

*Inria*

RESEARCH CENTER

FIELD

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

Activity Report 2019

# **Section Partnerships and Cooperations**

Edition: 2020-03-21



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## COAST Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

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

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

Partners: TVPaint Development, Inria

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.

## 9.2. National Initiatives

### 9.2.1. *OpenPaas NG (2015–2019)*

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

Partners: Linagora, XWiki, Nexedi, Université de Lorraine, LIX.

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

This project is funded 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 is responsible for 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.

## 9.3. International Research Visitors

### 9.3.1. *Visits of International Scientists*

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

### 9.3.2. *Research Stays Abroad*

François Charoy was invited by Heiko Ludwig to spend 3 month (March-May 2019) at IBM Almaden Research Center in San Jose, CA. He worked on P2P Federated Learning. A replication protocol has been designed that is under evaluation thanks to a shared internship. It also led to an ANR submission on the topic with a french company.

François Charoy was invited by Akhil Kumar to spend 6 weeks at Penn State University to collaborate to on a long transaction protocol implementation on a permissioned blockchain. This work is based on previous work done in the Coast project-team. It is also ongoing and has led to the submission of a project to a proposal submission with a local startup.

## CTRL-A Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. 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 currently funding two “alternance” student positions and a PhD position might be provided in September 2020 and supervised by Stephane Mocanu.

## 9.2. National Initiatives

### 9.2.1. 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, InPixaI.

In Ctrl-A, it has been 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.

### 9.2.2. 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.

### 9.2.3. IRT Nanoelec Pulse program

The Pulse program aims the development for SCADA cybersecurity demonstrators. It has funded a Master grant in 2019 and two master grants in 2020. A PhD position was also approved for September 2020 and it will be co-supervised by Stéphane Mocanu

### 9.2.4. 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).

### 9.2.5. 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).

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

Program: ECSEL

Project acronym: CPS4EU

Project title: Cyber Physical Systems for Europe

Duration: july 2019 - june 2022

Coordinator: VALEO

Other partners: 38 participants

Abstract: CPS4EU proposes to address technical issues and organizational issues in an integrated way. Hence, CPS4EU promotes a high level of sharing, so that an operational ecosystem, with adequate skills and expertise all along the value chain can enable, at the end of the project, the European industry to lead strategic markets based on CPS technologies.

In this project, the Ctrl-A team is involved in WP4 and WP9 mainly, on topics of Software Architectures for Self-Adaptive systems in CPS, and our main industrial collaboration is with RTE.

## 9.4. International Initiatives

### 9.4.1. 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 9th Workshop of the JLESC at Knoxville, TE, USA, in April 2019, and visited ANL in Chicago.

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>

### 9.4.2. Inria International Partners

#### 9.4.2.1. 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 Project-Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### 7.1.1. ANR

#### 7.1.1.1. AdeCoDS (2019–2023)

Title: Programming, verifying, and synthesizing Adequately-Consistent Distributed Systems (Ade-CoDS).

Members: Université de Paris (project leader), Sorbonne-Université LIP6, ARM, Orange.

Funding: The total funding of AdeCoDS from ANR is 523 471 euros, of which 162 500 euros for Delys.

Objectives The goal of the project is to provide a framework for programming distributed systems that are both correct and efficient (available and performant). The idea is to offer to developers a programming framework where it is possible, for a given application, (1) to build implementations that are correct under specific assumptions on the consistency level guaranteed by the infrastructure (e.g., databases and libraries of data structures), and (2) to discover in a systematic way the different trade-offs between the consistency level guaranteed by the infrastructure and the type and the amount of synchronization they need to use in their implementation in order ensure its correctness. For that, the project will develop a methodology based on combining (1) automated verification and synthesis methods, (2) language-based methods for correct programming, and (3) techniques for efficient system design.

#### 7.1.1.2. ESTATE - (2016–2021)

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.

#### 7.1.1.3. 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. 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.

#### *7.3.1.2. 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.

#### 7.3.1.3. *STIC Amsud*

Title: ADMITS - Architecting Distributed Monitoring and Analytics for IoT in Disaster Scenarios

International Partners (Institution - Laboratory - Researcher):

Universidad Diego Portales and Universidad Tecnica Federico Santa Maria (Chile)

Universidade Federal de Uberlandia, Universidade Federal do Rio Grande do Norte and Instituto Federal Sul-Rio-Grandense (Brazil)

Universidad de la Republica (Uruguay)

Duration: 2019 - 2020

Start year: 2019

Develop algorithms, protocols and architectures to enable a decentralized distributed computing environment to provide support for failure monitoring and data analytics in Internet-of-Things (IoT) disaster scenarios.

## 7.4. International Research Visitors

### 7.4.1. *Visits of International Scientists*

- AMOZARRAIN Ugaitz, PhD Student, University of San Sebastian (Spain), Feb. 2019 - Mar. 2019
- CORREA Leonardo, PhD Student, Federal University of Rio Grande do Sul (Brazil), Jan 2019 - Oct. 2019
- GOUVEIA LIMA Luan Teylo, PhD Student, UFF (Brazil), Sep. 2019-Mar. 2020
- PELC Andrzej, Professor, Université du Québec en Outaouais (Canada), Sep. 2019 - Oct. 2019
- DIEUDONNE Yoann, Associate Professor, Amiens Univ., Sep. 2019-Oct. 2019
- LONG Darrell, Professor, Univ. California Santa Cruz (USA), Feb. 2019 - Mar. 2019
- PARIS Jehan-François, Professor, University of Houston (USA), Feb. 2019 - Mar. 2019

### 7.4.2. *Visits to International Teams*

Marc Shapiro spent three weeks visiting Technical University Kaiserslautern during the Spring.

Luciana Arantes and Pierre Sens have been invited for 10 days at New-York University Shanghai

Luciana Arantes visited the network team at Pontifical Catholic University of Rio de Janeiro - PUC (Brazil)

Luciana Arantes and Pierre Sens visited the computer science department at Universidade Federal Fluminense - UFF (Brazil)

## 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 BetterNet

**Participants:** Renata Teixeira, Vassilis Christophides, Giulio Grassi.

- **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.

#### 9.1.1.2. Inria ADT SocialBus

**Participants:** Valérie Issarny , Rafael Angarita, Nikolaos Georgantas, Ehsan Ahvar , Lior Diler .

- **Name:** SocialBus – *Contributing to the development of SocialBus - A Universal Social Network Bus*
- **Period:** [July 2018 – June 2019 ; November 2019 – October 2020]
- **Partners:** Inria MiMove.

Computer-mediated communication can be defined as any form of human communication achieved through computer technology. From its beginnings, it has been shaping the way humans interact with each other, and it has influenced many areas of society. There exist a plethora of social interaction services enabling computer-mediated social communication (e.g., Skype, Facebook Messenger, Telegram, WhatsApp, Twitter, Slack, etc.). Based on personal preferences, users may prefer a social interaction services rather than another. As a result, users sharing same interests may not be able to interact since they are using incompatible technologies.

To tackle the above interoperability barrier, we propose SocialBus, a middleware solution targeted to enable the interaction via heterogeneous social interaction services. The ADT specifically supports the related implementation through the funding an engineer, toward technology transfer in the mid-term.

The SocialBus software is available under the AGPL open source license at <https://gitlab.inria.fr/usnb/universal-social-network-bus>.

## 9.2. International Initiatives

### 9.2.1. Inria International Labs

**Inria@EastCoast**

Associate Team involved in the International Lab:

#### 9.2.1.1. *HOMENET*

Title: Home network diagnosis and security

International Partner (Institution - Laboratory - Researcher):

Princeton (United States) - Computer Science - Nick Feamster

Start year: 2017

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

Modern households connect a multitude of networked devices (ranging from laptops and smart-phones 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 Muse brings an existing Web-based measurement platform, and expertise in traffic-based profiling and anomaly detection.

#### **Inria@SiliconValley**

Associate Team involved in the International Lab:

#### 9.2.1.2. *MINES*

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

International Partner (Institution - Laboratory - Researcher):

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.

### **9.2.2. Inria International Partners**

#### 9.2.2.1. *Informal International Partners*

- Northeastern University (Prof. David Choffnes): We are working on methods based on active probing to diagnose poor video quality.
- Universidade Federal do Rio de Janeiro, Brazil (Prof. Edmundo Souza e Silva): We are working on characterizing Internet bottlenecks.
- Universidade Federal de Goias, Brazil (Prof. Fabio Costa): We are working on service selection and cloud resource allocation for QoS-aware enactment of service choreographies.

## **9.3. International Research Visitors**

### ***9.3.1. Visits of International Scientists***

Mark Crovella from Boston University was visiting professor at Inria.

### ***9.3.2. Visits to International Teams***

#### *9.3.2.1. Sabbatical programme*

Renata Teixeira is visiting scholar at the Computer Science Department at Stanford University.

#### *9.3.2.2. Research Stays Abroad*

Georgios Bouloukakis was Inria postdoctoral fellow at University of California, Irvine, in the context of the Inria@SiliconValley program.

## Myriads Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

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

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

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 funded the PhD of Anna Giannakou (defended in 2017) and Amir Teshome Wonjiga (defended in 2019). Clément Elbaz is partially funded by the Brittany Regional Council in the PEC framework.

## 8.2. National Initiatives

### 8.2.1. ADEME RennesGrid (2017-2020)

**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.

### 8.2.2. Inria ADT Mc SimGrid (2019-2021)

**Participants:** Ehsan Azimi, Martin Quinson.

The Mc SimGrid technological development action funded by INRIA targets the refactoring of model checker that is integrated to the SimGrid simulation framework. Its software quality should be improved to be on par with the rest of the SimGrid framework. Our ultimate goal is to make this model-checker usable in production, both to assess real-size applications and as a workbench for the researchers designing new techniques and algorithms for the verification of distributed asynchronous applications and algorithms.

The technical actions envisioned for this ADT are the complete re-factoring of this software module, and the exposure of a sensible python interface to experiment with new exploration algorithms. This work is lead by Ehsan Azimi, in collaboration with Thierry Jérón from the Sumo team.

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

**Participants:** 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.

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

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

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.

The Anh Pham defended his thesis on December 6., on techniques to mitigate the state space explosion while verifying asynchronous distributed applications. He proposed a new algorithm to mitigate the state space explosion problem (published this year [19]), 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.

During her 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.

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

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

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 2019, we focused on autoscaling and placement for Stream Processing applications.

In 2019, 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.

### 8.2.6. 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.



## 8.3. European Initiatives

### 8.3.1. H2020 Projects

#### 8.3.1.1. H2020 MSCA FogGuru

**Participants:** Hamidreza Arkian, Davaadorj Battulga, Mozhdeh Farhadi, Julie Montégu, Guillaume Pierre, Mulugeta Ayalew Tamiru, Cédric Tedeschi, Paulo Rodrigues de Souza Junior.

Title: FogGuru – Training the Next Generation of European Fog Computing Experts

Program: H2020 MSCA ITN EID

Duration: September 2017 - August 2021

Coordinator: Guillaume Pierre

Participants:

University of Rennes 1, France (coordinator)

Technische Universität Berlin, Germany

Elastisys AB, Sweden

U-Hopper srl, Italy

EIT Digital Rennes, France

Las Naves, Spain

Abstract: 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.

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

#### 8.3.2.1. EIT Digital DriveTrust

**Participant:** Guillaume Pierre.

Program: EIT Digital

Project acronym: DriveTrust

Project title: AI-Powered Driving Evaluation

Duration: January 2019 - December 2019

Coordinator: University of Rennes 1, France

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.

### 8.3.3. Inria Associate Teams Not Involved in an Inria International Labs

#### 8.3.3.1. FogCity

**Participants:** Ayan Mondal, Nikos Parlavatzas, Guillaume Pierre.

Title: QoS-aware Resource Management for Smart Cities

International Partner (Institution - Laboratory - Researcher):

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

IIT Kanpur (India) - Department of Industrial and Management Engineering - Subhas Chandra Misra

Start year: 2018

See also: <https://team.inria.fr/myriads/projects/fogcity/>

Abstract: The FogCity associate team proposal concerns a collaboration between the Myriads project-team, and two research teams at Indian Institute of Technology Kharagpur and Indian Institute of Technology Kanpur. 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 different teams have complementary expertise in theoretical research (Indian partners) and system research (Inria Myriads project-team) and share a strong research interest in IoT and Fog Computing.

#### 8.3.3.2. FogRein

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

Title: Steering Efficiency for Distributed Applications

International Partner: Gene Cooperman, College of Computer and Information Science, Northeastern University (USA).

Start year: 2019

In Fog Computing, the Internet of Things (IoT), and Intermittent Computing, low-power devices migrate geographically, and are required to rapidly assimilate new data in a power-efficient manner. This is a key component of any Smart Interfaces solution as devices migrate from the IT infrastructure to the Edge of the Cloud in order to provide Function-as-a-Service, High-availability mobility, and IT infrastructure malleability. A three-tier strategy is proposed toward steering Fog applications in order to optimize the energy efficiency and sustainability. The strategy will leverage the backgrounds of the participants in Fog Computing, checkpointing, scheduling, Green Levers within the IT infrastructure, and a simulation infrastructure for predicting and efficiently steering such distributed applications. The Inria team and the Northeastern team are uniquely positioned to make rapid progress due to their long history of collaborative research based on visits by both permanent members and PhD students in the two directions.

### 8.3.4. Inria International Partners

#### 8.3.4.1. Informal International Partners

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

Tlemcen University (Algeria): We collaborate with Dr. Djawida Dib 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.

University of Bologna (Italy): We collaborate with Prof. Paolo Bellavista on the design of performance-efficient fog computing platforms. Lorenzo Civolani from University of Bologna spent 6 months in the Myriads team to complete his master thesis internship. A paper on his work has been accepted for publication [14].

Umeå University (Sweden): We collaborate with Prof. Erik Elmroth on the control of large-scale cloud and fog computing platforms. Ali Fahs spent 6 months at Umeå University where he worked on autoscaling techniques for future fog computing platforms.

Rutgers University (USA): We collaborate with Prof. Manish Parashar on improving the energy efficiency of distributed data-intensive applications. This collaboration is outlined by a joint publication in [20].

University of Hawaii (USA): We collaborate with Prof. Henri Casanova on simulating the energy consumption of scientific workflows. This collaboration is outlined by a joint publication in [16].

University of Southern California (USA): We collaborate with Dr. Rafael Ferreira da Silva and Prof. Ewa Deelman on simulating the energy consumption of scientific workflows. This collaboration is outlined by a joint publication in [16].

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

#### *8.3.5.1. Inria International Chairs*

##### **Deborah AGARWAL**

Title: Workflow, user centered design, and data management as well as mobile applications for data science

International Partner (Institution - Laboratory - Researcher):

Université californienne de Santa Barbara (United States) - Computational Research Division - Deborah Agarwal

Duration: 2015 - 2019

Start year: 2015

## **8.4. International Research Visitors**

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

#### *8.4.1.1. Internships*

Lorenzo CIVOLANI

Date: Sep 2018 - Feb 2019

Institution: University of Bologna (Italy)

Supervisor: Guillaume Pierre

Adrien GOUGEON

Date: Feb 2019 - Jun 2019

Institution: ENS Rennes

Supervisors: Anne-Cécile Orgerie and Benjamin Camus

Archana WALE

Date: Jan 2019 - Jun 2019

Institution: University of Rennes 1

Supervisor: Guillaume Pierre

Romain Olivo

Date: Juin 2019 - Aug 2019

Institution: Inria

Supervisor: Matthieu Simonin

## SPIRALS Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. Région Hauts-de-France

#### 9.1.1.1. CIRRUS

**Participants:** Stéphanie Challita, Guillaume Fieni, Alexandre Garnier, Christophe Gourdin, Philippe Merle [contact person], 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:** Abderrahman Lahiaoui, Philippe Merle [contact person], Romain Rouvoy, Lionel Seinturier.

Alloy@Scale is a 12-month (2018–19) 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.

#### 9.1.1.3. Rigorous Component-Based Design of Correct-by-Construction Software and Systems: Application to Cloud Computing

**Participants:** Simon Bliudze [contact person], Larisa Safina.

This 24-month (2019–20) project is funded in the context of the STaRS program. It aims at the development of methods and tools for rigorous design of cloud computing platforms and applications, which can be proven to be correct by construction. First results have been published in [17], [31], [3].

#### 9.1.1.4. Indoor Analytics

**Participants:** Pierre Bourhis, Remy Raes, Romain Rouvoy [contact person], Lionel Seinturier.

Indoor Analytics is a 32-month (2019–21) project funded in the context of CPER Data program. Indoor Analytics aims at collaborating with the Mapwize company on the development of novel analytics for indoor location systems. In particular, Mapwize and Spirals target the joint delivery of an open-source software solution devoted to the acquisition, storage and processing of location events at scale.

#### 9.1.1.5. COMMODE

**Participants:** Pierre Bourhis, Laurence Duchien, Clément Quinton [contact person].

COMMODE (Knowledge COMpilation for feature MODEls) is a 24-month (2019–21) project funded in the context of CPER Data program. COMMODE aims at using techniques from knowledge compilation, a subarea of artificial intelligence, for feature models, a representation of software products used in software engineering.

### 9.1.2. Inria Lille - Nord Europe

#### 9.1.2.1. North European Lab LLEX

**Participants:** Benjamin Danglot, Martin Monperrus, Lionel Seinturier [contact person].

North European Lab LLEX (2017–19) is an international initiative supported by the Inria Lille - Nord Europe Center that takes place in the context of a collaboration between Inria and KTH. LLEX deals with research on automated diagnosis and repair of software bugs. Automated software repair is the process of fixing software bugs automatically. An automated software repair system fixes software bugs with no human intervention. The goal of automated software repair is to save maintenance costs and to enable systems to be more resilient to bugs and unexpected situations. This research may dramatically improve the quality of software systems. This initiative led to several results that have been published [24], [21], [45], [36], [10] and to the PhD thesis of Benjamin Danglot [11] that have been defended in November 2019.

#### 9.1.2.2. ADT FingerKit

**Participants:** Antoine Canda, Walter Rudametkin Ivey [contact person], 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 PhD thesis of Antoine Vastel [14].

#### 9.1.2.3. ADT e-Lens

**Participants:** Arthur d’Azémar, Guillaume Fieni, Romain Rouvoy [contact person].

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 [68] and Maxime Colmant [52], 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 [contact person], 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. Several results and publications have been obtained in the context of this project [6], [5], [76]. The paper [5] won the Best Paper award at the 19th International Conference on Distributed Applications and Interoperable Systems (DAIS 2019). The PhD thesis of Lakhdar Meftah [13], supervised by Romain Rouvoy and Isabelle Chrisment (Inria Nancy), was defended in December 2019 in the context of this project. This project is in relation with the Inria IPL BetterNet.

#### 9.2.1.2. ANR SATAS

**Participants:** Alexandre Garnier, Philippe Merle [contact person], Romain Rouvoy, Lionel Seinturier.

SATAS is a 48-month project (2015–20) 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. Our results from this project have been published in the following papers [53], [60].

#### 9.2.1.3. ANR Headwork

**Participants:** Pierre Bourhis [contact person], 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 a 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. Our results from this project have been published in the following paper [1].

#### 9.2.1.4. ANR Delta

**Participant:** Pierre Bourhis [contact person].

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. Several results and publications have been obtained in the context of this project [18], [16], [28], [27].

#### 9.2.1.5. ANR CQFD

**Participant:** Pierre Bourhis [contact person].

CQFD is a 48-month project (2018–22) funded by ANR. The project focuses on the complex ontological queries over federated heterogeneous data. The project targets to set the foundations, to provide efficient algorithms, and to provide query rewriting oriented evaluation mechanisms, for ontology-mediated query answering over heterogeneous data models. This project is coordinated by Federico Ulliana from Inria Sophia Antipolis. Other partners include LaBRI, Inria Saclay, IRISA, LTCI, and LIG.

#### 9.2.1.6. ANR FP-Locker

**Participants:** Vikas Mishra, Walter Rudametkin Ivey [contact person].

FP-Locker is a 42-month project (2019–23) funded by ANR in the context of the JCJC program. This project proposes to investigate advanced browser fingerprinting as a configurable authentication mechanism. We argue that it has the potential to be the only authentication mechanism when used in very low-security, public websites; it can be used to block bots and other fraudulent users from otherwise open websites. It also has the potential to be used as a second factor authentication mechanism, or as an additional factor in Multi-Factor Authentication (MFA) schemes. Besides strengthening a session's initial authentication, it can also be used for continuous session authentication to protect against session hijacking. In many contexts, fingerprinting is fully transparent to users, meaning that contrary to authentication processes that rely on external verification cards, code generating keys, special apps, SMS verification codes, users do not have to do anything to improve their security. In more restricted contexts, administrators can enforce different policies, for example, enrolling fingerprints from devices that connect from trusted IP addresses (e.g., an internal network), and then verifying these fingerprints when the same users connect from untrusted IP addresses. Consequently, we plan to design an architecture and implement it to be able to plug the browser fingerprinting authentication process to an existing authentication system.

#### 9.2.1.7. ANR Koala

**Participants:** Pierre Bourhis, Clément Quinton [contact person].

Koala is a 42-month project (2019–23) funded by ANR in the context of the JCJC program. The project aims to deliver a series of innovative tools, methods and software to deal with the complexity of fog computing environments configurations and adaptations. In particular, we take a step back on the current limitations of existing approaches (e.g., lack of expressiveness and scalability) and address them placing knowledge as a first-class citizen. We plan to tackle configuration issues from a novel perspective in the field of variability management, using recent techniques from the area of knowledge compilation. Specifically, we will investigate the best-suited d-DNNF representation for each reasoning operation, and we plan to provide new variability modeling mechanisms (e.g., dimensions, priorities and scopes) required in a fog context. Regarding adaptation concerns, we want to leverage machine learning techniques to improve adaptation management and evolution under uncertainty, relying on a continuously enriched and reusable knowledge base. In particular, we plan to propose an approach for suggesting evolution scenarios in a predictive manner, relying on an evolution-aware knowledge base acquired at run-time through machine learning feedback.

## **9.2.2. Competitivity Clusters**

### *9.2.2.1. FUI StoreConnect*

**Participants:** Romain Rouvoy, Lionel Seinturier [contact person].

StoreConnect is a 36-month project (2016–19) funded by FUI and labelled by the PICOM (**Pôle des Industries du COMmerce**) competitiveness 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. Several results and publications have been obtained in the context of this project [5], [38], [66].

## **9.2.3. Inria National Initiatives**

### *9.2.3.1. Inria IPL BetterNet*

**Participants:** Lakhdar Meftah, Romain Rouvoy [contact person].

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. Our results in the context of this project have been published in [66].

## **9.2.4. CNRS Momentum**

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

**Participants:** Pierre Bourhis [contact person], 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. Several results and publications have been obtained in the context of this project [32], [29], [30].

## 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 [contact person].

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 [contact person].

### 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 [contact person].

## 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 a 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. Partnership for joint Curriculum Development and Research in Energy Informatics (PACE)*

**Participants:** Mohammed Chakib Belgaid, Arthur d'Azémar, Guillaume Fieni, Alexandre Garnier, Zakaria Ournani, Clément Quinton, Romain Rouvoy [contact person], Lionel Seinturier.

PACE is a 3-year (2019–21) project funded by the Research Council of Norway. The goal of the project is to establish a sustained education and research-oriented collaboration between four partner universities in energy informatics and green computing that will strengthen quality academic relations and mutually improve each other's quality of research and researcher training both at PhD and master level. Partner universities are: University of Oslo (Norway), University of Stavanger (Norway), TU Munich (Germany), Université de Lille.

## **9.5. International Research Visitors**

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

#### *9.5.1.1. Internships*

Jonatan Enes, PhD Student in Computer Science from University of A Coruña, visited us for 3 months from April to July.

Alejandro Grez, from Pontifical Catholic University of Chile, visited us for 1 month in April.

## STACK Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. 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.

### 9.1.2. SHLARC

**Participants:** Mario Südholt [coordinator], Sirine Sayadi.

The SHLARC project is an international network involving more than 20 partners from more than 15 countries located on four continents. The network aims at improving HLA imputation techniques in the domain of immunobiology, notably by investigation better computational methods for the corresponding biomedical analyses.

The ambition of the SHLARC is to bring together international expertise to solve essential questions on immune-related pathologies through innovative algorithms and powerful computation tool development. To achieve this goal, we determined 3 main objectives

- **Data.** By bringing together scientists from around the world, we will collectively increase the amount of SNP+HLA data available, both in terms of quantity and diversity.
- **Applied mathematical and computer sciences.** We will further optimize SNP-HLA imputation methods using the attribute-bagging HIBAG tool, and particularly for genetically diverse and admixed populations.
- **Accessibility and service to the scientific community.** Following the Haplotype Reference Consortium (HRC) initiative, the network envisions building a free, user-friendly webserver where researchers can access improved imputation protocols by simply uploading their data and obtaining the best possible HLA imputation for their dataset.

In this context, the STACK team is working on improved analysis techniques that harness distributed infrastructures.

This project is financed by the Nantes excellency initiative in Medecine and Informatics (NExT) from 2019-22.

### 9.1.3. 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.

## 9.2. National Initiatives

### 9.2.1. Ademe

#### 9.2.1.1. GLAMA

**Participants:** Brice Nédelec, Thomas Ledoux [coordinator].

The Green Label for Microservices Architecture (GLAMA) project aims to design and develop a technological platform (tools, framework, dedicated languages) for the self management of eco-responsible micro-service architectures for the Cloud. The experiments will be carried out through case studies provided by Sigma Informatique and the presence of renewable energy will initially be simulated. At the end of the project, the technological platform will be deployed as part of the CPER SeDuCe platform. This project is founded by the Ademe (call Perfecto) running for 18 months (starting in September 2019).

### 9.2.2. CominLabs laboratory of excellence

#### 9.2.2.1. 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 STACK team is mainly involved in providing solutions for the second and third challenges.

#### 9.2.2.2. 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 10K€ for one year, it aims at studying the energy footprint of extreme edge infrastructure.

### 9.2.3. ANR

#### 9.2.3.1. 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 522K€, 90K€ for STACK).

The consortium is composed of 4 partners: Qarnot Computing (coordinator) and 3 academic research group (DATAMOVE and AMA from the LIG in Grenoble and STACK 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. To move forward to this objective, we have been designing a simulator to innovate in designing scheduling and data management systems. This similar leverage the Simgrid/PyBATSIM solution [27].

### 9.2.3.2. 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 238K€).

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.

## 9.2.4. FSN

### 9.2.4.1. Hydda (FSN)

**Participants:** H el ene 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?

## 9.2.5. CPER

### 9.2.5.1. 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).

## 9.2.6. Inria Project Labs

### 9.2.6.1. DISCOVERY

**Participants:** Javier Rojas Balderrama, H el ene Coullon, Marie Delavergne, Shadi Ibrahim, Adrien Lebre [coordinator], Ronan-Alexandre Cherrueau, 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 an unified and friendly manner.

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 led the DISCOVERY IPL and contributes mainly around two axes: VM life cycle management and deployment/reconfiguration challenges.

The IPL ended in July 2019.

### 9.2.7. InriaHub

#### 9.2.7.1. 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>.

The Mercury action ended in July 2019.

#### 9.2.7.2. Apollo/Soyuz

**Participants:** Javier Rojas Balderrama, 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>.

The Apollo/Soyuz ended in Dec 2019.

### 9.2.8. Fonds d'amorçage IMT Industrie du Futur 2017

#### 9.2.8.1. aLIFE

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

As a follow-up of the aLIFE workshop (Nantes, Jan. 2018), organized in partnership with colleagues from IMT Atlantique and gathering both academic and industrial partners, we have written a booklet [29] summarizing the workshop discussions and proposing a shared vision of what software research could bring to Industry 4.0 initiatives.

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

### 9.2.9. Connect Talent

#### 9.2.9.1. 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 201K€).

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.

### 9.2.10. Etoiles Montantes

#### 9.2.10.1. VeRD*i*

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

VeRD*i* is an acronym for Verified Reconfiguration Driven by execution. The VeRD*i* 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 VeRD*i* 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. International Initiatives

### 9.3.1. Inria International Labs

#### **Inria@SiliconValley**

Associate Team involved in the International Lab:

#### 9.3.1.1. Hermes

Title: Accelerating the Performance of Multi-Site Scientific applications through Coordinated Data management.

International Partner (Institution - Laboratory - Researcher):

Lawrence Berkeley National Laboratory (United States) - Scientific Data Management Group - Suren Byna.

Start year: 2019

See also: <http://hermes-ea2019.gforge.inria.fr>.

Advances in computing, experimental, and observational facilities are enabling scientists to generate and analyze unprecedented volumes of data. A critical challenge facing scientists in this era of data deluge is storing, moving, sharing, retrieving, and gaining insight from massive collections of data efficiently. Existing data management and I/O solutions on high-performance computing (HPC) systems require significant enhancements to handle the three V’s of Big Data (volume, velocity, and variety) in order to improve productivity of scientists. Even more challenging, many scientific Big Data and machine learning applications require data to be shared, exchanged, and transferred among multiple HPC sites. Towards overcoming these challenges, in this project, we aim at accelerating scientific Big Data application performance through coordinated data management that addresses performance limitations of managing data across multiple sites. In particular, we focus on challenges related to the management of data and metadata across sites, distributed burst buffers, and online data analysis across sites.

### 9.3.2. Inria International Partners

#### 9.3.2.1. Informal International Partners

Huazhong university of Science and Technology (HUST): We collaborate on resource management for stream data applications in the edge, I/O scheduling for SDDs and network-aware task scheduling for MapReduce.

National University of Singapore (NUS): We collaborate on resource management for workflows in the clouds and optimizing graph processing in geo-distributed data-centers.

ShenZhen University: We collaborate on resource management for workflows in the clouds and optimizing graph processing in geo-distributed data-centers.

## **9.4. International Research Visitors**

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

- Suren Byna, a Staff Scientist in the Scientific Data Management Group at Lawrence Berkeley National Lab (LBNL), visited the STACK team from September 30 to October 4 2019. This visit was in the context of the Hermes Associate team.
- Twinkle Jain, a PhD student at Northeastern university, visited the STACK team from May 1 to July 31 2019. Twinkle was working with S. Ibrahim on stragglers mitigation in big data systems. The visit was funded by the ANR KerStream and the Apollo Connect Talent projects.

#### *9.4.1.1. Internships*

- Asha Begam Mohamed Mubarak, a master student at University of Rennes 1, joined the team as a research intern from April 2019 until August 2019. Her thesis was on fast Container Image Retrieval in the Edge.

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

#### *9.4.2.1. Research Stays Abroad*

HUST, China: From August 23 to September 2, S. Ibrahim visited the Services Computing Technology and System Lab at Huazhong university of Science and Technology.

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

#### 9.3.1.1. *CSG*

Title: Proving Concurrent Multi-Core Operating Systems

International Partner (Institution - Laboratory - Researcher):

University of Sydney (Australia) - Willy Zwaenepoel

Start year: 2019

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

The initial topic of this cooperation is the development of proved multicore schedulers. Over the last two years, we have explored a novel approach based on the identification of key scheduling abstractions and the realization of these abstractions as a Domain-Specific Language (DSL), Ipanema. We have introduced a concurrency model that relies on execution of scheduling events in mutual execution locally on a core, but that still permits reading the state of other cores without requiring locks.

In the three next years, we will leverage on our existing results towards the following directions: (i) Better understanding of what should be the best scheduler for a given multicore application, (ii) Proving the correctness of the C code generated from the DSL policy and of the Ipanema abstract machine, (iii) Extend the Ipanema DSL to the domain of I/O request scheduling, (iv) Design of a provable complete concurrent kernel.

### 9.3.2. *Inria International Partners*

#### 9.3.2.1. *Informal International Partners*

Julia Lawall and Gilles Muller collaborate with David Lo and Lingxiao Jiang of Singapore Management University in the context of the ANR-NRF funded project ITrans. This project supports the PhD of Lucas Serrano. In 2019, this collaboration led to an experience paper at ECOOP on a transformation tool (a variant of Coccinelle) for Java [21] and a tool paper at ICSE on using machine learning for identifying bug-fixing patches for the Linux kernel [19]. The latter has been extended to a journal article published in the IEEE Transactions on Software Engineering [11]. Lawall and Serrano spent two weeks visiting Lo and Jiang at Singapore Management University in December 2019.

Julia Lawall collaborates with Jia-Ju Bai at Tsinghua University on bug finding for the Linux kernel. In 2019, this collaboration led to a paper at SANER on detecting data races in device drivers [17], a paper at ISSRE on extending Linux kernel fuzzing to be able to detect bugs in error-handling code [20], a paper at ASPLOS on detection of unnecessary spinning in the Linux kernel [14], a paper at USENIX ATC on detection of use-after free concurrency bugs in the Linux kernel [13]. Bai visited the Whisper team for 2 months starting in January 2019. Lawall visited Bai at Tsinghua University for one week in August.

Michele Martone of the Leibniz Supercomputing Centre in Munich, Germany has been using Coccinelle in an HPC context and giving workshops on Coccinelle in the HPC research engineer community. Martone has contributed some patches to Coccinelle and we keep in touch with him about possible improvements to Coccinelle that may have an impact on its use in the HPC community.

## **9.4. International Research Visitors**

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

Jia-Ju Bai visited the Whisper team for 2 months starting in January 2019. During this time, he and Julia Lawall worked on a prototype of an interprocedural program analysis tool for C code.

Victor Miraldo (Utrecht University) visited the Whisper team for 2 weeks in June 2019, where he worked with Pierre-Évariste Dagand on data structures for efficient differencing of data structures.

#### **9.4.1.1. Internships**

Pierre-Évariste Dagand has supervised the Master 2 research internship of Pierre Nigron (University Paris Diderot), from April to August 2019, on the topic of “Effectful programs and their proofs in a dependently-typed setting”. Pierre Nigron was awarded a DGA-Inria grant to pursue a PhD under Julia Lawall’s supervision, co-supervised by Pierre-Évariste Dagand.

Pierre-Évariste Dagand has supervised the Bachelor research internship of Quentin Corradi (École Normale Supérieure de Lyon), for 6 weeks starting in June 2019, on the topic of “A Formal Semantics of SIMD Instruction Sets”.

Pierre-Évariste Dagand has supervised a pre-doctoral internship of Rémi Oudin (École Normale Supérieure de Cachan), from April to August 2019, on the topic of “Hardware interfaces for transiently-powered systems”. Rémi Oudin was awarded a “Contrat Doctoral Spécifique pour Normaliens”.

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

Gilles Muller spent two weeks in November 2019 visiting the University of Sydney as part of our associated team.

Julia Lawall spent one week at Tsinghua University visiting the group of Jia-Ju Bai in August 2019. Julia Lawall and Lucas Serrano spent two weeks at Singapore Management University visiting the group of David Lo and Lingxiao Jiang in December 2019. During the latter visit, Lawall and Serrano also visited National University of Singapore and Lawall also visited Yale-NUS.

## 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. *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.

### 8.2.2. *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.

### 8.2.3. *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.

#### 8.2.4. *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. *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 is a step in this inescapable direction.

### 8.4. International Research Visitors

Roberto Rodrigues Filho (Lancaster University, UK), July–September 2019.

Mohamed Lechiakh, (ENSIAS, Ecole Nationale Supérieure d’Informatique et d’Analyse des Systèmes, Rabat, Morocco), March–May 2019.

Hasnaa Dyani, (ENSIAS, Ecole Nationale Supérieure d’Informatique et d’Analyse des Systèmes, Rabat, Morocco), April–June 2019.

Chaimaa Tarzi, (ENSIAS, Ecole Nationale Supérieure d’Informatique et d’Analyse des Systèmes, Rabat, Morocco), April–June 2019.

Arsany Guirguis, (EPFL, Lausanne, Switzerland), July–September 2019.

Marcus Kaboret, (Laboratoire de Mathématiques et Informatique, Joseph Ki-Zerbo University, Ouagadougou, Burkina Faso), September–October 2019.

Hayk Saribekyan (University of Cambridge, UK), 2–12 April 2019.

Giorgi Nadiradze (IST Austria), 20–24 May 2019.

Emanuele Natale (CNRS, Sophia-Antipolis), 13–17 March 2019.

#### 8.4.1. *Visits to International Teams*

Adrien Luxey visited Paulo Ferreira, University of Oslo, Norway, from the 1st May to the 30th of June 2019.

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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 - april 2019

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 ( $\mu m$ ) where the microbial habitats are localized, the meso-scale of cores at which laboratory measurements on CO<sub>2</sub> and N<sub>2</sub>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.

#### 9.2.1.5. Muffin

ANR appel à projet générique 2019.

S. Hirstoaga and P.-H. Tournier are members of the project MUFFIN, whose objective is to explore and optimize original computational scenarios for multi-scale and high dimensional transport codes, with priority applications in plasma physics. Several approximation methods are planned to be developed. It is at the frontier of computing and numerical analysis and intends to reduce the computational burden in the context of intensive calculation. Principal Investigator: B. Després (Sorbonne University).

## 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.

#### 9.3.1.2. *ERC Synergy grant EMC2*

Title: Extreme-scale Mathematically-based Computational Chemistry (EMC2)

Programm: ERC

Duration: September 2019 - August 2025

PIs: E. Cancès (ENPC), L. Grigori (Inria), Y. Maday (Sorbonne University), J. P. Piquemal (Sorbonne University)

Molecular simulation is one of the most dynamic areas of scientific computing. Its field of application is very broad, ranging from theoretical chemistry and drug design to materials science and nanotechnology. Its importance in modern science has been acknowledged by two Nobel Prizes (Kohn & Pople in 1998; Karplus, Levitt & Warshel in 2013). It is also a gold mine of exciting problems for mathematicians and computer scientists.

Molecular simulation can be used as a virtual microscope to study more or less complex molecules with atomic-scale space-time resolution. It can also be used as a tool for computer-aided design (CAD) and the engineering of new molecules, materials and nano-devices.

However, molecular simulation still has important limitations. In particular, the simulation of very large molecular systems, or smaller systems in which electrons interact strongly with each other, remains out of reach today. Overcoming these limitations is extremely difficult. This requires joint breakthroughs in several disciplines, and can, in our opinion, only be achieved through an intensive multidisciplinary effort such as those made possible by ERC-Synergy-type funding.

Our objective is to overcome some of the current limitations in this field and to provide academic communities and industrial companies with new generation, dramatically faster and quantitatively reliable molecular simulation software, to enable those communities to address major technological and societal challenges of the 21st century (in health, energy, and the environment, for example).

## 9.4. International Initiatives

### 9.4.1. *Inria International Partners*

#### 9.4.1.1. *Informal International Partners*

- J. Demmel, UC Berkeley, USA
- M. Grote, Université de Bâle, Suisse
- F. Assous, Israel
- K.-M. Perfekt, Reading, UK
- T. Chacon, Seville, Spain

## 9.5. International Research Visitors

### 9.5.1. *Visits to International Teams*

#### 9.5.1.1. *Research Stays Abroad*

- Visit of Laura Grigori to the group of J. Demmel at U.C. Berkeley, july-august 2019.

## AVALON Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. CPER

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

The LECO experimental platform is a new medium size scientific instrument deployed in Grenoble in 2018 and in Lyon in 2019. It was funded by the CPER 2015-2020 LECO++ to investigate research related to BigData and HPC.

### 8.1.2. Action Exploratoire Inria: EXODE

**Participant:** Thierry Gautier.

In biology, the vast majority of systems can be modeled as ordinary differential equations (ODEs). Modeling more finely biological objects leads to increase the number of equations. Simulating ever larger systems also leads to increasing the number of equations. Therefore, we observe a large increase in the size of the ODE systems to be solved. A major lock is the limitation of ODE numerical resolution software (ODE solver) to a few thousand equations due to prohibitive calculation time. The AEx ExODE tackles this lock via 1) the introduction of new numerical methods that will take advantage of the mixed precision that mixes several floating number precisions within numerical methods, 2) the adaptation of these new methods for next generation highly hierarchical and heterogeneous computers composed of a large number of CPUs and GPUs. For the past year, a new approach to Deep Learning has been proposed to replace the Recurrent Neural Network (RNN) with ODE systems. The numerical and parallel methods of ExODE will be evaluated and adapted in this framework in order to improve the performance and accuracy of these new approaches.

## 8.2. National Initiatives

### 8.2.1. Inria Large Scale Initiative

8.2.1.1. *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.

#### 8.2.1.2. 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.

## 8.3. European Initiatives

### 8.3.1. FP7 & H2020 Projects

#### 8.3.1.1. Energy oriented Centre of Excellence for computing applications (EoCoE-II)

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

Program: H2020 RIA european project, call H2020-INFRAEDI-2018-1

Project acronym: EoCoE-II

Project title: Energy oriented Centre of Excellence for computing applications

Duration: 2018-2021

Coordinator: CEA

Other partners: CEA, FZJ, ENEA, BSC, CNRS, Inria, CERFACS, MPG, FRAUNHOFER, FAU, CNR, UNITN, PSNC, ULB, UBAH, CIEMAT, IFPEN, DDN, RWTH, UNITOV

Abstract: Europe is undergoing a major transition in its energy generation and supply infrastructure. The urgent need to halt carbon dioxide emissions and prevent dangerous global temperature rises has received renewed impetus following the unprecedented international commitment to enforcing the 2016 Paris Agreement on climate change. Rapid adoption of solar and wind power generation by several EU countries has demonstrated that renewable energy can competitively supply significant fractions of local energy needs in favourable conditions. These and other factors have combined to create a set of irresistible environmental, economic and health incentives to phase out power generation by fossil fuels in favour of decarbonized, distributed energy sources. While the potential of renewables can no longer be questioned, ensuring reliability in the absence of constant conventionally powered baseload capacity is still a major challenge.

The EoCoE-II project will build on its unique, established role at the crossroads of HPC and renewable energy to accelerate the adoption of production, storage and distribution of clean electricity. How will we achieve this? In its proof-of-principle phase, the EoCoE consortium developed a comprehensive, structured support pathway for enhancing the HPC capability of energy-oriented numerical models, from simple entry-level parallelism to fully-fledged exascale readiness. At the top end of this scale, promising applications from each energy domain have been selected to form the basis of 5 new Energy Science Challenges in the present successor project EoCoE-II that will be supported by 4 Technical Challenges

#### 8.3.1.2. PRACE 6th Implementation Phase Project (PRACE6-IP)

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

Program: H2020 RIA european project, call H2020-INFRAEDI-2018-1

Project acronym: PRACE-6IP

Project title: PRACE 6th Implementation Phase Project

Duration: May 2019-Dec 2021

Coordinator: FZJ

Other partners: HLRS, LRZ, GENCI, CEA, CINES, CNRS, IDRIS, Inria, EPCC, BSC, CESGA, CSC, ETH-CSCS, SURFsara, KTH-SNIC, CINECA, PSNC, CYFRONET, WCNS, UiOsingma2, GRNET, UC-LCA, Univ MINHO, ICHEC, UHEM, CASTORCm NCSA, IT4I-VSB, KIFU, UL, CCSAS, CENAERO, Univ Lux, GEANT

Abstract: PRACE, the Partnership for Advanced Computing is the permanent pan-European High Performance Computing service providing world-class systems for world-class science. Systems at the highest performance level (Tier-0) are deployed by Germany, France, Italy, Spain and Switzerland, providing researchers with more than 17 billion core hours of compute time. HPC experts from 25 member states enabled users from academia and industry to ascertain leadership and remain competitive in the Global Race. Currently PRACE is finalizing the transition to PRACE 2, the successor of the initial five year period. The objectives of PRACE-6IP 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 development of PRACE 2; strengthening the internationally recognised PRACE brand; continuing and extend advanced training which so far provided more than 36 400 person-training days; preparing strategies and best practices towards Exascale computing, work on forward-looking SW solutions; coordinating and enhancing the operation of the multi-tier HPC systems and services; and 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 7 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; assistance to PRACE 2 development; 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. This will be monitored through a set of KPIs.

## 8.4. International Initiatives

### 8.4.1. Inria International Labs

#### 8.4.1.1. Joint Laboratory for Extreme Scale Computing (JLESC) (2014-2023)

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

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.

#### **Inria@EastCoast**

Associate Team involved in the International Lab:

##### 8.4.1.2. SUSTAM

Title: Sustainable Ultra Scale compuTing, dAta and energy Management

International Partner (Institution - Laboratory - Researcher):

Start year: 2017

See also: <http://avalon.ens-lyon.fr/sustam>

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).

## 8.5. International Research Visitors

### 8.5.1. Visits of International Scientists

Carlos Henrique Cardonha, IBM Research Brazil, from Jun 2019 until Jul 2019.

Jean-Philippe Aboumou, SAHAM Life Insurance, from Oct 2019.

#### 8.5.1.1. Internships

Ibrahim Jouwad, M2, *Optimisation de la migration d'un ensemble de machines virtuelles dans un datacentre à l'aide d'un graphe d'états*

Laurent Turpin, M2, *Formalisation de paramètres, évaluation de performance et auto-configuration d'une application HPC en mémoire partagée : application au simulateur Aevol*

Josee Alvine Kouamen, M2, *Prise en main d'une infrastructure cloud et Big data pour l'analyse des fraudes a la simbox*

Zakaria Fraoui, *Distributed Stream Processing in the Edge: The Internet of Things Usecase*

Mohamed Hammache, PFE, *Optimisation d'un environnement de calculs distribués pour la bio-informatique*

Alice Andres, M1, *Cloud vs Edge: fighting for energy !*

Adrien Berthelot, M1, *Revisiting low tech IT protocols*

Pierre Jacquot, L3, *Analysis of DDFacet/KillMS pipeline*

Marouane Azzouz, IUT, *Mode clients/serveur pour le projet CartomENSia*

## **DATAMOVE Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. National Initiatives**

### **9.1.1. 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.

### **9.1.2. Competitvity Clusters**

- **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).

### **9.1.3. 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/>

## **9.2. European Initiatives**

### **9.2.1. FP7 & H2020 Projects**

- **H2020 EoCoE-II (2019-2021)**
  - Energy oriented Center of Excellence on HPC.
  - H2020 RIA european project, call H2020-INFRAEDI-2018-1.
  - PI: CEA.
  - Partners: CEA, FZL, ENEA, BSC, CNRS, Inria, CERFACS, Max-Planck-Gesellschaft, FRAUNHOFER, FAU, CNR, UNITN, PSNC, ULB, UBAH, CIEMAT, IFPEN, DDN. Datamove is leading the WP5 (Ensemble Runs)
  - Summary: The EoCoE-II project will build on its unique, established role at the cross-roads of HPC and renewable energy to accelerate the adoption of production, storage and distribution of clean electricity. How will we achieve this? In its proof-of-principle phase, the EoCoE consortium developed a comprehensive, structured support pathway for enhancing the HPC capability of energy-oriented numerical models, from simple entry-level parallelism to fully-fledged exascale readiness. At the top end of this scale, promising applications from each energy domain have been selected to form the basis of 5 new Energy Science Challenges:
    - \* Wind turbine modelling, from detailed understanding single turbine dynamics to flow across entire wind farms in complex terrain;
    - \* Energy Meteorology, where probabilistic forecasting is needed to predict the production efficiency of solar and wind parks and their impact on energy trading across the grid;

- \* Design and study of new energy materials for photovoltaic cells, batteries and super-capacitors;
- \* Water for energy to manage geothermal and hydro-power including the influence of climate change on these resources;
- \* And fusion for energy, where the mandatory kinetic modelling of plasma turbulence and transport from the core to the edge of complex tokamak magnetic geometries requires exascale resources.

### 9.2.2. 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.

## 9.3. International Initiatives

### 9.3.1. Inria International Labs

#### 9.3.1.1. 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).

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

#### 9.3.2.1. UNIFY

- Title: Intelligent Unified Data Services for Hybrid Workflows Combining Compute-Intensive Simulations and Data-Intensive Analytics at Extreme Scales

- Partners:
  - Inria teams: KerData, DataMove
  - Argonne National Lab (Tom PETERKA)
- Duration: 2019-2021

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

#### *9.3.3.1. STIC AmSud SAQED*

- Title: Scalable Approximate Query Evaluation on Document Inverted Files for GPU based Big-Data Applications
- International Partner:
  - Universidad Nacional de San Luis - UNSL, Argentina
  - Universidad de Santiago de Chile - USACH, Chile
  - Universidade Federal de São Carlos - UFSCAR, Brazil
- Duration: 2019-2021
- Develop efficient and scalable approximate search and document similarity evaluation on large datasets based on document inverted files using high performance computing and GPUs.

#### *9.3.3.2. LICIA*

- Title: International Laboratory in High Performance and Ubiquitous Computing
- International Partner (Institution - Laboratory - Researcher):
  - UFRGS (Brazil)
- Duration: Funded by CNRS in 2011-2018, by Univ Grenoble Alpes for 2019-2020.
- 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.

## **9.4. International Research Visitors**

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

- Professor visit: Alfredo Goldman, Professor at Universidade de São Paulo, visited Datamove from June to July 2019.

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## HIEPACS Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. HPC-Ecosystem

**Participants:** Emmanuel Agullo, Olivier Beaumont, Olivier Coulaud, Aurélien Esnard, Lionel Eyraud-Dubois, Mathieu Faverge, Luc Giraud, Abdou Guermouche, Pierre Ramet, Guillaume Sylvand.

**Grant:** Regional council

**Dates:** 2018 – 2020

**Partners:** EPIs **STORM**, **TADAAM** from Inria Bordeaux Sud-Ouest, Airbus, CEA-CESTA, INRA

**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:** Aurélien Esnard, Mathieu Faverge, Pierre Ramet.

**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. *SOLHARIS: SOLvers for Heterogeneous Architectures over Runtime systems, Investigating Scalability*

**Participants:** Emmanuel Agullo, Olivier Beaumont, Mathieu Faverge, Lionel Eyraud-Dubois, Abdou Guermouche, Pierre Ramet, Guillaume Sylvand.

**Grant:** ANR-19-CE46-0009

**Dates:** 2019 – 2023

**Overview:** The **SOLHARIS** project aims at addressing the issues related to the development of fast and scalable linear solvers for large-scale, heterogeneous supercomputers. Because of the complexity and heterogeneity of the targeted algorithms and platforms, this project intends to rely on modern runtime systems to achieve high performance, programmability and portability. By gathering experts in computational linear algebra, scheduling algorithms and runtimes, **SOLHARIS** intends to tackle these issues through a considerable research effort for the development of numerical algorithms and scheduling methods that are better suited to the characteristics of large scale, heterogeneous systems and for the improvement and extension of runtime systems with novel features that more accurately fulfill the requirements of these methods. This is expected to lead to fundamental research results and software of great interest for researchers of the scientific computing community.

### 8.2.2. *FUI*

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

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

**Grant:** FUI-22

**Dates:** 2016-2020

**Partners:** SAFRAN, SIEMENS, IFPEN, ONERA, DISTENE, CENAERO, GDTECH, Inria, CORIA, CERFACS.

**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.



### 8.2.3. Inria Project Labs

#### 8.2.3.1. IPL HPC BigData

The goal of the 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. 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. Within the IPL, we are in particular involved in a tight collaboration with Zenith Team (Montpellier) on how to parallelize and how to deal with memory issues in the context of the training phase of PI@ntnet (<https://www.plantnet.org>). Alexis Joly (Zenith) co supervises with Olivier Beaumont the PhD Thesis of Alena Shilova.

## 8.3. European Initiatives

### 8.3.1. FP7 & H2020 Projects

#### 8.3.1.1. EoCoE-II

Title: Energy oriented Centre of Excellence for computer applications

Program: H2020

Duration: January 2019 - December 2021

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: Bruno Raffin

The Energy-oriented Centre of Excellence (EoCoE) applies cutting-edge computational methods in its mission to accelerate the transition to the production, storage and management of clean, decarbonized energy. EoCoE is anchored in the High Performance Computing (HPC) community and targets research institutes, key commercial players and SMEs who develop and enable energy-relevant numerical models to be run on exascale supercomputers, demonstrating their benefits for low carbon energy technology. The present project will draw on a successful proof-of-principle phase of EoCoE-I, where a large set of diverse computer applications from four such energy domains achieved significant efficiency gains thanks to its multidisciplinary expertise in applied mathematics and supercomputing. During this 2nd round, EoCoE-II will channel its efforts into 5 scientific Exascale challenges in the low-carbon sectors of Energy Meteorology, Materials, Water,

Wind and Fusion. This multidisciplinary effort will harness innovations in computer science and mathematical algorithms within a tightly integrated co-design approach to overcome performance bottlenecks and to anticipate future HPC hardware developments. A world-class consortium of 18 complementary partners from 7 countries will form a unique network of expertise in energy science, scientific computing and HPC, including 3 leading European supercomputing centres. New modeling capabilities in selected energy sectors will be created at unprecedented scale, demonstrating the potential benefits to the energy industry, such as accelerated design of storage devices, high-resolution probabilistic wind and solar forecasting for the power grid and quantitative understanding of plasma core-edge interactions in ITER-scale tokamaks. These flagship applications will provide a high-visibility platform for high-performance computational energy science, cross-fertilized through close working connections to the EERA and EUROfusion consortia.

#### 8.3.1.2. PRACE 6IP

Title: PRACE Sixth Implementation Phase (PRACE-6IP) project

Duration: May 2019 - December 2021

Partners: see the following [url](#)

Inria contact: Luc Giraud

PRACE, the Partnership for Advanced Computing is the permanent pan-European High Performance Computing service providing world-class systems for world-class science. Systems at the highest performance level (Tier-0) are deployed by Germany, France, Italy, Spain and Switzerland, providing researchers with more than 17 billion core hours of compute time. HPC experts from 25 member states enabled users from academia and industry to ascertain leadership and remain competitive in the Global Race. Currently PRACE is finalizing the transition to PRACE 2, the successor of the initial five year period. The objectives of PRACE-6IP 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 development of PRACE 2; strengthening the internationally recognised PRACE brand; continuing and extend advanced training which so far provided more than 36 400 person-training days; preparing strategies and best practices towards Exascale computing, work on forward-looking SW solutions; coordinating and enhancing the operation of the multi-tier HPC systems and services; and 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 7 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; assistance to PRACE 2 development; 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. This will be monitored through a set of KPIs.

#### 8.3.1.3. EOSC-Pillar

Title: Coordination and Harmonisation of National and Thematic Initiatives to support EOSC

Duration: 2019 - 2023

Partners: see the following [url](#)

Inria contact: Stefano Zacchiroli

The project aims to support the coordination and harmonization of national initiatives relevant to EOSC in Europe and investigate the option for them to interfederate at a later stage, help integrating initiatives and data/cloud providers through the development of common policies and tools, and facilitate user communities in adopting and using these services and propose new ones born from their scientific domain. To this end, the project will integrate a bottom-up approach (by voicing the requirements and needs expressed by the different scientific communities operating at the national level) and a top-down one (by harmonising the national strategies and translating them in a viable

work plan). In the longer term, this is expected to facilitate the design and adoption of common policies and streamline the process of joining EOSC for service providers and user communities while helping populating the EOSC with useful services of wider European interest, based on the real needs and interests of the European scientific communities. In order to maximise this simplification process, the project will collaborate with related regional and thematic initiatives.

#### 8.3.1.4. EXDCI-2

Title: European Extreme Data & Computing Initiative

Duration: 2010 - 2020

Partners: see the following [url](#)

Inria contact: Olivier Beaumont

Through the joint action of PRACE and ETP4HPC, EXDCI-2 mobilises the European HPC stakeholders. The project participates in the support of the European HPC Ecosystem with two main goals. First, the development and advocacy of a competitive European HPC Exascale Strategy by supporting the implementation of a common European HPC strategy, open to synergistic areas including High Performance Data Analytics (HPDA) and Artificial Intelligence (AI). Secondly, the coordination of the stakeholder community for European HPC at the Exascale through joint community structuring and synchronisation, such as (i) the development of relationships with other ecosystems including upstream technologies as Big Data (BDVA) (ii) in the context of the upcoming European Data Infrastructure (EDI) a road mapping activity toward future converged HPC, HPDA and AI needs and new services from PRACE users communities and CoE and (iii) the continuation of BDEC activities, for international participation of European stakeholders on the integration from edge computing to HPC, including Data Analytics and AI.

## 8.4. International Initiatives

### 8.4.1. Inria International Labs

There is an ongoing research activity with Argonne National Laboratory in the framework of the JLESC International Lab, through a postdoc funded by the DPI, namely Nick Schenkels, who work on data compression techniques in Krylov methods for the solution of large linear systems. The objective is to use agnostic compressor developed at Argonne to compress the basis involved in Krylov methods that have a large memory footprint. The challenge is to design algorithm that reduce the memory consumption, hence the energy, while preserving the numerical convergence of the numerical technique.

## KERDATA Project-Team

# 8. Partnerships and Cooperations

## 8.1. National Initiatives

### 8.1.1. ANR

#### 8.1.1.1. OverFlow (2015–2019)

**Participants:** Alexandru Costan, Pedro de Souza Bento Da Silva, Paul Le Noac’h.

Project Acronym: OverFlow

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

Coordinator: Alexandru Costan

Duration: October 2015–October 2019

Other Partners: None (Young Researcher Project, JCJC)

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

Web site: <https://sites.google.com/view/anoverflow>

This project investigates approaches to data management enabling an efficient execution of geographically distributed workflows running on multi-site clouds.

In 2019, we focused on the challenges of stream processing at the Edge. In particular, Edge computing presents a significant opportunity to realize the potential of distributed ML models with regards to low latency, high availability and privacy. It allows for instance inferences on simple image, video or audio classification; as only the final result is transmitted, delays are minimized, while privacy and bandwidth are preserved in IoT applications. Also, neural networks could be partitioned such that some layers are evaluated at the Edge and the rest in the cloud.

In this context we proposed an architecture in which the initial layers can be used for feature-abstraction functions: as data travels through the neural network, they abstract into high-level features, which are more lightweight, helping reduce latency.

### 8.1.2. Other National Projects

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

**Participants:** Gabriel Antoniu, Alexandru Costan, Daniel Rosendo, Pedro de Souza Bento Da Silva.

Project Acronym: HPC-BigData

Project Title: The HPC-BigData Inria Project Lab

Coordinator: Bruno Raffin

Duration: 2018–2022

Web site: <https://project.inria.fr/hpcbigdata/>

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.

In 2019, Daniel Rosendo, who was hired in the context of this IPL project, focused on assessing the state of the art in high performance analytics on hybrid HPC/Big Data infrastructure. In particular, a new path for future work was identified: running Machine Learning algorithm at the Edge.

### 8.1.2.2. ADT Damaris 2

**Participants:** Ovidiu-Cristian Marcu, Gabriel Antoniu, Luc Bougé.

Project Acronym: ADT Damaris

Project Title: Technology development action for the Damaris environment

Coordinator: Gabriel Antoniu

Duration: 2019–2021

Web site: <https://project.inria.fr/damaris/>

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.

Ovidiu Marcu has been funded through this project to document, test and extend the **Damaris** software and make it a safely distributable product. In 2019, the main goal was to add Big Data analytics support in Damaris. We have extended Damaris with a streaming interface for writing and analyzing in real-time simulation data through KerA, a distributed streaming storage system.

KerA is further coupled with RAMCloud for in-memory key-value transactions and with Apache Flink for streaming analytics in an architecture that leverages Apache Arrow as in-memory columnar data representation for co-located streaming. This hybrid HPC-Big Data architecture is subject to further exploration within the **ZettaFlow.io** startup.

### 8.1.2.3. Grid'5000

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

## 8.2. European Initiatives

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

#### 8.2.1.1. ZettaFlow: Unified Fast Data Storage and Analytics Platform for IoT

Program: EIT Digital Innovation Factory

Project acronym: ZettaFlow

Project title: ZettaFlow: Unified Fast Data Storage and Analytics Platform for IoT

Duration: October 2019–December 2020

Technical Coordinator: Ovidiu Marcu

Other partners: Technische Universität Berlin and System@tic

Web site: <https://zettaflow.io/>

The objective of this project is to create a startup in order to commercialize the ZettaFlow platform: a dynamic, unified and auto-balanced real-time storage and analytics industrial IoT platform. ZettaFlow is based on KerA, a streaming storage system prototype developed within the KerData team. ZettaFlow will provide real-time visibility into machines, assets and factory operations and will automate data driven decisions for high-performance industrial processes.

#### 8.2.1.2. FlexStream: Automatic Elasticity for Stream-based Applications

Program: PHC PROCOPE 2020

Project acronym: FlexStream

Project title: Automatic Elasticity for Stream-based Applications

Duration: January 2020–December 2021

Coordinator: Alexandru Costan

Other partners: University of Dusseldorf (UDUS)

Elasticity is one of the key features of cloud computing providing virtual resources as needed according to dynamically changing workloads. This allows to minimize costs and reduce time-to-decision of IoT edge-cloud applications. However, while the underlying resources may easily be scaled many applications and services are not designed to support elastic scalability or require an administrator to manually control elastic scaling.

This project aims at developing concepts providing automatic scaling for stream processing applications. In particular, FlexStream aims at developing and evaluating a prototype which will integrate a stream ingestion-system from IRISA and an in-memory storage from UDUS. For this approach a tight cooperation is mandatory in order to be successful which in turn requires visits on both sides and longer exchanges, especially for the involved PhD students, in order to allow an efficient integrated software design, development as well as joint experiments on large platforms and preparing joint publications.

## 8.2.2. Collaborations with Major European Organizations

### 8.2.2.1. BDVA and ETP4HPC

Gabriel Antoniu (as a working group leader) and Alexandru Costan (as a working group member) contributed to the new Strategic Research Agenda (version 4) of **European Technology Platform in the area of High-Performance Computing** (ETP4HPC).

Gabriel Antoniu and Alexandru Costan are serving as Inria representatives in the working group dedicated to *HPC-Big Data* convergence within the **Big Data Value Association** (BDVA).

### 8.2.2.2. International Initiatives

#### 8.2.2.2.1. 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 series of invitation-based international workshops.

In 2019 Gabriel Antoniu was invited again to contribute to the second and third workshops of the BDEC2 series, where he presented two white papers on HPC-Big Data convergence at the level of data processing.

## 8.3. International Initiatives

### 8.3.1. Inria International Labs

#### 8.3.1.1. UNIFY: An associated team involved in the JLESC international lab

Title: UNIFY: Intelligent Unified Data Services for Hybrid Workflows Combining Compute-Intensive Simulations and Data-Intensive Analytics at Extreme Scales

Inria International Lab: JLESC: Joint Laboratory for Extreme Scale Computing

International Partner: Argonne National Laboratory (USA) — Department of Mathematics, Symbolic Computation Group — **Tom Peterka**

Start year: 2019

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

The landscape of scientific computing is being radically reshaped by the explosive growth in the number and power of digital data generators, ranging from major scientific instruments to the Internet of Things (IoT) and the unprecedented volume and diversity of the data they generate. This requires a rich, extended ecosystem including simulation, data analytics, and learning applications, each with distinct data management and analysis needs.

Science activities are beginning to combine these techniques in new, large-scale workflows, in which scientific data is produced, consumed, and analyzed across multiple distinct steps that span computing resources, software frameworks, and time. This paradigm introduces new data-related challenges at several levels.

The UNIFY Associate Team aims to address three such challenges. First, to allow scientists to obtain fast, real-time insight from complex workflows combining extreme-scale computations with data analytics, we will explore how recently emerged Big Data processing techniques (e.g., based on stream processing) can be leveraged with modern in situ/in transit processing approaches used in HPC environments.

Second, we will investigate how to use transient storage systems to enable efficient, dynamic data management for hybrid workflows combining simulations and analytics.

Finally, the explosion of learning and AI provides new tools that can enable much more adaptable resource management and data services than available today, which can further optimize such data processing workflows.

### 8.3.2. Inria Associate Teams Not Involved in an Inria International Labs

#### 8.3.2.1. SmartFastData

Title: Efficient Data Management in Support of Hybrid Edge/Cloud Analytics for Smart Cities

International Partner: Instituto Politécnico Nacional (Mexico) — Centro de Investigación en Computación — **Rolando Menchaca-Mendez**

- Start year: 2019
- See also: <https://team.inria.fr/smartfastdata/>

The proliferation of small sensors and devices that are capable of generating valuable information in the context of the Internet of Things (IoT) has exacerbated the amount of data flowing from all connected objects to private and public cloud infrastructures. In particular, this is true for Smart City applications, which cover a large spectrum of needs in public safety, water and energy management. Unfortunately, the lack of a scalable data management subsystem is becoming an important bottleneck for such applications, as it increases the gap between their I/O requirements and the storage performance.

The vision underlying the SmartFastData associated team is that, by smartly and efficiently combining the data-driven analytics at the edge and in the cloud, it becomes possible to make a substantial step beyond state-of-the-art prescriptive analytics through a new, high-potential, faster approach to react to the sensed data.

The goal is to build a data management platform that will enable comprehensive joint analytics of past (historical) and present (real-time) data, in the cloud and at the edge, respectively, allowing to quickly detect and react to special conditions and to predict how the targeted system would behave in critical situations.

In 2019, the first objective of the associated team (i.e., exploring analytical models for performance evaluation of stream storage and ingestion systems) was achieved by means of the two internships of José Canepa and Edgar Romo (described in the New Results section) as well as the visit of Mario Rivero as an Invited Professor, who set up the main research agenda for those internships.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

**Rosa Badia:** Barcelona Supercomputing Center, Spain. Dates: 13-14 March 2019

**Michael Schottner:** University of Dusseldorf, Germany. Dates: 13-15 March 2019

**Valentin Cristea:** Politehnica University of Bucharest, Romania. Dates: 13-15 March 2019

**Toni Cortés:** Universitat Politècnica Catalunya, Spain. Dates: 4-5 November 2019

**Kate Keahey:** Argonne National Lab, USA. Dates: 4-5 November 2019

**Matthieu Dorier:** Argonne National Lab, USA. Dates: 4-5 November 2019

#### 8.4.1.1. Invited Professors

**Mario Rivero** (Professor, Instituto Politécnico Nacional, Mexico) was an invited professor in the KerData team from June to July 2019, through the *Scientist Invitation Program* of IRISA and ISTIC. During his stay, he gave several talks at Inria/IRISA and worked on the modeling Smart City applications, laying the path for the work program of the upcoming internships of José Aguilar-Canepa and Edgar Romo.

#### 8.4.1.2. Internships

Jose Aguilar-Canepa (PhD student, Instituto Politécnico Nacional, Mexico) has done a 3-month internship within the team, working with Alexandru Costan and Pedro Silva on hybrid Edge/Cloud stream processing. This work is validated through large scale experiments on Grid'5000 and is subject to a journal paper in submission, currently on the works, to be submitted by January 2020.

Edgar Romo (PhD student, Instituto Politécnico Nacional, Mexico) did a 3-month internship at KerData from September to November 2019. He worked on Objective 2 of the SmartFastData Associate Team, specifically on designing a complex model for predicting the stream arrival rates for vehicular networks in Smart Cities. To validate this proposal, he carried out several experiments on Grid'5000; this work is currently the topic of a workshop paper submission.

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

Alexandru Costan and Gabriel Antoniu visited the NDS-Lab team at Instituto Politécnico Nacional from October 24 to November 3, 2019, in the context of the SmartFastData associate team. Working closely with Rolando Menchaca, they defined the work program for the upcoming year with respect to the team's objectives. They also presented KerData's vision on future hybrid analytics combining Edge, Cloud and HPC computing.



## **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. Grenoble INP grant**

Patrick Loiseau and Bary Pradelski received a grant from the Presidency of Grenoble INP that covers half of the funding of PhD student Dimitrios Moustakas to work on dynamic matching. This PhD is done in collaboration with Univ. Zurich (Heinrich Nax), which covers the rest.

### **9.2.3. 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.

### **9.2.4. 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.

### **9.2.5. PEPS**

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

### **9.2.6. Fondation Blaise Pascal**

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

### **9.2.7. MIAI @ Grenoble Alpes**

MIAI @ Grenoble Alpes (Multidisciplinary Institute in Artificial Intelligence) is the 3IA institute of Grenoble that was selected by the government in 2019. With the MIAI institute, Patrick Loiseau is the co-holder of a chair on "Explainable and Responsible AI" of which Nicolas Gast and Bary Pradelski are also members; and Panayotis Mertikopoulos is a member of the "Optimization and Learning" chair.

### 9.2.8. ANR

- Nicolas Gast obtained funding from the ANR JCJC for the project REFINO. 250k euros. Duration: 4 years
- Bary Pradelski (PI), P. Mertikopoulos and P. Loiseau obtained funding from the ANR for the project ALIAS (Adaptive Learning for Interactive Agents and Systems). This is a bilateral PRCI (collaboration internationale) project joint with Singapore University of Technology and Design (SUTD). The Singapore team consists of G. Piliouras and G. Panageas.
- *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

#### 9.3.1.1. ReDaS

Title: Reproducible Data Science

International Partner (Institution - Laboratory - Researcher):

Universidade Federal do Rio Grande do Sul (Brazil) - Industrial Engineering and Operations Research Departments - Lucas Mello Schnorr

Start year: 2019

See also: <https://associatedteam.gitlabpages.inria.fr/redas>

Data science builds on a variety of technique and tools that makes analysis often difficult to follow and reproduce. The goal of this project is to develop interactive, reproducible and scalable analysis workflows that provide uncertainty and quality estimators about the analysis.

#### 9.3.1.2. International Initiatives

##### GENE

Title: Stochastic dynamics of large games and networks

International Partners (Institution - Laboratory - Researcher):

Universidad de Buenos Aires (Argentina) - Matthieu Jonckheere

Universidad de la Republica Uruguay (Uruguay) - Federico La Rocca

CNRS (France) - Balakrishna Prabhu

Universidad ORT Uruguay (Uruguay) - Andrés Ferragut

Duration: 2018 - 2019

Start year: 2018

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: - Mean-field games and their application to load balancing and resource allocations, - Scaling limits for centralized and decentralized load balancing strategies and implementation of practical policies for web servers farms, - Information diffusion and communication protocols in large and distributed wireless networks.

## **9.4. International Research Visitors**

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

We have hosted multiple international scientists for short (typically one-week) visits: Jonathan Newton, Paul Duetting, Jason Marden, Bruno Ziliotto

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

- V. Danjean spent one week at Porto Alegre (Brasil) at UFRGS, hosted by Lucas M. Schnorr to work on the research subject: Tracing of multi-tasked OpenMP Application.
- A. Legrand spent 10 days at Porto Alegre (Brasil) at UFRGS, hosted by Lucas M. Schnorr to teach scientific methodology and Performance Evaluation and to work on the visual performance analysis of dynamic task-based applications.
- G. Huard visited UFRGS (Porto Alegre, Brasil) in the context of the ReDaS Inria associated team from Nov. 27th to Dec 16th along with Alexis Janon. During this visit we worked with Lucas Schnorr on several application trace analysis cases using our own custom analysis framework and leveraging UFRGS expertise on the design and conduct of practical data analysis.
- B. Pradelski was invited for seminars at several places: IHP Game Theory Seminar, Bar-Ilan University Economic Theory seminar, University of Oxford Game Theory seminar. He is also an associate member of the Oxford Man Institute.

#### *9.4.2.1. Research Stays Abroad*

P. Mertikopoulos was invited to spend a three-month research visit at the Ecole Polytechnique Fédérale de Lausanne (EPFL). He was hosted by the LIONS lab (headed by V. Cevher).

## ROMA Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

ANR Project SOLHARIS (2019-2023), 4 years. The ANR Project SOLHAR was launched in November 2019, for a duration of 48 months. It gathers five academic partners (the HiePACS, ROMA, Re-alOpt, STORM and TADAAM) Inria project-teams, and CNRS-IRIT) and two industrial partners (CEA/CESTA and Airbus CRT). This project aims at producing scalable methods for direct methods for the solution of sparse linear systems on large scale and heterogeneous computing platforms, based on task-based runtime systems.

The proposed research is organized along three distinct research thrusts. The first objective deals with the development of scalable linear algebra solvers on task-based runtimes. The second one focuses on the deployment of runtime systems on large-scale heterogeneous platforms. The last one is concerned with scheduling these particular applications on a heterogeneous and large-scale environment.

## 9.2. International Initiatives

### 9.2.1. Inria International Labs

#### 9.2.1.1. 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.

## **9.2.2. Inria International Partners**

### *9.2.2.1. 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.

## **9.2.3. 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 PROFER 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 four 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 Mingsong Chen have lead 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.

## **9.3. International Research Visitors**

### **9.3.1. Visits to International Teams**

#### *9.3.1.1. 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.

## STORM Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### HPC/Big-Data Convergence

- Team 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.

## 9.2. 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.

### 9.2.1. 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.

### 9.2.2. ADT - Inria Technological Development Actions

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

**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, Kun He.

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

Coordinator: Denis Barthou

Other partners: C.Jégo 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 electronics engineers. 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.

### 9.2.3. IPL - Inria Project Lab

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

**Participants:** Samuel Thibault, 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.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

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.

### 9.3.2. 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 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.

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.

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

Inria@SiliconValley

Associate Team involved in the International Lab:

#### 9.4.1.1. *COHPC*

Title: Correctness and Performance of HPC Applications

International Partner (Institution - Laboratory - Researcher):

Lawrence Berkeley National Laboratory (United States) - Costin Iancu

Start year: 2019

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

High Performance Computing (HPC) plays an important role in many fields like health, materials science, security or environment. The current supercomputer hardware trends lead to more complex HPC applications (heterogeneity in hardware and combinations of parallel programming models) that pose programmability challenges. As indicated by a recent US DOE report, progress to Exascale stresses the requirement for convenient and scalable debugging and optimization methods to help developers fully exploit the future machines; despite all recent advances these still remain manual complex tasks.

This collaboration aims to develop tools to aid developers with problems of correctness and performance in HPC applications for Exascale systems. There are several requirements for such tools: precision, scalability, heterogeneity and soundness. In order to improve developer productivity, we aim to build tools for guided code transformations (semi-automatic) using a combination of static and dynamic analysis. Static analysis techniques will enable soundness and scalability in execution time. Dynamic analysis techniques will enable precision, scalability in LoCs and heterogeneity for hybrid parallelism. A key aspect of the collaboration is to give precise feedback to developers in order to help them understand what happens in their applications and facilitate the debugging and optimization processes.

## 9.5. International Research Visitors

### 9.5.1. *Visits of International Scientists*

- Scott Baden, LBNL (USA), from April 29 to May 3, 2019

## 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. 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 PALLEZ (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.

ANR Solharis SOLvers for Heterogeneous Architectures over Runtime systems, Investigating Scalability .

AAPG ANR 2019, 2019 - 2023 (48 months)

Coordinator: Alfredo BUTTARI (IRIT-INPT)

Abstract: The Solharis project aims at producing scalable methods for the solution of large sparse linear systems on large heterogeneous supercomputers, using the STARPU runtime system, and to address the scalability issues both in runtime systems and in solvers.

## 9.2.2. 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.

## 9.2.3. IPL - Inria Project Lab

High-Performance computing and BigData

**Participants:** Guillaume Pallez, Emmanuel Jeannot, Nicolas Vidal, Francieli Zanon-Boito

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

## 9.2.4. Collaboration with CERFACS

Developments on the HIPPO software

**Participants:** Brice Goglin, Guillaume Mercier

A Memorandum of Understanding is currently being negotiated between Inria and CERFACS to organize the collaboration between both entities pertaining to the developments on the HIPPO software. The goal is to provide a portable solution to address the issue of dynamic placement of hybrid coupled MPI + OpenMP applications, especially for climate modelling. Météo France is one of the target of this work but other teams/institutes around the globe have expressed an interest in HIPPO. Therefore we want to create a solution that would match the needs of the community on the whole.

## 9.3. European Initiatives

### 9.3.1. 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 Urbanna 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) as well as network performance prediction.

Partner 2: Vanderbilt University

Subject 2: Scheduling for Neurosciences [7.8](#)

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

Partner 4: Lawrence Livermore National Laboratory

Subject 4: Exposing Heterogeneous Memory Characteristics to HPC Applications [7.1](#)

## **9.5. International Research Visitors**

### *9.5.1. Visits of International Scientists*

- Ana Gainaru, Research Assistant Professor at U. Vanderbilt, visited the team for one week in December 2019.

## **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. 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 run time, 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. DGA**

#### *8.2.2.1. LangComponent (CYBERDEFENSE)*

- Coordinator: DGA
- Partners: DGA MI, Inria
- Dates: 2019-2022

- Abstract: in the context of this project, DGA-MI and the Inria team DiverSE explore the existing approaches to ease the development of formal specifications of domain-Specific Languages (DSLs) dedicated to paquet filtering, while guaranteeing expressiveness, precision and safety. In the long term, this work is part of the trend to provide to DGA-MI and its partners a tooling to design and develop formal DSLs which ease the use while ensuring a high level of reasoning.

### **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 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 raises confidence and foster adoption of DevOps by the European IT industry. The project gathers 3 academic partners with strong software testing expertise, 5 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 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.

McGill University (Canada): language reuse, model composition, and models for sustainability.

CWI (The Netherlands): language engineering.

JKU Linz (Austria): model analysis and Model-Based DevOps.

RWTH Aachen (Germany): models for industry 4.0

## 8.4. International Initiatives

### 8.4.1. Inria International Labs

#### III 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)
- University of Lancaster (UK)
- University of Namur (Belgium)
- Università degli Studi di Cagliari (Italy)
- Università degli Studi dell'Aquila (Italy)



- JKU Linz (Austria)
- TU Wien (Austria)
- Michigan State University (MSU)
- RWTH 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 coordinate research partners worldwide to develop breakthrough software language engineering (SLE) approaches that support 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 provided 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 a GEMOC 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, July and October 2019.
- Nelly Bencomo, Lecturer in Computer Science Aston University, UK, visited the team from October 2019 to June 2020.
- Martin Montperrus, Professor at KTH, Sweden, visited the team in December 2019.
- Nicolas Harrand, PhD Student at KTH, Sweden, visited the team in December 2019.
- Paul Temple, postdoc at University de Namur, visited the team in February 2019.
- Thomas Degueule, postdoc at CWI, visited the team in December 2019
- Alfonso Pierantonio, Associate Professor at Università degli Studi dell'Aquila, visited the team in June 2019
- Mark van den Brand, Professor at Eindhoven University of Technology, visited the team in June 2019

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

- Pierre JeanJean visited CWI for 1 week in December 2019 in the context of the Associated Team ALE.
- Benoit Combemale made several short visits at CWI in the context of the Associated Team ALE, visited McGill University in June 2019, and visited TU Eindhoven in November 2019.
- Olivier Barais made several short visits at KTH in the context of a collaboration with Prof Monperrus and Prof Baudry.
- Djamel E. Khelladi made a one week research visit in December 2019 to the DIRO laboratory at University of Montreal, Canada.

## **EASE Project-Team**

# **8. Partnerships and Cooperations**

## **8.1. Regional Initiatives**

### **Chantier 3.0**

Coordinator: JM. Bonnin

Starting: Jan 2019; Ending : Dec 2021

Partners: Agemos, YoGoKo, IMT Atlantique

Abstract: Co-founded by "Région Bretagne" Chantier 3.0 is a "PME Project" aiming at increasing safety of workers in construction sites and road works. In these scenarios, vehicles represent a danger for the workers. Knowing the position of the vehicles and workers, it is possible to alert workers who are located in a safety perimeter around the vehicles. The project addresses the challenges of 1) precise localisation with low or medium cost wearable devices and 2) of dynamically setting up a reliable communication network in harsh environments mixing indoor and outdoor conditions. The key technologies used to solve these issues include: fusion of localisation data (GPS, acceleration integration, location anchors, angle of arrival and time of flight of radio signals), opportunistic short range broadcast communications, ITS communication protocols and system integration. EASE brings its expertise in all of these domains in order to enhance the reliability of the system, to make it affordable and to pave the way for its standardisation.

## **8.2. National Initiatives**

### **SCOOP@F part 2**

Coordinator: JM. Bonnin

Starting: Jan 2016; Ending: Dec 2019

Partners: MEDE, Renault, PSA, IMT Atlantique

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.

### **InDiD**

Coordinator: JM. Bonnin

Starting: mid 2019; Ending: Dec 2023

Partners: 20+ French partners including cities (Paris, Grenoble...), road operators, transport operators, academics ( incl. IMT Atlantique) and industrials

Abstract: InDiD is one of 13 French projects out of 148 European projects selected by the European Commission within the framework of the last Connecting Europe Facility (CEF) call for proposals. The project benefits from a co-funding rate of 50% on behalf of the European Union. It follows the Smart Cooperative Transport Systems projects SCOOP@F, C-ROADS France and InterCor. The project aims at expanding the coverage of use cases deployed in previous projects (emergency braking, accident, work...) and develop new use cases dealing with urban area, but also use cases of increased perception for autonomous vehicle. In addition, it deals with high definition digital mapping of the infrastructure. Connectivity along with mapping shape the digital infrastructure of tomorrow, an essential addition to the physical infrastructure. InDiD aims at continuing the deployment of Cooperatives Intelligent Transport Systems on new road experimentation sites in order to expand the services coverage offered by the infrastructure. Pilot sites are located on 4 main French geographic areas, on the Mediterranean side, in the south-west area, at the centre and in the north of France.

#### **TAGRI**

Coordinator: P. Couderc

Starting: Nov 2019; Ending: Nov 2020

Abstract: Tagri is a 12 months innovation action supported by a CominLabs grant, started on 2019-11-01 and ending on October 2020. It follows up the previous Pervasive\_RFID project, a joint Inria - IETR collaboration. Tagri aims at developing an operational UHF RFID solution for agricultural applications where tags are used as a pervasive storage to track important data related to the production. Tagri is using the RFID research facility from Pervasive\_RFID project to study the behavior and performance level of UHF RFID in the context of agricultural applications, which is new as the standard RFID technology used in farming is LF based: historically, LF was selected because it was reliable for bio-tags attached to animal, and the driver application for RFID in smart farming was breeding. A new research engineer, Alexis Girard, has integrated the team in November 2019 on this project.

## **8.3. International Research Visitors**

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

Three years ago we initiated a collaboration with Valerie Gay and Christopher Lawrence (UTS / Australia) on adapting smart spaces for eHealth applications. We continued the collaboration and Jean-Marie Bonnin visited UTS last August. He participated in the definition of research IoT infrastructure for a new maternity clinic dedicated to aboriginal community. The goal was to design an efficient research infrastructure to study how pervasive technologies could be used to adapt the environment to the people. To prepare this visit, Christopher Lawrence came in France and visit the team in March 2019.

### **8.3.2. Visits of International Scientists**

Christopher Lawrence, Associate Professor, University of Technology Sydney, visited the team in March/April 2019.

## FOCUS Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

- DCore (Causal debugging for concurrent systems) is a 4-years ANR project that started on March 2019. The overall objective of the project is to develop a semantically well-founded, novel form of concurrent debugging, which we call “causal debugging”. Causal debugging will comprise and integrate two main engines: (i) a reversible execution engine that allows programmers to backtrack and replay a concurrent or distributed program execution and (ii) a causal analysis engine that allows programmers to analyze concurrent executions to understand why some desired program properties could be violated. Main persons involved: Lanese, Medic.
- 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 finished 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.
- PROGRAMme (“What is a program? Historical and philosophical perspectives”), is an ANR project started on October 2017 and that will finish on October 2022; PI: Liesbeth De Mol (CNRS/Université de Lille3). The aim of this project is to develop a coherent analysis and pluralistic understanding of “computer program” and its implications to theory and practice. Main person involved: Martini.

## 9.2. European Initiatives

### 9.2.1. 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 project aims to bring the existing prototype tools based on these technologies to mainstream programming languages and development frameworks used in industry.
- 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).

## 9.2.2. 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.

## 9.3. International Initiatives

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

#### 9.3.1.1. 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.

### **9.3.2. 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.

## **9.4. International Research Visitors**

### **9.4.1. 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.

- Ornela Dardha (University of Glasgow) and Laura Bocchi (University of Kent): collaboration within BehAPI RISE H2020 project, September 2019.
- Guilhem Jaber (University of Nantes): “Game semantics for higher-order functions with state”, December 2019.
- Naohiko Hoshino, April 2019 and October 2019.
- Gilles Barthe, May 2019.
- Boaz Barak, July 2019.
- Francesco Dagnino, “Generalizing Inference Systems by Corules”, November 2019.

#### *9.4.1.1. Sabbatical programme*

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

#### *9.4.1.2. Research Stays Abroad*

- Ugo Dal Lago has spent overall a few weeks in Japan: RIMS (Kyoto) and NII (Tokyo), as part of ongoing collaborations with Naohiko Hoshino and Shin-ya Katsumata.
- Ivan Lanese has visited Xibis Limited and University of Leicester, UK (in particular Irek Ulidowski and Emilio Tuosto) from 3/7/2019 to 2/8/2019, to work on choreographies, and the University of Torun, Poland (in particular Lukasz Mikulski and Kamila Barylska), from 13/8/2019 to 29/8/2019, to work on reversible Petri nets.
- Cosimo Laneve and Gianluigi Zavattaro have spent overall a few weeks in Malta visit to Prof. Adrian Francalanza at the University of Malta within the BehAPI RISE H2020 project.
- Michael Lodi has visited Prof. Tim Bell and the Computer Science Education Research Group at the Department of Computer Science and Software Engineering, University of Canterbury, Christchurch, New Zealand, from 26th of October 2018 to 17th of April 2019, as part of his Ph.D. course.

## INDES Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. *Skini*

Skini was used for the production of a musical piece as part of SACEM's "Music Factory" program in collaboration with the *CIRM* in Nice and the *Conservatory of Nice*. This piece was designed, and produced in May at the Nice Conservatory, by 12 years old pupils of the Nucéra secondary school in Nice after a dozen working sessions within the school. This production is followed by a similar project with 14 years old pupils as part of the "Cordé de la résussite" programme run by Inria with the objective of a musical production in spring 2020.

## 8.2. National Initiatives

### 8.2.1. *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.

### 8.2.2. *ANR PrivaWeb*

The PrivaWeb project (Privacy Protection and ePrivacy Compliance for Web Users) is funded by the ANR JCJC program for 48 months, started 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.

### 8.2.3. *PIA ANSWER*

The ANSWER project (Advanced aNd Secured Web Experience and seaRch) is funded by PIA program for 36 months, starting January 1, 2018. The aim of the ANSWER project is to develop the new version of the <http://www.qwant.com> search engine by introducing radical innovations in terms of search criteria as well as indexed content and users' privacy. The partners of this project include QWANT and Inria teams Wimmics, Indes, Neo and Diana.

## 8.3. Inria Internal Funding

### 8.3.1. *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.

### 8.3.2. AEx DATA4US

DATA4US is a joint project between two teams in Inria Sophia Antipolis and Inria Grenoble - Rhône-Alpes that tackles these interdisciplinary challenges by establishing collaborations with researchers in Law. Members are Nataliia Bielova (INDES) and Cedric Lauradoux (Privatics).

DATA4US will propose a new architecture for exercising access rights that will explain the users whether their data has been legally collected and eventually help contact DPAs for further investigations.

### 8.3.3. 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 is part of this project.

## 8.4. European Initiatives

### 8.4.1. H2020 Sparta

SPARTA (Strategic Programs for Advanced Research and Technology in Europe) is a novel cybersecurity competence network, with the objective to collaboratively develop and implement top-tier research and innovation actions. Strongly guided by concrete challenges forming an ambitious Cybersecurity Research & Innovation Roadmap, SPARTA will tackle hard innovation challenges, leading the way in building transformative capabilities and forming a world-leading cybersecurity competence network across the EU. Four initial research and innovation programs will push the boundaries to deliver advanced solutions to cover emerging issues, with applications from basic human needs to economic activities, technologies, and sovereignty.

See also: <https://www.sparta.eu/>

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

#### 8.4.2.1. 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 was the first European network of excellence aimed at coordinating research on reversible computation.

See also: <http://www.revcomp.eu>

#### 8.4.2.2. 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 was 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 objective of the project was to study formal models for reliable distributed communication-centric software systems. The project focussed on analysis and validation techniques based on behavioural types, aimed at enforcing various properties (safety, liveness, security) of structured communications.

## 8.5. International Initiatives

### 8.5.1. Inria International Partners

#### 8.5.1.1. Informal International Partners

- We are collaborating 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. Benoit Baudry from KTH Royal Institute of Technology, Sweden and with Pierre Laperdrix from Stony Brook University on the survey of browser fingerprinting technologies.
- We are setting a new collaboration with Dr. Zinaida Benenson from University of Erlangen-Nuremberg, Germany, to study Human Factors in Privacy: in particular, to set up user studies to evaluate their perception and understanding of the cookie banners design and measure the influence of dark patterns on user decisions.
- We are setting a new collaboration with Prof. Martin Johns from TU Braunschweig, Germany, to work on cryptographic primitives to include proof of ownership in browser cookies that would facilitate the exercise of GDPR subject access rights. This is a joint collaboration with Cedric Lauradoux from Privatics.
- 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. This year, this collaboration was extended to Dr. Ross Horne from the University of Luxemburg. 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 pursuing our collaboration on reactive programming and on higher contracts for security with Prof. Robby Findler from Northwestern University in Chicago.
- We are pursuing our collaboration with Prof. Marc Feeley from University of Montréal on the compilation of dynamic languages.

### 8.5.2. Participation in Other International Programs

#### 8.5.2.1. International Initiatives

##### **DAJA**

Title: Detection strategies based on Software Metrics for Multitier JavaScript

International Partners (Institution - Laboratory - Researcher):

Universidad de Chile (Chile), Intelligent Software Construction laboratory (ISCLab) - Alexandre Bergel

Universidad Nacional del Centro de la Provincia de Buenos Aires (Argentina) Computer Science Departement - 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.

## 8.6. International Research Visitors

### 8.6.1. Visits of International Scientists

- We are collaborating with Cristiana Teixeira Santos from University Toulouse 1-Capitole. Cristiana is a postdoc in Data Protection Law with whom we have been analyzing legal requirements for GDPR consent, and cookie banners in particular. Cristiana has visited us two times in 2019 and will be hired as a postdoc for Inria AEx project DATA4US in 2020.
- As part of our ongoing collaboration on GDPR Subject Access Rights, Cedric Lauradoux has visited us several times in 2019, to expand our existing work [13] and establish new research directions. Cedric is a co-PI for Inria AEx project DATA4US.
- We are collaborating with Prof. Marc Feeley from University of Montréal. For the third consecutive year, M. Feeley has visited us for studying implementation of dynamic languages, and in particular we started a study of the efficient compilation of the Python programming language.
- We are collaborating with Prof. Andrei Sabelfeld from Chalmers University of Technology. A.Sabelfeld has visited us for one month in July 2019 for studying remote timing attackers in the context of IoT frameworks.
- Prof. Robby Findler and his PhD student Spencer Florence visited us in July, where we have organized a mini-workshop during a week, working with Prof. G. Berry and J. Krishnamurthy on the semantics and implementation of reactive languages.

#### 8.6.1.1. Internships

- Nataliia Bielova has co-supervised Hicham Lesfari for 3 months together with Frederic Giroire from Inria Coati team.
- Nataliia Bielova has supervised the intern Michael Toth as a "relai-de-these" for 2 months.
- Iliaria Castellani and Tamara Rezk supervised the intern Carlo Prato for 6 months.
- Tamara Rezk supervised the ENS L3 internship of Maxime Legoupil for 7 weeks in June and July 2019.
- Tamara Rezk has co-supervised the ENS L3 internship of Clément Ogier in July 2019.
- Tamara Rezk supervised the internship of Adam Khayam for 6 months.
- Tamara Rezk supervised -as tutor- the internship of Ayoub Ider Aghbal in a company.

### 8.6.2. Visits to International Teams

For the third consecutive year, Manuel Serrano and Gérard Berry visited Prof. Robby Findler at University of Northeastern in Chicago. This time, Tamara Rezk joined the delegation that also visited Prof. Christos Dimoulas also working at Northeastern University. The Indes team and Findler's team have applied for the second time to the Inria Associated Team program.

## **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.

Pablo Tesone did a PhD co-supervised by RMOD and Pr. L. Fabresse and N. Bouraqadi (finished in 2018). Currently, three PhD Students are co-supervised:

- PhD in progress: Théo Rogliano, *On multiple language kernel*, started Oct 2019, Stéphane Ducasse, Luc Fabresse
- PhD in progress: Pierre Misse-Chanabier, *Modular, green, versatile Virtual Machines*, started Oct 2019, Stéphane Ducasse, Noury Bouraqadi
- PhD in progress: Carolina Hernández, *Tools for MicroKernels* Guillermo Polito and Luc Fabresse

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 Thierry Goubier (CEA List)  
From 2016, PhD finished 2019.

Jason Lecerf started a shared PhD Oct 2016 and finished November 2019: *Designing Language-Agnostic Code Transformation Engines*.

## **9.3. European Initiatives**

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

#### **University of Novi Sad, Serbia**

Participants: Stéphane Ducasse, Anne Etien, Nicolas Anquetil, Vincent Aranega

A collaboration with the University of Novi Sad, Serbia, started in 2018 with the university joining the Pharo Consortium as an academic member.

We have handed in a bilateral project (Campus France) between Novi Sad and RMOD: *An innovative visual environment in service of developer experience*. We expect results by the end of this year.

A Master thesis has been cosupervised. Nina Medic: *Graph library with layout algorithms in Pharo*.

Visitors:

- Sebastijan Kaplar [University of Novi Sad, Serbia, Aug 2019]
- Gordana Rakic [University of Novi Sad, Serbia, from Nov 2019]
- Nina Medic [University of Novi Sad, Serbia, from Jun 2019 until Jul 2019]

#### **University of Prague, Czech Republic**

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, the next lecture is planned for 2020.

#### **University of Cagliari, Italy**

Participants: Stéphane Ducasse

We are working on software engineering problems in the context of blockchain based software.

Visitor: Giuseppe Antonio Pierro [University of Cagliari, until July 2019].

#### **University of Bern, Switzerland**

Participants: Stéphane Ducasse, Marcus Denker

We are working on dynamic software update to, for example, automatically transform users of deprecated code.

Visitor: Manuel Leuenberger [University of Bern, from Sep 2019 until Nov 2019]

#### **Siemens AG, Germany**

Participants: Stéphane Ducasse, Anne Etien, Nicolas Anquetil

The Siemens Digital Industry Division approached our team to help them restructure a large legacy systems. The joined work resulted in a publication in 2019: *Decomposing God Classes at Siemens* [1].

## **9.4. International Initiatives**

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

Discussions with Inria Chile have started about organizing Pharo lectures in Chile. A first visit to Inria Chile in fall 2019 did not happen due to the political situation in Chile.

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

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

Participants: Guillermo Polito, Stéphane Ducasse, Marcus Denker.

Collaboration with SOFT started 2016, from 2020 Inria Lille North-European associated team funding with SOFT/VUB for 2 years.

Student: Matteo Marra, collaboration with Eliza Gonzalez Boix.

Marcus Denker gave a lecture at VUB in October 2019.

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

#### **9.4.3.1. 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

- Abdelhakim Bouremel [University of Skikda, Algeria, Oct 2019]
- Mohamad Chakroun [Mar 2019]
- Victor Martín Dias [University of Chile, Chile, until Sep 2019]
- Christopher Fuhrman [École de technologie supérieure de Montréal, Canada, until Sep 2019]
- Yann-Gaël Guéhéneuc [Concordia University, Canada, from Apr 2019 until May 2019]
- Sebastijan Kaplar [University of Novi Sad, Serbia, Aug 2019]
- Manuel Leuenberger [University of Bern, Switzerland, from Sep 2019 until Nov 2019]
- Milton Mamani Torres [Object Profile SpA, Chile, Aug 2019]
- Nina Medic [University of Novi Sad, Serbia, from Jun 2019 until Jul 2019]
- Hayatou Oumarou [University of Maroua, Cameroun, from Sep 2019 until Oct 2019]
- Giuseppe Antonio Pierro [University of Cagliari, Italy, until July 2019]
- Gordana Rakic [University of Novi Sad, Serbia, from Nov 2019]
- Moussa Saker [University Badji Mokhtar-Annaba, Algeria, from Dec 2019]

#### 9.5.1.1. Internships

- Dayne Lorena Guerra Calle [Inria, from Feb 2019 until Aug 2019]
- Chia Yu Li [Inria, until Jul 2019]
- Iona Thomas [Centrale Lille, from Jul 2019 until Aug 2019]
- Oleksandr Zaitsev [Inria, until Feb 2019]

## AGORA Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

- FIL Grant, 2019  
 Participants: Razvan Stanica  
 The partners of this project, supported by the *Fédération d'Informatique de Lyon*, are: CITI, LIP.  
 WLANs (Wireless Local Area Networks) are typically based on IEEE 802.11 (known as WiFi). However, WLANs are prone to performance issues such as unfairness and inefficiencies. 802.11 includes a Rate Adaptation (RA) mechanism that allows user devices to change their transmission rate with regard to the current quality of the radio channel. The RA mechanism is based on preset values that may lead to suboptimal WLAN performance. Our goal is to address this issue by making fine adjustments to the parameters related to the RA mechanism. The search for an adequate setting is made complex due to the vast number of parameters to be considered that precludes the finding of general closed-form expressions. We propose to explore a data-driven approach based on techniques from Machine Learning to design an adaptive and distributed solution.
- Labex IMU 3M' Air 2018-2021  
 Participants: Walid Beckhit, Ahmed Boubriha, 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 explores 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, 2016-2019.  
 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, 2017-2019  
 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 information 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  
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  
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 2018 - 2020.  
Participants: Solohaja Rabenjamina, Razvan Stanica.  
The ANR CoWorkWorlds (Sustainability and spatiality in co-workers' mobility practices) project is led by ENTPE. Its focus is on the study of co-working environments, and more precisely on the mobility behavior 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. GDR CNRS RSD - Pôle ResCom

- Ongoing participation (since 2006)  
Communication networks, working groups of GDR ASR/RSD, CNRS ([https://gdr-rsd.cnrs.fr/pole\\_rescom](https://gdr-rsd.cnrs.fr/pole_rescom)). Hervé Rivano is member of the scientific committee of ResCom.

### 9.2.3. EquipEx

- SenseCity  
We have coordinated the participation of several Inria teams to the SenseCity EquipEx. Within the SenseCity project, several small reproductions 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 test 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 built, the information system is operational since April 2018.

## 9.3. European Initiatives

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

- Herve Rivano is member of European COST action CA18204 - Dynamics of placemaking and digitization in Europe's cities on behalf of Ecole Urbaine de Lyon and Labex IMU.

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.
- **Digital Catapult, London, UK.** 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.
- **Rice University.** Collaboration around network deployment and data assimilation for air quality monitoring with the group of Prof. Edward W. Knightly.
- **University of Edinburgh, UK.** Joint publications and visits to/from the group of Dr. Paul Patras.
- **Biskra University, Algeria.** Joint publications and visits from Prof. Abdelmalik Bachir.

### 9.4.2. Participation in Other International Programs

#### 9.4.2.1. PHC Campus France

- **University College Cork, Ireland.** PHC Ulysses (2019-2021) on real-world characterisation of long range wireless networks, a collaboration with Khaled Abdelfadeel.
- **INPT Rabat, Morocco.** PHC Toubkal (2019-2021) on efficient data collection for smart building and smart city applications, a collaboration with the group of Prof. Loubna Echabbi.
- **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: visiting professor at INSA Lyon (november, 2019).
- Ravi Mazumdar, Waterloo University, Canada, visiting scientist at INSA Lyon (february, 2019).
- Priscilla Solis, Professor, Brasilia University, Brazil, visiting the Agora team to prepare a sabbatical.

#### *9.5.1.1. Internships*

- Sami Abdelatif, PhD student, Biskra University, Algeria: visiting professor at INSA Lyon (november, 2019).

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

#### *9.5.2.1. Research Stays Abroad*

- Mihai Popescu visited the group of Prof. Gabriela Czibula, at University of Cluj-Napoca, Romania (2 periods of 1 month duration: April and July 2019).
- Fabrice Valois visited Prof. Catherine Rosenberg, University of Waterloo, Canada (6 weeks between January and March 2019).

## COATI Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. 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.

## 9.2. National Initiatives

### 9.2.1. DGA/Inria Brainside, 2019-2023

**Participants:** Francesco d'Amore, Emanuele Natale.

Program: DGA/Inria

Project acronym: Brainside

Project title: Algorithms for simplifying neural networks

Duration: October 2019 - March 2023

Coordinator: Emanuele Natale

Other partners: Inria Paris, EP GANG

Abstract: The widespread use of neural networks on devices with computationally-low capabilities, demands for lightweight and energy-efficient networks. Despite such need, and despite the strategies employed to prevent overfitting by removing a substantial part of their edges, the question of how to reduce their size in terms of the number of neurons appears largely unexplored. The aim of the project is to investigate algorithmic procedures to reduce the size of neural networks, in order to improve the speed with which they can be evaluated and to shed light on how much information about the computational problem at hand can be encoded within neural networks of small size.

### 9.2.2. ANR-17-CE22-0016 MultiMod, 2018-2022

**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 2022

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/>

### 9.2.3. 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: CNRS LIRMM (Montpellier), Syddansk universitet (Odense, Denmark)

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 are 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.

### 9.2.4. GDR Actions

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

Members of COATI are involved in the working group RESCOM (*Réseaux de communications*) of GDR RSD, CNRS ([http://gdr-rsd.cnrs.fr/pole\\_rescom](http://gdr-rsd.cnrs.fr/pole_rescom)). In particular, David Coudert is co-chair of this working group since 2017.

We are also involved in the working group "Energy" of GDR RSD ([http://gdr-rsd.cnrs.fr/action\\_green](http://gdr-rsd.cnrs.fr/action_green)). In particular, Frédéric Giroire is co-chair of this working group.

#### 9.2.4.2. 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.

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

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

### 9.3. International Initiatives

#### 9.3.1. Inria Associate Teams Not Involved in an Inria International Labs

##### 9.3.1.1. EfDyNet

Title: Efficient Dynamic Resource Allocation in Networks

International Partner (Institution - Laboratory - Researcher):

Concordia University (Canada) - Department of Electrical Engineering - Brigitte Jaumard

Start year: 2019

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

Networks are evolving rapidly in two directions. On the one hand, new network technologies are developed for different layers, and in particular flexible optical technologies (enabling to allocate a fraction of the optical spectrum rather than a fixed wavelength), Software Defined Networks, and Network Function Virtualization. On the other hand, the traffic patterns evolve and become less predictable due to the increase of cloud and mobile traffic. In this context, there are new possibilities and needs for dynamic resource allocations. We will study this problem mainly in two directions: network reconfiguration and the allocation of virtualized resources. The associated team will build on an already fruitful collaboration between COATI and Concordia. The two teams address design and management optimization problems in networks (WDM, wireless, SDN) with complementary tools and expertise.

#### 9.3.2. Inria International Partners

##### 9.3.2.1. 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.

#### 9.3.3. Participation in Other International Programs

##### 9.3.3.1. International Initiatives

###### **GALOP**

Program: STICAmSud

Title: Graphs ALgorithms for Optimization Problems

International Partners (Institution - Laboratory - Researcher):

Universidad Diego Portales (Chile) - Facultad de Ingeniería y Ciencias - Karol Suchan

Universidade Federal do Ceará (Brazil) - ParGo team - Julio Araujo

Duration: 2019 - 2020

Start year: 2019

See also: <https://team.inria.fr/coati/projects/sticamsud-galop/>

This project aims at allowing to continue the fruitful and long-standing collaboration between Inria and UFC and between Inria and UAI. Another goal is to reinforce the collaboration between UFC and UAI that has been recently initiated. Our goal is to study the Computational Complexity of several important problems arising in networks (routing, resources assignment...). In particular, we will focus on the computation of metric or structural properties and parameters of large networks (e.g., transportation and social networks...). We plan to design efficient exact algorithms for solving these problems or to theoretically prove that such algorithms cannot exist. In the latter case, we will then design approximation algorithms, or prove that none exists. In all cases, we aim at implementing our algorithms and use them on real-world instances such as large road networks or huge social networks.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

- Hossein Baktash: Sharif Institute of Technology, Tehran, Iran. July 15 - September 15, 2019.
- Joergen Bang-Jensen: Southern Denmark University, Odense, Denmark, January 7-11 2019.
- Brigitte Jaumard: Concordia University, Montréal, Québec, Canada. June 17-28 and December 7-21, 2019.
- Malgorzata Sulkowska: Faculty of Fundamental Problems of Technology, Wroclaw University of Science and Technology, Wroclaw, Poland. September 23-27th, 2019.
- Karol Suchan: Universidad Diego Portales, Santiago, Chile. December 8-22th, 2019.
- Julio-Cesar Silva Araújo: Universidad do Ceara, Fortaleza, Brazil. December 5-28th, 2019.
- Karol Maia de Oliveira: Universidad do Ceara, Fortaleza, Brazil. December 5-28th, 2019.
- Claudia Linhares Sales: Universidad do Ceara, Fortaleza, Brazil. December 5-28th, 2019.
- Leonardo Sampaio Rocha: Universidad do Ceara, Fortaleza, Brazil. until June 2019.
- Xavier Defago: Tokyo Institute of Technology, Tokyo, Japan. January 7-11, 2019.
- Takako Kodate: Tokyo Woman's Christian University, Tokyo, Japan. March 18-31, 2019.

### 9.4.2. Visits to International Teams

#### 9.4.2.1. Research Stays Abroad

- Julien Bensmail :
  - Indian Statistical Institute, Kolkata, India. January 26-February 9, 2019.
  - Universidade Federal do Ceará, Fortaleza, Brazil. May 4-May 17, 2019.
  - Xidian University, Xi'an, China. August 31-September 14, 2019.
  - Northwestern Polytechnical University, Xi'an, China. October 19-November 2, 2019.
- David Coudert :
  - Concordia University, Montréal, Québec, Canada. July 12-27, 2019.
- Adrien Gausseran :
  - Concordia University, Montréal, Québec, Canada. September 2 - December 2, 2019.
- Frédéric Giroire :
  - Concordia University, Montréal, Québec, Canada. October 8-18th, 2019.
- Joanna Moulhierac :
  - Concordia University, Montréal, Québec, Canada. October 8-18th, 2019.
- Emanuele Natale :
  - Max Planck Institute for Informatics, Sarrebruck, Germany. January 19 - February 28, 2019.
  - University of Melbourne, Melbourne, Australia & University of Otago, Dunedin, New Zealand. October 1-30, 2019.
  - University of Rome Tor Vergata, Rome, Italy. 1 November 2019 - 31 January 2020.
- Nicolas Nisse :
  - Univ. Federal do Ceara, Fortaleza, Brazil, May 4-18th, 2019.
  - Xidiang University, Xi'an, China. September 1-15th, 2019.

## DANTE Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. *I dex Lyon ACADEMICS*

**Participants:** Paulo Gonçalves, Rémi Gribonval, Marion Foare, Amélie Barbe, Gaetan Frusque.

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.

### 9.1.3. *FIL PerfWiFi*

**Participants:** Guérin-Lassous Isabelle [correspondant], Grünblatt Rémy.

Duration of the project: **January 2019 - December 2020.**

The goal of the project **PerfWiFi** is to set up a Wi-Fi experimental platform that will be, in the future, open to interested researchers. This platform consists in devices (cards, routers) implementing the last versions of Wi-Fi (Wi-Fi 5 and Wi-Fi 6) and with different chipsets from different manufacturers. This platform will also be interconnected to a fleet of UAVs equipped with Wi-Fi interfaces. The Wi-Fi devices are chosen to be as open as possible in order to have a large set of possibilities in terms of parameterization of the Wi-Fi parameters.

In 2019, a first version of the platform has been set up along with a set of software tools to automatically launch Wi-Fi experiments. The first experiments can monitor, during a long period, all the possible Wi-Fi channels and their medium use ratio. We intend to provide these data via an open website.

#### **9.1.4. *FIL ALIENOR***

**Participant:** Begin Thomas [correspondant].

Duration of the project: **January 2019 - December 2020.**

The goal of ALIENOR (Artificial Intelligence-assisted NetwORks) is to develop an approach to dynamically select adequate values for the IEEE 802.11 parameters related to the Rate Adaptation (RA) mechanism to the WLAN context. The search for an adequate setting for the RA parameters is made complex due to the vast number of parameters (e.g., the used amendment of 802.11, the channel transmission rate, the number of competing nodes, the Frame Error Rate (FER), the offered load, and the transport protocol to name a few) that may affect a WLAN behavior.

In ALIENOR, we propose to explore a new approach to determine an adequate setting of the RA parameters using a data-driven approach based on techniques of Machine Learning (ML) in Artificial Intelligence (AI). Our approach consists of three stages. First, we will build a large dataset of measurements that will serve as the training set. Second, we will use ML techniques to discover a function that fits the mapping between the dataset output and the inputs. Lastly, WLAN devices will embed and use this learned function to predict (approximately) what will be their attained throughput under various possible settings of their RA, and then select their best option.

#### **9.1.5. *ENS Lyon project Vehicular project***

**Participants:** Begin Thomas [correspondant], Guérin Lassous Isabelle, Busson Anthony.

Duration of the project: **January 2017 - December 2020.**

The goal of this project is to design new performance tools to improve the sharing of communication resources in vehicular networks. In particular, we focus on the use case of delivering a Video on Demand service to vehicles traveling along a highway. Through the development of a simple and yet accurate performance modeling approach, we were able to demonstrate the feasibility of using IEEE 802.11p to deliver video content to vehicles. Our work also underlines the benefit of blocking the lowest transmission rates for the sake of a collective gain in terms of attained throughput and interruption time in the video playback. This somehow surprising property derives from the well-established performance anomaly of 802.11-based networks.

## **9.2. National Initiatives**

### **9.2.1. *ANR DataRedux***

**Participants:** Paulo Gonçalves [correspondant], Rémi Gribonval, Marion Foare.

Duration of the project: **February 2020 - January 2024.**

DataRedux puts forward an innovative framework to reduce networked data complexity while preserving its richness, by working at intermediate scales (“mesoscales”). Our objective is to reach a fundamental breakthrough in the theoretical understanding and representation of rich and complex networked datasets for use in predictive data-driven models. Our main novelty is to define network reduction techniques in relation with the dynamical processes occurring on the networks. To this aim, we will develop methods to go from data to information and knowledge at different scales in a human-accessible way by extracting structures from high-resolution, diverse and heterogeneous data. Our methodology will involve the identification of the most relevant subparts of time-resolved datasets while remapping the remaining parts of the system, the simultaneous structural-temporal representations of time-varying networks, the development of parsimonious data representations extracting meaningful structures at mesoscales (“mesostructures”), and the building of models of interactions that include mesostructures of various types. Our aim is to identify data aggregation methods at intermediate scales and new types of data representations in relation with dynamical processes, that carry the richness of information of the original data, while keeping their most relevant patterns for their manageable integration in data-driven numerical models for decision making and actionable insights.

### 9.2.2. ANR Darling

**Participants:** Paulo Gonçalves [correspondant], Rémi Gribonval, Marion Foare.

Duration of the project: **February 2020 - January 2024.**

This project meets the compelling demand of developing a unified framework for distributed knowledge extraction and learning from graph data streaming using in-network adaptive processing, and adjoining powerful recent mathematical tools to analyze and improve performances. The project draws on three major parallel directions of research: network diffusion, signal processing on graphs, and random matrix theory which DARLING aims at unifying into a holistic dynamic network processing framework. Signal processing on graphs has recently provided a comprehensive set of basic instruments allowing for signal on graph filtering or sampling, but it is limited to static signal models. Network diffusion on the opposite inherently assumes models of time varying graphs and signals, and has pursued the path of proposing and understanding the performance of distributed dynamic inference on graphs. Both areas are however limited by their assuming either deterministic graph or signal models, thereby entailing often inflexible and difficult-to-grasp theoretical results. Random matrix theory for random graph inference has taken a parallel road in explicitly studying the performance, thereby drawing limitations and providing directions of improvement, of graph-based algorithms (e.g., spectral clustering methods). The ambition of DARLING lies in the development of network diffusion-type algorithms anchored in the graph signal processing lore, rather than heuristics, which shall systematically be analyzed and improved through random matrix analysis on elementary graph models. We believe that this original communion of as yet remote areas has the potential to path the pave to the emergence of the critically needed future field of dynamical network signal processing.

### 9.2.3. Equipex FIT (Futur Internet of Things)

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

Duration of the project: **February 2011 - December 2019.**

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. 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.

### 9.2.4. ANR SoSweet

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

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.

### 9.2.5. ANR DylNet

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

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.

### 9.2.6. *Inria PRE LIAISON*

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

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.

### 9.2.7. *HOTNET - IXXI*

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

Duration of the project: **January 2019 - December 2021.**

The purpose of the HOTNet (Higher-order representation of temporal networks) project is to develop a pipeline for the embedding of temporal networks that captures higher order correlations relevant for dynamical processes. We propose to detach from the straightforward representations of networks — as successions of static networks — by focusing on representations that better reflects the higher-order neighbourhood and temporal paths. To project plans to develop a framework that learns from this representation an embedding sufficient to estimate the outcome of spreading processes that might take place on top of the original network.

This is a small-scale collaborative project funded by the IXXI Complex System Institute to foster collaborations between MK and Laetitia Gauvin (ISI Torino) for the period of 2019-2021.

### 9.2.8. *Inria & HCERES*

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

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 of 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,

### 9.2.9. Inria IPL BetterNet

**Participant:** Éric Guichard.

An Observatory to Measure and Improve Internet Service Access from User Experience.

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. International Initiatives

### 9.3.1. Participation in Other International Programs

#### 9.3.1.1. International Initiatives

##### **MOTif**

Title: Mobile phone sensing of human dynamics in techno-social environment

International Partners (Institution - Laboratory - Researcher):

Universidad de Buenos Aires (Argentina) - Instituto de Cálculo - Alejo Salles

Universidade Federal de Minas Gerais (Brazil) - Jussara M. Almeida

Duration: 2018 - 2019

Start year: 2018

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.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

- Jaqueline Faria has been a long term visitor in the DANTE team as a visiting PhD student from the PUC Minas University of Belo Horizonte (Brazil). Her stay between May-December was supported by the CAPES.

- Alexandre Brandwajn from University of California, Santa Cruz (USA) has been a visiting Professor in the DANTE team between Feb and Mar 2019.
- Dorsaf Ghozlani, PhD student at Ecole Nationale d'Ingénieurs de Tunis, has been a visitor in the Dante team from April to July 2019.

#### *9.4.1.1. Internships*

- Maxime De Freitas, Télécom Physique Strasbourg, from Jun 2019 until Aug 2019.
- Julien Alamelle, Université Claude Bernard Lyon 1, from Oct 2019 until Dec 2019.
- Juan Pablo Astudillo, Universitat Politècnica de Catalunya, PhD, from Apr 2019 until Jul 2019.
- Simon Fernandez, Master 2 student, ENS Lyon, from February 2019 until June 2019.
- Paul Grangette, Master 2 student, Université Claude from November 2019 to July 2020 (work-study contract).

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

#### *9.4.2.1. Research Stays Abroad*

- Christophe Crespelle is on leave with a Marie Skłodowska-Curie Grant from EU. He is currently at the University of Bergen (Norway) until February 1st, 2020.

## DIANA Project-Team

# 8. Partnerships and Cooperations

## 8.1. Inria Internal Funding

### 8.1.1. IPL Betternet

**Participants:** Giulio Grassi, Imane Taibi, Chadi Barakat.

The DIANA team is part of the Inria Project Lab BetterNet (<http://project.inria.fr/betternet/>). Within this lab, Inria is funding the PhD of Imane Taibi who is hosted by the Dionysos team in Rennes and is co-supervised by Chadi Barakat from the DIANA project-team and Gerardo Rubino and Yassine Hadjadj-Aoul from the DIONYSOS project-team. The PhD of Imane Taibi 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 was 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)
- 12 months business developer from Inria ATT for June 2019 - May 2020 (David Migliacci)
- 12 months engineer from Inria ATT for June 2019 - May 2020 (Mondri Ravi)

### 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 targets a solution based on algorithms previously developed in the DIANA project-team (BitHoc and HBSD) to achieve networking in a sparse scenario following the multi-hop communication principle. The project got a funding for one year engineer from the Labex UCN@SOPHIA. Zeineb Guizani has worked on this project from July 2018 to May 2019 and has proposed an architecture based on NDN-opp to support such communications.

## 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 Partners (Institution - Laboratory - Researcher):

UniCamp (Brazil) - Department of Computer Engineering and Industrial Automation - Mateus Augusto Silva Santos

UNICAMP (Brazil) - Department of Computer Engineering and Industrial Automation - Christian Esteve Rothenberg

UC Santa Cruz (USA) - Department of Computer Science and Engineering- Katia Obraczka

Start year: 2018

See also: <https://team.inria.fr/diana/drive-associated-team/>

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).

## 8.6. International Research Visitors

### 8.6.1. Visits of International Scientists

Mark Crovella, Professor at Boston University, visited us in March 2019 and gave a talk at Forum Numerica of Université Côte d'Azur. Mark is currently collaborating with Chadi Barakat on network-wide anomaly detection within the IPL BetterNet.

### 8.6.2. Internships

Houssam Elbouanani

Date: from March 2019 to August 2019

Institution: Ubinet Master 2 program at Université Côte D'Azur

Supervisors: Chadi Barakat and Guillaume Urvoy-Keller

Subject: Measurement as a Service in modern Data Centers

Anas Errahali

Date: from March 2019 to August 2019

Institution: Ubinet Master 2 program at Université Côte D'Azur

Supervisor: Walid Dabbous and Thierry Turletti

Subject: Enhancing geolocation accuracy in LoRa Low Power Wide Area Networks

Youssef Rachid

Date: from March 2019 to August 2019

Institution: Ubinet Master 2 program at Université Côte D'Azur

Supervisor: Arnaud Legout

Subject: Exploring bias in the YouTube recommendation system.

Tareq Si Salem

Date: from March 2019 to August 2019

Institution: Ubinet Master 2 program at Université Côte D'Azur

Supervisor: Arnaud Legout

Subject: Identifying exposure profiles of Electrosmart users.

### 8.6.3. Visits to International Teams

Mohamed Naoufal Mahfoudi spent six months (October 2018, March 2019) PhD internship in University of California at San Diego in Professor Xinyu Zhang team. During this period he worked on a new passive localization system based on deep learning.

Tingting Yuan spent a 3-week visit at UNICAMP, Brazil, in the context of the DrIVE associated team (Oct 21 – Nov 8, 2019).

## 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, Sofiene Jelassi and Gerardo Rubino are participating at 20% of their time to the IRT BCOM granted by the ANR.
- Yann Busnel is a member of the two following projects: 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.

**Inria Exploratory Action SNIDE** We are leading of the Inria Exploratory Action SNIDE (Search Non neutrality DEtection) 2019-2023, involving Dionysos and MIMR (Grenoble).

Search engines play a key role to access content and are accused to bias their results to favor their own services among others. This has led to the sensitive search neutrality debate, similar to the network neutrality debate currently discussed on the role of ISPs. Our goal in this project is to develop and apply a methodology aiming at highlighting a bias and quantifying its impact.

An initial version of our meta-engine (which will be further develop by incorporating outlier detection tests) can be found at <https://snide.irisa.fr/>.

## 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.
- Gerardo Rubino has a long collaboration with Sebastián Basterrech at the VSB-Technical University of Ostrava, Czech Republic, on Machine Learning.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Informal International Partners

We keep a long collaboration in research with the CalPoly at Pomona, USA, on the transient analysis of Markovian models.



### 9.4.2. Participation in Other International Programs

#### 9.4.2.1. Ecos Sud program

##### Project “Masc”

Title: Mathematical Algorithms for Semantic Cognition

International Partner (Institution - Laboratory - Researcher):

Universidad de la República (Uruguay) - Biophysics - Eduardo Mizraji, Jorge Graneri

Universidad de la República (Uruguay) - Computer science - Pablo Rodríguez-Bocca

Duration: 2018 – 2020

Start year: 2018

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 tools applied to the analysis of cognition pathologies.

#### 9.4.2.2. Math and Stic AmSud programs

##### Project “RareDep”

Title: Rare events analysis in multi-component systems with dependent components

International Partner (Institution - Laboratory - Researcher):

Universidad Adolfo Ibañez (Chile) - Faculty of Engineering and Sciences - Javiera Barrera

Universidad de la República Uruguay (Uruguay) - Computer Science - Héctor Cancela

Universidade Federal de Pernambuco (Brazil) - Mathematics - Pablo Martín Rodríguez

Duration: 2019 – 2020

Start year: 2019

See also: <http://mansci-web.uai.cl/raredep/RareDep/Welcome.html>

The RareDep project focus on developing new techniques addressing two central elements for the improvement of the available tools for risk analysis of complex systems. One is the case of rare events, occurring both in performance and in dependability evaluation of systems modeled as made of many components. Rare events preclude the use of Monte Carlo techniques when the event of interest has a small probability of occurring, and specific methods are necessary, with many open problems in the area. Independence is the usual assumption when building models (more precisely, in almost all works in the field make this assumption), but we know that the assumption is almost never satisfied. We often are constrained by the necessity of assuming independent components in order to be able to use the available methods. In RareDep, we intend to address both problems simultaneously. This needs to develop new variance reduction techniques, for instance in the Importance Sampling family, or in the Splitting one, to be able to exploit data concerning dependencies between the components of the models. This will be built on top of our accumulated experience in the Monte Carlo area (and related fields, such as Quasi-Monte Carlo, numerical integration, etc.), and a starting effort to begin the exploration of what happens when we relax the omnipresent independence hypothesis. We will also explore what happens if we consider new ideas (several coming from the participants of the proposal) for defining new metrics in some specific areas. In these cases, everything is to be done: procedures to deal with rare events, modeling techniques to deal with dependencies between the system’s components, and then, both issues at the same time. Our main application area will concern different types of modern networks (in communications, or in energy distribution, for instance).

**Project “ACCON”**

Title: Algorithms for the Capacity Crunch problem in Optical Networks

International Partner (Institution - Laboratory - Researcher):

Universidad de la República Uruguay (Uruguay) - Computer Science - Héctor Cancela

UTFSM (Chile) - Télématica - Reinaldo Vallejos

Universidad de Valparaiso (Chile) - Computer Science - Marta Barría

Duration: 2019 – 2020

Start year: 2019

See also: <http://acon.elo.usm.cl/>

The rapid increase in demand for bandwidth from existing networks has caused a growth in the use of telecommunications technologies, especially WDM optical networks. So far, communication technologies have been able to meet the bandwidth demand. Nevertheless, this decade researchers have anticipated a coming “Capacity Crunch” potential problem associated with these networks. It refers to fact that the transmission capacity limit on optical fibers is close to be reached in the near future. It is then urgent to make the current network architectures evolve, in order to satisfy the relentless exponential growth in bandwidth demand. In other words, the performance bottleneck for optical infrastructures is concentrated around this limiting situation, and the most efficient way of preparing the future of these fundamental technological systems that support the backbone of the Internet is to focus on solving the related management problems. In the previously described scientific context, the ACCON project has a main scientific goal: the development of new strategies capable to provide better resource management techniques to face the threat of the Capacity Crunch. To this end, we will explore the utilization of different analytical techniques to evaluate the performance of several network architecture paradigms, in order to assess their viability in the near future. This will provide us the needed insight leading to finding new strategies for efficiently managing the network resources, and consequently, to contribute addressing this coming Capacity Crunch problem.

#### 9.4.2.3. PHC Ulysses

**Project “AFFINE”**

Title: Achieving Energy Efficient Communication in Future Networks by Supporting Multi-Access Edge Computing in Internet of Things (IoT)

International Partners (Institution - Laboratory - Researcher):

University College Dublin (Ireland) - Computer Science - Lina Xu

Duration: 1 year

Start year: January 2019

Yassine Hadjadj-Aoul and Lina Xu received a grant from the PHC Ulysses (for French-Irish collaboration). The aim of this project is to improve the energy efficiency for data transmission and communication in IoT networks and therefore to reduce electricity consumption and  $CO_2$  emissions.

Yann Busnel has taken part in several events to develop Indo-French collaborations, notably within the framework of Campus France. In particular, he led the round table on Artificial Intelligence and Mathematics at the Knowledge Summit 2 in Lyon in October 2019, in the presence of the Minister, Frédérique Vidal.

## **9.5. International Research Visitors**

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

We have received the following international scientists:

- M. Nakayama (New Jersey Institute of Technology, USA): one week in July 2019.
- DanHua ShangGuan (Institute of Applied Physics and Computational Mathematics, Beijing, China), one month in September 2019.
- Vamsi Bulusu from VJTI Mumbai visited us for 4 months between August and Novembre 2019.
- Jorge Graneri (Sep.–Oct.) and Eduardo Mizraji (Sep.), UDELAR, Uruguay, in the context of the MASC project.
- Nicolás Jara, UTFSM, Chile, Dec., in the context of the ACCON project.
- Franco Robledo, UDELAR, Uruguay, in Feb.

## DYOGENE Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. 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.

### 9.1.2. PGM0

Dyogene participates in the PGM0 (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).

## 9.2. National Initiatives

### 9.2.1. 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.

### 9.2.2. 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>

### 9.2.3. 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.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. NEMO

NEMO, NETwork MOtion <https://cordis.europa.eu/project/id/788851>, <https://project.inria.fr/ercnemo> is an ERC Advanced Grant (2019 – 2024, PI François Baccelli). It is an inter-disciplinary proposal centered on network dynamics. The inter-disciplinarity spans from communication engineering to mathematics, with an innovative interplay between the two. NEMO's aim is to introduce dynamics in stochastic geometry. General mathematical tools combining stochastic geometry, random graph theory, and the theory of dynamical systems will be developed. NEMO will leverage interactions of Inria with Ecole Normale Supérieure on the mathematical side, and with Nokia Bell Labs and Orange on the engineering side. In March 2019, an inaugural workshop *Processus ponctuels et graphes aléatoires unimodulaires* <https://project.inria.fr/ercnemo/fr/presentation> was organized at Inria Paris.

### 9.3.2. Collaborations with Major European Organizations

Partner: VITO (Belgium); <https://vito.be/en>.

Co-advising of PhD student I. Shilov. Started: Nov 2019. Topic: “Algorithmic Games and Distributed Learning for Peer-to-Peer Energy Trading”. PhD scholarship by VITO.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. 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).
- Sharif University, Tehran; Collaborations with O. Mirsadeghi.
- UC Berkeley; Collaborations with V. Anantharam.
- Indian Statistical Institute (ISI), Bangalore; Collaborations with Yogeshwaran D.

### 9.4.2. Participation in Other International Programs

#### 9.4.2.1. Indo-French Center of Applied Mathematics

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. Yogeshwaran D. was visiting Dyogene for two weeks in March and November 2019.

#### 9.4.2.2. Microsoft Research-Inria collaboration

Microsoft Research-Inria collaboration: Laurent Massoulié heads the Microsoft Research-Inria Joint Centre, and also participates to the “Distributed Machine Learning” project of the Joint Centre, together with Francis Bach (Inria), Sébastien Bubeck and Lin Xiao (MSR Redmond), and PhD student Hadrien Hendrikx.

#### 9.4.2.3. Inria International Chairs

##### **IIC- MEYN Sean**

Title: Distributed Control and Smart Grid

International Partner (Institution - Laboratory - Researcher):

University of Florida (United States) - Department of Electrical and Computer Engineering  
- Sean Meyn

Duration: 2019 – 2023

Start year: 2019

See also: [https://www.inria.fr/sites/default/files/2019-12/ HOLDERSChairesInt\\_EN.pdf](https://www.inria.fr/sites/default/files/2019-12/ HOLDERSChairesInt_EN.pdf)

TOPIC: “Distributed Control and Smart Grid”

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

- Ali Khezeli [School of Mathematical Sciences, Tehran, Iran],
- Christian Hirsch [Bernoulli Institute, University of Groningen,
- David Métivier [Los Alamos National Laboratory, USA]
- Deepjyoti Deka [Los Alamos National Laboratory, USA]
- Guenter Last [Karlsruhe Institute of Technology, Germany],
- Hermann Thorisson [University of Islande],
- Holger Keeler [University of Melbourne, Australia] ,
- Hrvoje Pandžić [University of Zagreb, Croatia]
- Itai Benjamini [Weizmann Institute of Science, Rehovot, Israel],
- Joe Yukich [Lehigh University, Bethelam, PA, USA],
- Josu Doncel [University of the Basque Country, Spain],
- Lucas Pereira [Técnico Lisboa, Portugal]
- Miklós Abért [MTA Renyi Institute, Budapest, Hungary],
- Mir-Omid Haji-Mirsadeghi [Sharif University, Tehran, Iran],
- Natasa Dragovic [The University of Texas at Austin, TX, USA],
- Nelson Antunes [University of Faro, Portugal],
- Venkatachalam Anantharam [University of California, Berkeley, CA USA],
- Yogeshwaran D. [ISI, Bangalore, India],

#### 9.5.1.1. Internships

- Bastien Dubail [École Normale Supérieure de Lyon],
- Emmanuel Kravitzch [Inria],
- Erwan Pichon [Inria].
- Ge Jin [Inria],
- Maxence Lefort [Inria].

### 9.5.2. Visits to International Teams

- C. Fricker: University of Faro, Portugal (one week).

#### 9.5.2.1. Research Stays Abroad

- A.Busic: program participant (5 weeks in total) of “The mathematics of energy systems”, Isaac Newton Institute for Mathematical Sciences, Cambridge, UK. Spring 2019, <https://www.newton.ac.uk/event/mes>

## EVA Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. Inria Project Labs, Exploratory Research Actions and Technological Development Actions

- IPL SPARTA
- ATT SmartMarina, 2019. Help transfer the technology of the SmartMarina project to startup Falco. Keoma Brun-Laguna is lead.
- ADT 6TiSCH, 2018-2020. Benchmark the performance of 6TiSCH under realistic scenarios, through experimentaion using the OpenTestbed. Tengfei Chang is lead.
- ADT DASMU (Distributed Adaptive Scheduling for MULTichannel Wireless Sensor Networks), 2018-2019. DASMU focuses on a distributed scheduling algorithm which relies on realistic assumptions, does not require complex computation, is valid for any traffic load, is adaptive and compliant with the standardized protocols used in the 6TiSCH working group at IETF. First results have been obtained and an intensive simulation campaign made with the 6TiSCH simulator has provided comparative performance results. Our proposal, called YSF, outperforms MSF, the 6TiSCH Minimal Scheduling Function, in terms of end-to-end latency and end-to-end packet delivery ratio. Thanks to this ADT, Yasuyuki Tanaka has joined the EVA team for two years.

### 9.1.2. 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 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.

### 9.1.3. 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 runs the Cap d'Agde marina, as part of Falco startup.
- EVA has an ongoing collaboration with SELOR company, which runs the Lorient marinas, as part of the Falco startup.

## 9.2. European Initiatives

### 9.2.1. FP7 & H2020 Projects

The H2020 following project is ongoing:

- H2020 SPARTA, Jan 2019 – December 2020.

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

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. The 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.

### 9.3.2. 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-led 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 party.

#### 9.3.2.2. *Informal International Partners*

The Inria-EVA team 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.

## 9.4. International Research Visitors

### 9.4.1. *Visits of International Scientists*

1. **Martina Brachmann (RISE, Sweden)** (November 2019) working on TSCH on the RISE: Current Research and Future Directions in Networked Embedded Systems with Thomas Watteyne, Malisa Vucinic, Tengfei Chang
2. **Ana Laura Diedrichs (UTN, Argentina)** (Oct-Nov 2019) working on WirelessWine with Thomas Watteyne, Keoma Brun-Laguna
3. **Prof Leila Seidane Azouz** 1-30 October 2019 working with **Pascale Minet** and **Paul Muhlethaler** on wireless networks.
4. **Prof Ruben Milocco** visited EVA from 1-30 October 2019 working with **Pascale Minet** on evaluation of data center performance and **Paul Muhlethaler** on wireless network relaying.
5. **Prof. Diego Dujovne (UDP, Chile)** (July 2019) working on WirelessWine with Thomas Watteyne
6. **Prof. Branko Kerkez (U. Michigan)** (May 2019) working on REALMS associate team with Thomas Watteyne
7. **Mikolaj Chwalisz (TU Berlin)** (May 2019) working on Towards efficient coexistence of IEEE 802.15.4e TSCH and IEEE 802.11 Collaboration with Tengfei Chang, Thomas Watteyne

#### 9.4.1.1. *Internships*

1. Amy Hane, Intern, from Sep 2019 until Dec 2019
2. Camilo Andres Lopez Lopez, Intern, from May 2019 until Aug 2019
3. Ba Hai Le, Intern, Apr-Aug 2019
4. Victor Kenichi Nascimento Kobayashi, Intern, from May 2019 until Aug 2019
5. Sharut Gupta, Intern, from May 2019 until July 2019
6. Miguel Landry Foko Sindjoung, Intern, from Mar 2019 until Jun 2019.

#### 9.4.1.2. *Research Stays Abroad*

- **Thomas Watteyne** spent the month of August 2019 at UC Berkeley, working with Prof. Glaser on the SnowHow project, and with Prof. Pister on Smart Dust and OpenWSN.
- Tengfei Chang spent June 2019 in California working with Prof. Pister working on Smart Dust UC Berkeley.

## FUN Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. StoreConnect

**Participants:** Nathalie Mitton [contact person], Valeria Loscri, 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.

### 8.1.2. LumiCAR

**Participants:** Valeria Loscri [contact person], Antonio Costanzo, Meysam Mayahi.

Title: LumiCAR

Type: ISITE

Duration: October 2019 - October 2021

Vehicle-to-Vehicle and Vehicle-RSU (Roadside Units) communication (V2X) has become a very active topic of research in recent years as it appears to be a means of improving road safety and make effective and timely intervention of road safety actors. To date, most research activities are based on the use of conventional radio frequency (RF) technology. However, faced with multiple constraints, these vehicular communications are not always effective. In the LumiCar project we will base the V2X communication mainly on the Visible Light Communication (VLC) technology and we will focus on the coexistence of the VLC with other technologies. VLC has already started to work in other indoor applications such as connected stores for geolocation of customers. The properties offered by light (speed, directional, controlled containment ...) suggest that VLC technology is more suitable for vehicular communications and can effectively meet the needs of a reliable, robust and with increasing flow to consider new applications such as virtual reality in future cars. In addition, VLC technology can be recognized as a "green" technology because it is based on the exploitation of LEDs and lamps already used for lighting and visibility. It is therefore a question of optimizing the use (by the transmission of information) of an energy already consumed.

## 8.2. National Initiatives

### 8.2.1. Exploratory Action

#### 8.2.1.1. Ethicam

**Participants:** Valeria Loscri [contact person], Carola Rizza.

Duration: October 2019 - October 2022

The evolution of the Internet of Things (IoT) towards the Internet of Everything (IoE) paradigm represents an important and emerging research direction, capable to connect and interconnect massive number of heterogeneous nodes, both inanimate and living entities, encompassing molecules, nanosensors, vehicles and people. This new paradigm demands new engineering communication solutions to overcome miniaturization and spectrum scarcity. Novel pervasive communication paradigms will be conceived by the means of a cutting edge multidisciplinary research approach integrating (quasi) particles (e.g. phonons) and specific features of the (meta)material (e.g. chirality) in the design of the communication mechanisms. In particular, by the means of the meta-materials, it would be possible to control the propagation environment. More specifically, through this paradigm it will be possible to manipulate not only the desired signals, but also the interfering signals.

## 8.2.2. ADT

### 8.2.2.1. Catimex

**Participants:** Matthieu Berthome, Nathalie Mitton [contact person], 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.

## 8.2.3. Equipements d'Excellence

### 8.2.3.1. FIT

**Participants:** Nathalie Mitton [contact person], 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.

## 8.3. European Initiatives

### 8.3.1. H2020 Projects

#### 8.3.1.1. VESSEDIA

**Participants:** Rehan Malak, Nathalie Mitton, Allan Blanchard [contact person].

Title: Verification Engineering of Safety and Security Critical Dynamic Industrial Applications

Program: H2020

Duration: January 2017 - Dec. 2019

Coordinator: 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 Framac 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 2019: [17], [18], [35].

#### 8.3.1.2. *CyberSANE*

**Participants:** Valeria Loscri, Nathalie Mitton [contact person], Edward Staddon.

Title: Cyber Security Incident Handling, Warning and Response System for the European Critical Infrastructures

Program: H2020

Duration: September 2019 - September 2022

CyberSANE aims to enhance the security and resilience of Critical Information Infrastructures (CIIs) by providing a dynamic collaborative, warning and response system supporting and guiding security officers and operators (e.g. Incident Response professionals) to recognize, identify, dynamically analyze, forecast, treat and respond to advanced persistent threats (APTs) and handle their daily cyber incidents utilizing and combining both structured data (e.g. logs and network traffic) and unstructured data (e.g. data coming from social networks and dark web).

In achieving that aim, CyberSANE will introduce a holistic and privacy-aware approach in handling security incidents, addressing the complexity of these nets consisting of cyber assets hosted in cross-border, heterogeneous Critical Information Infrastructures (CIs). Moreover, CyberSANE is fully in-line with relevant regulations (such as the GDPR and NIS directive), which requires organizations to increase their preparedness, improve their cooperation with each other, and adopt appropriate steps to manage security risks, report and handle security incidents.

## 8.4. International Initiatives

### 8.4.1. *Inria International Labs*

#### 8.4.1.1. *Agrinet*

**Participants:** Christian Salim, Brandon Foubert, Nathalie Mitton [contact person].

Title: Agrinet

International Partner (Institution - Laboratory - Researcher): Stellenbosch University, South Africa, Riaan Wolhuter

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 2019 are: [12], [16].

## 8.4.2. Inria International Partners

### 8.4.2.1. Declared Inria International Partners

**Università Mediterranea di Reggio Calabria (UNIC) (Italy):** The 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, such that is independent of the network topology, in a reliable and flexible way. The result is an 'ecosystem' of self-organized and self-sustained objects, 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.

### 8.4.2.2. Informal International Partners

**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 2019 [23], [33], [15], [24], [32].

## 8.4.3. Participation in Other International Programs

### 8.4.3.1. International Initiatives

#### **CroMo**

Title: Crowd data in the mobile cloud

International Partner (Institution - Laboratory - Researcher):

Universidade Federal do Rio de Janeiro (Brazil) - GTA Laboratory - Luis Henrique Costa

Duration: 2015 - 2019

Start year: 2015

CroMo's main goal is to investigate alternatives to efficiently offload multiple data collected from mobile users to the cloud. To achieve this goal, CroMo will focus on three complementary objectives:

- Objective 1 (Data acquisition): In a wireless environment, data can be sourced at a multitude of wireless devices. Hence, the first objective of this project is to identify the most relevant information from all the data available by using local criteria. The notion of local can be concerned with a single wireless device or a set of nearby wireless devices. The goal is to only send relevant data to the cloud or to assign a higher priority to it.
- Objective 2 (Data transmission): The large-scale sensing system forces massive transmission to the cloud. Hence, transmitting the data in a reliable and timely fashion is the purpose of this second objective.
- Objective 3 (Data computation): Mobile clouds must be available for wireless users to receive and process data. Hence, the cloud infrastructure must be efficient enough to process data from users in a efficient fashion. The third objective of this project is to evaluate cloud availability and to propose performance improvements for data computation. Such improvements are concerned with cloud infrastructure adaptation according to users' demands.

In this context, our project is original and ambitious. Indeed, compared to other studies in wireless networking, our project is focused on a global approach from raw data acquisition to information creation at the mobile cloud infrastructure.

## 8.5. International Research Visitors

### 8.5.1. Visits of International Scientists

Several researchers have visited our group in 2019, mainly from our partner universities but not only:

- Gewu Bu, LIP6, France, January 2019
- Noura Mares, University of Sfax, Tunisia, from June 2019 until July 2019
- Marco Di Renzo, Centrale Supélec, France, August 2019
- Riaan Wolhuter, Stellenbosch University, South Africa, September 2019

## GANG Project-Team

# 8. Partnerships and Cooperations

## 8.1. National Initiatives

### 8.1.1. ANR DESCARTES

**Participants:** Carole Gallet Delporte, Hugues Fauconnier, Pierre Fraigniaud, Adrian Kosowski, Laurent Viennot.

Cyril Gavaille (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.

### 8.1.2. 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.

### 8.1.3. ANR FREDDA

**Participants:** Carole Gallet Delporte, 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.

### 8.1.4. 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.

### 8.1.5. 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.

## 8.2. European Initiatives

### 8.2.1. 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.

### 8.2.2. 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.

## 8.3. International Initiatives

### 8.3.1. 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/>).

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

#### **8.3.2.1. 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).

## **8.4. International Research Visitors**

### **8.4.1. Visits to International Teams**

- Laurent Viennot has visited Archontia Giannopoulou at National and Kapodistrian University of Athens from July 1st to July 7th.
- Michel Habib has visited Prof. M. Chen (Xiamen University of Technology) and Prof. Lin Cheng-Kuan (Fuzhou University) in China, 9-15 december.

## GANG Project-Team

# 8. Partnerships and Cooperations

## 8.1. National Initiatives

### 8.1.1. ANR DESCARTES

**Participants:** Carole Gallet Delporte, Hugues Fauconnier, Pierre Fraigniaud, Adrian Kosowski, Laurent Viennot.

Cyril Gavaille (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.

### 8.1.2. 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.

### 8.1.3. ANR FREDDA

**Participants:** Carole Gallet Delporte, 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.

### 8.1.4. 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.

### 8.1.5. 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.

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## 8.3. International Initiatives

### 8.3.1. 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/>).

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

#### **8.3.2.1. 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).

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## **8.4. International Research Visitors**

### **8.4.1. Visits to International Teams**

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- Michel Habib has visited Prof. M. Chen (Xiamen University of Technology) and Prof. Lin Cheng-Kuan (Fuzhou University) in China, 9-15 december.

## MARACAS Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

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

## 9.2. National Initiatives

### 9.2.1. ANR

- ANR EPHYL *Enhanced PHY for Cellular Low Power Communication IoT* (2016-2019, 183 keuros, leader : Sequans). This project aims to investigate coming and future LPWA technologies with the aim to improve coverage, data rate and connectivity while keeping similar level of complexity and power consumption at the node for the access. New waveforms enablers will be investigated and trialled in order to increase the efficiency of future systems and to provide efficient and fair access to the radio resource. The proposed new waveforms should comply with system constraints and with the coexistence of multiple communications.
- ANR ARBURST *Achievable region of bursty wireless networks* (2016-2020, 195 KEuros, leader : MARACAS). In this project, we propose an original approach complementary to other existing projects, devoted to the study of IoT networks fundamental limits. Instead of proposing one specific technical solution, our objective is to define a unified theoretical framework. We aim at establishing the fundamental limits for a decentralized system in a bursty regime which includes short packets of information and impulsive interference regime. We are targeting the fundamental limits, their mathematical expression (according to the usual information theory framework capturing the capacity region by establishing a converse and achievability theorems). We will use the recent results relative to finite block-length information theory and we will evaluate the margin for improvement between existing approaches and these limits and we will identify the scientific breakthrough that may bring significant improvements for IoT/M2M communications. This project will contribute to draw the roadmap for the development of IoT/M2M networks and will constitute a unified framework to compare existing techniques, and to identify the breakthrough concepts that may afford the industry the leverage to deploy IoT/M2M technical solutions.
- ANR EquipEx FIT/CorteXlab (2009-2020, 1M€, leader : UPMC). The FIT projet is a national equipex headed by the Lip6 laboratory. As a member of Inria, Maracas is in charge of the development of the Experimental Cognitive Radio platform (CorteXlab) that is used as a testbed for SDR terminals and cognitive radio experiments. This has been operational since 2014 and is maintained for a duration of 7 years. To give a quick view, the user will have a way to configure and program through Internet several SDR platforms (MIMO , SISO , and baseband processing nodes).

### 9.2.2. Autres sections...

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

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects



1. COM-MED, *COMMunication systems with renewable Energy micro-grid*
  - Programm: H2020
  - Duration: October 2016 - October 2019
  - Coordinator: Inria
  - Inria contact: Samir M. Perlaza
  - Summary : A smart micro-grid is a small-scale power-grid system consisting of a number of distributed energy sources and loads which is responsible to ensure power sufficiency in a small area. The effectiveness of a smart micro-grid depends on the proper implementation of a communications and networking system which monitors, controls and manages the grid's operations. Due to the ever growing worldwide energy consumption, the need of an efficient framework for managing the way power is distributed and utilized has increased. The main objective of the project COM-MED is to study the fundamental interplay between communications and power networks in the context of smart micro-grids and renewable energy sources. On one hand, we study advanced signal processing techniques and communications methods to optimize the operation of smart micro-grid systems. On the other hand, we focus on mobile communications networks with renewable energy base-stations (BSs) and we investigate communications and networking techniques that take into account both data traffic and energy profiles to support high quality-of-service (QoS). The objectives of each technical WP have been assigned in such a way as to ensure that the project's target is realized during the project's time period. The theoretical results derived from the WPs 3, 4 and 5 will be tested using the telecommunication network of MTN in Cyprus but also the state-of-the-art equipment of the CITI/Inria research lab in France. The outcome of this project will provide a theoretical framework for the optimal cooperation between communications networks and power networks in the context of smart micro-grids and renewable energy sources. This is in line with the objectives of the call's theme "Renewable Energy" and is of paramount importance for the Mediterranean area. The consortium of the project has the expertise and the infrastructure to implement the objectives set and to bring the project to a successful end.
2. WindMill, *Machine Learning for Wireless Communications*
  - Programm: H2020; European Training Network (ETN).
  - Duration: January 2019 - December 2022.
  - Coordinator: Aalborg University, DK
  - Inria contact: Jean-Marie Gorce
  - Summary : With their evolution towards 5G and beyond, wireless communication networks are entering an era of massive connectivity, massive data, and extreme service demands. A promising approach to successfully handle such a magnitude of complexity and data volume is to develop new network management and optimization tools based on machine learning. This is a major shift in the way wireless networks are designed and operated, posing demands for a new type of expertise that requires the combination of engineering, mathematics and computer science disciplines. The ITN project WindMill addresses this need by providing Early Stage Researchers (ESRs) with an expertise integrating wireless communications and machine learning. The project will train 15 ESRs within a consortium of leading international research institutes and companies comprising experts in wireless communications and machine learning. This a very timely project, providing relevant interdisciplinary training in an area where machine learning represents a meaningful extension of the current methodology used in wireless communication systems. Accordingly, the project will produce a new generation of experts, extremely competitive on the job market, considering the scale by which machine learning will impact the future and empower the individuals that are versed in it. The project will also nurture the sense of responsibility of the ESRs and the other participants through personal engagement in the training program and by promoting teamwork through collaborative joint projects.

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

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

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Informal International Partners

- Princeton University, School of Applied Science, Department of Electrical Engineering, NJ. USA. This cooperation with Prof. H. Vincent Poor is on topics related to decentralized wireless networks. Samir M. Perlaza has been appointed as Visiting Research Collaborator at the EE Department for the academic period 2016-2017. Scientific-Leaders at Inria: Samir M. Perlaza and Jean-Marie Gorce.
- Technical University of Berlin, Dept. of Electrical Engineering and Computer Science, Germany. This cooperation with Prof. Rafael Schaffer is on secrecy and covert communications. Scientific-Leaders at Inria: Samir M. Perlaza.
- National University Singapore (NUS), Department of Electrical and Computer Engineering, Singapore. This collaboration with Prof. Vincent Y. F. Tan is on the study of finite block-length transmissions in multi-user channels and the derivation of asymptotic capacity results with non-vanishing error probabilities. Scientific-Leaders at Inria: Samir M. Perlaza
- University of Sheffield, Department of Automatic Control and Systems Engineering, Sheffield, UK. This cooperation with Prof. Inaki Esnaola is on topics related to information-driven energy systems and multi-user information theory. Scientific-in-charge at Inria: Samir M. Perlaza.

- University of Arizona, Department of Electrical and Computer Engineering, Tucson, AZ, USA. This cooperation with Prof. Ravi Tandon is on topics related to channel-output feedback in wireless networks. Scientific-Leader at Inria: Samir M. Perlaza.
- University of Cyprus, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, Cyprus. This cooperation with Prof. Ioannis Krikidis is on topics related to energy-harvesting and wireless communications systems. Scientific-Leaders at Inria: Guillaume Villemaud and Samir M. Perlaza.
- Queen's University Belfast, UK. This collaboration is on molecular communication and massive MIMO with Prof. Trung Q. Duong. Scientific-in-charge at Inria: Malcolm Egan
- Czech Technical University in Prague, Czech Republic. This collaboration is on optimisation methods related to machine learning with Dr. Vyacheslav Kungurtsev. Scientific-in-charge at Inria: Malcolm Egan
- TUMCREATE, Singapore. This collaboration is on signal processing in communications with Dr. Ido Nevat. Scientific-in-charge at Inria: Malcolm Egan.
- UMNG (Universidad Militar de Nueva Granada), Telecommunications Department, Bogota, Colombia. Ongoing collaboration on security for GSM networks using deep learning. Scientific-in-charge at Inria: Leonardo S. Cardoso.
- Department of Power, Electronic and Communication Engineering, University of Novi Sad, Serbia. This collaboration is on GNU radio and signal processing around FIT/CorteXlab with Prof. Dejan Vukobratovic. Scientific-in-charge at Inria: Jean-Marie Gorce.

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

#### 9.5.1.1. Internships

1. Huy Duy Do, February-July 2019, Master Thesis MONABIPHOT, ENS Cachan, "Biological Circuits for Detection in Molecular Communication".
2. Antoine Dejonghe, September 2018-July 2020, Telecommunication Department's Research Track, INSA-Lyon, "Techniques for Massive Access in Dense IoT Networks" (Provisional Title)
3. Nuria Vinyes, September 2019-January 2020, Master Thesis, UPC Barcelona, "Simultaneous Information and Energy Transmission: Towards Feasible Systems"
4. Charlotte Hoefler-Hoerle – Undergraduate Student at INSA de Lyon (programme "parcours recherche" de l'INSA de Lyon), Leonardo S. Cardoso and Samir M. Perlaza.
5. INSA de Lyon, Département des Télécommunications. I have advised the following students during their final projects for obtaining the title of Engineer of INSA of Lyon: Samia Bouchareb (2015) and Naslaty Ali Kari (2016), L'elio Chetot (2016), Matias Dwek (2016), and Mamy Niang (2016), Charlotte Hoefler-Hoerle (2019), Adam Ben-Ltaifa (2019), Carl Hatoum (2019).
6. ENS de Lyon, Département d'Informatique. I have advised the following students during their M2-level projects: Lucas Venturini (2019) and Tran Xuan Thang (2019).
7. Matei Catalin Moldoveanu – Master Student at University of Sheffield (Research Intern, Summer 2019).

### 9.5.2. Visits to International Teams

#### 9.5.2.1. Research Stays Abroad

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

## NEO Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. MYDATA (Sept. 2018 - Nov. 2020)

**Participant:** Giovanni Neglia.

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". It involves the participation of Vidhya Kannan.

## 9.2. National Initiatives

### 9.2.1. PIA ANSWER

**Participants:** Konstantin Avrachenkov, Abhishek Bose, Kishor Yashavant Patil.

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.

### 9.2.2. ANR MAESTRO5G

**Participant:** Eitan Altman.

Project Acronym: MAESTRO5G

Project Title: MAnagEment of Slices in The Radio access Of 5G networks

Coordinator: Orange Labs

Duration: February 2019 – January 2022

Others Partners: Nokia Bell Labs, Univ Avignon, Inria Project-Team AGORA, Sorbonne Univ, Telecom SudParis, CentraleSupélec.

Abstract: The project develops enablers for implementing and managing slices in the 5G radio access network, not only for the purpose of serving heterogeneous services, but also for dynamic sharing of infrastructure between operators. MAESTRO-5G develops a framework for resource allocation between slices and a business layer for multi-tenant slicing. It provides an orchestration framework based on Software Define Networking that manages resources and virtual functions for slices. A hardware demonstrator brings the slicing concept to reality and showcases the project's innovations.

## 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.Avrachenkov/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, Erdos-Renyi 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) - Computer Science Department - Daniel Rattón Figueiredo

Start year: 2017

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

This team is the follow-up of a joint Inria-UFRJ team (funded by FAPERJ in Rio de Janeiro, Brazil) with the same name and almost the same permanent researchers involved. During the first three years THANES has studied how services in Online Social Networks (OSNs) can be efficiently designed and managed. The joint research activity continued along the line of network science with a focus on network growth models, community detection, information spreading, and recommendation systems for online social networks. A new research axis on deep learning spawned during 2018.

### 9.4.2. Participation in Other International Programs

#### 9.4.2.1. 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

Mindaugas Bloznelis, Date: 2-7 Oct, Institution: Vilnius Univ (Lithuania)

Damiano Carra, Date: 17-26 Jun, Institution: Univ of Verona (Italy)

Mahmoud El Chamie, Date: 16-20 Dec, Institution: United Technologies Research Center, East Hartford (USA)

Lasse Leskela, Date: 8-19 April, Institution: Aalto Univ (Finland)

Nelly Litvak, Date: 20 May-2 Jun, Institution: Univ of Twente (Netherlands)

Vincenzo Mancuso, Date: 16-18 Jul, Institution: IMDEA Networks Institute (Spain)

Angelia Nedich, Date: 8-10 Dec, Institution: Arizona State Univ (USA)

Sreenath Ramanath, Date: 2-7 Jul, Institution: Lekha Wireless (India)

Daniel Sadoc Menasche, Date: 24-28 Jun, Institution: UFRJ (Brazil)

Neeraja Sahasrabudhe, Date: 9 May - 4 Jun and 16-20 Dec, Institution: IIT Bombay (India)

Matteo Sereno, Date: 15-17 July, Institution: Univ of Turin (Italy)

Georgiy Shevlyakov, Date: 3-17 Nov, Institution: Peter the Great St. Petersburg Polytechnic Univ (Russia)

Gugan Thoppe, Date: 25 Nov - 6 Dec, Institution: IISc Bangalore (India)

Don Towsley, Date: 1-4 Apr, Institution: UMass Amherst (USA)

Kavitha Voleti Veeraruna, Date: 27 May - 8 Jun, Institution: IIT Bombay (India)

#### 9.5.1.2. Postdoc/PhD Students

Tejas Bodas, Date: 12-22 Apr and 11-22 Jun, Postdoc at IIS Bangalore (India)  
 Mikhail Grigorev, Date: 2-31 Jan, PhD student at MFTI Moscow (Russia)  
 Eduardo Hargreaves, Date: 24-28 Jun, PhD student at UFRJ (Brazil)  
 Maksim Mironov, Date: 2-31 Jan and 24 Aug - 7 Sep, PhD student at MFTI Moscow (Russia)  
 Maksim Ryzhov, Date: 4 Apr - 3 May, PhD student at MFTI Moscow (Russia)  
 Anirudh Sabnis, Date: 1 Jul - 6 Oct, PhD student at UMass Amherst (USA)

### 9.5.2. Internships

Note: UCA is the Univ Côte d'Azur.

Younes Ben Mazziane, Date: 19 Nov-13 Dec, Institution: PFE Master Ubinet, UCA, Supervisors: S. Alouf and G. Neglia  
 Vidhya Kannan, Date: from Dec, Institution: UCA, Supervisor : G. Neglia  
 Carlos Eduardo Marciano, Date: 13 Sep-9 Dec, Institution: Master student at UFRJ, Brazil, Supervisor: G. Neglia  
 Kaiyun Pan, Date: 19 Nov-13 Dec, Institution: PFE Master Ubinet, UCA, Supervisor: G. Neglia  
 Quentin Petitjean, Date: 11 Jun-26 Jul, Institution: ENS Cachan, Supervisors: S. Alouf and A. Jean-Marie  
 Vilc Queupe Rufino, Date: 17-19 Jun, Institution: Master student at UFRJ, Brazil, Supervisor: D. Sadoc Menasche (UFRJ)  
 Varvara Samoili, Date: 11 Jan-10 Jul, Institution: Bodossaki Foundation, Supervisor: G. Neglia  
 Nicola Sebastianelli, Date: 1 Mar-31 Aug, Institution: Master Ubinet, UCA, Supervisor: G. Neglia  
 Adeel Siddiqui, Date: until Jan 2019, Institution: UCA, Supervisor : G. Neglia  
 Siemo Zhang, Date: 1 Sep-30 Nov, Institution: Master student at Univ of Twente, Netherlands, Supervisor: K. Avrachenkov

## 9.6. Visits to International Teams

### 9.6.1. Research Stays Abroad

Eitan Altman

- Date: 29 January - 4 February, 28 March - 6 April, 20 June - 10 July, 18 October - 4 December, Institution: Technion and Univ Tel-Aviv (Israel)

Konstantin Avrachenkov

- Date: 17-22 February, Institution: Friedrich-Alexander Univ (Germany)
- Date: 4-15 March, Institution: Petrozavodsk State Univ (Russia)
- Date: 26-28 October, Institution: IISc Bangalore (India)
- Date: 30 October - 2 November, Institution: IIT Bombay (India)
- Date: 24-26 November, Institution: Univ Twente (The Netherlands)

Maximilien Drevetton

- Date: 24 May - 9 June, Institution: Aalto Univ (Finland)

Alain Jean-Marie

Date: 17 October - 4 November, Institution: GERAD (Montréal, Canada)

Giovanni Neglia

- Date: 20-22 February, Institution: Univ Florence and Univ Pisa (Italy)
- Date: 23-26 September, Institution: Northeastern Univ and Boston Univ (Massachusetts, United States)

## RESIST Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

Olivier Festor is leading the Grand Est PACTE initiative on cyber-security. This initiative led to a total funding of 400 K€ to acquire, develop and operate the first Cyber Range in the Grand Est. This unique equipment is deployed at TELECOM Nancy and serves as the main platform for cyber-security training in the Grand Est region for both civil and military staff.

## 9.2. National Initiatives

### 9.2.1. ANR

#### 9.2.1.1. ANR BottleNet

**Participants:** Isabelle Chrisment [contact], Antoine Chemardin, Thibault Cholez.

- Acronym: BottleNet
- Title: Understanding and Diagnosing End-to-End Communication Bottlenecks of the Internet
- Coordinator: Inria
- Duration: October 2015 - extended to September 2020
- 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.

#### 9.2.1.2. 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-Décembre 2020
- Others Partners: TELECOM Nancy, 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 an (extended) duration of 5 years. It includes 14 academic partners (engineering schools including Telecom Nancy), industrial partners (Airbus, Orange) and innovative startups (the MOOC agency, and Isograd). 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.

### 9.2.1.3. ANR MOSAICO

**Participants:** Thibault Cholez [contact], Olivier Festor.

- Acronym: MOSAICO
- Title: Multi-layer Orchestration for Secured and low lAtency applICatiOns
- Coordinator: Orange Labs
- Start: 01/12/2019
- Duration: 4 years
- Others Partners: Orange Labs, Montimage, ICD-UTT
- Abstract:

For several years, programmability has become increasingly important in network architectures. The last trend is to finely split services into micro-services. The expected benefits relies on an easier development and maintenance, better quality, scalability and responsiveness to new scenarios than monolithic approaches, while offering more possibilities for operators and management facilities through orchestration. As a consequence, it appears that network functions, such as routing, filtering, etc. can be split in several micro-services, implemented through different means, according to the software environments, and at different topological locations, thus opening the way to fully end-to-end programmable networks. This need for multi-level and multi-technology orchestration is even more important with the emergence of new services, such as immersive services, which exhibit very strong quality of service constraints (i.e. latency cannot exceed a few milliseconds), while preserving end-to-end security. The MOSAICO project proposes to design, implement and validate a global and multi-layer orchestration solution, able to control several underlying network programmability technologies (SDN, NFV, P4) to compose micro-services forming the overall network service. To reach this objective, the project will follow an experimental research methodology in several steps including the definition of the micro-services and of the global architecture, some synthetic benchmarking, the design of orchestration rules and the evaluation against the project use-case of a low latency network application.

The kick-off meeting of MOSAICO took place the 03/12/2019 in Orange Gardens. Our current work consists in surveying the latest technologies around NFV and Open Networking.

## 9.2.2. Inria joint Labs

### 9.2.2.1. Inria-Orange Joint Lab

**Participants:** Jérôme François [contact], Olivier Festor, Matthews Jose, 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.

### 9.2.3. Technological Development Action (ADT)

#### 9.2.3.1. ADT SCUBA

**Participants:** Abdelkader Lahmadi [Contact], Jérôme François, Thomas Lacour, Frédéric Beck.

- Acronym: SCUBA
- 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.

### 9.2.4. FUI

#### 9.2.4.1. 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.

### 9.2.5. Inria Project Lab

#### 9.2.5.1. IPL BetterNet

**Participants:** Isabelle Chrisment [contact], Antoine Chemardin, Frederic Beck, Thibault Cholez.

- Acronym: BetterNet
- Coordinator: RESIST (Isabelle Chrisment)
- Duration: October 2016-August 2020
- 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.

### 9.2.5.2. IPL Discovery

**Participant:** Lucas Nussbaum [contact].

- Coordinator: Adrien Lebre (STACK)
- End: June 2019
- Site: <http://beyondtheclouds.github.io>
- Others 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.

## 9.3. European Initiatives

### 9.3.1. H2020 Projects

#### 9.3.1.1. Fed4Fire+ (2017-2022)

Title: Federation for FIRE Plus

Program: H2020

Duration: January 2017 - December 2021

Coordinator: Interuniversitair Micro-Electronica centrum 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)

Abstract: 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.

#### 9.3.1.2. SecureIoT

Title: Predictive Security for IoT Platforms and Networks of Smart Objects

Duration: December 2017 - December 2020

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 Rechtsanwaltsgesellschaft 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

Url : <http://secureiot.eu>

Abstract: 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.

#### 9.3.1.3. SPARTA

Title: Strategic programs for advanced research and technology in Europe

Program: H2020

Duration: February 2019 - January 2022

Coordinator: Commissariat à l'Energie Atomique et aux Energies Alternatives

Partners: see web site

Inria contact: Jérôme François

Url : <http://www.sparta.eu>

Abstract: Cybersecurity is an urgent and major societal challenge. In correlation with the digitization of our societies, cyberthreats are having an increasing impact on our lives: it is essential to ensure digital security and strategic autonomy of the EU by strengthening its cybersecurity capacities. This challenge will require the coordination of Europe's best competences, along with strong international cooperations, towards common research and innovation goals.

SPARTA is a novel cybersecurity competence network, with the objective to collaboratively develop and implement top-tier research and innovation actions. Strongly guided by concrete challenges forming an ambitious Cybersecurity Research & Innovation Roadmap, SPARTA will tackle hard innovation challenges, leading the way in building transformative capabilities and forming a world-leading cybersecurity competence network across the EU. Four initial research and innovation programs will push the boundaries to deliver advanced solutions to cover emerging issues, with applications from basic human needs to economic activities, technologies, and sovereignty.

#### 9.3.1.4. CONCORDIA

**Participants:** Thibault Cholez [contact], Rémi Badonnel, Olivier Festor.

Acronym: CONCORDIA

Title: Cyber security cOmpeteNCe fOr Research and InnovAtion

Program: H2020

Start: 01/01/2019

Duration: 4 years

Coordinator: Research Institute CODE (Munich, Germany)

Partners: 52 partners, 26 academic and 26 industrial, from 19 countries (please see <https://www.concordia-h2020.eu/consortium>)

Url : <https://www.concordia-h2020.eu/>

Abstract: CONCORDIA is one of the 4 pilot projects whose goal is to structure and develop a network of cybersecurity competences across Europe. CONCORDIA has a research program to develop next-generation cybersecurity solutions by taking a holistic end-to-end data-driven approach from data acquisition, data transport and data usage, and addressing device-centric, network-centric, software-centric, system-centric, data-centric and user-centric security. The solutions will be integrated in sector-specific (vertical) and cross-sector (horizontal) industrial pilots with building incubators. Vertical pilots include Telecom, Finance, e-Health, Defence and e-Mobility, while horizontal pilots are about two European-scale federated platforms that are the DDoS clearing house and the Threat Intelligence platform . CONCORDIA also develops a CONCORDIA ecosystem by providing lab infrastructures, platforms, tools as "Living Labs" as well as advanced cybersecurity courses on cyber-ranges.

The project kick-off took place in Munich the 28/01/2019. The team is mainly involved in three tasks (research, education and European dimension). On the research side, we begun our work on assessing the reliability of blockchains' networking infrastructure (see section 7.1.3 ). Regarding the education in cybersecurity, we set up a cyber-range at TELECOM Nancy which was officially launched the 24/09/2019 and is already used by our M1 and M2 students to be trained in cybersecurity. We worked also for the task "Liaison with stakeholders" and were in particular the main editor of the 1st year deliverable of this task.

## 9.4. International Initiatives

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

#### 9.4.1.1. 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

Duration: 3 years

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 lead 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.

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

#### *9.4.2.1. Declared Inria International Partners*

The team is actively involved in the international program of LUE (Lorraine Université d'Excellence):

Prof. Raouf Boutaba (University of Waterloo): Inria International Chair and Professor@Lorraine

Abir Laraba: international PhD grant in cooperation with University of Waterloo

Mehdi Zakroum: international PhD grant in cooperation with International University of Rabat

#### *9.4.2.2. Informal International Partners*

Since 2019, we have started a collaboration with Sonia Mettali from the CRISTAL Lab at the ENSI engineering school (Tunisia) on the development of reinforcement learning methods for the monitoring of IoT. The work is done in the context of the PhD of Mohamed Said Frikha, jointly co-supervised by Sonia Mettali and Abdelkader Lahmadi.

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

#### *9.4.3.1. 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.

## **9.5. International Research Visitors**

### *9.5.1. Visits of International Scientists*

Professor Adel Bouhoula from SUP'COM (Tunisia) from June 2019 until July 2019 in collaboration with PESTO team to develop methods for optimal and verifiable security policies for software-defined networks.

Dashi Kondo, Assistant Professor in Osaka Prefecture University for two weeks in November 2019 to develop new scientific cooperation on network security.

#### *9.5.1.1. Internships*

Anthony Samer Abou Jaoude, from March 2019 until May 2019.

Tarek Nsiri, from June 2019 until September 2019.

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

### *9.5.2.1. Research Stays Abroad*

Abdelkader Lahmadi visited the team of Professor Raouf Boutaba in the University of Waterloo for two weeks during the month of June 2019. During this visit, he provided an IEEE seminar on the topic of Self-Driving Networks.

## SOCRATE Project-Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### 7.1.1. 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.

### 7.1.2. 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.

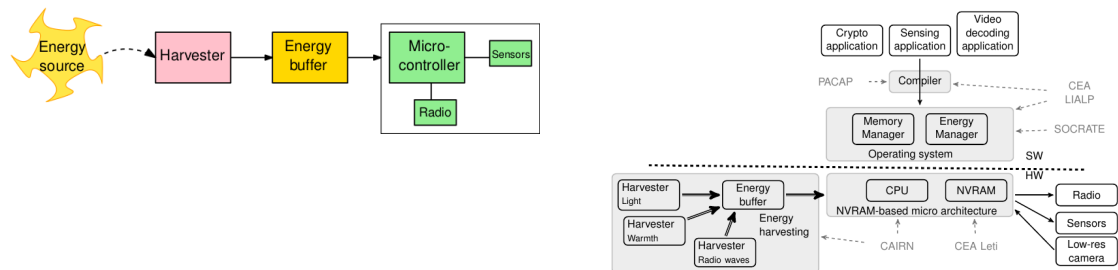


Figure 5. Example of system targeted by the ZEP project on the left, and on the right: the ZEP research program.

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 5 , 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.



### 7.1.3. 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.

### 7.1.4. ADT SytaRiot

The Riot system (<https://www.riot-os.org/>) is well known within Inria, it is a joint implementation of Inria and Freie Universität Berlin which is today one of the most widely used open-source OS on small embedded systems. The arrival of non-volatile memories promises a new generation of sensors on which the memory hierarchy will be more heterogeneous than today. The communicating system will be able to undergo a power cut, then complete and resume its current activity when power returns.

Sytare (<https://gitlab.inria.fr/citi-lab/sytare/>), developed for three years by the Socrates team (with the support of an ADT), targets intermittent feeding which will arrive when the technologies of *harvesting* (recovery of ambient energy) are democratized.

The objective of this ADT is to make Riot compatible with NVRAM-based architecture, therefore to integrate Sytare with Riot and thus open Riot to ultra low power platforms containing NVRAM, eg Texas microcontrollers Instrument MSP430FR5969.

### 7.1.5. Digital Hardware AI Architectures

Florent de Dinechin participates to the chair *Digital Hardware AI Architectures* held by Prof. Frédéric Pétrot at the Multidisciplinary Institute in Artificial Intelligence (MIAI) of Grenoble. The other participants are François Duhem (Spintec/CEA) and Fabrice Rastello (LIG/Inria), with industrial partners Google France, Kalray, STMicroelectronics, and Upmem.

This chair funds the PhD of Maxime Christ, which studies how very low-precision arithmetic formats may improve the efficiency of the learning phase of neural networks.

## 7.2. European Initiatives

### 7.2.1. 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 identified as one of the COST platform.

## 7.3. International Initiatives

### 7.3.1. Inria International Partners

#### 7.3.1.1. Informal International Partners

Socrate has collaborations with the following international partners.

- **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.
- **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.
- **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
- **Technical University of Fulda, Germany**. This collaboration with the group of Martin Kumm covers many aspects of computer arithmetic, with several joint papers, collaboration on the FloPoCo project, and work in progress on a textbook to appear in 2020. Scientific-in-charge at Inria: Florent de Dinechin
- **Imperial College, London, UK**, departments of Computing and Electrical Engineering. This collaboration with the groups of David Thomas and George Constantinides covers several aspects of reconfigurable computing and reconfigurable arithmetic. Scientific-in-charge at Inria: Florent de Dinechin

## TRIBE Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. *Digicosme - Thesis - ECOMICENE*

**Participants:** Cedric Adjih, Hirah Malik, Michel Kieffer [L2S, CNRS–CentraleSupélec–Univ Paris-Sud, Univ Paris-Saclay], Claudio Weidmann [ETIS / ENSEA - Université de Cergy-Pontoise, CNRS (UMR 8051)].

**Partners:** Centrale-Supélec L2S, ETIS-ENSEA

Subject : Efficient COding of Meta-information in Information-Centric NETworks.

### 8.1.2. *Digicosme - Post doc - ICN-based-Vehicles*

**Participants:** Cedric Adjih, Ines Khoufi [Telecom SudParis], Anis Laouiti [Telecom SudParis].

**Partners:** SAMOVAR, Telecom Sud-Paris (IPP)

Subject: In this work, the project is to design and propose a new architecture model that combines several new emerging research fields which are FANETs (Flying Ad-hoc NETworks). We will modelled a FANET problem of information gathering and distribution, reviewed related literature in [5]. We are now focusing on some mobility patterns for the FANETs in order to optimize the movement of the flying vehicles while they are enhancing the radio coverage for the VANETs and trying to improve data exchange experience between different damaged locations, using genetic algorithms. ([link](#))

### 8.1.3. *Digicosme - Engineer - LoRaWAN simulator*

**Participants:** Cedric Adjih, Kinda Khawam [UVSQ], Samer Lahoud [ESIB], Steven Martin [LRI, Université Paris-Saclay].

Subject: LoRa-MAB: A Flexible Simulator for Decentralized Learning Resource Allocation in IoT Networks

The simulator is available at <https://github.com/tuyenta/IoT-MAB>

## 8.2. National Initiatives

### 8.2.1. *Equipex FIT:*

**Participants:** Cedric Adjih, Alexandre Abadie [Inria, SED], Emmanuel Baccelli.

**Partners:** Sorbonne Université, Inria (Lille, Sophia-Antipolis, Grenoble), INSA, 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.

## 8.2.2. ANR

### 8.2.2.1. MITIK

**Participants:** Aline Carneiro Viana, Catuscia Palamidessi.

Funding instrument/scientific committee: PRC/CE25

Project acronym: MITIK

Project title: Mobility and contact traces from non-intrusive passive measurements

Duration: 2020–2023

Coordinator: Aline Carneiro Viana

Other partners: COMETE/Inria, Universite de la Rochelle, Sorbonne Universite.

Abstract: The MITIK project is a 42-month ANR project that will start in February 2020. Mitik's primary objective is the design of an entirely new methodology to help the community obtain real wireless contact traces that are non-intrusive, representative, and independent of third parties. The secondary outcome of the project is be the public release of (1) the measurement tool designed for the easy contact gathering task; (2) contact traces which are clean, processed, and privacy-preserving, i.e., protecting both the anonymity and the location privacy of the users; and (3) their spatiotemporal statistical analysis. We expect that Miti's outcomes will support non-biased research on the modeling as well as on the leveraging of wireless contact patterns.

### 8.2.2.2. GORILLA

**Participants:** Cedric Adjih, Aline Carneiro Viana, Nadjib Achir.

Funding instrument/scientific committee: Under submission to the PRC/CE25 (Phase I)

Project acronym: GORILLA

Project title: GeO-distributed pRivacy-preserving InteLLigent orchestrAtion of data-hungry Services

Duration: 2021–2024

Coordinator: Cedric Adjih

Other partners: IRIT – Toulouse INP, LS2N – IMT Atlantique L2TI – University Paris 13.

Abstract: The GORILLA project has been submitted to the ANR - PCR program (PHASE I). Users of mobile applications keep calling for better user privacy while getting better user experience, and this fact has become a competitive challenge for application developers. As of today, privacy is often promoted through personal storage and is sometimes opposed to cloud solutions which are nevertheless well-established. GORILLAS proposes to revisit this dilemma with the recent emergence of edge computing. The idea is to leverage edge computing as a middle ground that will act as a trusted third party that ensures privacy and confidentiality requirements. GORILLAS will design a framework that captures the user's privacy requirements, the services requirements as well as current and future users, networks, edge, and cloud operational contexts to perform privacy-persistent and QoE-aware data placement in addition to a tailored QoE-aware service computing orchestration over edge and cloud resources

## 8.3. European Initiatives

### 8.3.1. H2020 SPARTA project

**Participants:** Emmanuel Baccelli, Francois-Xavier Molina.

Program: H2020 SU-ICT-03-2018: Establishing and operating a pilot for a Cybersecurity Competence Network to develop and implement a common Cybersecurity Research & Innovation Roadmap

Project acronym: SPARTA

Project title: Strategic Programs for Advanced Research and Technology in Europe

Duration: 2019-2022

Participant from TRiBE: Emmanuel Baccelli, Francois-Xavier Molina

Other partners include CEA, TU Muenchen, IMT among many others

Abstract: The Sparta project is a 3-year H2020 project started in February 2019, which will put in motion a competence network on cybersecurity, with a view to shape a future EU-wide cybersecurity agency. In more details: TRiBE participates on topics around low-power IoT security, whereby RIOT is used as the base platform on top of which advances will be experimented with and made available in practice.

## 8.4. International Initiatives

### 8.4.1. Inria Project Lab RIOT-fp

Project lead: Emmanuel Baccelli

Full name: Reconcile IoT & Future-Proof Security

Partners: teams EVA, PROSECCO (Inria Paris), teams GRACE, TRiBE (Inria Saclay), team TEA, CELTIQUE (Inria Rennes), Freie Universitaet Berlin

Project Start: April 2019

Project Length: 4 years

Website: <https://future-proof-iot.github.io/>

Summary:

Today's Internet of Things (IoT) does not provide an acceptable tradeoff of functionality vs. risk for end-users. To improve this tradeoff, we must simultaneously

(i) enrich IoT functionality and (ii) improve IoT cyber-security with respect to diverse attack vectors. Concerning the former, RIOT is emerging as one of the major open-source software platforms for low-end IoT devices. Concerning the latter, research challenges must be addressed in various domains including secure network protocol stacks, cryptography, software execution guarantees, embedded system design. RIOT-fp is a research project on IoT cyber-security. Taking a global and practical approach, RIOT-fp gathers partners planning a scientific agenda aiming to enhance RIOT with an array of security mechanisms. The main scientific challenges tackled by RIOT-fp are: (1) developing high-speed, high-security, low-memory IoT crypto primitives, (2) providing guarantees for software execution on low-end IoT devices, and (3) enabling secure IoT software updates and supply-chain, over the network.

### 8.4.2. Inria Associate Teams Not Involved in an Inria International Labs

#### 8.4.2.1. 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 – Ending year: 2019

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.

Nest steps: A new proposal extending the EMBRACE project was submitted in Nov. 2019. Besides, partners keep going their collaborations with two students currently visiting the team (Lucas Santos from UFMG and Felipe Fonseca from UFG) and with two researchers from UFG starting their sabbatical year from February 2020.

### 8.4.3. Inria International Partners

#### 8.4.3.1. 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.

#### 8.4.3.2. Informal International Partners

1. Although the project has finished, the team keep going their collaboration with UFMG and UFG institutions, previous partners of EMBRACE project, on human behavior leveraging in 5G networks.
2. Collaboration with Mark Crovella from Boston University, where Licia Amichi will spend 5 months in an internship from March 2020. She will work on our current collaboration on the modelling and analysis of novelty-seeking preferences in human mobility.
3. Collaboration with Javier Bustos from NIC Lab/University of Chile, involving the PhD co-advising of Diego Madriaga, who is doing a joint PhD between Univ. of Chile and IPP and is working on short-term time series analysis and prediction for anticipatory Nnetworking.
4. Collaboration with Ana Aguiar from University of Porto, involving the PhD co-advising of Emanuel Lima, who is working on data offloading via mobile crowdsensing.
5. Collaboaration with Marco Fiore from IMDEA on adaptive sampling of human mobility. This collaboration involves the participation of Diego Madriaga.
6. Informal collaborations with ENSI Tunis and ENIso.

### 8.4.4. Participation in Other International Programs

#### 8.4.4.1. 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.

## 8.5. International Research Visitors

### 8.5.1. Visits of International Scientists

**Prof. Kleber Vieira Cardoso and Sand Luz Correa** from UFG, Brazil, will do their sabbatical year at the TRiBE team, under Brazilian funding and in the context of the EMBRACe project. They will work with Aline C. Viana and Felipe Fonseca on trajectory reconstruction of tourists and their 5G resource optimization.

### 8.5.2. Internships

**Felipe Fonseca** is doing an internship of 3 months in our team (Nov 201-Jan 2020). He work with Aline C. Viana, Kleber V. Cardoso and Sand L. Correa on trajectory reconstruction of tourists.

**Lucas Santos** is doing an internship of 3 months in our team (Nov 201-Jan 2020) 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.

**Douglas Teixeira** did an internship of 10 months our team (May 2019-Jan 2020) in the context of EMBRACE associated team. He is in cotutelle between IPP and UFMG and is co-advised by Aline C. Viana and Jussara Almeida on the limits of a context-aware predictability of human mobility.

**Amina Ben Hassine** did an intership of 6 months (2019) in collaboration with Ichrak Amdouni (ENSISo) and Anis Laouiti (Telecom SudParis) on the subject of "Unmanned Aerial Vehicles Path Planning Using Machine Learning" using reinforcement learning.

### 8.5.3. Visits to International Teams

#### 8.5.3.1. Research Stays Abroad

Aside of working for Inria, **Emmanuel Baccelli** is also Professor at Freie Universitaet (FU) Berlin, within the context of a chair resulting of a partnership between Inria, FU Berlin and Einstein Center for Digital Future (ECDF: umbrella organization for Berlin's technical universities). The topic of this chair is *Open and Secure IoT Ecosystem*. In this context, Emmanuel Baccelli stays at FU Berlin. See online: <https://www.digital-future.berlin/en/about-us/professors/prof-dr-emmanuel-baccelli/>