdue Univ. (USA) - Computer Science Department - Bruno Ribeiro

Start year: 2017

See also: <https://team.inria.fr/thanes/>

We plan move beyond the study of a single network and focus on multiplex networks, i.e. multiple interacting networks. Multiplex networks have recently raised as “one of the newest and hottest themes in the statistical physics of complex networks.” They originate from the observation that many complex systems, ranging from living organisms to critical infrastructures, operate through multiple layers of distinct interactions among their constituents. In particular we plan to work on the co-evolution of the different layers of a multiplex network and on how epidemics spread in such setting.

## **9.4.2. Inria International Partners**

### *9.4.2.1. Informal International Partners*

NEO has continued collaborations with researchers from GERAD, Univ. Montreal (Canada), Flinders Univ. (Australia), Univ. of South Australia (Australia), National Univ. of Rosario (Argentina), Technion - Israel Institute of Technology (Israel), Univ. of Arizona (USA), Univ. of Illinois at Urbana-Champaign (USA), Univ. of Liverpool (UK), Univ. of Massachusetts at Amherst (USA), Univ. of Florence (Italy), Univ. of Palermo (Italy), Univ. of Twente (The Netherlands), Saint Petersburg State Univ. (Russia), Petrozavodsk State Univ. (Russia) and Ghent Univ. (Belgium).

## **9.4.3. Participation in Other International Programs**

### *9.4.3.1. Indo-French Center of Applied Mathematics (IFCAM)*

NEO is involved in the IFCAM with the MALENA project. See §9.4.1.1 .

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

#### *9.5.1.1. Professors/Researchers*

Damiano Carra, Date: 23-27 April, Institution: Univ. of Verona (Italy)  
 Daniel Figueiredo, Date: 9-13 July, Institution: UFRJ (Brazil)  
 Giulio Iacobelli, Date: 9-13 July, Institution: UFRJ (Brazil)  
 Nikhil Karamchandani, Date: 11-15 June, Institution: IIT Bombay (India)  
 Nelly Litvak, Date: 2-14 July, Institution: Univ. of Twente (Netherlands)  
 Vladimir Mazalov, Date: 16-17 July, Institution: Petrozavodsk State Univ. (Russia)  
 Daniel Sadoc Menasché, Date: 31 August - 6 September, Date: 8-12 December, Institution: UFRJ (Brazil)  
 Bruno Ribeiro, Date: 9-18 July, Institution: Purdue Univ. (USA)  
 Vikas Vikram Singh, Date: 1-8 June, Institution: IIT Delhi (India)  
 Rajesh Sundaresan, Date: 15-26 January, Institution: IISc Bangalore (India)

#### *9.5.1.2. Postdoc/PhD Students*

Víctor Bucarey López, Date: 18-19 October, Institution: Université Libre de Bruxelles (Belgium)  
 Yuzhou Chen, Date: 7 June - 6 September, Institution: Southern Methodist Univ. (USA)  
 Eduardo Hargreaves, Date: 31 August - 6 September, Institution: UFRJ (Brazil)  
 Mayank Kakodkar, Date: 9-13 July, Institution: Purdue Univ. (USA)  
 Mikhail Kamalov, Date: 1 September - 30 November, Institution: Univ. St. Petersburg (Russia)  
 Maria Kleshnina, Date: 2-8 July, Institution: Queensland Univ. (Australia)  
 Suhail Mohamad Shah, Date: 18 June - 14 August, Institution: IIT Bombay (India)

### **9.5.2. Internships**

Note: UNS is the Univ. Nice Sophia-Antipolis.

- Nour Elhouda Ayari, Date: 4 April - 8 October, Institution: Tunis SUP'COM, Supervisors: E. Altman and M. Haddad (UAPV), Subject: Speed Estimation in Mobile Networks
- Gianmarco Calbi, Date: 15 March - 31 August, Institution: Master RIF, UNS, Supervisor: G. Neglia, Subject: Asynchronous Approximate Distributed Computation for Machine Learning
- Yu-Zhen Chen, Date: 1 June - 31 July, Institution: The Chinese Univ. of Hong Kong, Supervisor: K. Avrachenkov, Subject: Application of deep learning for graphlet statistics estimation
- Kostantinos Dermentzis, Date: 20 November 2017 - 19 May 2018, Institution: National Technical Univ. of Athens (Greece), Supervisor: G. Neglia, Subject: Caching Policies with Partial Future Knowledge: the case of Spark
- Vladyslav Fedchenko, Date: 1 March - 31 August, Institution: Master IFI Ubinet, UNS, Supervisor: G. Neglia, Subject: Estimating Content Popularity in Cache Networks
- Pulkit Goel, Date: 15 May - 31 July, Institution: IIT New Delhi (India), Supervisor: K. Avrachenkov, Subject: Application of Deep Learning for Recovering Graph Motifs
- Nisha Mishra, Date: 5 February - 20 July, Institution: ENSIMAG, Supervisor: E. Altman and C. Touati, Subject: Routing Games
- Utsav Sen, Date: 15 May - 31 July, Institution: IIT New Delhi (India), Supervisor: K. Avrachenkov, Subject: Asynchronously distributed and randomized methods for computing network centralities
- Adeel Siddiqui, Date: 1 October 2018 - 30 September 2019, Institution: Univ. Côte d'Azur, Supervisor: G. Neglia, Subject: Achieve Web Privacy by Obfuscation
- Xing Yafei, Date: 1 March - 31 August, Institution: Master IFI Ubinet, UNS, Supervisor: K. Avrachenkov, Subject: Distributed Approaches for Graph-based Unsupervised Learning
- Xiawen Zhu, Date: 1 March - 31 August, Institution: Master IFI Ubinet, UNS, Supervisor: K. Avrachenkov, Subject: Distributed Approaches for Graph-based Unsupervised Learning

### 9.5.3. Visits to International Teams

#### 9.5.3.1. Research Stays Abroad

Eitan Altman

- Date: 1-8 March, Institution: Technion (Israel)
- Date: 12-23 April, Institution: Technion and Univ. Tel-Aviv (Israel)
- Date: 10-21 December, Institution: IIT Bombay (India)

Konstantin Avrachenkov

- Date: 29 January - 2 February, Institution: Univ. Liverpool (United Kingdom)
- Date: 21-22 May, Institution: Saint Petersburg State Univ. (Russia)
- Date: 17-18 September, Institution: Univ. Leiden (The Netherlands)
- Date: 19-23 September, Institution: Univ. Twente (The Netherlands)
- Date: 15-18 October, Institution: IIT Bombay (India)

Abhishek Bose

- Date: 19-23 November, Institution: IIT Bombay (India)

Swapnil Dhamal

- Date: 17-18 September, Institution: IISc Bangalore (India)
- Date: 19 September, Company: IBM Research Labs Bangalore (India)

Alain Jean-Marie

- Date: 24 September - 14 October, Institution: Univ. of Montreal (Canada)
- Date: 2-27 November, Institution: National Univ. of Rosario (Argentina)

Giovanni Neglia

- Date: 11-16 November, Institution: Purdue Univ. (USA)
- Date: 3-8 November, Institution: IIT Bombay (India)

## POEMS-POST Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

- ANR project NonlocalDD (*Non-local domain decomposition methods in electromagnetics*)  
Partners: Inria Alpines, Inria POEMS, Inria Magique 3D  
Start: 10/2015. End: 09/2019. Administrator: Inria  
Participants of POEMS: S. Chaillat, P. Joly  
Coordinator: X. Claeys (LJLL, EPI ALPINES)
- ANR project MODULATE (*Modeling lOng-perioD groUnd motions, and assessment of their effects on Large-scale infrAsTructurEs*)  
Partners: ENSTA (UME), Inria POEMS, CentraleSupélec, BRGM, GDS  
Start: 11/2018. End: 10/2021. Administrator: ENSTA  
Participant of POEMS: S. Chaillat  
Coordinator: K. Meza Fajardo (BRGM)

### 9.1.2. DGA

- Contracts between DGA and POEMS:
  - Contract on *inverse problems*  
Participants: L. Bourgeois  
Start: 10/2016. End: 09/2018. Administrator: ENSTA
  - Contract on *boundary element methods and high-frequency problems*  
Participants: E. Lunéville, M. Lenoir, N. Kielbasiewicz.  
Start: 10/2015. End: 2021. Administrator: ENSTA  
*In partnership with F. Alouges and M. Aussal (CMAP, Ecole Polytechnique).*
  - Contract on *the preconditioning of fast BEM solvers*  
Participants: S. Chaillat, F. Amlani  
Start: 10/2017. End: 12/2018. Administrator: ENSTA
- DGA provides partial funding for several PhD students:
  - A. Bera on the *design of invisible obstacles for acoustic and electromagnetic waves* (Start: 10/2016)
  - C. Beneteau on the *asymptotic analysis of time harmonic Maxwell equations in presence of metamaterials* (Start: 10/2017)
  - D. Chicaud on *domain decomposition methods for time-harmonic electromagnetic wave problems with complex media* (Start: 10/2018)

## 9.2. International Initiatives

### 9.2.1. Inria International Partners

#### 9.2.1.1. Informal International Partners

Wilkins Aquino (Duke University, USA)

Juan Pablo Borthagaray (University of Maryland, College Park, USA)

Fioralba Cakoni (University of Rutgers, USA)

Mahadevan Ganesh (Colorado School of Mines, USA)

Camille Carvalho (UC Merced, Merced, USA)  
Christophe Geuzaine (Université de Liège, Belgium)  
Bojan Guzina (University of Minnesota, USA)  
Marcus Grote (Universitaet Basel, Switzerland)  
Jean-François Molinari (EPFL, Lausanne, Switzerland)  
Sergei Nazarov (Saint-Petersburg University, Russia)  
Jerónimo Rodríguez (University of Santiago de Compostela, Spain)  
Adrien Semin (TU Darmstadt, Germany)  
Ricardo Weder (Universidad Nacional Autonoma, Mexico)  
Shravan Veerapaneni (Univ. of Michigan at Ann Arbor, USA)  
Jun Zou (Chinese University of Hong Kong, HK)

### **9.3. International Research Visitors**

#### ***9.3.1. Visits of International Scientists***

- Mahadevan Ganesh (Colorado School of Mines) – July 2018
- Bojan Guzina (University of Minnesota, USA) – Summer 2018, 1 month
- Michael Weinstein (Columbia University, USA) – May-June 2018
- Fedor Bakharev (Saint Petersburg State University, Russia) – July 2018

## RESIST Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

#### 9.1.1.1. ANR BottleNet

**Participants:** Isabelle Chrisment [contact], Thibault Cholez, Vassili Rivron.

- Acronym: BottleNet
- Title: Comprendre et diagnostiquer les dégradations des communications de bout en bout dans l'Internet
- Coordinator: Inria
- Duration: October 2015- March 2018
- Others Partners: Inria Muse, Inria Diana, Lille1 University, Telecom Sud-Paris, Orange, IP-Label.
- Abstract: The Quality of Experience (QoE) when accessing the Internet, on which more and more human activities depend on, is a key factor for today's society. The complexity of Internet services and of users' local connectivity has grown dramatically in the last years with the proliferation of proxies and caches at the core and access technologies at the edge (home wireless and 3G/4G access), making it difficult to diagnose the root causes of performance bottlenecks. The objective of BottleNet is to deliver methods, algorithms, and software systems to measure end-to-end Internet QoE and to diagnose the cause of the experienced issues. The result can then be used by users, network and service operators or regulators to improve the QoE.

#### 9.1.1.2. ANR Doctor

**Participants:** Thibault Cholez [contact], Xavier Marchal, Daishi Kondo, Olivier Festor.

- Acronym: DOCTOR
- Title: Deployment and securisation of new functionalities in virtualized networking environments
- Coordinator: Orange Labs (Bertrand Matthieu)
- Duration: December 2014-December 2018
- Partners: Orange Labs, Thales, Montimage, UTT and LORIA
- Site: <http://www.doctor-project.org>
- Abstract: The DOCTOR project is an applied research project that advocates the use of virtualized network equipment (Network Functions Virtualization), to enable the co-existence of new Information-Centric Networking stacks (e.g.: Named-Data Networking) with IP, and the progressive migration of traffic from one stack to another while guaranteeing the good security and manageability of the network. Therefore in DOCTOR, the main goals of the project are: (1) the efficient deployment of NDN as a virtualized networking environment; (2) the monitoring and security of this virtualized NDN stack.

### 9.1.1.3. ANR FLIRT

**Participants:** Rémi Badonnel [contact], Olivier Festor, Thibault Cholez, Jérôme François, Abdelkader Lahmadi, Laurent Andrey.

- Acronym: FLIRT
- Title: Formations Libres et Innovantes Réseaux et Télécoms
- Coordinator: Institut Mines-Télécom (Pierre Rolin)
- Duration: January 2016-January 2020
- Others Partners: Institut Mines-Télécom, Airbus, Orange, the MOOC Agency, Isograd
- Site: <http://flirtmooc.wixsite.com/flirt-mooc-telecom>
- Abstract: FLIRT (Formations Libres et Innovantes Réseaux & Télécom) is an applied research project led by the Institut Mines-Télécom, for a duration of 4 years. It includes 14 academic partners (engineering schools including Telecom Nancy), industrial partners (Airbus, Orange), innovative startups (the MOOC agency, and Isograd), as well as professional or scientific societies (Syntec Numérique, Unetel, SEE). The project is to build a collection of 10 MOOCs (Massive Open Online Courses) in the area of networks and telecommunications, three training programmes based on this collection, as well as several innovations related to pedagogical efficiency (such as virtualization of practical labs, management of student cohorts, and adaptive assessment). The RESIST team is leading a working group dedicated to the building and operation of a MOOC on network and service management. This MOOC covers the fundamental concepts, architectures and protocols of the domain, as well as their evolution in the context of future Internet (e.g. network programming, flow monitoring). It corresponds to a training program of 5 weeks. The main targeted skills are to understand the challenges of network and service management, to know the key methods and techniques related to this area, and to get familiar with the usage and parameterization of network management solutions. We have also performed the maintenance of the different contents of the MOOC, in preparation of the second session, which will start January 2019.

### 9.1.1.4. Inria-Orange Joint Lab

**Participants:** Jérôme François [contact], Rémi Badonnel, Olivier Festor, Maxime Compastie, Paul Chaignon.

- Acronym: IOLab
- Title: Inria - Orange Joint Laboratory
- Duration: September 2015 - August 2020
- Abstract: The challenges addressed by the Inria-Orange joint laboratory relate to the virtualization of communication networks, the convergence between cloud computing and communication networks, and the underlying software-defined infrastructures. Our work concerns in particular monitoring methods for software-defined infrastructures, and management strategies for supporting software-defined security in multi-tenant cloud environments.

## 9.1.2. Technological Development Action (ADT)

### 9.1.2.1. ADT SCUBA

**Participants:** Abdelkader Lahmadi [Contact], Thomas Lacour, Frédéric Beck.

- Acronym: CUBA
- Duration: January 2018-January 2020
- Abstract: The goal of this ADT is to develop a tool suite to evaluate the security of industrial and general public IoT devices in their exploitation environment. The Tool suite relies on a set of security probes to collect information through passive and active scanning of a running IoT device in its exploitation environment to build its Security Knowledge Base (SKB). The knowledge base contains all relevant information of the device regarding its network communications, the enumeration of its used hardware and software, the list of its known vulnerabilities in the CVE format associated to their Common Weakness Enumeration (CWE) and Common Attack Pattern Enumeration and Classification (CAPEC) descriptions. The collected information is used to evaluate the devices associated with their usage scenarios and to identify intrusion chains in an automated way.

### 9.1.3. FUI

#### 9.1.3.1. FUI PACLIDO

**Participants:** Abdelkader Lahmadi [contact], Mingxiao Ma, Isabelle Chrisment, Jérôme François.

- Acronym: PACLIDO
- Title: Lightweight Cryptography Protocols and Algorithms for IoT (Protocoles et Algorithmes Cryptographiques Légers pour l'Internet des Objets)
- Coordinator: ADS (Airbus Defence and Space)
- Duration: September 2017- August 2020
- Others Partners: Sophia Conseil, Université de Limoges, Cea tech, Trusted Objects, Rtone, Saint Quentin En Yvelines.
- Abstract: The goal of PACLIDO is to propose and develop lightweight cryptography protocols and algorithms to secure IoT communications between devices and servers. The implemented algorithms and protocols will be evaluated in multiple use cases including smart home and smart city applications. PACLIDO develops in addition an advanced security monitoring layer using machine learning methods to detect anomalies and attacks while traffic is encrypted using the proposed algorithms.

#### 9.1.3.2. FUI HUMA

**Participants:** Jérôme François [contact], Soline Blanc, Isabelle Chrisment, Quang Vinh Dang, Abdelkader Lahmadi, Giulia de Santis.

- Acronym: HuMa
- Title: L'HUmain au cœur de l'analyse de données MASSives pour la sécurité
- Coordinator: Intrinsec
- Duration: September 2015-March 2018
- Others Partners: ICube, Idemia, Airbus Defence and Space, Wallix, Sydo.
- Abstract: HuMa targets the analysis of Advanced Persistent Threats. APT are long and complex attacks which thus cannot be captured with standard techniques focused on short time windows and few data sources. Indeed, APTs may be several months long and involve multiple steps with different types of attacks and approaches. The project will address such an issue by leveraging data analytics and visualization techniques to guide human experts, which are the only ones able to analyze APT today, rather than targeting a fully automated approach.

### 9.1.4. Inria Project Lab

#### 9.1.4.1. IPL BetterNet

**Participants:** Isabelle Chrisment [contact], Thibault Cholez, Vassili Rivron.

- Acronym: BetterNet
- Coordinator: RESIST (Isabelle Chrisment)
- Duration: October 2018-August 2023
- Others Partners: Inria MiMove, Inria Diana, Inria Spirals, Inria Dionysos, ENS-ERST and IP-Label
- Site: <https://project.inria.fr/betternet>
- Abstract: BetterNet's goal is to build and deliver a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. We will propose new user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Tools, models and algorithms will be provided to collect data that will be shared and analyzed to offer valuable service to scientists, stakeholders and the civil society.



#### 9.1.4.2. IPL Discovery

**Participant:** Lucas Nussbaum [contact].

- Partners: Orange, RENATER
- Abstract: To accommodate the ever-increasing demand for Utility Computing (UC) resources, while taking into account both energy and economical issues, the current trend consists in building larger and larger Data Centers in a few strategic locations. Although such an approach enables UC providers to cope with the actual demand while continuing to operate UC resources through a centralized software system, it is far from delivering sustainable and efficient UC infrastructures for future needs.

The DISCOVERY initiative aims at exploring a new way of operating Utility Computing (UC) resources by leveraging any facilities available through the Internet in order to deliver widely distributed platforms that can better match the geographical spread of users as well as the ever increasing demand. Critical to the emergence of such locality-based UC (also referred as Fog/Edge Computing) platforms is the availability of appropriate operating mechanisms. The main objective of DISCOVERY is to design, implement, demonstrate and promote a new kind of Cloud Operating System (OS) that will enable the management of such a large-scale and widely distributed infrastructure in an unified and friendly manner.

## 9.2. European Initiatives

### 9.2.1. Fed4Fire+ (2017-2022)

Title: Federation for FIRE Plus

Program: H2020

Duration: January 2017 - December 2021

Coordinator: Interuniversitair Micro-Electronicacentrum Imec VZW

Partners:

Universidad de Malaga; National Technical University of Athens - NTUA; The Provost, Fellows, Foundation Scholars & the other members of board of the College of the Holy & Undivided Trinity of Queen Elizabeth Near Dublin; Ethniko Kentro Erevnas Kai Technologikis Anaptyxis; GEANT Limited; Institut Jozef Stefan; Mandat International Alias Fondation Pour la Cooperation Internationale; Universite Pierre et Marie Curie - Paris 6; Universidad De Cantabria; Fundacio Privada I2CAT, Internet I Innovacio Digital A Catalunya; EURESCOM-European Institute For Research And Strategic Studies in Telecommunications GMBH; Nordunet A/S; Technische Universitaet Berlin; Instytut Chemii Bioorganicznej Polskiej Akademii Nauk; Fraunhofer Gesellschaft zur Foerderung Der Angewandten Forschung E.V.; Universiteit Van Amsterdam; University of Southampton; Martel GMBH; Atos Spain SA; Institut National de Recherche en Informatique et automatique.

Inria contact: David Margery (for RESIST: Lucas Nussbaum)

Fed4FIRE+ is a successor project to Fed4FIRE. In Fed4FIRE+, we more directly integrate Grid'5000 into the wider eco-system of experimental platforms in Europe and beyond using results we developed in Fed4FIRE. We will also provide a generalised proxy mechanisms to allow users with Fed4FIRE identities to interact with services giving access to different testbeds but not designed to support Fed4FIRE identities. Finally, we will work on orchestration of experiments in a federation context.

### 9.2.2. SecureIoT

Title: Predictive Security for IoT Platforms and Networks of Smart Objects

Duration: 3 years

Coordinator: INTRASOFT International SA

Partners:

Fujitsu Technology Solutions GMBH; Atos Spain S.A.; Siemens SRL; Singularlogic S.A.; IDIADA Automotive Technology SA; P@SSPORT Holland B.V.; UBITECH LIMITED; Innovation Sprint Sprl; DWF Germany Rechtsanwalts-gesellschaft mbH; LuxAI S.A.; Institut National de Recherche en Informatique et automatique; it's OWL Clustermanagement GmbH; Research and Education Laboratory in Information Technologies – Athens Information Technology (AIT).

Inria contact: Jérôme François

SecureIoT is a joint effort of global leaders in IoT services and IoT cybersecurity to secure the next generation of dynamic, decentralized IoT systems, that span multiple IoT platforms and networks of smart objects, through implementing a range of predictive IoT security services. SecureIoT will integrate its security services in three different application scenarios in the areas of: Digital Automation in Manufacturing (Industry 4.0), Socially assistive robots for coaching and healthcare and Connected cars and Autonomous Driving.

Emerging cross-platform interactions and interactions across networks of smart objects require more dynamic, scalable, decentralized and intelligent IoT security mechanisms. Such mechanisms are highly demanded by the industry in order to secure a whole new range of IoT applications that transcend the boundaries of multiple IoT platforms, while involving autonomous interactions between intelligent CPS systems and networks of smart objects. In this direction, the main objectives of the project are to: Predict and anticipate the behavior of IoT systems, facilitate compliance to security and privacy regulations and provide APIs and tools for trustworthy IoT solutions.

## 9.3. International Initiatives

### 9.3.1. Inria Associate Teams Not Involved in an Inria International Labs

#### 9.3.1.1. Masdin

Title: MAnagement of Software-Defined INfrastructure

International Partner (Institution - Laboratory - Researcher):

University of Luxembourg (Luxembourg) - SnT (Interdisciplinary Centre for Security, Reliability and Trust) - Radu State

Start year: 2016

See also: <https://project.inria.fr/masdin>

Networking is deeply evolving with the rise of programmability and virtualization. The concept of SDI (Software-Defined Infrastructure) has emerged from SDN (Software-Defined Networking) and NFV (Network Function Virtualization) making thus the configuration of the network highly dynamic and adaptable in real-time. However, new methods and tools have to be defined to properly monitor and configure this type of infrastructure. Current works are mainly limited to applying former approaches but do not exploit the novel capabilities offered by SDI. The goal of the associate team is thus to define methodologies taking benefit of them for an efficient monitoring and use of SDI resources while investigating the security issues it brings.

#### 9.3.1.2. NetMSS

Title: NETwork Monitoring and Service orchestration for Softwarized networks

International Partner (Institution - Laboratory - Researcher):

University of Waterloo (Canada), David R. Cheriton School of Computer Science - Raouf Boutaba

Start year: 2018

See also: <https://team.inria.fr/netmss/>

Evolution towards softwarized networks are greatly changing the landscape in networking. In the last years, effort was focused on how to integrate network elements in cloud-based models. This led to the advent of network function virtualization primarily relying on regular virtualization technologies and on some advances in network programmability. Several architectural models have been proposed and, even if no full consensus has been reached yet, they highlight the major components. Among them, monitoring and orchestration are vital elements in order to ensure a proper assessment of the network conditions (network monitoring) serving as the support for the decision when deploying services (orchestration). With softwarization of networks, these elements can benefit from a higher flexibility but the latter requires new methods to be efficiently handled. For example, monitoring softwarized networks necessitates the collection of heterogeneous information, regarding the network but also cloud resources, from many locations. Targeting such a holistic monitoring will then support better decision algorithms, to be applied in a scalable and efficient manner, taking advantage of the advanced capabilities in terms of network configuration and programmability. In addition, real-time constraints in networking are very strong due to the transient nature of network traffic and are faced with high throughputs, especially in data-center networks where softwarization primarily takes place. Therefore, the associate team will promote (1) line-rate and accurate monitoring and (2) efficient resource uses for service orchestration leveraging micro-services.

### **9.3.2. Participation in Other International Programs**

#### **9.3.2.1. ThreatPredict**

- Title: ThreatPredict, From Global Social and Technical Big Data to Cyber Threat Forecast
- Coordinator: Inria
- Duration: December 2017 - November 2020
- Others Partners: International University of Rabat (IUR), Carnegie Mellon University
- Funding: North Atlantic Treaty Organization
- Abstract: Predicting attacks can help to prevent them or at least reduce their impact. Nowadays, existing attack prediction methods make accurate predictions only hours in advance or cannot predict geo-politically motivated attacks. ThreatPredict aims to predict different attack types days in advance. It develops machine-learning algorithms that capture the spatio-temporal dynamics of cyber-attacks and global social, geo-political and technical events. Various sources of information are collected, enriched and correlated such as honeypot data, darknet, GDELT, Twitter, and vulnerability databases. In addition to warning about attacks, this project will improve our understanding of the effect of global events on cyber-security.

## **9.4. International Research Visitors**

### **9.4.1. Visits of International Scientists**

#### **9.4.1.1. Internships**

- Visit of Anthony (Anthony) Ang in RESIST, Ms Student, from June 4 to August 26 2018, new scheduler for micro-service based VNF [6]
- Visit of Shihabur Chowdhury in RESIST, PhD Student, from June 4 to August 26 2018, new scheduler for micro-service based VNF [6], intelligent traffic engineering

## SOCRATE Project-Team

# 8. Partnerships and Cooperations

## 8.1. National Initiatives

### 8.1.1. Equipex FIT- Future Internet of Things

The FIT project is a national equipex (*équipement 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.

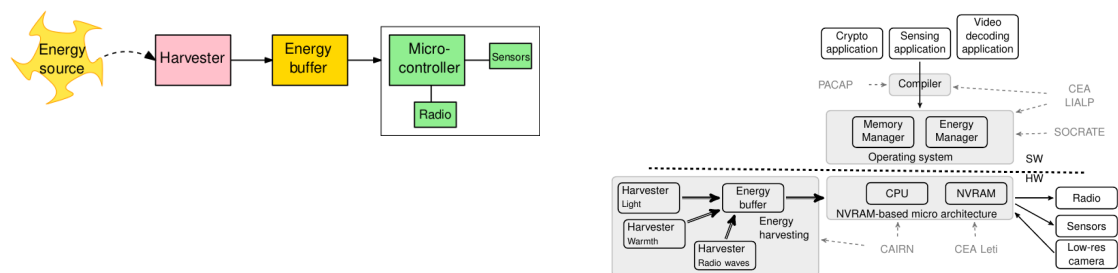


Figure 4. Example of system targeted by the ZEP project on the left, and on the right: the ZEP research program.

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-electronics and FPGA. The objective 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 building 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 Arbust - “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 resources 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), Bogotá, 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.