



RESEARCH CENTER

FIELD

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

# Activity Report 2017

## Section Partnerships and Cooperations

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## ASAP Project-Team

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### 7.1.1. ANR project *SocioPlug*

**Participants:** Davide Frey, Anne-Marie Kermarrec, Pierre-Louis Roman, Francois Taiani.

SocioPlug is a collaborative ANR project involving Inria (ASAP team), the Univ. Nantes, and LIRIS (INSA Lyon and Univ. Claude Bernard Lyon). The project emerges from the observation that the features offered by the Web 2.0 or by social media do not come for free. Rather they bring the implicit cost of privacy. Users are more or less consciously selling personal data for services. SocioPlug aims to provide an alternative for this model by proposing a novel architecture for large-scale, user centric applications. Instead of concentrating information of cloud platforms owned by a few economic players, we envision services made possible by cheap low-end plug computers available in every home or workplace. This will make it possible to provide a high amount of transparency to users, who will be able to decide their own optimal balance between data sharing and privacy.

### 7.1.2. *DeSceNt CominLabs*

**Participants:** Resmi Ariyattu Chandrasekharannair, Davide Frey, Michel Raynal, Francois Taiani.

The DeSceNt project aims to ease the writing of distributed programs on a federation of plug computers. Plug computers are a new generation of low-cost computers, such as Raspberry pi (25\$), VIA- APC (49\$), and ZERO Devices Z802 (75\$), which offer a cheap and readily available infrastructure to deploy domestic on-line software. Plug computers open the opportunity for everyone to create cheap nano-clusters of domestic servers, host data and services and federate these resources with their friends, colleagues, and families based on social links. More particularly we will seek in this project to develop novel decentralized protocols than can encapsulate the notion of privacy-preserving federation in plug-based infrastructures. The vision is to use these protocols to provide a programming toolkit that can support the convergent data types being developed by our partner GDD (Gestion de Données Distribuées) at Univ. Nantes.

### 7.1.3. ANR *Blanc* project *Displexity*

**Participants:** George Giakkoupis, Anne-Marie Kermarrec, Michel Raynal.

The Displexity project started in 2011. The aim of this ANR project that also involves researchers from Paris and Bordeaux is to establish the scientific foundations for building up a consistent theory of computability and complexity for distributed computing. One difficulty to be faced by DISPLEXITY is to reconcile two non necessarily disjoint sub-communities, one focusing on the impact of temporal issues, while the other focusing on the impact of spatial issues on distributed algorithms.

### 7.1.4. ANR project *PAMELA*

**Participants:** Davide Frey, George Giakkoupis, Francois Taiani.

PAMELA is a collaborative ANR project involving ASAP, Inria Lille, 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 first answers to modern information systems built by interconnecting many personal devices holding private user data in the search of personalized suggestions and recommendations. More precisely, we will focus on learning in a collaborative way with the help of neighbors in a network. We aim to lay the first blocks of a scientific foundation for these new types of systems, in effect moving from graphs of data to graphs of data and learned models. We argue that this shift is necessary in order to address the new constraints arising from the decentralization of information that is inherent to the emergence of big data. We will in particular focus on the question of learning under communication and privacy constraints. 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. They will contribute to translate this fundamental research effort into concrete outcomes by developing personalized and privacy-aware assistants able to provide contextualized recommendations on small devices and smartphones.

#### 7.1.5. ANR project *OBrowser*

**Participants:** David Bromberg, Davide Frey, Francois Taiani.

OBrowser is a collaborative ANR project involving Inria (ASAP team), the Univ. Nantes, the Bretagne Sud. University, and Orange. The project emerges from the vision of designing and deploying distributed application 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. The introduction of browser-to-browser communication with WebRTC's Datachannel has made these scenarios closer, but today only experts can afford to tackle the technical challenges associated with large-scale browser-based deployments such as decentralized instant-messaging (Firechat) and Infrastructure-less Mission Critical Push To Talk. O'Browser aims to solve these challenges by means of a novel programming framework.

#### 7.1.6. ANR project *DESCARTES*

**Participants:** George Giakkoupis, Michel Raynal, Francois Taiani.

DESCARTES is a collaborative ANR project involving ASAP, Labri (U. Bordeaux), Lafia (U. Paris Diderot), Vérimag (Grenoble), LIF (Marseilles), and LINA (Nantes). 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. In this project, 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.

#### 7.1.7. ANR-ERC *Tremplin* project *NDFUSION*

**Participant:** George Giakkoupis.

NDFUSION is an 18-month ANR project awarded to the PI to support his preparation for his upcoming ERC grant application. The idea of intervening in a network diffusion process to enhance or retard its spread has been studied in various contexts, e.g., to increase the spread or speed of diffusion by choosing an appropriate set of seed nodes (a standard goal in viral marketing by word-of-mouth), or achieve the opposite effect either by choosing a small set of nodes to remove (a goal in immunization against diseases), or by seeding a competing diffusion (e.g., to limit the spread of misinformation in a social network). The aim of this project is to consolidate existing work under a single, comprehensive framework, and using this framework to develop

new, efficient algorithms for optimizing (maximizing or minimizing) the spread of diffusion processes. Novel aspects of the project involve issues of scalability, multiple concurrent diffusions, and the use of multistage online strategies to optimize diffusions. Results from this project are likely to be relevant to many different disciplines, from network optimization in computing to disease containment in medicine.

## 7.2. International Initiatives

### 7.2.1. Inria International Labs

- Anne-Marie Kermarrec is the scientific co-chair (with Willy Zwaenepoel) of the EPFL/Inria International Lab

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

#### 7.2.2.1. 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/lidicoequipeassociee/>

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

## 7.3. International Research Visitors

### 7.3.1. Visits of International Scientists

- Peter Kling (U of Hamburg) visited ASAP (hosted by G Giakkoupis), Jan 19–25.
- Emanuele Natale (Max Planck, Saarbrücken) visited ASAP (hosted by G Giakkoupis), Apr 23–29.
- Thomas Sauerwald (U of Cambridge) visited ASAP (hosted by G Giakkoupis), Aug 21–24.
- Robert Elsässer (Salzburg U) visited ASAP (hosted by G Giakkoupis), Sep 25–29.

#### 7.3.1.1. Internships

- Jodi Spacek from University of British Columbia, Research internship from May 2017 until Aug 2017, supervised by David Bromberg.
- Stewart Grant from University of British Columbia, Research internship from May 2017 until Aug 2017, supervised by David Bromberg.
- Hayk Saribekyan from MIT, research Internship from June 2017 to August 2017.

### 7.3.2. Visits to International Teams

#### 7.3.2.1. Research Stays Abroad

- Michel Raynal was at the Hong Kong Polytechnic University from 15 September to 14 October 2017,
- David Bromberg did a visit at USP - Department of Computer Science University of São Paulo, Sao Paulo, Brazil from February 22, 2017 to March 24, 2017

## COAST Project-Team

# 7. Partnerships and Cooperations

## 7.1. Regional Initiatives

### 7.1.1. Region Lorraine TV Paint (2016–2017)

**Participants:** Claudia-Lavinia Ignat [contact], Gérald Oster, Quang Vinh Dang, Matthieu Nicolas.

Partners: TVPaint Development, Inria COAST project-team

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

This is a project in collaboration with TVPaint Development financed by Region Lorraine. The goal is to contribute to the creation of a collaborative system dedicated to animation movies, that allows to manipulate high quantities of digital artifacts in a collaborative way.

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

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

Partners: TVPaint Development, Inria COAST project-team

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

This is a follow-up project in collaboration with TVPaint Development financed by Region Grand Est.

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 implements a commercial product. In the framework of this project, we bring our expertise in data management, business process management, distributed systems and collaborative systems.

Coast funding : 81,600 €

## 7.2. National Initiatives

### 7.2.1. OpenPaas NG (2015–2019)

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

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

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

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



## 7.3. International Initiatives

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

#### 7.3.1.1. USCOAST2

Title: User Studies on Trustworthy Collaborative Systems

International Partner (Institution - Laboratory - Researcher):

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

Start year: 2016

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

The proposed project addresses the perception of trust by users, the appropriateness of a trust-based security approach and the role of trust metrics in the management of distributed work. The main challenge of this project is how to measure trust based on user behaviour and to verify by means of experimental studies with users that the trust-based mechanism is acceptable by users. We plan to apply this trust-based mechanism for two types of applications. The first one is collaborative editing where user trust will be computed based on the quality of user contributions for a document or project. The second type of application is in the management of work over a large group of people in order to conduct efficient, high-yield, high-density real time crowdsourcing activities.

Partners of USCOAST2 project have complementary expertise. COAST provides expertise in collaborative methods, systems and related technologies. Coast will propose algorithms that track and manipulate trust metrics. Kno.e.sis provides expertise on the analysis of human work-related behavior, including methods of data collection and data analysis, as well as a theoretical foundation for the evaluation of human performance. Knoesis will analyse trust from a psychological phenomenon point of view.

## 7.4. International Research Visitors

### 7.4.1. Visits of International Scientists

Valerie Shalin from Wright State University spent one month and a half (May-July 2017) in our team as part of the USCoast2 Inria associated team.

Weihai Yu from Arctic University of Norway spent two weeks in March 2017 in the team as invited professor.

### 7.4.2. Visits to International Teams

#### 7.4.2.1. Research Stays Abroad

- Béatrice Linot spent 3 months at Wright State University as part of our collaboration with Dr Valerie Shalin and Prof. Amit Sheth, funded by her LUE PhD grant.

## CTRL-A Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. HPES action-team of the Labex Persyval-lab

The Labex Persyval-lab is a large regional initiative, supported by ANR, where we are contributing through the project *Equipe-action HPES*.

This project (2013-17) groups members from Inria, LIG, Gipsa-lab, TIMA and Gipsa-lab, around the topic of High-Performance Computing benefitting from technologies originally developed for Embedded Systems : <https://persyval-lab.org/en/sites/hpes>. Ctrl-A is directly involved in the co-advising of the PhD of Naweiluo Zhou, with J.F. Méhaut (Corse team of Inria/LIG), on the topic of autonomic management of software transactional memory mechanisms : <https://persyval-lab.org/en/research/phd/autonomic-thread-parallelism-and-mapping-control-software-transactional-memory>.

In 2017 we organized a workshop on Autonomic Computing and Control in Grenoble, supported by HPES (<https://team.inria.fr/ctrl-a/members/eric-rutten/autoctrl/>).

### 8.1.2. EcoSesa Cross-Disciplinary Project of the Idex

The Eco-SESA project, “Eco-district: Safe, Efficient, Sustainable and Accessible energy”, aims to produce knowledge, concepts, tools and methods to rethink the planning, management and governance of urban energy systems and the design of their components. Ctrl-A contributes to the research front 4 : Architectures for integration of renewable on-the-spot generation. A Post-doctoral position shared with G2Elab research lab will be funded.

## 8.2. National Initiatives

### 8.2.1. ANR HPeC

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

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

### 8.2.2. ANR Sacade

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

### 8.2.3. Informal National Partners

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

#### **8.2.4. Informal National Industrial Partners**

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

### **8.3. International Initiatives**

#### **8.3.1. Inria International Labs**

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

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

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

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

##### *8.3.2.1. Informal International Partners*

We have ongoing relations with international colleagues in the emerging community on our topic of control for computing e.g., in Sweden at Lund (K.E. Arzen, M. Maggio) and Linnaeus Universities (D. Weyns, N. Khakpour), in the Netherlands at CWI/leiden University (F. Arbab), 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).

## MIMOVE Team

## 9. Partnerships and Cooperations

### 9.1. National Initiatives

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

#### 9.1.1. Inria Support

##### 9.1.1.1. Inria IPL CityLab@Inria

**Participants:** Valérie Issarny [correspondent], Fadwa Rebhi.

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

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

##### 9.1.1.2. Inria IPL BetterNet

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

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

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

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

##### 9.1.1.3. Inria ADT MOSQUITO

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

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

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

## 9.2. European Initiatives

### 9.2.1. FP7 & H2020 Projects

#### 9.2.1.1. H2020 ICT CHOReVOLUTION

**Participants:** Nikolaos Georgantas [correspondent], Valérie Issarny [correspondent].

**Name:** CHOReVOLUTION – *Automated Synthesis of Dynamic and Secured Choreographies for the Future Internet*

**URL:** <http://www.chorevolution.eu>

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

**Topic:** Tools and Methods for Software Development

**Period:** [January 2015 - December 2017]

**Partners:** CEFRIEL (Italy), Inria MiMove, OW2 Consortium (France), Thales Communications S.A. (France) [**coordinator**], Università degli Studi dell'Aquila (Italy) [**scientific leader**], Softeco Sismat Srl (Italy), Tirasa (Italy), Viktoria Swedish ICT (Sweden).

The Future Internet (FI) represents an age of unprecedented opportunities for social, economic, and business growth thanks to the global scale connectivity of the virtual as well as of the physical world. This indeed opens up a wealth of innovative and revolutionary real-life scenarios, as for instance illustrated by the smarter cities perspectives where envisioned scenarios significantly ease daily human activities and give support for the growth of new markets and employment opportunities. However, leveraging the FI for the development of innovative software applications remain a challenging task even though major enablers are readily available by ways of service-oriented and cloud computing. It is in particular our vision that enabling the choreography of FI services shall play a significant role in the provisioning of innovative applications. However, existing choreography-based service composition approaches are rather static and are poorly suited to the need of the FI that is a highly dynamic networking environment, further bringing together highly heterogeneous services ranging from Thing- to Business-based services that span different security domains. As a result, the technology is not mature enough for market take-up. CHOReVOLUTION elevates the Readiness Level of existing choreography technologies in order to drop the dynamism and cross-organization security barriers via the automated synthesis of dynamic and secured choreographies in the FI. To meet its objectives, CHOReVOLUTION undertakes both research and innovation tasks. The former concentrates on choreography modelling, synthesis, adaptation, service bus, security, and cloud; the latter focus on industrial validation, development support and integration platform, and the establishment of a CHOReVOLUTION community and market take-up. Last but not least CHOReVOLUTION outcomes are assessed by experimenting with new applications in the field of Intelligent Transportation Systems.

#### 9.2.1.2. H2020 ICT FIESTA-IoT

**Participants:** Valérie Issarny [correspondent], Nikolaos Georgantas [correspondent].

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

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

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

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

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

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

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

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

### 9.2.2.1. EIT Digital Env&You

**Participant:** Valérie Issarny [correspondent].

**Name:** Env&You – *Personalizing environmental science for your home, your neighborhood and your life*

**URL:** <http://ambiciti.io>

**Period:** [January 2017 - December 2017]

**Partners:** Ambiciti (F), Forum Virium Helsinki (FI), Inria CLIME/ANGE, Inria MIMOVE [**coordinator**], NumTech (F), TheCivicEngine (USA).

There is a clear, and probably increasing, desire from the citizens to better know their individual exposure to pollution. Partial solutions exist to the exposure data problem but each focuses on one or another domain of information – crowdsourcing exposure, translating government open data to usable consumer information, harnessing social media information, harnessing biometrics – what is unique about Env&You is that we assimilate a multi-dimensional picture of exposure and provide the integrated information to citizen, government, and business use (spanning: B2G, B2B and B2C business cases).

### 9.2.2.2. EIT Digital CivicBudget

**Participants:** Valérie Issarny [correspondent], Nikolaos Georgantas [correspondent].

**Name:** CivicBudget – *Software platform supporting Internet-based participatory budgeting campaigns*

**Period:** [January 2017 - December 2017]

**Partners:** CITRIS@UCB (USA), Inria MIMOVE, MissionsPubliques (F) [**coordinator**], Nexus (DE), and TU Berlin (DE).

Many cities in Europe and the U.S.A, and around the world, commit a percentage of their annual budget (often 5%) to implement citizen-proposed projects through a process called Participatory Budgeting (PB). However, supporting urban-scale participatory budgeting campaigns is greatly challenged as it still principally relies on physical meetings. CivicBudget addresses this challenge by leveraging latest ICT so as to promote urban-scale inclusion. CivicBudget fosters a new and inclusive urban public sphere of citizenship. It is especially designed for community groups and activists who want to participate in the PB process. City governments will also be able to promote its use. CivicBudget will facilitate the mobilization of residents both to promote their proposals and to monitor their progress through the PB process to implementation.

## 9.3. International Initiatives

### 9.3.1. Inria International Labs

Valérie Issarny acts as scientific manager of the Inria@Silicon Valley program (<https://project.inria.fr/inria-siliconvalley/>) since summer 2013; she is visiting scholar at the EECS Department of University of California, Berkeley, and hosted by CITRIS.

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

#### 9.3.2.1. HOMENET

**Title:** *Home network diagnosis and security*

**International Partner:** Princeton (United States) - Nick Feamster

**Start year:** 2017

**Website:** <https://team.inria.fr/homenet/>

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

#### 9.3.2.2. ACHOR

**Participant:** Nikolaos Georgantas [correspondent].

**Title:** *Adaptive enactment of service choreographies*

**International Partner:** Universidade Federal de Goiás (UFG), Brazil - Fabio Costa

**Start year:** 2016

**Website:** <http://www.inf.ufg.br/projects/achor>

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

### 9.3.3. Inria International Partners

#### 9.3.3.1. Informal International Partners

Northeastern University (Prof. David Choffnes and his student Arash Molavi): we are working on monitoring and diagnosing Internet QoE.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

#### 9.4.1.1. Internships

Kushagra Singh (from Jun 2017 until Jul 2017)

Internship funded by H2020 CHOReVOLUTION project.

Subject: *Towards correction of outliers in spatial dataset*

Institution: Indraprastha Institute of Information Technology (IIIT) Delhi (India)

### 9.4.2. Visits to International Teams

#### 9.4.2.1. Research Stays Abroad

- Valérie Issarny is visiting scholar at the EECS Department at UC Berkeley; she is hosted by CITRIS in the context of which she carries out collaborative research in the area of smart cities and acts as scientific coordinator of the Inria@SiliconValley program.
- Rachit Agarwal was visiting professor at Fundacao Getulio Vargas (FGV), Rio De Janeiro, Brazil (from Jun 2017 until Aug 2017). He was hosted at EMap (Escola de Matematica Aplicada) department within FGV. He taught a Network Science course to Master's students.



## MYRIADS Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. CominLabs EPOC project (2013-2017)

**Participants:** Sabbir Hasan Rochi, Yunbo Li, Anne-Cécile Orgerie, Jean-Louis Pazat.

In this project, partners aim at focusing on energy-aware task execution from the hardware to application's components in the context of a mono-site data center (all resources are in the same physical location) which is connected to the regular electric Grid and to renewable energy sources (such as windmills or solar cells). In this context, we tackle three major challenges:

- Optimizing the energy consumption of distributed infrastructures and service compositions in the presence of ever more dynamic service applications and ever more stringent availability requirements for services.
- Designing a clever cloud's resource management which takes advantage of renewable energy availability to perform opportunistic tasks, then exploring the trade-off between energy saving and performance aspects in large-scale distributed systems.
- Investigating energy-aware optical ultra high-speed interconnection networks to exchange large volumes of data (VM memory and storage) over very short periods of time.

Sabbir Hasan Rochi has defended his PhD on SLA driven Cloud autoscaling for optimizing energy footprint on May 3rd, 2017. Yunbo Li has defended his PhD on Resource allocation in a Cloud partially powered by renewable sources on June 12th, 2017.

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

**Participants:** Anna Giannakou, Christine Morin, Jean-Louis Pazat, Louis Rilling, Amir Teshome Wonjiga, Clément El Baz.

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

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

The considered enforcement and evaluation mechanisms should have a minimal impact on performance. The funding from DGA funds two PhD students: Anna Giannakou and Amir Teshome Wonjiga. Clément El Baz is partially funded by the Brittany Regional Council in the PEC framework.

## 9.2. National Initiatives

### 9.2.1. ADEME RennesGrid

**Participants:** 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 will closely collaborate with Anne Blavette (CR CNRS in electrical engineering, SATIE, Rennes) and co-supervise a post-doc on evaluating the impact of the IT infrastructure in the management of smart grids.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

During his first year of PhD thesis, The Anh Pham conducted an analysis of the formal methods and algorithms used in SimGrid. This work, co-advised by Martin Quinson with Thierry Jéron (team SUMO, formal methods), was important to bridge the gap between the involved communities. The resulting work has been published in a workshop gathering the intersection between the communities of formal methods and HPC [44].

Another PhD thesis will start in December 2017, co-advised by Laurent Lefèvre (Avalon team, Lyon), Martin Quinson and Anne-Cécile Orgerie. This thesis will focus on simulating the energy consumption of continuum computing between heterogeneous numerical infrastructures for HPC.

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

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

The distributed nature of Cloud infrastructures involves that their components are spread across wide areas, interconnected through different networks, and powered by diverse energy sources and providers, making overall energy monitoring and optimization challenging. The COSMIC project aims at taking advantage of the opportunity brought by the Smart Grids to exploit renewable energy availability and to optimize energy management in distributed Clouds. This PRE, led by Anne-Cécile Orgerie also involves Fanny Dufossé from Dolphin team (Inria Lille), Anne Blavette from SATIE laboratory (electrical engineering, Rennes), and Benjamin Camus, who has started a 18 months post-doc in October 2016 in the context of this project. A paper on this project has been presented at SMARTGREENS 2017 and two others are currently under submission.

#### 9.2.8. MIHMES ANR Investissements d'Avenir (2012 - 2017)

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

The MIMHES project (<http://www.inra.fr/mihmes>) led by INRA/BioEpAR aimed at producing scientific knowledge and methods for the management of endemic infectious animal diseases and veterinary public health risks. The role of Myriads was to help MIMHES researchers improve the performance of their simulation applications and take advantage of computing resources provided by clouds. To that end, Myriads developed a framework, named DiFFuSE, that provides design support, reusable code, and tools for building and executing epidemic simulations in the cloud.

In 2017, we further developed DiFFuSE and extended the framework to make use of the PaaSage open-source platform, the main outcome of a European FP7 IP project in which Myriads participated (2012-2016). Thanks to PaaSage, DiFFuSE allows deploying and managing services in multi-cloud environments. We applied DiFFuSE to restructure an application that simulates the spread of the bovine viral diarrhoea virus (BVDV) and conducted experiments to evaluate DiFFuSE [45].

### 9.2.9. *SESAME ASTRID project (2016-2019)*

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

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

### 9.2.10. *PIA ELCI (2015-2018)*

**Participant:** Anne-Cécile Orgerie.

The PIA ELCI project deals with software environment for computation-intensive applications. It is leaded by BULL. In the context of this project, we collaborate with ROMA and Avalon teams from Lyon: we co-supervise a PhD student (Issam Rais) funded by this project with these teams on multi-criteria scheduling for large-scale HPC environments. This collaboration has led to two publications in 2017: a journal article published in IJHPCA and a conference paper presented at EuroPar.

### 9.2.11. *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. In particular, it has led in December 2016 to the publication of an ADEME report jointly with Deloitte Développement Durable, Futuribles, CREDOC and ADEME on the potential contribution of digital to the reduction of environmental impacts: state of play and challenges for the prospective.

## 9.3. European Initiatives

### 9.3.1. *FP7 & H2020 Projects*

#### 9.3.1.1. *FogGuru*

**Participant:** Guillaume Pierre.

Title: MSCA ITN EID

Programm: H2020

Duration: September 2017 - August 2021

Coordinator: Guillaume Pierre

Participants:

University of Rennes 1, France (coordinator)

Technisch Universität Berliun, Germany

Elastisys AB, Sweden

U-Hopper srl, Italy

EIT Digital Rennes, France

Las Naves, Spain

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

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

**Participants:** David Margery, Yue Li.

Title: Federation for FIRE Plus

Programm: H2020

Duration: January 2017 - December 2021

Coordinator: Interuniversitair Micro-Electronicacentrum Imec VZW

Partners:

Universidad de Malaga

National Technical University of Athens - NTUA

The Provost, Fellows, Foundation Scholars & the other members of board of the College of the Holy & Undivided Trinity of Queen Elizabeth Near Dublin

Ethniko Kentro Erevnas Kai Technologikis Anaptyxis

GEANT Limited

Institut Jozef Stefan

Mandat International Alias Fondation Pour la Cooperation Internationale

Université Pierre et Marie Curie - Paris 6

Universidad De Cantabria

Fundacio Privada I2CAT, Internet I Innovacio Digital A Catalunya

EUROSCOM-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

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 have developed a generalized proxy mechanisms to allow users with Fed4FIRE identities to interact with services giving access to different testbeds but not designed to support Fed4FIRE identities. Fed4FIRE+ has started January 1st, 2017.

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

#### 9.3.2.1. NESUS

**Participant:** Anne-Cécile Orgerie.

Program: ICT COST

Project acronym: NESUS

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

Duration: 2014 - 2018

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

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

Abstract: Ultrascale systems are envisioned as large-scale complex systems joining parallel and distributed computing systems that will be two to three orders of magnitude larger than today's systems. The EU is already funding large scale computing systems research, but it is not coordinated across researchers, leading to duplications and inefficiencies. The goal of the NESUS Action is to establish an open European research network targeting sustainable solutions for ultrascale computing aiming at cross fertilization among HPC, large scale distributed systems, and big data management. The network will contribute to gluing disparate researchers working across different areas and provide a meeting ground for researchers in these separate areas to exchange ideas, to identify synergies, and to pursue common activities in research topics such as sustainable software solutions (applications and system software stack), data management, energy efficiency, and resilience. Some of the most active research groups of the world in this area are members of this proposal. This Action will increase the value of these groups at the European-level by reducing duplication of efforts and providing a more holistic view to all researchers, it will promote the leadership of Europe, and it will increase their impact on science, economy, and society. Anne-Cécile Orgerie is co-responsible of the focus group on metrics, monitoring, instrumentation and profiling in the Working Group 5 on Energy Efficiency. A joint paper has been accepted in 2017 on this topic at the Elsevier journal on Sustainable Computing.

### 9.3.3. Collaborations with Major European Organizations

Partner 1: EPFL, Network architecture lab (Switzerland)

We collaborate with Katerina Argyraki's research group on the integration of networking and cloud computing technologies in order to support placement constraints between cloud resources.

Partner 2: University of Neuchâtel, dept. of Computer Science (Switzerland)

We collaborate with Pascal Felber's research group on energy efficiency in Clouds and in particular on the design of energy cost models for virtual machines. A joint journal paper has been accepted in 2017 for publication in Sustainable Computing: Informatics and Systems, Elsevier.

Partner 3: Catholic University of Louvain (Belgium)

We collaborate with Etienne Riviere's research group on the efficient service placement and discovery in a SaaS context.

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

#### 9.4.1.1. DALHIS

**Participants:** Christine Morin, Deborah Agarwal, Anna Giannakou, Amir Teshome Wonjiga, Subarna Chatterjee.

Title: Data Analysis on Large Heterogeneous Infrastructures for Science

International Partner (Institution - Laboratory - Researcher):

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

Start year: 2016

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

Data produced by scientific instruments (large facilities like telescopes or field data), large-scale experiments, and high-fidelity simulations are increasing in magnitude and complexity. Existing data analysis methods, tools and infrastructure are often difficult to use and unable to provide the complete data management, collaboration, and curation environment needed to manage these complex, dynamic, and large-scale data analysis environments. The goal of the Inria-LBL DALHIS associate team involving the Myriads (PI) and Avalon Inria project-teams and the Data Science and Technology (DST) department at Lawrence Berkeley National Laboratory (LBL) is to create a collaborative distributed software ecosystem to manage data lifecycle and enable data analytics on distributed data sets and resources. Specifically, our goal is to build a dynamic software stack that is user-friendly, scalable, energy-efficient and fault tolerant. Our research will determine appropriate execution environments that allow users to seamlessly execute their end-to-end dynamic data analysis workflows in various resource environments and scales while meeting energy-efficiency, performance and fault tolerance goals. We will engage in deep partnerships with scientific teams (Fluxnet in environmental science and SNFactory and LSST experiences in cosmology) and use a mix of user research with system software R&D to address specific challenges that these communities face. In 2017, we worked on evaluating data streaming environments (see Section 7.1.4) and on producing tools to help users (scientist in the climate and environment community) to explore the carbon flux datasets from AmeriFlux (Americas) and FLUXNET (global) (see Section 7.4.2.2). We also worked on two facets of security in the context of HPC distributed computing infrastructures: (i) building a workflow for data analysis for anomaly detection and (ii) using the block-chain technology to leverage data integrity at the network and some portion of computation levels.

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

##### 9.4.2.1. SUSTAM associated team

**Participants:** Anne-Cécile Orgerie, Yunbo Li.

Anne-Cécile Orgerie participates in the associated team named SUSTAM (Sustainable Ultra Scale compuTing, dAta and energy Management) led by Laurent Lefèvre (Avalon team, Lyon) with Prof. Manish Parashar (RDI2, Rutgers University, NJ, USA). 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.

#### 9.4.3. Inria International Partners

##### 9.4.3.1. Informal International Partners

Partner: Rutgers University, dept. of Computer Science (New Jersey, United States)

We collaborate with Manish Parashar's research group on energy efficiency in edge Clouds and in particular on the design of energy cost models for such environments involving renewable energy. A joint paper has been presented at IEEE/ACM CCGrid 2017.

Partner: Northeastern University, dept. of Computer Science (Massachusetts, United States)

We collaborate with Gene Cooperman's research group on the study of large-scale distributed systems. More specifically, we actively collaborate on virtualization technologies and system snapshotting (we obtained a postdoc funding on that topic from the Brittany Regional Council, but all applicants declined in the last minute). We plan to reinforce and extend our collaboration to formal methods for distributed systems in the next year.

Partner: University of Guadalajara (Mexico)

We collaborate with the team of Prof. Hector Duran-Limon on application and resource management in the cloud. In 2017, we produced a joint publication [46]. Nikos Parlavantzas is co-advising a PhD student enrolled in the University of Guadalajara (Carlos Ruiz Diaz).

Partner: Tlemcen University (Algeria)

We collaborate with Djawida Dib on energy-efficient fault-tolerant resource and application management in containerized clouds. Christine Morin and Nikos Parlavantzas have been co-advising Yasmina Bouizem, a PhD student enrolled in the University of Tlemcen from December 2016.

## 9.5. International Research Visitors

### 9.5.1. Visits of International Scientists

Deb Agarwal, senior scientist at Lawrence Berkeley National Laboratory, who has been awarded an Inria International Chair for the 2015-2019 period, visited Myriads team during two months from August 1st to October 15th, 2017.

Professor Gene Cooperman, Northeastern University, Boston, USA, visited the Myriads team for one week in July to reinforce our collaboration on the virtualization of large-scale distributed systems.

#### 9.5.1.1. Internships

Betsegaw Lemma Amersho

Date: Feb-June 2017

Institution: University of Rennes 1 & Aalto University (Finland)

Supervisors: Anne-Cécile Orgerie and Martin Quinson

Vinothkumar Nagasayanan

Date: May-August 2017

Institution: University of Rennes 1 & TU Berlin (Germany)

Supervisor: Guillaume Pierre

Salsabil Amri

Date: May-August 2017

Institution: University of Rennes 1

Supervisor: Guillaume Pierre

Bérenger Nguyen Nhon

Date: July-August 2017

Institution: University of Rennes 1

Supervisor: Guillaume Pierre

### 9.5.2. Visits to International Teams

#### 9.5.2.1. Research Stays Abroad

- Genc Tato started a 6-month research visit at the Catholic University of Louvain in November 2017 to work with Etienne Riviere on service placement and discovery in a SaaS context.
- Amir Teshome Wonjiga did a 3-month research internship in the Data Science and Technology department of the Lawrence Berkeley National Laboratory from April to June 2017. He worked with Sean Peisert, staff scientist, on ensuring data integrity in the workflow of high performance applications.
- Anne-Cécile Orgerie visited for 1 week the team of Prof. Manish Parashar in the RDI2 laboratory at Rutgers University in October 2017.



## REGAL Project-Team

## 7. Partnerships and Cooperations

### 7.1. National Initiatives

#### 7.1.1. Labex SMART - (2012–2019)

Members: ISIR (UPMC/CNRS), LIP6 (UPMC/CNRS), LIB (UPMC/INSERM), LJLL (UPMC/CNRS), LTCI (Institut Mines-Télécom/CNRS), CHArt-LUTIN (Univ. Paris 8/EPHE), L2E (UPMC), 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 Regal is responsible of the axe “Autonomic Distributed Environments for Mobility.”

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

#### 7.1.2. ESTATE - (2016–2020)

Members: LIP6 (Regal, 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 Regal.

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.

#### 7.1.3. RainbowFS - (2016–2020)

Members: LIP6 (Regal, project leader), Scalify 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 Regal.

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.

## 7.2. European Initiatives

### 7.2.1. FP7 & H2020 Projects

#### 7.2.1.1. *LightKone*

Title: Lightweight Computation for Networks at the Edge

Programm: H2020-ICT-2016-2017

Duration: January 2017 - December 2019

Coordinator: Université Catholique de Louvain

Partners:

Université Catholique de Louvain (Belgium)

Technische Universitaet Kaiserslautern (Germany)

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

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

Universitat Politecnica De Catalunya (Spain)

Scality (France)

Gluk Advice B.V. (Netherlands)

Inria contact: Marc Shapiro

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

## 7.3. International Initiatives

### 7.3.1. Participation in Other International Programs

#### 7.3.1.1. *STIC Amsud*

Title: PaDMetBio - Parallel and Distributed Metaheuristics for Structural Bioinformatics

International Partners (Institution - Laboratory - Researcher):

Universidade Federal do Rio Grande do Sul (Brazil)- Márcio Dorn

Universidad Nacional de San Luis (Argentina) - Verónica Gil-Costa

Universidad de Santiago de Chile (Chile) - Mario Inostroza-Ponta

Duration: 2017 - 2018

Start year: 2017

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

#### 7.3.1.2. CNRS-Inria-FAP's

Title: Autonomic and Scalable Algorithms for Building Resilient Distributed Systems

International Partner (Institution - Laboratory - Researcher):

Universida de Federal do Paraná (UFPR), Brazil, Prof. Elias Duarte

Duration: 2015–2017

In the context of autonomic computing systems that detect and diagnose problems, self-adapting themselves, the VCube (Virtual Cube), proposed by Prof. Elias Duarte, is a distributed diagnosis algorithm that organizes the system nodes on a virtual hypercube topology. VCube has logarithmic properties: when all nodes are fault-free, processes are virtually connected to form a perfect hypercube; as soon as one or more failures are detected, links are automatically reconnected to remove the faulty nodes and the resulting topology, connecting only fault-free nodes, keeps the logarithmic properties. The goal of this project is to exploit the autonomic and logarithmic properties of the VCube by proposing self-adapting and self-configurable services.

#### 7.3.1.3. Capes-Cofecub

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

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

International Partners (Institution - Laboratory - Researcher):

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

Duration: 2014–2018

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

#### 7.3.1.4. 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.

## 7.4. International Research Visitors

### 7.4.1. Visits of International Scientists

#### 7.4.1.1. Internships

Ajay Singh of Indian Institute Of Technology Hyderabad, India, was invited for a six-month internship, on data structures for concurrency and persistent memory. This work is published at the HiPC SRS 2017 workshop [43].

## SPIRALS Project-Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

#### 9.1.1. Région Hauts-de-France

##### 9.1.1.1. Citizen Awareness and Contribution to Air Quality Monitoring

**Participants:** Moncef Ouadia, Romain Rouvoy [correspondant], Lionel Seinturier, Antoine Veuiller.

This is a 3-year project (2015–17) in the context of the so-called "*Chercheur citoyen*" program. The partners are LISIC/Université Côte d'Opale (leader), ATMO Nord-Pas De Calais, Association Bâisseurs d'Economie Solidaire. This project targets the distributed monitoring of air quality with crowd-sensing solutions obtained via sensors connected to smart devices. We aim at inciting citizens to perform their own measures, and to obtain thanks to GPS geo-localization a large-scale database and a dynamic fine-grained cartography of air quality. This project takes advantage of the APISENSE<sup>®</sup> crowdsensing platform.

##### 9.1.1.2. CIRRUS

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

CIRRUS is an 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.

#### 9.1.2. Inria Lille - Nord Europe

##### 9.1.2.1. ADT LibRepair

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

ADT LibRepair (2016–18) is a technology development initiative supported by the Inria Lille - Nord Europe Center that aims at supporting the development of an integrated library of automated software repair algorithms and techniques. This ADT builds on our results about with the Astor, Nopol and NpeFix that have been obtained in the context of the defended PhD theses of Matias Martinez [65] and Benoit Cornu [54].

##### 9.1.2.2. North European Lab LLEX

**Participants:** Martin Monperrus, Lionel Seinturier [correspondant].

North European Lab LLEX (2015–17) is an international initiative supported by the Inria Lille - Nord Europe Center that takes place in the context of a collaboration between Inria and University College London. LLEX deals with research on automatic diagnosis and repair of software bugs. Automatic software repair is the process of fixing software bugs automatically. An automatic software repair system fixes software bugs with no human intervention. The goal of automatic 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. The objective of the partnership is to work on the automated diagnosis of exceptions with a focus on null pointer exceptions.

### 9.2. National Initiatives

#### 9.2.1. ANR

##### 9.2.1.1. ANR BottleNet

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

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

#### 9.2.1.2. ANR SATAS

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

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

#### 9.2.1.3. ANR Headwork

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

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

#### 9.2.1.4. ANR Delta

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

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

### 9.2.2. Competitiveness Clusters

#### 9.2.2.1. FUI StoreConnect

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

StoreConnect is a 24-month project (2016–18) 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.

### 9.2.3. Programme Investissement d'Avenir (PIA)

#### 9.2.3.1. PIA OCCLware

**Participants:** Stéphanie Challita, Christophe Gourdin, Romain Rouvoy, Philippe Merle [correspondant], Lionel Seinturier, Faiez Zalila.

**OCCIware** is a 36-month project (2014–17) of the Programme Investissement d’Avenir Cloud Computing and Big Data 4th call for projects. The partners are Smile (leader), ActiveEon SA, Scalair, Institut Mines-Télécom/Télécom SudParis, Inria, Linagora GSO, Obeo, OW2 Consortium, and Université Grenoble Alpes. The project aims at defining a formal framework for managing every digital resources in the clouds, based on *Open Cloud Computing Interface* (OCCI) recommendations from *Open Grid Forum* (OGF).

## 9.2.4. Inria National Initiatives

### 9.2.4.1. Inria IPL BetterNet

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

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

## 9.2.5. Others

### 9.2.5.1. CNRS MASTODONS 2017 DoMaSQ’Air

**Participants:** Moncef Ouadia, Romain Rouvoy [correspondant].

DoMaSQ’Air is a 1-year project funded by the CNRS INS2I MASTODONS program on research in big data. This project gathers a pluridisciplinary team on the measurement and the continuous analysis of indoor and outdoor air quality. This project takes advantage of crowds of cheap and miniaturized sensors in relation with the Internet of Things and smart cities. In addition to the challenges raised by the massive amount of data generated by these cyber-physical systems, the project tackles questions related to the quality and privacy of data. DoMaSQ’Air is led by Romain Rouvoy with the participation of the PC2A laboratory on PhysicoChemistry of Combustion of the Atmosphere (CNRS/U. Lille) and the LISIC laboratory on Computer Science, Signal and Image (U. Côte d’Opale).

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

Program: H2020 ICT-10-2016.

Project acronym: STAMP.

Project title: Software Testing Amplification.

Duration: 36 months (2016–19).

Coordinator: Inria.

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

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

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

Program: H2020 JU Shift2Rail.

Project acronym: X2Rail-1.

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

Duration: 36 months (2016–19).

Coordinator: Siemens.

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

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

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

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

Program: EUREKA Celtic-Plus.

Project acronym: SENDATE.

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

Duration: 36 months (2016–19).

Coordinator: Nokia.

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

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

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

## 9.4. International Initiatives

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

#### 9.4.1.1. SOMCA

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

International Partner (Institution - Laboratory - Researcher):

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

Start year: 2017

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

The long-term goal of this research program is to propose a novel and innovative methodology embodied in 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. PHC Zenon Cyprus - Project RRI-MobDev

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



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

## **9.5. International Research Visitors**

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

Fernanda Madeiral Delfim, PhD Student from the Federal University of Uberlândia, Brazil, visited us from January to May 2017, and again in September 2017.

#### ***9.5.1.1. Internships***

Mohammad Naseri, MSc. Student in Computer Science from Saarland University, Germany, is visiting us for 3 months, starting in November 2017.

Chaima Chakhava, MSc. Student in Computer Science from ESI Alger, Algeria, is visiting us for 6 months, starting in December 2017.

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

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

Thomas Durieux, PhD Student, spent 4 months from September to December 2017 in KTH, Sweden.

## WHISPER Project-Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

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

### 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.

### 9.3. International Initiatives

#### 9.3.1. Inria International Labs

- EPFL-Inria Lab Our work on the Ipanema DSL [17] is done as part of the EPFL-Inria Lab. Baptiste Lepers (EPFL) is supported in 2017 as a joint postdoc between the Whisper and the groups of V. Kuncak and W. Zwaenepoel.

#### 9.3.2. Inria International Partners

##### 9.3.2.1. Informal International Partners

- We collaborate with David Lo and Lingxiao Jiang of Singapore Management University, who are experts in software mining, clone detection, and information retrieval techniques. Our work with Lo and/or Jiang has led to 8 joint publications since 2013 [12], [68], [78], [83], [84], [85], [88], [86], at conferences including ASE and ICSME. The ITrans ANR is a joint project with them.
- We collaborate with Christoph Reichenbach of the University of Lund and Krishna Narasimhan of Itemis (Germany) on program transformation [18] and the design of tools for code clone management.

- We collaborate with Wouter Swierstra of the University of Utrecht (Netherlands) on type-directed structured differences [20].
- We collaborate with Eric Tanter of the University of Chile (Chile) on the theoretical and practical aspects of dependent interoperability [38] in type theory.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

As part of the Invited Professor program of LIP6, we have hosted Prof. Éric Tanter (University of Chile) for two weeks (December 2017) who took this opportunity to give an introductory master class as well as a research seminar on the topic of gradual typing.

#### 9.4.1.1. Internships

- Lukas Gnirke, Oberlin College, January 2017, evaluation of our methodology for searching for examples to guide driver porting [16].
- Adina Johnson, Oberlin College, May - August 2017, analysis of the differences between the Linux kernel and the Android kernel.
- Jonathan Carroll, Oberlin College, May - August 2017, use of machine learning to identify stable-kernel relevant patches.
- Bhumika Goyal, October - November 2017, constification of Linux kernel structures, supported by the Linux Foundation's Core Infrastructure Initiative.
- Peio Borthelle, École Normale Supérieure de Lyon, June - July 2017, solving the Oware on a single machine.
- Darius Mercadier, Université Pierre et Marie Curie, January - August 2017, designing and implementing Usuba, a bitslicing compiler.

#### 9.4.1.2. Research Stays Abroad

- Julia Lawall, visit to David Lo and Lingxiao Jiang at Singapore Management University (two weeks in May 2017).

**ALPINES Project-Team****9. Partnerships and Cooperations****9.1. National Initiatives****9.1.1. ANR****9.1.1.1. 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.

**9.1.1.2. Medimax**

ANR-MN (Modèles Numériques) October 2013 - September 2017

The main goal is the methodological and numerical development of a new robust inversion tool, associated with the numerical solution of the electromagnetic forward problem, including the benchmarking of different other existing approaches (Time Reverse Absorbing Condition, Method of Small-Volume Expansions, Level Set Method). This project involves the development of a general parallel open source simulation code, based on the high-level integrated development environment of FreeFem++, for modeling an electromagnetic direct problem, the scattering of arbitrary electromagnetic waves in highly heterogeneous media, over a wide frequency range in the microwave domain. The first applications considered here will be medical applications: microwave tomographic images of brain stroke, brain injuries, from both synthetic and experimental data in collaboration with EMTensor GmbH, Vienna (Austria), an Electromagnetic Medical Imaging company.

**9.1.1.3. 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.

**9.1.1.4. 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.

**9.1.1.5. Soilμ-3D**

ANR appel à projet générique October 2015 - September 2020

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

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

To achieve this aim, it will be necessary to work at different scales: the micro-scale of pores ( $\mu\text{m}$ ) where the microbial habitats are localized, the meso-scale of cores at which laboratory measurements on 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. European Initiatives

### 9.2.1. FP7 & H2020 Projects

#### 9.2.1.1. NLA FET

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

Programm: H2020

Duration: November 2015 - November 2018

Coordinator: UMEÅUniversitet

Partners:

Science and Technology Facilities Council (United Kingdom)

Computer Science Department, UmeåUniversitet (Sweden)

Mathematics Department, The University of Manchester (United Kingdom)

Inria contact: Laura Grigori

The NLA FET 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.

#### 9.2.1.2. EXA2CT

Title: EXascale Algorithms and Advanced Computational Techniques

Programm: FP7

Duration: September 2013 - August 2016

Coordinator: IMEC

Partners:

Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V (Germany)

Interuniversitair Micro-Electronica Centrum Vzw (Belgium)

Intel Corporations (France)

Numerical Algorithms Group Ltd (United Kingdom)

T-Systems Solutions for Research (Germany)

Universiteit Antwerpen (Belgium)

Universita della Svizzera italiana (Switzerland)

Université de Versailles Saint-Quentin-En-Yvelines. (France)

Vysoka Skola Banska - Technicka Univerzita Ostrava (Czech Republic)

Inria contact: Luc Giraud

Numerical simulation is a crucial part of science and industry in Europe. The advancement of simulation as a discipline relies on increasingly computing intensive models that require more computational resources to run. This is the driver for the evolution to exascale. Due to limits in the increase in single processor performance, exascale machines will rely on massive parallelism on and off chip, with a complex hierarchy of resources. The large number of components and the machine complexity introduce severe problems for reliability and programmability. The former of these will require novel fault-aware algorithms and support software. In addition, the scale of the numerical models exacerbates the difficulties by making the use of more complex simulation algorithms necessary, for numerical stability reasons. A key example of this is increased reliance on solvers. Such solvers require global communication, which impacts scalability, and are often used with preconditioners, increasing complexity again. Unless there is a major rethink of the design of solver algorithms, their components and software structure, a large class of important numerical simulations will not scale beyond petascale. This in turn will hold back the development of European science and industry which will fail to reap the benefits from exascale. The EXA2CT project brings together experts at the cutting edge of the development of solvers, related algorithmic techniques, and HPC software architects for programming models and communication. It will take a revolutionary approach to exascale solvers and programming models, rather than the incremental approach of other projects. We will produce modular open source proto-applications that demonstrate the algorithms and programming techniques developed in the project, to help boot-strap the creation of genuine exascale codes.

## 9.3. International Initiatives

### 9.3.1. Inria International Partners

#### 9.3.1.1. Informal International Partners

- J. Demmel, UC Berkeley, USA

- R. Hipmair, ETH Zurich
- M. Grote (Université de Bâle, Suisse)
- F. Assous (Israel)

## **9.4. International Research Visitors**

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

- Ralf Hiptmair (ETH Zürich) came to visit Xavier Claeys for a sabbatical semester, from January to June 2017.
- Mahadevan Ganesh (Colorado School of Mines) came to visit Xavier Claeys from the 4th of July 2017 to 18th of July 2017.
- Carlos Jerez-Hanckes (Pontificia Universidad Catolica, Santiago, Chile) came to visit Xavier Claeys from the 3rd of December to the 16th of December 2017.

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

#### ***9.4.2.1. Research Stays Abroad***

- Laura Grigori has spent 3 weeks at UC Berkeley, from July 21, 2016 to August 13, 2016.
- Xavier Claeys visited Catalin Turc (New Jersey Institute of Technology) from the 5th of November to the 14th of November 2017.

## 8. Partnerships and Cooperations

### 8.1.1. PIA

**Participants:** Thierry Gautier, Laurent Lefèvre, Christian Perez, Issam Rais, Jérôme Richard.

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

**Participants:** Laurent Lefèvre, Mathilde Boutigny, Christian Perez, Frédéric Suter.

We propose to investigate new functionalities to add at low cost in actual large scale schedulers and programming standards, for a better use of the resources according to various objectives and criteria. We propose to revisit the principles of existing schedulers after studying the main factors impacted by job submissions. Then, we will propose novel efficient algorithms for optimizing the schedule for unconventional objectives like energy consumption and to design provable approximation multi-objective optimization algorithms for some relevant combinations of objectives. An important characteristic of the project is its right balance between theoretical analysis and practical implementation. The most promising ideas will lead to integration in reference systems such as SLURM and OAR as well as new features in programming standards implementations such as MPI or OpenMP.

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



Since January 2013, the team is participating to the C2S@Exa Inria Project Lab (IPL). This national initiative aims at the development of numerical modeling methodologies that fully exploit the processing capabilities of modern massively parallel architectures in the context of a number of selected applications related to important scientific and technological challenges for the quality and the security of life in our society. At the current state of the art in technologies and methodologies, a multidisciplinary approach is required to overcome the challenges raised by the development of highly scalable numerical simulation software that can exploit computing platforms offering several hundreds of thousands of cores. Hence, the main objective of C2S@Exa is the establishment of a continuum of expertise in the computer science and numerical mathematics domains, by gathering researchers from Inria project-teams whose research and development activities are tightly linked to high performance computing issues in these domains. More precisely, this collaborative effort involves computer scientists that are experts of programming models, environments and tools for harnessing massively parallel systems, algorithmists that proposes algorithms and contributes to generic libraries and core solvers in order to take benefit from all the parallelism levels with the main goal of optimal scaling on very large numbers of computing entities and, numerical mathematicians that are studying numerical schemes and scalable solvers for systems of partial differential equations in view of the simulation of very large-scale problems.

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

**Participants:** Jad Darrous, Gilles Fedak, 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.

**8.1.3.3. HAC SPECIS, High-performance Application and Computers, Studying PErformance and Correctness In Simulation, 4 years, 2016-2020**

**Participants:** 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.

## 8.2. European Initiatives

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

#### 8.2.1.1. COST IC1305 : Nesus

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

Program: COST

Project acronym: IC1305

Project title: Network for Sustainable Ultrascale Computing (NESUS)

Duration: 2014-2019

Coordinator: Jesus Carretero (Univ. Madrid)

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

## 8.3. International Initiatives

### 8.3.1. Inria International Labs

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

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

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

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

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

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

**Participant:** Frédéric Suter.

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

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

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

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

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

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

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

#### 8.3.3. Participation in Other International Programs

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

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

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

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

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

Joao Ferreira Lima (visit from January 30<sup>th</sup> to March 2nd) from UFSM, Santa Maria, Brazil. Research collaboration funded by Labex Milyon. During the visit, he worked on energy consumption of OpenMP runtimes with Thierry Gautier.

Leila Helali (visit from June 5<sup>th</sup> to June 31<sup>th</sup>). Research collaboration with the University of Sousse (Tunisia). During the visit she worked with Eddy Caron on autonomic deployment and licenses management.

Manuel Dolz (from 25<sup>th</sup> September to 7<sup>th</sup> October 2017) from University Carlos III from Madrid, Spain. Research collaboration funded by the NESUS COST IC1305 european project. During the visit, he worked on operators placement for efficient data-streaming scenario with Marcos Dias de Assuncao, Laurent Lefevre and Alexandre Veith.

## DATAMOVE Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

- **ANR grant MOEBIUS (2013-2017).** Multi-objective scheduling for large computing platforms. Coordinator: Grenoble-INP (DataMove). Partners: Grenoble-INP, Inria, BULL-ATOS .
- **ANR grant GRECO (2017-2020).** Resource manager for cloud of things. Coordinator: Quarnot Computing. Partners: Grenoble-INP, Inria,

### 9.1.2. Competitvity Clusters

- **PIA Avido (2015-2018).** In situ analysis and visualization for large scale numerical simulation. Coordinator: EDF SA. Partners: EDF SA, Total SA, Kitware SAS , Université Pierre et Marie CURIE, Inria (DataMove).
- **FUI OverMind (2015-2017).** Task planification and asset management for the cartoon productions. Coordinator: Teamto Studio. Partners: Teamto Studio, Folimage Studio, Ecole de Gobelins, Inria (DataMove).

### 9.1.3. Inria

- Inria PRE COSMIC (exploratory research project), 2017-2019. Photovoltaic Energy Management for Distributed Cloud Platforms. Myriads, DataMove.

## 9.2. International Initiatives

### 9.2.1. Inria International Labs

#### 9.2.1.1. 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).

### 9.2.2. Participation in Other International Programs

#### 9.2.2.1. LICIA

Title: International Laboratory in High Performance and Ubiquitous Computing

International Partner (Institution - Laboratory - Researcher):

UFRGS (Brazil)

Duration: 2011 - 2018

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

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

## **9.3. International Research Visitors**

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

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

PhD in progress: Jorge Veiga Fachal, High Performance Map-Reduce, Universidade da Coruña, Spain. 3 month stay. Local adviser: Bruno Raffin.

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

Yes Denneulin spent 3 months at University of Los Andes, Bogota, Columbia.

PhD in progress: Clement Mommessin spent 6 months at ANL, Argonne, USA. Adviser: Tom Perterka.

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## HIEPACS Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

#### 9.1.1.1. SOLHAR: SOLvers for Heterogeneous Architectures over Runtime systems

**Participants:** Emmanuel Agullo, Mathieu Faverge, Abdou Guermouche, Pierre Ramet, Jean Roman, Guillaume Sylvand.

**Grant:** ANR-MONU

**Dates:** 2013 – 2017

**Partners:** Inria (**REALOPT**, **STORM** Bordeaux Sud-Ouest et **ROMA** Rhone-Alpes), IRIT/INPT, CEA-CESTA et Airbus Group Innovations.

**Overview:**

During the last five years, the interest of the scientific computing community towards accelerating devices has been rapidly growing. The reason for this interest lies in the massive computational power delivered by these devices. Several software libraries for dense linear algebra have been produced; the related algorithms are extremely rich in computation and exhibit a very regular pattern of access to data which makes them extremely good candidates for GPU execution. On the contrary, methods for the direct solution of sparse linear systems have irregular, indirect memory access patterns that adversely interact with typical GPU throughput optimizations.

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 computer 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. To date, the approaches proposed to achieve this objective are mostly based on a simple offloading of some computational tasks 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. The development of a production-quality, sparse direct solver requires a considerable research effort along three distinct axes:

- linear algebra: algorithms have to be adapted or redesigned in order to exhibit properties that make their implementation and execution on heterogeneous computing platforms efficient and reliable. This may require the development of novel methods for defining data access patterns that are more suitable for the dynamic scheduling of computational tasks on processing units with considerably different capabilities as well as techniques for guaranteeing a reliable and robust behavior and accurate solutions. In addition, it will be necessary to develop novel and efficient accelerator implementations of the specific dense linear algebra kernels that are used within sparse, direct solvers;
- runtime systems: tools such as the **StarPU** runtime system proved to be extremely efficient and robust for the implementation of dense linear algebra algorithms. Sparse linear algebra algorithms, however, are commonly characterized by complicated data access patterns, computational tasks with extremely variable granularity and complex dependencies. Therefore, a substantial research effort is necessary to design and implement features as well as interfaces to comply with the needs formalized by the research activity on direct methods;
- scheduling: executing a heterogeneous workload with complex dependencies on a heterogeneous architecture is a very challenging problem that demands the development of effective scheduling algorithms. These will be confronted with possibly limited views of dependencies among tasks and multiple, and potentially conflicting objectives, such as minimizing the makespan, maximizing the locality of data or, where it applies, minimizing the memory consumption.

Given the wide availability of computing platforms equipped with accelerators and the numerical robustness of direct solution methods for sparse linear systems, it is reasonable to expect that the outcome of this project will have a considerable impact on both academic and industrial scientific computing. This project will moreover provide a substantial contribution to the computational science and high-performance computing communities, as it will deliver an unprecedented example of a complex numerical code whose parallelization completely relies on runtime scheduling systems and which is, therefore, extremely portable, maintainable and evolvable towards future computing architectures.

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

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

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

**Dates:** 2014 – 2018

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

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

#### 9.1.1.3. *TECSER: Novel high performance numerical solution techniques for RCS computations*

**Participants:** Emmanuel Agullo, Luc Giraud, Matthieu Kuhn.

**Grant:** ANR-14-ASTRID

**Dates:** 2014 – 2017

**Partners:** Inria EPI NACHOS (leader), Corida, HiePACS; Airbus Group Innovations, Nucléotides.

**Overview:** the objective of the TECSER projet is to develop an innovative high performance numerical methodology for frequency-domain electromagnetics with applications to RCS (Radar Cross Section) calculation of complicated structures. This numerical methodology combines a high order hybridized DG method for the discretization of the frequency-domain Maxwell in heterogeneous media with a BEM (Boundary Element Method) discretization of an integral representation of Maxwell's equations in order to obtain the most accurate treatment of boundary truncation in the case of theoretically unbounded propagation domain. Beside, scalable hybrid iterative/direct domain decomposition based algorithms are used for the solution of the resulting algebraic system of equations.



## 9.2. European Initiatives

### 9.2.1. FP7 & H2020 Projects

#### 9.2.1.1. EoCoE

Title: Energy oriented Centre of Excellence for computer applications

Programm: H2020

Duration: October 2015 - October 2018

Coordinator: CEA

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

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

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

Consiglio Nazionale Delle Ricerche (Italy)

The Cyprus Institute (Cyprus)

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

Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)

Instytut Chemii Bioorganicznej Polskiej Akademii Nauk (Poland)

Forschungszentrum Julich (Germany)

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

University of Bath (United Kingdom)

Universite Libre de Bruxelles (Belgium)

Universita Degli Studi di Trento (Italy)

Inria contact: Michel Kern

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

#### 9.2.1.2. HPC4E

Title: HPC for Energy

Programm: H2020

Duration: December 2015 - November 2017

Coordinator: Barcelona Supercomputing Center

Partners:

Centro de Investigaciones Energeticas, Medioambientales Y Tecnologicas-Ciemat (Spain)

Iberdrola Renovables Energia (Spain)

Repsol (Spain)

Total S.A. (France)

Lancaster University (United Kingdom)

Inria contact: Stéphane Lanteri

This project aims to apply the new exascale HPC techniques to energy industry simulations, customizing them, and going beyond the state-of-the-art in the required HPC exascale simulations for different energy sources: wind energy production and design, efficient combustion systems for biomass-derived fuels (biogas), and exploration geophysics for hydrocarbon reservoirs. For wind energy industry HPC is a must. The competitiveness of wind farms can be guaranteed only with accurate wind resource assessment, farm design and short-term micro-scale wind simulations to forecast the daily power production. The use of CFD LES models to analyse atmospheric flow in a wind farm capturing turbine wakes and array effects requires exascale HPC systems. Biogas, i.e. biomass-derived fuels by anaerobic digestion of organic wastes, is attractive because of its wide availability, renewability and reduction of CO<sub>2</sub> emissions, contribution to diversification of energy supply, rural development, and it does not compete with feed and food feedstock. However, its use in practical systems is still limited since the complex fuel composition might lead to unpredictable combustion performance and instabilities in industrial combustors. The next generation of exascale HPC systems will be able to run combustion simulations in parameter regimes relevant to industrial applications using alternative fuels, which is required to design efficient furnaces, engines, clean burning vehicles and power plants. One of the main HPC consumers is the oil & gas (O&G) industry. The computational requirements arising from full wave-form modelling and inversion of seismic and electromagnetic data is ensuring that the O&G industry will be an early adopter of exascale computing technologies. By taking into account the complete physics of waves in the subsurface, imaging tools are able to reveal information about the Earth's interior with unprecedented quality.

## 9.3. International Initiatives

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

#### 9.3.1.1. FASTLA

Title: Fast and Scalable Hierarchical Algorithms for Computational Linear Algebra

International Partner (Institution - Laboratory - Researcher):

Stanford (United States) - Institute for Computational and Mathematical Engineering)

ICME - Eric Darve

Start year: 2012

See also: [http://people.bordeaux.inria.fr/coulaud/projets/FastLA\\_Website/](http://people.bordeaux.inria.fr/coulaud/projets/FastLA_Website/)

In this project, we propose to study fast and scalable hierarchical numerical kernels and their implementations on heterogeneous manycore platforms for two major computational kernels in intensive challenging applications. Namely, fast multipole methods (FMM) and sparse linear solvers that appear in many intensive numerical simulations in computational sciences. For the solution of large linear systems, the ultimate goal is to design parallel scalable methods that rely on efficient sparse and dense direct methods using H-matrix arithmetic. Finally, the innovative algorithmic design will be essentially focused on heterogeneous manycore platforms by using task based runtime systems. The partners, Inria HiePACS, Lawrence Berkeley Nat. Lab and Stanford University, have strong, complementary and recognized experiences and backgrounds in these fields

## 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, Paul Le Noac’h.

- Project Acronym: OverFlow.
- Project Title: Workflow Data Management as a Service for Multisite Applications.
- Coordinator: Alexandru Costan.
- Duration: Octobre 2015–October 2019.
- Other Partners: None (Young Researcher Project).
- External collaborators: **Kate Keahey** (University of Chicago and Argonne National Laboratory), **Bogdan Nicolae** (Huawei Research) and **Christophe Blanchet** (Institut Français de Bioinformatique).
- Abstract: This JCJC project led by Alexandru Costan investigates approaches to data management enabling an efficient execution of geographically distributed workflows running on multi-site clouds.
- Progress: In 2017, we have reviewed in depth the technical and architectural needs of data storage for the use cases that drive OverFlow, in order to consolidate a set of requirements for its future architecture. Based on these workflow traces, in a second step, we have investigated the suitable benchmarks that reasonably represent them. In this direction, we have first focused on ingestion and storage optimisations for such complex deployments, in particular the novel support for concurrent writes. The project was successfully reviewed at T0+18.

#### 8.1.1.2. KerStream (2017–2021)

**Participant:** Shadi Ibrahim.

- Project Acronym: KerStream.
- Project Title: Big Data Processing: Beyond Hadoop!
- Coordinator: Shadi Ibrahim .
- Duration: January 2017–January 2021.
- Other Partners: None (Young Researcher Project).
- Abstract: This JCJC project led by Shadi Ibrahim aims to address the limitations of Hadoop when running stream Big Data applications on large-scale clouds and to do a step beyond Hadoop by proposing a new approach, called KerStream, for scalable and resilient stream Big Data 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.
- Note: Shadi Ibrahim left the KerData team in April 2017, so that this contract is no longer managed within the KerData team.

### 8.1.2. Other National Projects

#### 8.1.2.1. ADT Damaris

**Participants:** Hadi Salimi, Alexandru Costan, Luc Bougé.

- Project Acronym: ADT Damaris
- Project Title: Technology development action for the Damaris environment.
- Coordinator: Alexandru Costan.
- Duration: 2016–2018.
- Abstract: This action aims to support the development of the Damaris software. Inria's *Technological Development Office* (D2T, *Direction du Développement Technologique*) provided 2 years of funding support for a senior engineer.

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

#### 8.1.2.2. 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. FP7 & H2020 Projects

#### 8.2.1.1. BigStorage

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

Programme: H2020.

Duration: January 2015–December 2018.

Coordinator: Universidad Politécnica de Madrid (UPM).

Partners:

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

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

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

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

### 8.2.2. Collaborations with Major European Organizations

Gabriel Antoniu and Alexandru Costan are serving as Inria representatives in the working groups dedicated to *HPC-Big Data* convergence within the **Big Data Value Association** (BDVA) and the **European Technology Platform in the area of High-Performance Computing** (ETP4HPC). They are contributing to the respective Strategic Research Agendas of BDVA and ETP4HPC.

## 8.3. International Initiatives

### 8.3.1. Inria International Labs

#### 8.3.1.1. JLESC: Joint Laboratory on Extreme-Scale Computing

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

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

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

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

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

Project Acronym: Data@Exascale 2.

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

International Partner: Argonne National Laboratory (United States) — Mathematics and Computer Science Division (MCS) — **Rob Ross**.

Start year: 2013.

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

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

To face the challenges generated by the exponential data growth (a general phenomenon in many fields), a certain progress has already been made in the recent years in the rapidly-developing, industry-led field of cloud-based Big Data analytics, where advanced tools emerged, relying on machine-learning techniques and predictive analytics.

Unfortunately, these advances cannot be immediately applied to Exascale computing: the tools and cultures of the two worlds, HPC (High-Performance Computing) and BDA (Big Data Analytics) have developed in a divergent fashion (in terms of major focus and technical approaches), to the detriment of both. The two worlds share however multiple similar challenges and unification now appears as essential in order to address the future challenges of major application domains that can benefit from both.

The scientific program we propose for the Data@Exascale 2 Associate Team is defined from this new, highly-strategic perspective and builds on the idea that the design of innovative approaches

to data I/O, storage and processing allowing Big Data analytics techniques and the newest HPC architectures to leverage each other clearly appears as a key catalyst factor for the convergence process.

Activities in 2017 are described on the web site of the Associate Team.

### 8.3.2. *Inria International Partners*

#### 8.3.2.1. *Declared Inria International Partners*

##### 8.3.2.2. *DataCloud@Work*

Title: DataCloud@Work.

International Partner:

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

Duration: 5 years.

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

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

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

##### 8.3.2.3. *Informal International Partners*

Instituto Politécnico Nacional, IPN, Ciudad de México: We continued our informal collaboration in the area of stream processing. A PhD student from IPN (José Aguilar Canepa) was hosted by the KerData team for a 1-month internship, during which he identified optimization problems that can be subject to joint work (see Internships section below).

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

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

#### 8.3.3.1. *International Initiatives*

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

Since 2015, Gabriel Antoniu has been invited to participate to the yearly workshops of the international **Big Data and Extreme-scale Computing** (BDEC) working group, focused on the convergence of Extreme Computing (the latest incarnation of High-Performance Computing - HPC) and Big Data. BDEC is organized as an yearly series of invitation-based international workshops. In 2017 Gabriel Antoniu was solicited to co-lead the BDEC working group dedicated to exploring convergence-related challenges for hybrid architectures combining HPC systems, clouds and fog/edge computing infrastructures with **Geoffrey Fox** and **Ewa Deelman**. The contributions are reflected in the final report on convergence available on the BDEC web page.

## 8.4. *International Research Visitors*

### 8.4.1. *Visits of International Scientists*

José Aguilar Canepa (Instituto Politécnico Nacional, IPN, Mexico) visited the KerData team for one month (November 2017) in order to setup a common topic of research for the future proposal of an Associate Team Kerdata-IPN.

#### 8.4.1.1. *Internships*

Mukrram Rahman (M1, University of Rennes 1) has done a 3-month internship within the team, working with Ovidiu Marcu and Alexandru Costan on HDFS extensions for dedicated stream storage.

### 8.4.2. *Visits to International Teams*

#### 8.4.2.1. *Research Stays Abroad*

Pierre Matri has done a 3-month internship at Argonne National Lab, to work on extreme-scale logging through application-defined storage under the supervision of Phil Carns and Rob Ross. See Section *New Results* for details.

## POLARIS Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

Nicolas Gast received a grant from the IDEX UGA that fund a post-doctoral researcher for two years to work on the smart-grid project that focus on distributed optimization in electrical distribution networks.

### 9.2. National Initiatives

#### 9.2.1. Inria Project Labs

HAC SPECIS: 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. PGM O 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.

#### 9.2.3. ANR

- *GAGA (2014–2017)*  
GAGA is an ANR starting grant (JCJC) whose aim is to explore the Geometric Aspects of GAMES. The GAGA team is spread over three different locations in France (Paris, Toulouse and Grenoble), and is coordinated by Vianney Perchet (ENS Cachan). Its aim is to perform a systematic study of the geometric aspects of game theory and, in so doing, to establish new links between application areas that so far appeared unrelated (such as the use of Hessian Riemannian optimization techniques in wireless communication networks).
- *MARMOTE (2013–2017)*  
Partners: Inria Sophia (MAESTRO), Inria Rocquencourt (DIOGEN), Université Versailles-Saint-Quentin (PRiSM lab), Telecom SudParis (SAMOVAR), Université Paris-Est Créteil (*Spécification et vérification de systèmes*), Université Pierre-et-Marie-Curie/LIP6.  
The project aims at realizing a software prototype dedicated to Markov chain modeling. It gathers seven teams that will develop advanced resolution algorithms and apply them to various domains (reliability, distributed systems, biology, physics, economy).
- *NETLEARN (2013–2017)*  
Partners: Université Versailles – Saint-Quentin (PRiSM lab), Université Paris Dauphine, Inria Grenoble (POLARIS), Institut Mines–Telecom (Telecom ParisTech), Alcatel–Lucent Bell Labs (ALBF), and Orange Labs.  
The main objective of the project is to propose a novel approach of distributed, scalable, dynamic and energy efficient algorithms for mobile network resource management. This new approach relies on the design of an orchestration mechanism of a portfolio of algorithms. The ultimate goal of the proposed mechanism is to enhance the user experience, while at the same time ensuring the more efficient utilization of the operator's resources.

- *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.
- *ANR SONGS, 2012–2016.* Partners: Inria Nancy (Algorille), Inria Sophia (MASCOTTE), Inria Bordeaux (CEPAGE, HiePACS, RunTime), Inria Lyon (AVALON), University of Strasbourg, University of Nantes.

The last decade has brought tremendous changes to the characteristics of large scale distributed computing platforms. Large grids processing terabytes of information a day and the peer-to-peer technology have become common even though understanding how to efficiently exploit such platforms still raises many challenges. As demonstrated by the USS SimGrid project funded by the ANR in 2008, simulation has proved to be a very effective approach for studying such platforms. Although even more challenging, we think the issues raised by petaflop/exaflop computers and emerging cloud infrastructures can be addressed using similar simulation methodology.

The goal of the SONGS project (Simulation of Next Generation Systems) is to extend the applicability of the SimGrid simulation framework from grids and peer-to-peer systems to clouds and high performance computation systems. Each type of large-scale computing system will be addressed through a set of use cases and led by researchers recognized as experts in this area. Any sound study of such systems through simulations relies on the following pillars of simulation methodology: Efficient simulation kernel; Sound and validated models; Simulation analysis tools; Campaign simulation management. Such aspects are also addressed in the SONGS project.

#### 9.2.4. National Organizations

- Jean-Marc Vincent is member of the scientific committees of the CIST (Centre International des Sciences du Territoire).
- *REAL.NET (2017)*  
REAL.NET is a CNRS PEPS starting grant (JCJC) coordinated by Panayotis Mertikopoulos. Its objective is to provide dynamic control methodologies for nonstationary stochastic optimization problems that arise in wireless communication networks.

### 9.3. European Initiatives

#### 9.3.1. FP7 & H2020 Projects

##### 9.3.1.1. QUANTICOL

Program: The project is a member of Fundamentals of Collective Adaptive Systems (FOCAS), a FET-Proactive Initiative funded by the European Commission under FP7.

Project acronym: QUANTICOL

Project title: A Quantitative Approach to Management and Design of Collective and Adaptive Behaviours

Duration: 04 2013 – 03 2017

Coordinator: Jane Hillston (University of Edinburgh, Scotland)

Other partners: University of Edinburgh (Scotland); Istituto di Scienza e Tecnologie della Informazione (Italy); IMT Lucca (Italy) and University of Southampton (England).



**Abstract:** The main objective of the QUANTICOL project is the development of an innovative formal design framework that provides a specification language for collective adaptive systems (CAS) and a large variety of tool-supported, scalable analysis and verification techniques. These techniques will be based on the original combination of recent breakthroughs in stochastic process algebras and associated verification techniques, and mean field/continuous approximation and control theory. Such a design framework will provide scalable extensive support for the verification of developed models, and also enable and facilitate experimentation and discovery of new design patterns for emergent behaviour and control over spatially distributed CAS.

#### 9.3.1.2. HPC4E

**Title:** HPC for Energy

**Program:** H2020

**Duration:** 01 2016 – 01 2018

**Coordinator:** Barcelona Supercomputing Center

**Inria contact:** Stephane Lanteri

**Other partners:**

- **Europe:** Lancaster University (ULANC), Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Repsol S.A. (REPSOL), Iberdrola Renovables Energía S.A. (IBR), Total S.A. (TOTAL).
- **Brazil:** Fundação Coordenação de Projetos, Pesquisas e Estudos Tecnológicos (COPPE), National Laboratory for Scientific Computation (LNCC), Instituto Tecnológico de Aeronáutica (ITA), Petróleo Brasileiro S. A. (PETROBRAS), Universidade Federal do Rio Grande do Sul (INF-UFRGS), Universidade Federal de Pernambuco (CER-UFPE)

**Abstract:** The main objective of the HPC4E project is to develop beyond-the-state-of-the-art high performance simulation tools that can help the energy industry to respond future energy demands and also to carbon-related environmental issues using the state-of-the-art HPC systems. The other objective is to improve the cooperation between energy industries from EU and Brazil and the cooperation between the leading research centres in EU and Brazil in HPC applied to energy industry. The project includes relevant energy industrial partners from Brazil and EU, which will benefit from the project's results. They guarantee that TRL of the project technologies will be very high. This includes sharing supercomputing infrastructures between Brazil and EU. The cross-fertilization between energy-related problems and other scientific fields will be beneficial at both sides of the Atlantic.

Polaris is a member of the COST program on *Game Theory in Europe*.

#### 9.3.2. Collaborations with Major European Organizations

**TU Wien:** Research Group Parallel Computing, Technische Universität Wien (Austria). We collaborate with Sascha Hunold on experimental methodology and reproducibility of experiments in HPC. In particular we co-organize the REPPAR workshop on “Reproducibility in Parallel Computing”.

**BSC (Barcelona):** Barcelona Supercomputer Center (Spain). We collaborate with the performance evaluation group through the HPC4E project and through the JLESC.

**University of Edinburgh, Istituto di Scienza e Tecnologie della Informazione and IMT Lucca.** we used to strongly collaborate through the Quanticol European project. Several projects are still actively developed, concerning the mean field and refined mean field approximation.

### 9.4. International Initiatives

#### 9.4.1. Inria International Labs

##### 9.4.1.1. North America

- JLESC (former JLPC) (Joint Laboratory for Extreme-Scale Computing) with University of Illinois Urbana Champaign, Argonne Nat. Lab and BSC. Several members of POLARIS are partners of this laboratory, and have done several visits to Urbana-Champaign or NCSA.

### 9.4.2. Inria International Partners

#### 9.4.2.1. Declared Inria International Partners

- POLARIS has strong connections with both UFRGS (Porto Alegre, Brazil) and USP (Sao Paulo, Brazil). The creation of the LICIA common laboratory (see next section) has made this collaboration even tighter.
- POLARIS has strong bounds with the University of Illinois Urbana Champaign and Barcelona Supercomputer Center, within the (Joint Laboratory on Petascale Computing, see previous section).

### 9.4.3. Participation in Other International Programs

LICIA Bresil: Polaris is member of the common laboratory with Bresil. The founding director of LICIA is Jean-Marc Vincent.

#### 9.4.3.1. South America

- *LICIA*: The CNRS, Inria, the Universities of Grenoble, Grenoble INP, and Universidade Federal do Rio Grande do Sul have created the LICIA (*Laboratoire International de Calcul intensif et d'Informatique Ambiante*). LICIA's main research themes are high performance computing, language processing, information representation, interfaces and visualization as well as distributed systems. Jean-Marc Vincent is the director of the laboratory on the French side and visited Porto Alegre for two weeks in November 2016.

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

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

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

- POLARIS is the co-recipient of a project *STIC AmSud* that involves partners from Inria and CNRS (France), MINCYNT (Argentina) and ANII (from Uruguay).

## 9.5. International Research Visitors

### 9.5.1. Visits to International Teams

#### 9.5.1.1. Research Stays Abroad

- 3/17: Panayotis Mertikopoulos visited Stanford University (Z. Zhou, N. Bambos, P. Glynn, S. Boyd)
- 04/17: Panayotis Mertikopoulos visited University of Wisconsin-Madison (W. Sandholm)
- 10/17: Panayotis Mertikopoulos visited Lancaster University (D. Leslie)
- 11/17: Panayotis Mertikopoulos visited U. Marseille-Aix (M. Faure, S. Bervoets).

## ROMA Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

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

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

## 9.2. National Initiatives

### 9.2.1. *ANR*

ANR Project SOLHAR (2013-2017), 4 years. The ANR Project SOLHAR was launched in November 2013, for a duration of 48 months. It gathers five academic partners (the HiePACS, Cepage, ROMA and Runtime Inria project-teams, and CNRS-IRIT) and two industrial partners (CEA/CESTA and EADS-IW). This project aims at studying and designing algorithms and parallel programming models for implementing direct methods for the solution of sparse linear systems on emerging computers equipped with accelerators.

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

ANR JCJC Project CODAS (2018-2022), 4 years. The ANR project CODAS was accepted in July 2017. He will be launched in February 2018. It gathers a little team of five persons including Laure Gonnord (PI) and Christophe Alias.

This project aims at studying the combination of formal methods such as abstract interpretation and term rewriting to address the challenge of scheduling complex data structures as well as complex flow graph.

## 9.3. International Initiatives

### 9.3.1. *Inria International Labs*

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

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

Research areas include:

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

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

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

#### **9.3.2.1. Keystone**

Title: Scheduling algorithms for sparse linear algebra at extreme scale

International Partner (Institution - Laboratory - Researcher):

Vanderbilt University (United States) - Electrical Engineering and Computer Science -  
Padma Raghavan

Start year: 2016

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

The Keystone project aims at investigating sparse matrix and graph problems on NUMA multicores and/or CPU-GPU hybrid models. The goal is to improve the performance of the algorithms, while accounting for failures and trying to minimize the energy consumption. The long-term objective is to design robust sparse-linear kernels for computing at extreme scale. In order to optimize the performance of these kernels, we plan to take particular care of locality and data reuse. Finally, there are several real-life applications relying on these kernels, and the Keystone project will assess the performance and robustness of the scheduling algorithms in applicative contexts. We believe that the complementary expertise of the two teams in the area of scheduling HPC applications at scale (ROMA — models and complexity; and SSCL — architecture and applications) is the key to the success of this associate team. We have already successfully collaborated in the past and expect the collaboration to reach another level thanks to Keystone.

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

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

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

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

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

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

As for research, the JORISS program funds collaborative research projects between ENS Lyon and ECNU. Yves Robert and Changbo Wang (ECNU) are leading a JORISS project on resilience in HPC computing. Anne Benoit and Minsong Chen are leading a JORISS project on scheduling and resilience in cloud computing. In the context of this collaboration two students from ECNU, Li Han and Changjiang Gou, have joined Roma for their PhD.

#### *9.3.4.1. Informal International Partners*

- Christophe Alias has a regular collaboration with Sanjay Rajopadhye from Colorado State University (USA); this collaboration also includes Guillaume Iooss (Inria Parkas) and Sylvain Collange (Inria Rennes).

## **9.4. International Research Visitors**

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

#### *9.4.1.1. Internships*

- Louis-Claude Canon, Loris Marchal, and Frédéric Vivien supervised Dorel Butaciu, an Erasmus student, for three months (June–September 2017).
- Loris Marchal, Bertrand Simon and Frédéric Vivien supervised Hanna Nagy, an Erasmus student, for three months (June–September 2017).
- Laure Gonnord supervised Szabolcs-Martón Bagoly, an Erasmus student, for three months (June–September 2017).

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

#### *9.4.2.1. 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. He collaborates with several ICL researchers on high-performance linear algebra and resilience methods at scale.
- Anne Benoit and Bora Uçar visit the School of Computational Science and Engineering Georgia Institute of Technology, Atlanta, GA, USA (August 2017–May 2018). During this stay, Anne Benoit taught the course CSE-6140 Computational Science and Engineering (CSE) Algorithms, taken by both senior level undergraduate and graduate students, and by distant learners. Anne and Bora are collaborating with Prof. Çatalyürek and his group members on problems of high performance computing including partitioning, load balancing and scheduling.

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## STORM Project-Team

## 8. Partnerships and Cooperations

### 8.1. National Initiatives

#### 8.1.1. PIA

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

#### 8.1.2. ANR

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

ANR MONU 2013 Program, 2013 - 2017 (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 Songs** Simulation of next generation systems (<http://infra-songs.gforge.inria.fr/>).

ANR INFRA 2011, 01/2012 - 12/2015 (48 months)

Identification: ANR-11INFR01306

Coordinator: Martin Quinson (Inria Nancy)

Other partners: Inria Nancy, Inria Rhône-Alpes, IN2P3, LSIIT, Inria Rennes, I3S.

**Abstract:** The goal of the SONGS project is to extend the applicability of the SimGrid simulation framework from Grids and Peer-to-Peer systems to Clouds and High Performance Computation systems. Each type of large-scale computing system will be addressed through a set of use cases and lead by researchers recognized as experts in this area.

#### 8.1.3. ADT - Inria Technological Development Actions

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

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

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

Coordinator: Raymond Namyst

Abstract: The Inria action ADT SwLoc has the aim to develop a new library allowing dynamic flexible partitioning of computing resources in order to execute parallel regions.

#### 8.1.4. IPL - Inria Project Lab

C2S@Exa - Computer and Computational Sciences at Exascale **Participant:** Olivier Aumage.

Inria IPL 2013 - 2017 (48 months)

Coordinator: Stéphane Lantéri (team Nachos, Inria Sophia)

Since January 2013, the team is participating to the C2S@Exa [http://www-sop.inria.fr/c2s\\_at\\_exa](http://www-sop.inria.fr/c2s_at_exa) Inria Project Lab (IPL). This national initiative aims at the development of numerical modeling methodologies that fully exploit the processing capabilities of modern massively parallel architectures in the context of a number of selected applications related to important scientific and technological challenges for the quality and the security of life in our society. This collaborative effort involves computer scientists that are experts of programming models, environments and tools for harnessing massively parallel systems, algorithmists that propose algorithms and contribute to generic libraries and core solvers in order to take benefit from all the parallelism levels with the main goal of optimal scaling on very large numbers of computing entities and, numerical mathematicians that are studying numerical schemes and scalable solvers for systems of partial differential equations in view of the simulation of very large-scale problems.

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

**Participants:** Samuel Thibault, Luka Stanisic, Emmanuelle Saillard.

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.

## 8.2. European Initiatives

### 8.2.1. FP7 & H2020 Projects

#### 8.2.1.1. INTERTWINE

Title: Programming Model INTERoperability ToWards Exascale

Programm: H2020

Duration: October 2015 - October 2018

Coordinator: EPCC

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Deutsches Zentrum für Luft - und Raumfahrt Ev (Germany)

Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)

Institut National de Recherche en Informatique et en Automatique (France)

Kungliga Tekniska Hogskolan (Sweden)

T-Systems Solutions for Research (Germany)

The University of Edinburgh (United Kingdom)

Universitat Jaume I de Castellon (Spain)

The University of Manchester (United Kingdom)

Inria contact: Olivier Aumage

This project addresses the problem of programming model design and implementation for the Exascale. The first Exascale computers will be very highly parallel systems, consisting of a hierarchy of architectural levels. To program such systems effectively and portably, programming APIs with efficient and robust implementations must be ready in the appropriate timescale. A single, “silver bullet” API which addresses all the architectural levels does not exist and seems very unlikely to emerge soon enough. We must therefore expect that using combinations of different APIs at different system levels will be the only practical solution in the short to medium term. Although there remains room for improvement in individual programming models and their implementations, the main challenges lie in interoperability between APIs. It is this interoperability, both at the specification level and at the implementation level, which this project seeks to address and to further the state of the art. INTERTWinE brings together the principal European organisations driving the evolution of programming models and their implementations. The project will focus on seven key programming APIs: MPI, GASPI, OpenMP, OmpSs, StarPU, QUARK and PaRSEC, each of which has a project partner with extensive experience in API design and implementation. Interoperability requirements, and evaluation of implementations will be driven by a set of kernels and applications, each of which has a project partner with a major role in their development. The project will implement a co- design cycle, by feeding back advances in API design and implementation into the applications and kernels, thereby driving new requirements and hence further advances.

#### 8.2.1.2. *Mont-Blanc 2*

Title: Mont-Blanc

Programm: FP7

Duration: Sep. 2013 - Mar. 2017

Coordinator: BSC

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Atos/Bull (France)

ARM (United Kingdom)

Jülich (Germany)

LRZ (Germany)

University of Stuttgart (Germany)

CINECA (Italy)

CNRS (France)

CEA (France)

University of Bristol (United Kingdom)

Allinea Software (United Kingdom)

University of Cantabria (Spain)

Inria contact: Olivier Aumage

The Mont-Blanc project aims to develop a European Exascale approach leveraging on commodity power-efficient embedded technologies. The project has developed a HPC system software stack on ARM, and will deploy the first integrated ARM-based HPC prototype by 2014, and is also working on a set of 11 scientific applications to be ported and tuned to the prototype system.

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



Program: PRACE

Project acronym: PRACE-5IP

Project title: PRACE Fifth Implementation Phase

Duration: 01/2017

Coordinator: PRACE

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.

Inria contact for team STORM: Olivier Aumage

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**TADaaM Project-Team**

## 9. Partnerships and Cooperations

### 9.1. National Initiatives

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

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

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

##### 9.1.2. ANR

*ANR MOEBUS* Scheduling in HPC (<http://moebus.gforge.inria.fr/doku.php>).

ANR INFRA 2013, 10/2013 - 9/2017 (48 months)

Coordinator: Denis Trystram (Inria Rhône-Alpes)

Other partners: Inria Bordeaux Sud-Ouest, Bull/ATOS

Abstract: This project focuses on the efficient execution of parallel applications submitted by various users and sharing resources in large-scale high-performance computing environments.

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

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

Coordinator: Laurent Simon (LaBRI)

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

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

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

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

Coordinator: Guillaume AUPY (Tadaam)

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

## 9.2. European Initiatives

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

COLOC: the Concurrency and Locality Challenge (<http://www.coloc-itea.org>).

Program: ITEA2

Project acronym: COLOC

Project title: The Concurrency and Locality Challenge

Duration: November 2014 - November 2017

Coordinator: BULL/ATOS

Other partners: BULL/ATOS (France); Dassault Aviation (France) ; Enfeild AB (Sweden); Scilab entreprise (France); Teratec (France); Inria (France); Swedish Defebnse Research Agency - FOI (France); UVSQ (France).

Abstract: The COLOC project aims at providing new models, mechanisms and tools for improving applications performance and supercomputer resources usage taking into account data locality and concurrency.

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

Program: COST

Project acronym: NESUS

Project title: Network for Ultrascale Computing

Duration: April 2014 - April 2018

Coordinator: University Carlos III de Madrid

Other partners: more than 35 countries

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

### 9.2.2. Collaborations with Major European Organizations

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

Subject 1: Application modeling for hierarchical memory system

## 9.3. International Initiatives

### 9.3.1. 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.

### **9.3.2. Inria International Partners**

#### *9.3.2.1. Informal International Partners*

Partner 1: ICL at University of Tennessee

Subject 1: 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 2: Argonne National Lab

Subject 2: Topology-aware data aggregation for I/O intensive application

Partner 3: Vanderbilt University

Subject 3: Data-scheduling on hierarchical memories

## **9.4. Close cooperation with Industry**

- Advanced Micro Devices, Inc. (AMD): AMD Zen micro-architecture and EPYC processors topology support in the Linux kernel.
- Oracle Corporation: Topology detection for SPARC processors and Solaris operating systems.
- ARM Holdings and Cavium, Inc.: ARM processor ACPI PPTT firmwares and Linux kernel topology information.

## **9.5. International Research Visitors**

### *9.5.1. Visits of International Scientists*

- Aleksandar Ilic from University of Lisbon visited us to continue our collaboration on the Locality-aware Roofline Model [19].
- Tobias Fuchs from Ludwig-Maximilians-University of Munich visited us to improve the use of hardware locality in the DYLOC runtime system.

## ASCOLA Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. RFI Atlanstic 2020

#### 9.1.1.1. CoMe4ACloud

**Participants:** Thomas Ledoux [coordinator], Frederico Alvares de Oliveira Junior, Zakarea Al Shara.

The high-level objective of the 1-year CoMe4ACloud (Constraints and Model Engineering for Autonomic Clouds) project is to provide an end-to-end solution for autonomic Cloud services. To that end, we rely on techniques of Constraint Programming so as a decision-making tool and Model-driven Engineering to ease the automatic generation of the so-called autonomic managers as well as their synchronization with the managed system (i.e., the Cloud layers).

This year, we got the best paper award of CLOSER 2017 (the 7th International Conference on Cloud Computing and Services Science) [27]. We have also submitted two publications and provided two video-demonstrations of the early results.

CoMe4ACloud is an Atlanstic2020 funded project and supports a post-doc position. The project is led by Ascola research team and involves also AtlanModels and TASC, all of them from the LS2N and situated at IMT Atlantique. See <https://come4acloud.github.io> for more information.

#### 9.1.1.2. SyMeTRIC

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

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

## 9.2. National Initiatives

### 9.2.1. CominLabs laboratory of excellence

#### 9.2.1.1. EPOC

**Participants:** Jean-Marc Menaud [coordinator], Thomas Ledoux, Md Sabbir Hasan, Yunbo Li.

The project EPOC (Energy Proportional and Opportunistic Computing system) is a project running for 4 years. Four other partners collaborate within the project that is coordinated by ASCOLA: Myriads team, and the three institutions ENIB, ENSTB and University of Nantes. In this project, the partners focus on energy-aware task execution from the hardware to application components in the context of a *mono-site* data center (all resources are in the same physical location) which is connected to the *regular electric Grid and to renewable energy sources* (such as windmills or solar cells). Three major challenges are addressed in this context: optimize the energy consumption of distributed infrastructures and service compositions in the presence of ever more dynamic service applications and ever more stringent availability requirements for services; design a clever cloud's resource management which takes advantage of renewable energy availability to perform opportunistic tasks, then exploring the trade-off between energy saving and performance aspects in large-scale distributed system; investigate energy-aware optical ultra high-speed interconnection networks to exchange large volumes of data (VM memory and storage) over very short periods of time.

One of the strengths of the project is to provide a systematic approach, and use a single model for the system (from hard to soft) by mixing constraint programming and behavioral models to manage energy consumption in data centers.

#### 9.2.1.2. *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 Ascola team. The project provides funding of 330 KEUR altogether with an Ascola share of 120 KEUR.

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

The partners are working on three main challenges:

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

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

### 9.2.2. *ANR*

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

**Participant:** Adrien Lebre [Contact point].

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

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

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

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

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

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

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

### 9.2.3. *FSN*

#### 9.2.3.1. *Hosanna (FSN)*

**Participants:** Jean-Marc Menaud [coordinator], Remy Pottier.

The Hosanna project aims to scientifically and technically address the problem of deploying applications on a distributed multi-cloud virtual infrastructure (private cloud, Amazon, OVH, CloudWatt, Numergy etc.) This recent need is an important topic issue highlighted by recent major Outages in 2013 by the biggest players in the cloud such as Amazon or Netflix. This project aims to provide services that allow users to deploy their cloud multi-tier applications on hybrid Clouds infrastructures without any separation between IaaS. The Ascola team is extending its optimization solution to address the task placement problem in a multi-cloud environment and will develop a case study on a secure distributed file system. The project started in 2015 for a duration of 2 years.

#### 9.2.3.2. *Hyddda* (FSN)

**Participants:** Jean-Marc Menaud [coordinator], H  l  ne Coullon.

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

#### 9.2.4. CPER

#### 9.2.4.1. *SeDuCe*

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

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

### 9.2.5. Inria Project Labs

#### 9.2.5.1. DISCOVERY

**Participants:** H  l  ne Coullon, Shadi Ibrahim, Adrien Lebre [coordinator], Dimitri Pertin, Ronan-Alexandre Cherrueau, Alexandre Van Kempen, Mario S  dholt.

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 [26] 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.

ASCOLA leads the DISCOVERY IPL and contributes mainly around two axes: VM life cycle management and security concerns.

### **9.2.6. InriaHub**

#### **9.2.6.1. MERCURY**

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

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

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

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

#### **9.2.7.1. aLIFE**

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

The French engineering school IMT Atlantique is organizing the aLIFE workshop between industry and academia, in Nantes during two days on January, 30-31 2018. The objective of this workshop is to share various experiences and success stories, as well as open challenges related to the contribution of software-related research to Factories of the Future, in French apport de l'industrie du Logiciel à l'Industrie du Futur Européenne (aLIFE). To this end, big multinational companies, as well as SMEs and academics will exchange through plenary sessions and discussion panels.

### **9.2.8. Connect Talent**

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

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

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

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

## **9.3. European Initiatives**

### **9.3.1. FP7 & H2020 Projects**

#### **9.3.1.1. CoqHoTT**

Title: Coq for Homotopy Type Theory

Programm: H2020

Type: ERC

Duration: June 2015 - May 2020

Coordinator: Inria

Inria contact: Nicolas TABAREAU



Every year, software bugs cost hundreds of millions of euros to companies and administrations. Hence, software quality is a prevalent notion and interactive theorem provers based on type theory have shown their efficiency to prove correctness of important pieces of software like the C compiler of the CompCert project. One main interest of such theorem provers is the ability to extract directly the code from the proof. Unfortunately, their democratization suffers from a major drawback, the mismatch between equality in mathematics and in type theory. Thus, significant Coq developments have only been done by virtuosos playing with advanced concepts of computer science and mathematics. Recently, an extension of type theory with homotopical concepts such as univalence is gaining traction because it allows for the first time to marry together expected principles of equality. But the univalence principle has been treated so far as a new axiom which breaks one fundamental property of mechanized proofs: the ability to compute with programs that make use of this axiom. The main goal of the CoqHoTT project is to provide a new generation of proof assistants with a computational version of univalence and use them as a base to implement effective logical model transformation so that the power of the internal logic of the proof assistant needed to prove the correctness of a program can be decided and changed at compile time—according to a trade-off between efficiency and logical expressivity. Our approach is based on a radically new compilation phase technique into a core type theory to modularize the difficulty of finding a decidable type checking algorithm for homotopy type theory. The impact of the CoqHoTT project will be very strong. Even if Coq is already a success, this project will promote it as a major proof assistant, for both computer scientists and mathematicians. CoqHoTT will become an essential tool for program certification and formalization of mathematics.

#### 9.3.1.2. *BigStorage*

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

Programm: H2020

Duration: January 2015 - December 2018

Coordinator: Universidad politecnica de Madrid

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Ca Technologies Development Spain (Spain)

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

Deutsches Klimarechenzentrum (Germany)

Foundation for Research and Technology Hellas (Greece)

Fujitsu Technology Solutions (Germany)

Johannes Gutenberg Universitaet Mainz (Germany)

Universidad Politecnica de Madrid (Spain)

Seagate Systems Uk (United Kingdom)

Inria contact: G. Antoniu & A. Lebre

The consortium of this European Training Network (ETN) 'BigStorage: Storage-based Convergence between HPC and Cloud to handle Big Data' will train future data scientists in order to enable them and us to apply holistic and interdisciplinary approaches for taking advantage of a data-overwhelmed world, which requires HPC and Cloud infrastructures with a redefinition of storage architectures underpinning them - focusing on meeting highly ambitious performance and energy usage objectives. There has been an explosion of digital data, which is changing our knowledge about the world. This huge data collection, which cannot be managed by current data management systems, is known as Big Data. Techniques to address it are gradually combining with what has been traditionally known as High Performance Computing. Therefore, this ETN will focus on the convergence of Big Data, HPC, and Cloud data storage, its management and analysis. To gain value from Big Data it must be addressed from many different angles: (i) applications, which

can exploit this data, (ii) middleware, operating in the cloud and HPC environments, and (iii) infrastructure, which provides the Storage, and Computing capable of handling it. Big Data can only be effectively exploited if techniques and algorithms are available, which help to understand its content, so that it can be processed by decision-making models. This is the main goal of Data Science. We claim that this ETN project will be the ideal means to educate new researchers on the different facets of Data Science (across storage hardware and software architectures, large-scale distributed systems, data management services, data analysis, machine learning, decision making). Such a multifaceted expertise is mandatory to enable researchers to propose appropriate answers to applications requirements, while leveraging advanced data storage solutions unifying cloud and HPC storage facilities.'

## **9.4. International Initiatives**

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

#### *9.4.1.1. Informal International Partners*

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

## **9.5. International Research Visitors**

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

#### *9.5.1.1. Research Stays Abroad*

HUST and ShenZhen University, China: From October 28 to November 11, S. Ibrahim visited the Services Computing Technology and System Lab at Huazhong university of Science and Technology and the National High Performance Computing Center at Shenzhen University.

## **DIVERSE Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. National Initiatives**

### **9.1.1. ANR**

#### *9.1.1.1. SOPRANO*

- Coordinator: CEA
- CEA, University of Paris-Sud, Inria Rennes, OcamlPro, Adacore
- Dates: 2014-2017
- Abstract: Today most major verification approaches rely on automatic external solvers. However these solvers do not fill the current and future needs for verification: lack of satisfying model generation, lack of reasoning on difficult theories (e.g. floating-point arithmetic), lack of extensibility for specific or new needs. The SOPRANO project aims at solving these problems and prepare the next generation of verification-oriented solvers by gathering experts from academia and industry. We will design a new framework for the cooperation of solvers, focused on model generation and borrowing principles from SMT (current standard) and CP (well-known in optimisation). These ideas will be implemented in an open-source platform, with regular evaluations from the industrial partners.

#### *9.1.1.2. VaryVary ANR JCJC*

- Coordinator: Mathieu Acher
- DiverSE, Inria/IRISA Rennes
- Dates: 2017-2021
- Abstract: Most modern software systems (operating systems like Linux, Web browsers like Firefox or Chrome, video encoders like x264 or ffmpeg, servers, mobile applications, etc.) are subject to variation or come in many variants. Hundreds of configuration options, features, or plugins can be combined, each potentially with distinct functionality and effects on execution time, memory footprint, etc. Among configurations, some of them are chosen and do not compile, crash at runtime, do not pass a test suite, or do not reach a certain performance quality (e.g., energy consumption, security). In this JCJC ANR project, we follow a thought-provocative and unexplored direction: We consider that the variability boundary of a software system can be specialized and should vary when needs be. The goal of this project is to provide theories, methods and techniques to make vary variability. Specifically, we consider machine learning and software engineering techniques for narrowing the space of possible configurations to a good approximation of those satisfying the needs of users. Based on an oracle (e.g., a runtime test) that tells us whether a given configuration meets the requirements (e.g. speed or memory footprint), we leverage machine learning to retrofit the acquired constraints into a variability that can be used to automatically specialize the configurable system. Based on a relative small number of configuration samples, we expect to reach high accuracy for many different kinds of oracles and subject systems. Our preliminary experiments suggest that varying variability can be practically useful and effective. However, much more work is needed to investigate sampling, testing, and learning techniques within a variety of cases and application scenarios. We plan to further collect large experimental data and apply our techniques on popular, open-source, configurable software (like Linux, Firefox, ffmpeg, VLC, Apache or JHipster) and generators for media content (like videos, models for 3D printing, or technical papers written in LaTeX).

#### *9.1.1.3. CLARITY*

- Coordinator: Obéo
- Other partners: AIRBUS, Airbus Defence and Space, All4tec, ALTRAN Technologies, AREVA, Artal, C.E.S.A.M.E.S., Eclipse Foundation Europe, Inria Sophia Antipolis Méditerranée, PRFC, Scilab Enterprises, Thales Global Services, Thales Alenia Space, Thales Research & Technology, Thales Systèmes Aéroportés, Université de Rennes 1.
- Dates: 2014-2017
- Abstract: The CLARITY project aims to establish an international dimension ecosystem around Melody/Capella modeling workbench for systems engineering (MBSE) and engineering architectures (system, software, hardware).

#### *9.1.1.4. Occiware*

- Coordinator: Open Wide
- Open Wide, ActiveEon SA, CSRT - Cloud Systèmes Réseaux et Télécoms, Institut Mines-Télécom/Télécom SudParis, Inria, Linagora, Obeo, OW2 Consortium, Pôle Numérique, Université Joseph Fourier,
- Dates: 2014-2017
- Abstract: The Occiware project aims to establish a formal and equipped framework for the management of all cloud resource based on the OCCI standard.

### **9.1.2. DGA**

#### *9.1.2.1. FPML (CYBERDEFENSE)*

- Coordinator: DGA
- Partners: DGA MI, Inria
- Dates: 2014-2017
- 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.

### **9.1.3. Cominlabs**

#### *9.1.3.1. 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 working, 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.

## **9.2. European Initiatives**

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

#### **9.2.1.1. FP7 STREP HEADS**

- Coordinator: SINTEF
- Other partners: Inria, Software AG, ATC, Tellu, eZmonitoring
- Dates: 2013-2017
- Abstract: The idea of the HEADS project is to leverage model-driven software engineering and generative programming techniques to provide a new integrated software engineering approach which allow advanced exploitation the full range of diversity and specificity of the future computing continuum. The goal is to empower the software and services industry to better take advantage of the opportunities of the future computing continuum and to effectively provide new innovative services that are seamlessly integrated to the physical world making them more pervasive, more robust, more reactive and closer (physically, socially, emotionally, etc.) to their users. We denote such services HD-services. HD-services (Heterogeneous and Distributed services) characterize the class of services or applications within the Future Internet whose logic and value emerges from a set of communicating software components distributed on a heterogeneous computing continuum from clouds to mobile devices, sensors and/or smart-objects.

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

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

STAMP will raise confidence and foster adoption of DevOps by the European IT industry. The project gathers 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.

### **9.2.2. 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.

## **9.3. International Initiatives**

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

#### **9.3.1.1. ALE**

- Title: Agile Language Engineering

- International Partner (Institution - Laboratory - Researcher):
  - CWI (Netherlands)
- 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).

### **9.3.2. *Inria International Partners***

#### **9.3.2.1. *Informal International Partners***

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

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

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

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

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

## **9.4. International Research Visitors**

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

Yves Le Traon, Professor at the University of Luxembourg, visited the team in June and July 2017.

Tanja Mayerhofer, Junior Researcher at the TU Wien, visited the team in March 2017.

François Fouquet, Junior Researcher at the SnT (Lux), visited the team in November 2017.

#### ***9.4.1.1. Internships***

Koko armando Nguepi kenfack, Master interships at the University of Namur, visited the team from September 2017 to January 2018.

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

Manuel Leduc visited CWI for 3 weeks in September 2017

Benoit Combemale visited Professor Jorg Kienzle at McGill University (Canada) for 3 months in 2017; and made several short visits at CWI (The Netherlands).

#### ***9.4.2.1. Research Stays Abroad***

Marcelino Rodriguez-Cancio visited Vanderbilt University from November 2016 to September 2017.

## FOCUS Project-Team

# 8. Partnerships and Cooperations

## 8.1. National Initiatives

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

## 8.2. European Initiatives

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

- ICT COST Action IC1405 (Reversible computation - extending horizons of computing). Initiated at the end of April 2015 and with a 4-year duration, this COST Action studies reversible computation and its potential applications, which include circuits, low-power computing, simulation, biological modeling, reliability and debugging. Reversible computation is an emerging paradigm that extends the standard forwards-only mode of computation with the ability to execute in reverse, so that computation can run backwards as naturally as it can go forwards.  
Main persons involved: Lanese (vice-chair of the action).
- ICT COST Action IC1402 ARVI (Runtime Verification beyond Monitoring). Initiated in December 2014 and with a 4-year duration, this COST Action studies runtime verification, a computing analysis paradigm based on observing a system at runtime to check its expected behaviour.  
Main persons involved: Bravetti, Lanese.

### 8.2.2. 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, Vignudelli. Some visit exchanges during the year, in both directions. A joint PhD started in September 2016 (Adrien Durier).



- Inria EPI Spades (on models and languages for components, reversibility). Contact person(s) in Focus: Lanese.
- 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.
- LMU Munich (M. Hofmann) (on implicit computational complexity and IntML). Contact person(s) in Focus: Dal Lago.
- IMDEA Software, Madrid (G. Barthe) (on implicit computational complexity for cryptography). Contact person(s) in Focus: Dal Lago, Sangiorgi. Some visits during the year.
- Facultad de Informática, Universidad Complutense de Madrid (on web services). Contact person(s) in Focus: Bravetti. Bravetti is an external collaborator in the project "Desarrollo y Análisis formal de sistemas complejos en contextos DistribuidOS: fundamentos, herramientas y aplicaciones (DAR-DOS)" (Development and formal analysis of complex systems in distributed contexts: foundations, tools and applications) January 2016 - December 2018, funded by the Spanish Ministerio de Economía y Competitividad.

## 8.3. International Initiatives

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

#### 8.3.1.1. CRECOGI

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

International Partner (Institution - Laboratory - Researcher):

Tokyo (Japan) - Department of Computer Science, Graduate School of Information Science and Technology - Ichiro HASUO

Start year: 2015

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

Game semantics and geometry of interaction (GoI) are two closely related frameworks whose strength is to have the characters of both a denotational and an operational semantics. They offer a high-level, mathematical (denotational) interpretation, but are interactive in nature. The formalization in terms of movements of tokens through which programs communicate with each other can actually be seen as a low-level program. The current limit of GoI is that the vast majority of the literature and of the software tools designed around it have a pure, sequential functional language as their source language. This project aims at investigating the application of GoI to concurrent, resourceful, and effectful computation, thus paving the way to the deployment of GoI-based correct-by-construction compilers in real-world software developments in fields like (massively parallel) high-performance computing, embedded and cyberphysical systems, and big data. The presence of both the Japanese GoI community (whose skills are centered around effects and coalgebras) and the French GoI community (more focused on linear logic and complexity analysis) will bring essential, complementary, ingredients.

### **8.3.2. 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.

## **8.4. International Research Visitors**

### **8.4.1. 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.

- German Vidal and Adrián Palacios: “A Reversible Semantics for Erlang.” (2 visits, during the year)
- Matteo Acclavio: "Proof Diagrams for Multiplicative Linear Logic: Syntax and Semantics."
- Ken Sakayori: "A Truly Concurrent Game Model of the Asynchronous pi-Calculus."
- Marco Carbone: "Multiparty Session types and Linear Logic."
- Beniamino Accattoli: "The Complexity of Abstract Machines."
- Ulrich Schoepp, on Complexity analysis of probabilistic programs.

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

U. Dal Lago has spent two weeks in Japan (University of Kyoto and University of Tokyo). Topics: geometry of interaction for continuous probabilistic programming languages, and categorical models for multitoken machines.

## **INDES Project-Team**

# **6. Partnerships and Cooperations**

## **6.1. National Initiatives**

### **6.1.1. ANR AJACS**

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

### **6.1.2. FUI UCF**

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

#### **6.1.2.1. Actions marquantes**

Inria Sophia Antipolis Actions Marquantes is a special funding for 2 postdocs during one year to explore a new research direction. The joint project with DIANA team “User discrimination on the Web: measurement, causation and prevention” has obtained this funding. The goal of this project is to detect when users get discriminated on the Web, what are the technologies used to discriminate users and how we can prevent it without breaking the functionality and sometimes useful personalisation within Web applications.

## **6.2. European Initiatives**

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

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

Program: ICT COST Action

Project title: Reversible computation - extending horizons of computing

Duration: November 2014 - November 2018

Coordinator: Irek Ulidowski, University of Leicester

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

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

#### **6.2.1.2. Bilateral PICS project SuCCeSS**

Program: CNRS PICS project

Project acronym: SuCCeSS

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

Duration: June 2016 - June 2019

Coordinator: Cinzia Di Giusto, I3S, Sophia Antipolis

Partners: I3S, Inria, University of Groningen

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

## **6.3. International Initiatives**

### **6.3.1. Inria International Partners**

#### *6.3.1.1. Informal International Partners*

Since 2009, the team has been collaborating with Mariangiola Dezani’s group at the University of Torino.

## **6.4. International Research Visitors**

### **6.4.1. Visits of International Scientists**

In February-March, the team hosted for two weeks Professor Mariangiola Dezani-Ciancaglini from the University of Torino and Professor Paola Giannini from the University of Piemonte Orientale (Italy). The visit was partly funded by the COST Action on Reversibility.

Marc Feeley, professor at the University of Montréal has been visiting the team from April 1st to June 30th. The visit has been funded by the Labex UCN. M. Feeley has been working with M. Serrano on the compilation of functional languages in general, and JavaScript more specifically.

#### *6.4.1.1. Internships*

##### *Web Tracking through invisible Web beacons*

Imane Fouad made an internship from March 2017 until August 2017, followed by a second internship from October 2017 until December 2017. She is selected for a PhD in INDES, and will start on 1 January 2017.

Imane’s internship aimed at analyzing the new Web tracking technologies based on “Web beacon”, or “pixel image” tracking. This tracking technology uses an invisible 1x1 pixel image that is used to send information to third-party trackers, while being invisible to the user. Web beacon tracking is particularly invasive because it cannot be blocked by Private browsing mode, Adblock or Ghostery extensions, and not even by disabling JavaScript.

Imane Fouad has run automated Web experiments using the OpenWPM platform and performed large-scale measurement of the Web beacon tracking on the Web. She detected which companies use Web beacon, how this technology works, and is currently analysing cookie-based tracking techniques such as redirection chains and cookie synching with the ultimate goal to provide a fine-grained classification of existing Web tracking technologies.

## **PHOENIX Project-Team**

## **8. Partnerships and Cooperations**

### **8.1. Regional Initiatives**

#### ***8.1.1. Independent living with intellectual disabilities – ANDDI – 2014 - 2017***

ANDDI leverages the abilities of individuals with ID and the recent technological advances to develop a variety of assistive services addressing their daily needs. These services draw on our expertise in cognitive science and computer science, dedicated to assisting users with technologies. In particular, we use our platform, named HomeAssist, dedicated to the independently living of older adults. This project is funded by the Region of Aquitaine.

#### ***8.1.2. Populational Study of HomeAssist – HomeAssist 500 – 2015 - 2017***

We conduct a Randomized Controlled Trial (RCT) of HomeAssist with older adults, ranging from autonomous to mildly cognitively impaired (e.g., Alzheimer disease (AD) in its early stage). The RCT is considered as the gold standard of a true experimental design. Furthermore, it provides strong evidence for causal relationships, as well as the ability to generalize the results to people outside the study's sample. The study design will thus be a single-blinded RCT. It will include up to 500 participants, matched with non-equipped participants. The HomeAssist intervention will involve monitoring as well as compensation services to support independent living in place. The duration of the HomeAssist intervention is of 12 months. This project is funded by the Region of Aquitaine, the Districts of Gironde and Pyrénées Atlantique, CARSAT Aquitaine, UDCCAS, and CNSA.

### **8.2. National Initiatives**

#### ***8.2.1. School Inclusion for Children with Autism***

The objective of this project is to provide children with assistive technologies dedicated to the school routines. This project is in collaboration with the “Handicap et Système Nerveux” research group (EA 4136, Bordeaux University), the PsyCLÉ research center (EA 3273, Provence Aix-Marseille University) and the “Parole et Langage” research laboratory (CNRS, Provence Aix-Marseille University).

This work is funded by the French Ministry of National Education and Orange Foundation.

### **8.3. International Initiatives**

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

- International exchange program Idex (2016-17) — “Memory, aging, Parkinson disease, and Virtual Reality”, with Pr. Luc Noreau, Centre Interdisciplinaire de Recherche en réadaptation et intégration sociale-University of Laval, Canada. Coordinated by P. Dehail.
- Mobility program Idex UB-University of Waterloo, Canada — “Aging, Neurological conditions, and Assistance technologies” (2016-17). Coordinated by M. Fernandes and H. Sauzéon.

## **RMOD Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. Regional Initiatives**

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

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

From 2009, ongoing.

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

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

## **9.2. National Initiatives**

### **9.2.1. CEA List**

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

From 2016, ongoing.

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

## **9.3. European Initiatives**

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

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

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

From Sept 2016 to Dec. 2018.

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

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

#### **University of Turin (Italy)**

Participants: Marco Naddéo, Stéphane Ducasse.

From 2015 to 2017.

Marco Naddéo was a PhD student co-supervised by Damien Cassou, Stéphane Ducasse at RMoD and Viviana Bono from University of Turin (Italy): *A modular Approach of Object initialization for Pharo*, University Turin, November 2017.

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

Participants: Guillermo Polito, Stéphane Ducasse.

From 2016, ongoing.

Student: Matteo Marra, collaboration with Eliza Gonzalez Boix. Guillermo Polito co-supervised Matteo Marra's master thesis. This collaboration led to a workshop paper [29] and a paper under revision for Programming 2018.

#### **University of Prague**

Participants: Stéphane Ducasse.

From 2015, ongoing.

We are working with Dr. Robert Pergl from the University of Prague. Stéphane Ducasse gave a lecture at the University of Prague in 2017.

## **9.4. International Initiatives**

### **9.4.1. 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**

- Prof. Serge Demeyer, Universiteit Antwerpen, Belgium. September 1st until December 31st, 2017. Sabbatical on the topic of Test Automation
- Andrew Black, Department of Computer Science, Portland State University, September 1st until December 9th. Sabbatical, Implementing the Grace Language using Pharo
- Fernando Brito, Université de Lisbonne, 27 to 18/2/2017
- Sébastien Proksch, 09/02/2017
- Sébastien Martinez, Université de Rennes 1, 09/03/2017
- Sergiu Ivanov, CNRS Grenoble, 9 to 10/2/2017
- Coen de Rover, Université Bruxelles, 28/02/17
- Yoshiki Oshima, YCombinator Research, 13 to 17/3/17
- Abdelghani Alidra, Université de Skikda, 15/05 to 18/06/2017
- Sergiu Ivanov, CNRS Grenoble, 21/04/17
- Ronie Salgado, Université du Chili, 11/9 to 22/9/2017
- Andy Zaidman, Université de Delft, 08/11/17
- Laurence Tratt, King's College London, 15/09/17
- Elisa Gonzales, Université de Bruxelles, 15/09/17
- Théo D'Hondt, Université de Bruxelles, 15/09/17

- Rim Drira, RIADI Laboratory - National School of Computer Science, Tunisia, 09/11/17
- Gordana Rakic, Université de Belgrade - Serbie, 29/11 to 6/12/2017
- Henda Ben Gezahla, Ecole Nationale des Sciences de l'Informatique (ENSI) en Tunisie, 7/11 to 12/11/2017
- Abir Mbaya, Université de Lyon, 11 to 15/12/2017
- Olivier Flückiger (Northeastern University, US) 28/11 to 01/12. Talk: Correctness of Speculative Optimizations with Dynamic Deoptimization
- Gabriel Scherer (Parsifal, Inria Saclay, France) 28/11 to 29/11. Talk: Correctness of Speculative Optimizations with Dynamic Deoptimization

#### *9.5.1.1. Internships*

- Thomas Dupriez, ENS Cachan/Paris-Saclay, from 2017-03-16 until 2017-07-21, and from 2017-08-07 until 2017-08-11
- Sophie Kaleba, from Apr 2017 until Sep 2017
- Clement Mastin, from May 2017 until Aug 2017
- Amal Noussi Mbeyim, Ecole Normale Supérieure de Rennes, from May 2017 until Jul 2017
- Morgane Piggy, until Feb 2017
- Jeremie Regnault, from Jun 2017 until Aug 2017
- Benoit Verhaeghe, Université des Sciences et Technologies de Lille, from May 2017 until Aug 2017

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

- Anne Etien: Labri, Université Bordeaux 1, January 2017.
- Nicolas Anquetil, Julien Delplanque and Anne Etien, Visit Namur University (Belgium), Decembre 2017.
- Stéphane Ducasse: Technical University Prague, Czech Republic.
- Stéphane Ducasse: ENIS Tunisia.
- Stéphane Ducasse: University of Novi Sad, Serbia.
- Stéphane Ducasse: Maribor, Slovenia.
- Stéphane Ducasse: VUB Bussels, Belgium.
- Stéphane Ducasse: University de Bretagne Occidentale.
- Stéphane Ducasse: Software Vomposition Group University of Bern/Switzerland.
- Guillermo Polito: VUB Brussel, Belgium.



## **TACOMA Team**

## **8. Partnerships and Cooperations**

### **8.1. Regional Initiatives**

**Project: EkoHub**

Partner: Ekolis, Delaye transport, Telecom Bretagne

Starting: Nov 2014; Ending : Nov 2017

Contact: JM Bonnin

Abstract: The EkoHub project has been architected around our multi-technologies gateway and leverages on the one developed in the ITSSv6 European project. In addition to the multiple interfaces of our platforms, sensor devices have been incorporated into the project and we studied different scenarios elaborated with our professional partners (Layaye Logistics). Intelligent data management schemes are being studied to adapt to the communication environment and the needs of the application consuming the data. The data model has been derived from the outcomes of the SEAS project.

The final EkoHub demonstration held in november 2017 with project partners.

### **8.2. European Initiatives**

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

**Project: SCOOP@F part 2**

Partner: MEDE, Renault, PSA

Starting: Jan 2016; Ending : Dec 2018

Coordinator: JM Bonnin

Abstract: SCOOP@F is a Cooperative ITS pilot deployment project that intends to connect approximately 3000 vehicles with 2000 kilometers of roads. It consists of 5 specific sites with different types of roads: Ile-de-France, "East Corridor" between Paris and Strasbourg, Brittany, Bordeaux and Isère. SCOOP@F is composed of SCOOP@F Part 1 from 2014 to 2015 (ongoing) and SCOOP@F Part 2 from 2016 to 2018. 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).

**Project acronym: SEAS (ITEA3)**

Partners: Telecom Paris Tech, Telecom Saint Etienne, Mines Saint Etienne, Engie, Kerlink, BeNo-mad, ICAM, CNR, VTT

Starting: Feb 2014; ending: Jan 2017

Contact: JM Bonnin

**Abstract:** The SEAS project addresses the problem of inefficient and unsustainable energy consumption, which is due to a lack of sufficient means to control, monitor, estimate and adapt the energy use of systems versus the dynamic use situations and circumstances influencing the energy use. The objective of the SEAS project is to enable energy, ICT and automation systems to collaborate at consumption sites, and to introduce dynamic and refined ICT-based solutions to control, monitor and estimate energy consumption. Proposed solution should enable energy market participants to incorporate micro-grid environments and active customers. We are involved in the project to design a distributed system architecture and to implement two proofs of concept: the first one is related to the electric vehicle charging and the other one to the prevision of solar energy production.

**Project: SCHIEF**

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

**Starting:** Sept 2016; **Ending :** Dec 2018

**Coordinator:** JM Bonnin

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

## AGORA Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

- **Labex IMU UrPolSens 10/2015-10/2018**  
Participants: Amjed Belkhiri, Ahmed Boubrima, Leo Le Taro, Walid Bechkit, Hervé Rivano  
The partners in this project are Ifsttar, LMFA, EVS, TUBA, and Air Rhone-Alpes, with Inria Agora leading the project. UrPolSens deals with the monitoring of air pollution using low-cost sensors interconnected by a wireless networks. Although they are less accurate than the high-end sensors used today, low-cost autonomous air quality sensors allow to achieve a denser spatial granularity and, hopefully, a better monitoring of air pollution. The main objectives of this project are to improve the modeling of air pollution dispersion; propose efficient models to optimize the deployment the sensors while considering the pollution dispersion and the impact of urban environment on communications; deploy a small-scale network for pollution monitoring as a proof of concept; compare the measured and estimated levels of exposure; study the spatial disparities in exposure between urban areas.
- **ARC6 “Robot fleet mobility under communication constraints” 10/2016-09/2019**  
Participants: 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 Veleval 10/2017-10/2019**  
Participants: Hervé Rivano  
This pluridisciplinary project is leaded by the LAET and gathers researchers from EVS, LIRIS, LLSETI and CITI. The goal is to study, understand and model the behavior of cyclists in an urban environment with a methodology combining quantitative measurements of mobility traces and image analysis with qualitative informations from reactivation interviews. In particular the input of Agora is to provide crowdsourcing tools for gathering mobility data that are optimized for the practice of urban cycling.

### 9.2. National Initiatives

#### 9.2.1. ANR

- **ANR ABCD 10/2013-04/2017.**  
Participants: Razvan Stanica  
The partners in the ANR ABCD project are: Orange Labs, Ucopia, Inria Agora, UPMC LIP6 PHARE, Telecom ParisTech. The objective of ABCD is to characterize large-scale user mobility and content consumption in urban areas via mobile data mining, so as to achieve efficient deployment and management of cloud resources via virtual machines. Our contribution in the project consists on the characterization of human mobility and service consumption at a city scale, and the design of appropriate resource allocation techniques at the cellular network level.
- **ANR IDEFIX 10/2013-04/2017.**  
Participants: Soukaina Cherkaoui, Hervé Rivano, Fabrice Valois  
The partners in the ANR IDEFIX project are: Orange Labs, Alcatel Lucent - Bell Labs, Telecom Paris Tech, Inria Agora, Socrate and Dyogene.

#### 9.2.2. DGA

- **DGA CLOTHO 10/2016-03/2018.**  
Participants: Junaid Khan, Romain Pujol, Razvan Stanica, Fabrice Valois  
The partners in the DGA CLOTHO project are Traqueur and Sigfox. The objective of the project is to reduce the energy consumption of the device tracking functionality, by taking profit of short-range communications between the tracked objects.

### 9.2.3. PIA

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

### 9.2.4. Pôle ResCom

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

### 9.2.5. EquipEx

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

### 9.2.6. Inria Project lab

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

## 9.3. International Initiatives

### 9.3.1. Inria International Partners

#### 9.3.1.1. Informal International Partners

- **University of Waterloo, ON, Canada.** Joint publications and visits to/from the group of Prof. Catherine Rosenberg.
- **CNR-IEIIT, Turin, Italy.** Joint publications and projects with Dr. Marco Fiore.
- **IMDEA Networks, Madrid, Spain.** Collaboration around the OpenVLC platform with the group of Dr. Domenico Giustiniano.

### 9.3.2. Participation in Other International Programs

#### 9.3.2.1. PHC Campus France

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

## **9.4. International Research Visitors**

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

- Abdelmalik Bachir, Professor, Biskra University, Algeria: invited professor at INSA Lyon (Spring semester, 2017).
- Ramona Marfievici, Senior Researcher, Cork University of Technology, Ireland: visiting professor (one week, November 2017).

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

#### ***9.4.2.1. Research Stays Abroad***

- Jad Oueis visited the group of Prof. Catherine Rosenberg, at University of Waterloo, ON, Canada (3 months, Sep-Dec 2017).
- Mihai Popescu visited the group of Prof. Gabriela Czibula, at University of Cluj-Napoca, Romania (3 periods of 1 month duration: April, July and November 2017).
- Razvan Stanica visited the group of Prof. Catherine Rosenberg, at University of Waterloo, ON, Canada (1 month, Sep-Oct 2017).

## COATI Project-Team

## 8. Partnerships and Cooperations

### 8.1. National Initiatives

#### 8.1.1. ANR

##### 8.1.1.1. ANR Blanc STINT, 2014-2017

**Participants:** Julien Bensmail, Jean-Claude Bermond, David Coudert, Frédéric Havet, Luc Hogue, William Lochet, Nicolas Nisse, Stéphane Pérennes, Michel Syska.

The STINT project (*Structures INTerdites*) is led by the MC2 group (LIP, ENS-Lyon) and involves the G-SCOP laboratory (Grenoble).

The aim of STINT was to answer the following fundamental question: *given a (possibly infinite) family  $\psi$  of graphs, what properties does a  $\psi$ -free graph have?* To this end, it has firstly establish bounds on some classical graph parameters (e.g., clique number, stability number, chromatic number) for  $\psi$ -free graphs. Then, it has design efficient algorithms to recognize  $\psi$ -free graphs and to determine or approximate some parameters for those graphs. These studies have result in the development of new proof techniques.

(<http://www.ens-lyon.fr/LIP/MC2/STINT/>)

##### 8.1.2. GDR Actions

##### 8.1.2.1. Action ResCom, ongoing (since 2006)

Réseaux de communications, working group of GDR RSD, CNRS.

(<http://rescom.asr.cnrs.fr/>)

##### 8.1.2.2. Action Graphes, ongoing (since 2006)

Action Graphes, working group of GDR IM, CNRS.

(<http://gtgraphes.labri.fr/>)

### 8.2. International Initiatives

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

##### 8.2.1.1. ALDYNET

Title: distributed ALgorithms for DYnamic NETworks

International Partner (Institution - Laboratory - Researcher):

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

Duration: 2013-2018

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

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

### 8.2.2. Inria International Partners

#### 8.2.2.1. 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;  
 RWTH Aachen Univ., Lehrstuhl II für Mathematik (Aachen, Germany), Prof. Arie M.C.A. Koster;  
 Concordia Univ. (Montréal, Québec, Canada), Prof. Brigitte Jaumard.

### 8.3. International Research Visitors

#### 8.3.1. Visits of International Scientists

Jørgen Bang-Jensen  
 University of Southern Denmark, Odense, Denmark. January 2017.

Ararat Harutyunyan  
 Université de Toulouse III, France. February 2017.

Takako Kodate  
 Tokyo Woman's Christian University, Japan. From March 2017 until April 2017.

Claudia Linhares-Sales  
 Universidade Federal do Ceará, Fortaleza, Brazil. January 2017.

Joseph Peters  
 School of computing Science, Simon Fraser University, BC Canada. Since October 2017.

Leonardo Sampaio Rocha  
 Universidade Estadual do Ceará, Fortaleza, Brazil. June 2017.

Ana Shirley Ferreira Da Silva  
 Universidade Federal do Ceará, Fortaleza, Brazil. January 2017.

Karol Suchan  
 Universidad Adolfo Ibáñez, Chile. From February 2017 until March 2017.

Laurent Viennot  
 Inria Paris (EP Gang), France. February 2017.

Min-Li (Joseph) Yu  
 Univ. of the Fraser valley, Abbotsford, (BC), Canada. From March 2017 until April 2017.

#### 8.3.2. Visits to International Teams

##### 8.3.2.1. Research Stays Abroad

Julien Bensmail  
 LaBRI, Université de Bordeaux, April 24-28 and October 9-13, 2017.

Christelle Caillouet  
 Reunion Island University, LIM Laboratory, October 20-November 19, 2017.

David Coudert  
 Gran Sasso Science Institute (GSSI), L'Aquila, Italy, April 19-21, 2017;  
 Concordia University, Montréal, Québec, Canada, July 1-14, 2017;

Univ. Adolfo Ibáñez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AIDyNet, November 17-December 2, 2017.

Guillaume Ducoffe

Faculty of Mathematics and Informatics, University of Bucharest, January 18-August 31, 2017.

Frédéric Giroire

Department of Computer Science and Software Engineering, Concordia University, Montréal, Canada, October 11-24, 2017.

Frédéric Havet

Laboratoire ICube, Université de Strasbourg, November 8-10, 2017;

LABRI, Bordeaux, November 14-17, 2017.

William Lochet

LABRI, Université de Bordeaux, October 8-13, 2017;

LIRMM, Université de Montpellier, June 13-15, 2017.

Nicolas Nisse

LIF, Aix-Marseille Université, July 9-13, 2017;

Univ. Adolfo Ibáñez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AIDyNet, November 17-December 2, 2017.

Fionn Mc Inerney

Université de Montréal, Montréal, Canada, July 3-August 4, 2017;

Univ. Adolfo Ibáñez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AIDyNet, November 17-December 2, 2017.

Bruce Reed

IMPA, Unité CNRS Mixte, Rio de Janeiro, Brazil, January 1-March 24, 2017;

School of Computer Science, McGill University, November 1-December 31, 2017.

Andrea Tomassilli

Concordia University, Montréal, Canada, October 1-December 28, 2017.



## DANTE Project-Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

#### 9.1.1. IXXI

##### 9.1.1.1. ISI Torino / Dante

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

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 IXXI PhD student, Jacobo Levy Abitbol, to work out a method for temporal network embedding. Our idea is to extend the node2vec representation of static networks for time-varying structures, by using a local random walk to explore the structural-temporal neighbourhood of a node. Based on such local information we can effectively propose an embedding, which captures the temporal and structural properties of nodes in a temporal network.

### 9.2. National Initiatives

#### 9.2.1. ANR

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

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

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

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

**Participants:** Paulo Gonçalves [correspondant], Éric Fleury, Thomas Begin, Sarra Ben Alaya.

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

##### 9.2.1.3. ANR INFRA DISCO (*DIstributed SDN COntrollers for rich and elastic network services*)

**Participants:** Thomas Begin [correspondant], Anthony Busson, Isabelle Guerin Lassous, Huu Nghi Nguyen.

The DANTE team will explore the way SDN (Software Designed Network) can change network monitoring, control, urbanisation and abstract description of network resources for the optimisation of services. More specifically, the team will address the issues regarding the positioning of SDN controllers within the network, and the implementation of an admission control that can manage IP traffic prioritisation.

#### 9.2.1.4. ANR REFLEXION (*RE*silient and *FLEX*ible Infrastructure for Open Networking)

**Participants:** Thomas Begin [correspondant], Anthony Busson, Isabelle Guerin Lassous, Zidong Su.

The DANTE team will work on the monitoring of NFV proposing passive and light-weight metrology tools. They will then investigate the modelling of low-level resources consumptions and finally propose methods to dynamically allocate these resources taking into account performance constraints.

#### 9.2.1.5. ANR CONTINT CODDDE

**Participants:** Éric Fleury [correspondant], Christophe Crespelle, Márton Karsai.

It is a collaborative project between the ComplexNetwork team at LIP6/UPMC; Linkfluence and Inria Dante. The CODDDE project aims at studying critical research issues in the field of real-world complex networks study:

- How do these networks evolve over time?
- How does information spread on these networks?
- How can we detect and predict anomalies in these networks?

In order to answer these questions, an essential feature of complex networks will be exploited: the existence of a community structure among nodes of these networks. Complex networks are indeed composed of densely connected groups of that are loosely connected between themselves.

The CODDDE project will therefore propose new community detection algorithms to reflect complex networks evolution, in particular with regards to diffusion phenomena and anomaly detection.

These algorithms and methodology will be applied and validated on a real-world online social network consisting of more than 10 000 blogs and French media collected since 2009 on a daily basis (the dataset comprises all published articles and the links between these articles).

#### 9.2.1.6. ANR SoSweet

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

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.

#### 9.2.1.7. ANR DylNet

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

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 an 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.

### 9.2.2. CNRS

#### 9.2.2.1. CNRS CO3I

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

The CO3i project (Cognition individuelle et connaissance collective) is funded by the Mission pour l'Interdisciplinarité du CNRS. CO3i is an interdisciplinary theoretical project that aims at reanalyse and better articulate two distinctions: collective vs. individual and social vs. cognitive. Generally, the study of cognition is associated to the individual, whereas the social phenomena are seen as collective. In fact, there is an individual social cognition and there is a collective social knowledge. We have organised three days of interdisciplinary workshop confronting the views of sociologists, cognitive scientists, network scientists, linguists, and philosophers of science. Nourished by projects using various methodologies (massive data, experimentation, observation, corpus), the reflection will be finalised towards the publication of an international book. See: <https://co3i.hypotheses.org/>

### 9.2.3. Inria

#### 9.2.3.1. Inria PRE LIAISON

**Participants:** Márton Karsai [correspondant], Éric Fleury.

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.

### 9.2.4. HCERES

#### 9.2.4.1. HCERES/Inria

**Participants:** Éric Fleury, Eric, Philippe 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 revitalised by the internet. This reality invite them to discuss with philosophers or with other SHS scientists who have the same intuition (eg: cartography, visualisation).

The project is hence to measure these new forms or inter-multi-disciplinarity. The main source will be the publications of all academics of French SHS laboratories, to find out who writes a paper with somebody of a different discipline and/or laboratories. All data are anonymized,

### 9.2.5. Inria

#### 9.2.5.1. IPL BetterNet

**Participant:** Eric, Philippe Guichard.

BETTERNET: An Observatory to Measure and Improve Internet Service Access from User Experience <sup>0</sup>. BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks with a particular focus on geography and cartography.

<sup>0</sup><https://www.inria.fr/en/research/research-teams/inria-project-labs>

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. EMBERS

Title: Enabling a Mobility Back-End as a Robust Service

Programm: H2020

Duration: December 2015 - November 2018

Coordinator: UPMC

Partners:

Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)

Technische Universitat Berlin (Germany)

Universite Pierre et Marie Curie - Paris 6 (France)

Ubiwhere Lda (Portugal)

Inria contact: Eric Fleury

EMBERS will bring to market a back-end for smart city mobility that is developed by a European small enterprise based upon its smart parking and smart traffic management products that two municipalities in Portugal currently deploy. The Mobility Back-end as a Service (MBaaS) replaces such all-in-one systems, in which a municipality purchases the full set of components from a single vendor. Instead, the city manager can purchase best-of-breed devices and apps developed by third parties, with the only constraint being that they interoperate with the back-end via a free, open, smart city mobility API. This domain-specific API lowers barriers to entry for app and device developers, making it easier for innovative SMEs to enter the market. Furthermore, the API is offered via a variety of generic interfaces, including oneM2M, ETSI M2M, OMA LWM2M, and FIWARE NGSI. EMBERS thus clears the way for developers and to municipalities that have adopted any one of these potential emerging machine-to-machine (M2M) communication standards. Beyond its primary goal of bringing the MBaaS to market, EMBERS will stimulate development of an entire ecosystem around the MBaaS smart city mobility API. Separating out the back-end from the other components will, however, require rigorous testing. EMBERS will experiment with the system on two testbeds that are part of the FIRE OneLab facility: the FUSECO Playground, for M2M communications, and FIT IoT-LAB, for wireless sensor devices. EMBERS will host a hackathon and an app challenge to bring in third party developers. The project will also include three demonstrators by third parties via an open call. These activities will contribute back to FIRE by demonstrating successful experimentation by SMEs developing close-to-market products. The project will also conduct real world pilots in two or more cities as a final step in bringing the MBaaS to market.

#### 9.3.1.2. ARMOUR

Title: Large-Scale Experiments of IoT Security & Trust (Project n°688237)

Programm: H2020

Duration: 2015 Dec to 2018

Coordinator: UPMC

Partners:

Synelixis Lyseis Pliroforikis Automatismou & Tilepikoinonion Monoprosopi EPE (Greece)

Smartesting Solutions & Services (France)

Unparallel Innovation, Lda (Portugal)

Easy Global Market (France)

ODIN Solutions (Spain)

Universite Pierre et Marie Curie - Paris 6 (France)

Inria contact: Eric Fleury

ARMOUR will provide duly tested, benchmarked and certified Security & Trust solutions for large-scale IoT using upgraded FIRE large-scale IoT/Cloud testbeds properly-equipped for Security & Trust experimentations. ARMOUR takes the top large-scale FIT IoT-LAB testbed à a FIRE OpenLAB / FIT IoT LAB facility à and enhances it as to enable experimentally-driven research on a key research dimension: large-scale IoT Security & Trust. Presently, no proper installations exist to experiment IoT Security & Trust on large-scale conditions; ARMOUR will develop and install such capability.

#### 9.3.1.3. CLARIN-PLUS

Title: European Research Infrastructure for Language Resources and Technology

Programm: H2020 and part of CLARIN ERIC

Duration: 28 months, from September 2015 to December 2017

Coordinator: Franciska de Jong, CLARIN ERIC

Partners:

CLARIN ERIC,

EKUT,

UCPH,

CUNI

Inria contact: Jean-Philippe Magué

CLARIN-PLUS is dedicated to enhancing CLARIN. Following the recommendations of the 2013 ESFRI Assessment Expert Group, CLARIN-PLUS proposes to accelerate the implementation and to strengthen and consolidate CLARIN in the following areas: 1. The central (technical) hub; 2. The central office; 3. Partnerships with other infrastructures; 4. Outreach; 5. Governance.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Declared Inria International Partners

Taiwan, ACADEMIA SINICA & IIIS. Signature of a MoU in the framework of IoT-LAB.

Algorithms research group of the University of Bergen, Norway. PICS project of CNRS on graph editing problems for analysis and modeling of complex networks.

University of Massachusetts, Amherst, USA.

#### 9.4.1.2. Informal International Partners

University of Namur: Department of Mathematics/Naxys (Belgium). Collaboration with Renaud Lambiotte on dynamical processes on dynamical networks and communities detections.

Aalto University: Department of Biomedical Engineering and Computational Science (Finland). Collaboration with Jari Saramaki on modeling temporal networks and community like modular structure

Central European University (Hungary). Collaboration with János Kertész on modeling complex contagion phenomena.

ISI Foundation (Italy). Collaboration with Laetitia Gauvin on multiplex networks and transportation systems

University of South California (USA). Collaboration with Antonio Ortega on Graph Signal Processing

University of Pennsylvania (USA). Collaboration with Alejandro Ribeiro on Graph Signal Processing

LNCC, Petropolis (Brazil). Collaboration with Arthur Ziviani on Temporal Graph modeling and algorithms.

College of Information and Computer Sciences at the University of Massachusetts Amherst.

University of California, Santa Cruz (USA). Collaboration with Alexandre Brandwajn on the solutions to multi-server queues.

#### 9.4.2. Participation in Other International Programs

STIC AMSUD MOTIf with Grand Data from Argentina and LNCC from Brazil. ,

The general goal of the MOTIf project is to understand, model, and predict individual behavior embedded in social and technological environments. We propose to work in two directions in order to tackle this challenge: (1) aim to understand spatiotemporal patterns of service usage of individuals to learn when, where, and what people are doing. (2) aim to understand the fine-grained sociodemographic structure of society and see how the demographic characteristics of individuals in a social network correlate with the dynamics of their egocentric and global network evolution.

##### 9.4.2.1. PHC Peridot

**Participants:** Mohammed Amer, Thomas Begin, Anthony Busson, Isabelle Guerin Lassous.

Framework for Control and Monitoring of Wireless Mesh Networks (WMN) using Software-Defined Networking (SDN). The main objective of this project is propose mechanisms and modifications in the SDN architecture, specifically in the OpenFlow, which allow SDN mechanisms to operate over WMN considering the dynamic network topology that WMN may experience and some other relevant characteristics. The project will involve devising mechanisms for controlling mesh switches through controllers in a wireless environment, which will require developing novel and WMN-specific rules, actions and commands. The project will involve proposing mechanism that consider dynamic environment of WMN along with providing redundancy in the network. Besides, there is a requirement to have an adaptive measurement API for WMN. This is the second objective of our research project. The proposed measurement API will enable the network operators to monitor network traffic over WMN which may be content-specific or host-specific. This is a joint project between DANTE and M. A. Jinnah University, Islamabad. It started in June 2015 and will end in June 2018.

### 9.5. International Research Visitors

- Maximiliano Bueno Lopez from NTNU visited the Dante team for one week. His visit was part of an ERCIM program on Empirical Mode Decomposition.
- Alexandre Brandwajn, Professor Emeritus, Computer Engineering from UCSC (University of California, Santa Cruz) visited the Dante team for two months during Spring 2017. His visit was funded by ENS Lyon and Milyon labex.
- Cristhian Iza Paredes from UPC (Polytechnic University of Catalonia) visited the Dante team for three months. His visit was part of a Fonds Recherche project of ENS Lyon.
- Isabel Martin Faus from UPC (Polytechnic University of Catalonia) visited the Dante team for one month. Her visit was part of a Fonds Recherche project of ENS Lyon.
- Mukhtiar Bano and Sherjeel Gilani visited the Dante team for two weeks. Their visit was part of a Peridot project (PHC with Pakistan).
- Amir Qayyum visited the Dante team for one week. His visit was part of a Peridot project (PHC with Pakistan).
- Amer Mouawad (University of Bergen) visited the Dante team for one week in November 2017. His visit was part of a PICS project of CNRS with the Algorithms group of the University of Bergen, Norway.

- G. Iniguez from Aalto University visited M. Karsai two times for one week. One of these visits was financed from the CODDDE project, while the other was financed by the Finnish partner.

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

#### *9.5.1.1. Internships*

- Giuseppe Torrisi from Sapienza University, Erasmus Learning Agreement Student Mobility for Traineeships

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

#### *9.5.2.1. Research Stays Abroad*

- Philippe Nain stayed at UMass from September 2016 to January 2017.

## DIANA Project-Team

# 8. Partnerships and Cooperations

## 8.1. Inria internal funding

**ADT ACQUA:** In the context of the Inria ADT call, we have a funding for a two year engineering position on the ACQUA project for the 2015-2017 period. Thierry Spetebroot is hired on this position. In 2017, this ADT got extended by six months beyond the two years period to therefore end on March 2018.

**IPL BetterNet:** The Diana team is part of the Inria Project Lab BetterNet (<http://project.inria.fr/betternet/>). Within this lab, Inria has funded two PhD students in 2017 co-supervised by Chadi Barakat from the Diana project-team. The first PhD student is Thibaut Ehlinger hosted within the Diana team and co-supervised by Vassilis Christophides from the MiMove team in Paris. The second PhD student is Imane Taibi hosted by the Dionysos team in Rennes and co-supervised by Gerardo Rubino and Yassine Hadjadj-Aoul. Both PhDs started on the 1st of November 2017.

## 8.2. Regional Initiatives

**ElectroSmart:** This project benefits from the following fundings:

- a three year engineering position from the UCN@Sophia Labex for the 2016-2018 period (Ravi Mondy is hired on this position)
- 30KEuros from academy 1 of UCAJedi
- a two years engineering position from an Inria ADT for 2017/2018 (Abdelhakim Akodadi)
- a one year business developer from Inria ATT for june 2017-june 2018(David Migliacci)
- a 3 years 2017/2020 Ph.D. thesis from academy 1 of UCAJedi (Yanis Boussad)

**D2D Indoor:** This project is joint with the NFCOM startup in Nice, specialized in the development of new services for mobile phones. The project aims at leveraging mobile to mobile communications for offloading the cellular infrastructure, and will target a solution based on algorithms previously developed in the Diana project-team (BitHoc and HBSD). The project got a funding for one year engineer from the Labex. A position is open.

## 8.3. National Initiatives

### 8.3.1. ANR

- **ANR FIT** (2011-2018): 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. See also <http://fit-equipex.fr/>.



- **ANR DISCO** (2014-2017): DISCO (DIstributed SDN COntrollers for rich and elastic network services) aims at exploring the way how Software Defined Networking changes network monitoring, control, urbanisation and abstract description of network resources for the optimisation of services. The project works throughout experimentations and application use cases on the next generation of Software-Defined Networking solutions for large and critical distributed systems. The project studied the distribution of the current SDN control plane and the optimization of network operations that the integrated system view of cloud computing-based architectures allows. See also <http://anr-disco.ens-lyon.fr/>.
- **ANR REFLEXION** (2015-2017): REFLEXION (REsilient and FLEXible Infrastructure for Open Networking) research project will study the robustness and scalability of the current SDN architectures and the flexibility leveraged by SDN for provisioning resources and virtualized network functions (VNF). The project will address four main scientific objectives: (1) Fault and disruption management for virtualized services, (2) Robust and scalable control plane for next generation SDN, (3) Dynamic performance management of low level resources in SDN/NFV environments and (4) Distribution and optimization of virtual network functions in SDN environments. Our contribution in this project was focused on fault and disruption management for virtualized services. See also <http://anr-reflexion.telecom-paristech.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 Not Involved in an Inria International Labs

#### 8.5.1.1. UHD-on-5G

Title: Ultra High Definition video streaming on future 5G networks

International Partner (Institution - Laboratory - Researcher):

National Institute of Information and Communications Technology (NICT) (Japan) ICN project-team - Hitoshi Asaeda

Start year: 2016

See also: <https://team.inria.fr/diana/uhd-on-5g/>

The aim of this collaboration is to design and develop efficient mechanisms for streaming UHD video on 5G networks and to evaluate them in a realistic and reproducible way by using novel experimental testbeds.

Our approach leverages and extends when necessary ICN and SDN technologies to allow very high quality video streaming at large scale. We also plan to use Virtual Network Functions (VNF) in order to place easily and dynamically different functions (e.g. transcoding, caching) at strategic locations within the network. Specifically, the placement of these functions will be decided by SDN controllers to optimize the quality of experience (QoE) of users. Moreover, we plan to integrate ICN functionalities (e.g., name-based forwarding and multipath transport using in-network caching) with SDN/NFV to provide better QoE and mobility services support to users than traditional IP architectures. Monitoring mechanisms such as the Contrace tool we developed in the SIMULBED associated team will be helpful to provide an accurate view of the network at the SDN controllers side. In addition, we will build a large-scale testbed to evaluate our solutions through reproducible experimentations based on two testbeds: the ICN wired CUTEi testbed developed by NICT and the wireless R2lab testbed developed by Inria.

## 8.6. International Research Visitors

### 8.6.1. Visits of International Scientists

Katia Obraczka is Professor of Computer Engineering and Graduate Director at Department of Computer Engineering, UC Santa Cruz where she leads the Internetworking Research Group (i-NRG). She has visited us for four weeks in July 2017. The Labex UCN@Sophia has supported two one-month visits at the DIANA project-team, in July 2017 and during summer 2018 to work in particular on the decentralization of the SDN control plane applied to Intelligent Transport Systems (ITS).

#### 8.6.1.1. Internships

Neha Agarwal

Date: from Apr 2017 until Sep 2017

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Arnaud Legout

Subject: Automated Tests for ElectroSmart in Android Studio

Yanis Boussad

Date: from Mar 2017 until Aug 2017

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Arnaud Legout

Subject: Exploration of Electromagnetic Fields Metrics

Pretesh Chauhan

Date: from May 2017 until Jul 2017

Institution: Third year intern, National Institute of Technology, Hamirpur, INDIA.

Supervisor: Arnaud Legout

Subject: User Exposure Profiles in ElectroSmart

Giuseppe Di Lena

Date: from Mar 2017 until Aug 2017

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Damien Saucez and Thierry Turlatti

Subject: Robust Virtualized services in OpenStack

David Migliacci

Date: from Jul 2017

Institution: Intern, Skema Business School

Supervisor: Arnaud Legout

Subject: Business Development for ElectroSmart

Yassir Mrabet

Date: from Mar 2017 until Aug 2017

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Walid Dabbous and Thierry Turlatti

Subject: Anechoic Chamber Characterization for Trustful Evaluation of Wireless Protocols.

Imane Taibi

Date: from Mar 2017 until Aug 2017

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Chadi Barakat

Subject: Experimenting and modeling Web Quality of Experience

#### 8.6.2. Visits to International Teams

Thierry Turlatti visited NICT in Tokyo Japan in the context of the UHD-on-5G associated team in December 2017.

## DIONYSOS Project-Team

## 9. Partnerships and Cooperations

### 9.1. National Initiatives

#### 9.1.1. ANR

- Sofiène Jelassi is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Yassine Hadjadj-Aoul is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Yann Busnel is a member of the three following projects: SocioPlug granted by the ANR (ANR-13-INFR-0003), INSHARE granted by the ANR (ANR-15-CE19-0024) and BigClin granted by the LabEx CominLabs (ANR-10-LABX-07-01).

#### 9.1.2. IPL (Inria Project Lab) BetterNet

Yassine Hadjadj-Aoul, Gerardo Rubino and Bruno Tuffin are members of the IPL (Inria Project Lab) BetterNet: An Observatory to Measure and Improve Internet Service Access from User Experience, 2016-2020.

BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Our observatory can be defined as a vantage point, where: 1) tools, models and algorithms/heuristics will be provided to collect data, 2) acquired data will be analyzed, and shared appropriately with scientists, stakeholders and civil society, and 3) new value-added services will be proposed to end-users.

### 9.2. European Initiatives

#### 9.2.1. Eurostars Camion Project

**Participants:** Yassine Hadjadj-Aoul

We were involved in a 30 months Eurostars European Project named Camion, which started on October 2014, aiming at offering cost-efficient, QoE-optimized content delivery, allowing for faster content access, as well as offline operation, while improving wireless network capacity and coverage. Camion is leaded by JCP-Connect, and the partners are a SME (FON) and our team. The project ended by June 2017.

#### 9.2.2. Collaborations in European Programs

##### 9.2.2.1. FINTEROP

Program: H2020-ICT-12-2015

Project acronym: F-Interop

Project title: FIRE+ online interoperability and performance test tools to support emerging technologies from research to standardization and market launch

Duration: November 2015 – October 2018

Coordinator: UPMC-LIP6

Other partners: 9 partners including (F. Sismondi and C. Viho (Dionysos); T. Watteyne (Eva))

Abstract: The goal of F-Interop is to extend FIRE+ with online interoperability and performance test tools supporting emerging IoT-related technologies from research to standardization and to market launch for the benefit of researchers, product development by SME, and standardization processes.

### 9.2.3. Collaborations with Major European Organizations

Partner 1: Sapienza University of Rome, Italy.

We work with Nicolás Rivetti and Leonardo Querzoni on the analysis of stream processing systems.

## 9.3. International Initiatives

### 9.3.1. Inria International Partners

#### 9.3.1.1. Informal International Partners

- We maintain a strong line of collaborations with the Technical University Federico Santa María (UTFSM), Valparaíso, Chile. Over the years, this has taken different forms (associated team Manap, Stic AmSud project “AMMA”, Stic AmSud project “DAT”). In 2017, we had a joint PhD work running (PhD of Nicolás Jara, to be defended at the beginning of next year), and a new joint PhD to be started in 2018 (PhD of Jonathan Olavarría). The first one is on optical network analysis and design, the second one on modeling evaluation techniques, with focus on Stochastic Activity Networks.
- We started a collaboration 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, PhD student, whose co-advisors are Prof. Mizraji and G. Rubino from Dionysos. Our contribution to this project is around the use of mathematical models, in particular around neural structures.

### 9.3.2. Participation in Other International Programs

#### 9.3.2.1. International Initiatives

##### SM-HCD-HDD

Title: Statistical methods for highly complex and/or high dimensional data

International Partner (Institution - Laboratory - Researcher):

Universidad de la Republica Uruguay (Uruguay), Faculty of Sciences; Resp.: Ricardo Fraiman, Department of Mathematics

CNRS (France); Resp.: Catherine Aaron

Universidad Nacional del Litoral (Argentina); Resp.: Liliana Forzani

Duration: 3 years

Start year: 2016

In this project we work on specific statistical tools, mainly concerning predicting the behavior of time series. Our goal is to improve our tools for Perceptual Quality evaluation.

#### 9.3.2.2. International Initiatives

##### MOCQUASIN

Title: Monte Carlo and Quasi- Monte Carlo for rare event simulation

International Partner (Institution - Laboratory - Researcher):

Université de Montréal (Canada) - DIRO - Pierre L'Ecuyer

Duration: 3 years

Start year: 2013

See also: [http://www.irisa.fr/dionysos/pages\\_perso/tuffin/MOCQUASIN/](http://www.irisa.fr/dionysos/pages_perso/tuffin/MOCQUASIN/)

The goal of this team is to compute integrals, sums or to solve equations or optimization problems by means of Monte Carlo methods, which are statistical tools used when the models have a high complexity (for instance a large dimension). They are unavoidable tools in areas such as finance, electronics, seismology, computer science, engineering, physics, transport, biology, social sciences... Nonetheless, they have the reputation of being slow, i.e. to require a large computational time to reach a given precision. The goal of the project is to work on acceleration techniques, meaning methods allowing to reach the targeted precision in a shorter computational time. A typical framework is that of rare event simulation for which getting even only one occurrence of the event of interest could require a very long time. In this case, there are two main acceleration techniques: importance sampling and splitting, on which we work.

## **9.4. International Research Visitors**

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

- Pierre L'Ecuyer holds an Inria International Chair, Nov. 2013- Oct. 2018.
- Marvin Nakayama (New Jersey Institute of Technology, NJ, USA) visited us 3 days in October to work on the estimation of quantiles in the case of rare events.
- Jonathan Olavarría, from UTFSM, Chile, from January to March (for two months), to work on stochastic models.
- Prof. Leslie Murray, from University of Rosario, Argentina (one month, February) to work on Monte Carlo techniques for rare event analysis.
- Jorge Graneri, from UDELAR, Uruguay (two months in the last quarter of the year, to work on biological applications).
- Prof. Claudio Risso, from UDELAR, Uruguay (two weeks in the last quarter of the year, to work on time series predictions).
- Prof. Gustavo Guerberooff, from UDELAR, Uruguay (two weeks in the last quarter of the year, to work on time series predictions).

## DYOGENE Project-Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

DYOGENE is associated to the Laboratory of Information, Networking and Communication Sciences (LINCS) <http://www.lincs.fr/> co-founded in 2010 by Inria, Institut Mines-Télécom and UPMC, with Bell Labs Nokia (formerly Alcatel-Lucent) and SystemX joining it as strategic partners in 2011 and 2014, respectively. The LINCS is dedicated to research and innovation in the domains of future information and communication networks, systems and services.

### 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 Pierre Calka [Université de Rouen], Viet Chi Tran [Université de Lille] 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 IM

Members of Dyogene participate in GdR-IM (Informatique-Mathématiques), <https://www.gdr-im.fr/>, working groups ALEA and SDA2 (Systèmes dynamiques, Automates et Algorithmique).

#### 9.2.3. 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>

#### 9.2.4. PGM0

Gaspard Monge Program for Optimization and Operations Research project Decentralized control for renewable integration in smart-grids (2015-17). PI: A. Busic.

#### 9.2.5. ANR MARMOTE

Markovian Modeling Tools and Environments - coordinator: Alain Jean-Marie (Inria Maestro); local coordinator (for partner Inria Paris-Rocquencourt): A. Bušić; Started: January 2013; Duration: 48 months; partners: Inria Paris-Rocquencourt (EPI DYOGENE), Inria Sophia Antipolis Méditerranée (EPI MAESTRO), Inria Grenoble Rhône-Alpes (EPI MESCAL), Université Versailles-St Quentin, Telecom SudParis, Université Paris-Est Creteil, Université Pierre et Marie Curie.

The aim of the project was to realize a modeling environment dedicated to Markov models. One part developed the Perfect Simulation techniques, which allow one to sample from the stationary distribution of the process. A second one developed parallelization techniques for Monte Carlo simulation. A third one developed numerical computation techniques for a wide class of Markov models. All these developments were integrated into a programming environment allowing the specification of models and their solution strategy. Several applications have been studied in various scientific disciplines: physics, biology, economics, network engineering.

The project terminated in October 2017.

### 9.2.6. 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. International Initiatives

### 9.3.1. PARIS

Title: Probabilistic Algorithms for Renewable Integration in Smart Grid

International Partner (Institution - Laboratory - Researcher):

University of Florida (United States) - Laboratory for Cognition & Control in Complex Systems - Sean Meyn.

Start year: 2015

See also: <http://www.di.ens.fr/~busic/PARIS/>

The importance of statistical modeling and probabilistic control techniques in the power systems area is now evident to practitioners in both the U.S. and Europe. Renewable generation has brought unforeseen volatility to the grid that require new techniques in distributed and probabilistic control. In a series of recent papers the two PIs have brought together their complementary skills in optimization, Markov modeling, simulation, and stochastic networks that may help to solve some pressing open problems in this area. This new research also opens many exciting new scientific questions.

### 9.3.2. Inria International Partners

#### 9.3.2.1. Informal International Partners

- O. Mirsadeghi [Sharif University, Tehran],
- V. Anantharam [UC Berkeley],
- D. Yogeshwaran [Indian Statistical Institute].

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

- Venkat Anantharam [UC Berkeley, from Jun 2017 until Jul 2017]
- Prabir Barooah [University of Florida, from May 2017 until Jun 2017]
- Milan Bradonjic [Nokia, until Jan 2017]



- Adithya Munegowda Devraj [University of Florida, from Aug 2017 until Sep 2017]
- Christian Hirsch [LMU Munich, Sep 2017]
- Yuting Ji [Stanford, Oct 2017]
- Marc Olivier Buob [Bell Labs (Alcatel)]
- Josu Doncel [University of the Basque Country, Jul 2017]
- Mir Omid Haji Mirsadeghi [Sharif University, Tehran]

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

##### *9.4.2.1. Research Stays Abroad*

- B. Blaszcyszyn, October 1st – December 15th, Specially Appointed Professor at The School of Computing, Tokyo Institute of Technology.

## EVA Project-Team

## 9. Partnerships and Cooperations

### 9.1. National Initiatives

- EVA has a collaboration with Vedecom. **Paul Muhlethaler** supervises Younes Bouchaala's PhD funded by Vedecom. This PhD aims at studying vehicle-to-vehicle communication to improve roads safety.
- EVA has an ongoing collaboration with SODEAL company, which exploits the Cap d'Agde marina, as part of the SmartMarina project.

### 9.2. European Initiatives

#### 9.2.1. FP7 & H2020 Projects

The H2020 following projects are ongoing:

- H2020 F-Interop, <http://f-interop.eu/>, Nov 2015 – Oct 2018.
- H2020 ARMOUR, <https://www.armour-project.eu/>, Feb 2016 – Jan 2018.

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

##### 9.2.2.1. Collaborations with Major European Organizations

Inria-EVA has collaboration in 2017 with ETSI (the European Telecommunications Standards Institute) to organize the F-Interop 6TiSCH Interop Event in July 2017 in Prague.

### 9.3. International Initiatives

#### 9.3.1. Inria International Labs

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

##### 9.3.2.1. 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 IEEE802.15.4e (2012) standard introduced the Time Synchronized Channel Hopping (TSCH) which can provide end-to-end reliability of 99.999 % and an energy autonomy of many years. This exceptional performance prompted the IETF to create the 6TiSCH working group to standardize the integration of TSCH networks in the Internet. While the first experimental data have highlighted the great robustness of these networks, there is no data of a real network, accessible in real time, on a large scale and over a long period. Such data is needed to better model network performance and produce better products and standards. Teams of Professors Glaser and Kerkez are successfully deploying such networks to study mountain hydrology, monitor water quality and manage rainwater in urban environments. A model is missing to assist in the deployment and operation of these networks, as well as to monitor an operational network.

### 9.3.2.2. DIVERSITY

- Title: Measuring and Exploiting Diversity in Low-Power Wireless Networks
- International Partner (Institution - Laboratory - Researcher):
  - University of Southern California (United States) - Autonomous Networks Research Group (ANRG) - Bhaskar Krishnamachari
- Start year: 2016
- The goal of the DIVERSITY associate team is to develop the networking technology for tomorrow's Smart Factory. The two teams comes with a perfectly complementary background on standardization and experimentation (Inria-EVA) and scheduling techniques (USC-ANRG). The key topic addressed by the joint team will be networking solutions for the Industrial Internet of Things (IIoT), with a particular focus on reliability and determinism.

### 9.3.3. Inria International Partners

#### 9.3.3.1. Declared Inria International Partners

Inria-EVA has a long-standing Memorandum of Understanding with the OpenMote company (<http://www.openmote.com/>), which runs until 2020. OpenMote emerged as a spin-off of the OpenWSN project, co-lead by **Thomas Watteyne** and Prof. Xavier Vilajosana, Professor at the Open University of Catalonia and Chief Technical Officer at OpenMote.

The collaboration has been ongoing since 2012 and at the time of writing has resulted in:

- Joint academic publications, including 7 journal articles, 1 letter, 1 book chapter, 5 conference papers, 2 tutorials and invited talks.
- Joint standardization activities, in particular in the IETF 6TiSCH working group, co-chaired by **Thomas Watteyne** and for which Prof. Xavier Vilajosana is a key contributor. This activity has resulted in the joint participation in 12 IETF face-to-face meetings, joint participation in over 100 audioconferences, co-authorship of 3 Internet-Drafts and joint organization of 2 interop events.
- Joint software development, as both institutions closely collaborate in the maintenance, development, promotion and research along the OpenWSN project, including the development of the protocol stack, the integration of novel hardware technologies, the support to the community and the participation in standardization activities and interoperability events.

This MOU is NOT a commitment of funds by any part.

#### 9.3.3.2. Informal International Partners

The Inria-EVA collaborates extensively with Prof. Pister's group at UC Berkeley on the OpenWSN and Smart Dust projects. This activity translated into several members of the Pister team visiting Inria-EVA and vice-versa in 2017.

### 9.3.4. Participation in Other International Programs

#### 9.3.4.1. International Initiatives

- **PEACH**
- Title: PrEcision Agriculture through Climate researchH
- International Partners (Institution - Laboratory - Researcher):
  - Universidad Diego Portales (Chile) - Diego Dujovne
  - Universidad Tecnológica de Mendoza (Argentina) - Gustavo Mercado
- Duration: 2016 - 2017

- In 2013, 85% of the peach production in the Mendoza region (Argentina) was lost because of frost. Because less fruit was produced in the region, 600.000 less work days were needed to process the harvest between November 2013 and March 2014, a reduction in work force of 10.600 people. Across the Mendoza region, frost has caused a loss of revenue of 950 million Argentine pesos - roughly 100 million USD - in the peach business alone. A frost event happens when the temperature is so low that the crops cannot recover their tissue or internal structure from the effects of water freezing inside or outside the plant. For the peach production, a critical period is when the trees are in bloom and fruit set (Aug./Sept. in Mendoza), during which the temperature needs to be kept above -3 C. Even a few hours below that temperature causes flowers to fall, preventing fruits to grow. Because of the huge economic impact, countermeasures exist and are used extensively. Today, virtually all industrial peach orchards are equipped with a small number of meteorological stations which monitor temperature and humidity. If the temperature drops dangerously low, the most effective countermeasures is to install a number of furnaces in the orchard (typically coal-fueled) and fly helicopters above the orchard to distribute the heat and avoid cold spots. This countermeasure is effective, but suffers from false negatives (the helicopters are called in, but there is no frost event) and false positives (the meteorological stations don't pick up a frost event happening in some part of the orchard). What is missing is a dense real-time monitoring solution deployed in the orchard, and feeding a frost prediction model. For this, having a couple of meteorological stations doesn't provide the measurement density needed. Frost events are micro-climatic: cold and hot air have a different density, wind blows irregularly between the trees, so different parts of an orchard are affected very differently by frost. What is needed are a large number of sensing points (humidity, temperature, wind speed), at different elevations, throughout the orchard. Low-power wireless mesh networking technology has evolved significantly over recent years. With this technology, a node is the size of a deck of cards, is self-contained and battery-operated. When switched on, nodes form a multi-hop low-power wireless network, automatically. Off-the-shelf commercial solutions are available today which offer >99.999% end-to-end data reliability and a decade of battery lifetime. Rather than being installed at a fixed location, these nodes can be hung directly in the trees. A network is deployed in an orchard in a matter of hours, and if needed, sensing points can be moved to improve the accuracy of the prediction model in minutes. And this solution is cheap, too: for the price one meteorological station, one can build 10 low-power wireless mesh sensing nodes. We use machine learning and pattern recognition to build an micro-climate predictive model by continuously analyzing the gathered sensor data in real time. This model generates early frost warnings. If successful, the solution can be extended to other crops, and other regions. The goal of this project is to dramatically increase the predictability of frost events in peach orchards by using dense monitoring using low-power wireless mesh networking technology. The project is designed to be completed in 24-month, and involves: (1) building a dense sensing solution based on off-the-shelf networking and sensing products, (2) developing accurate frost prediction models based on the sensing data gathered, (3) conducting real-world deployments on peach orchards in the Mendoza region. This project brings together world experts in agronomic and networking fields in a symbiotic manner. Perfectly in line with the philosophy of STIC-AmSud, the teams are already conducting cutting-edge research in their respective fields the funding we are applying for would enable the teams to collaborate together in a cross-disciplinary manner.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

1. *David Burnett (UC Berkeley)*, Micro-Motes, collaboration with **Thomas Watteyne**, 30 November 2017.
2. *Prof. Xavi Vilajosana (UOC/OpenMote)*, OpenMote B, 6TiSCH, collaboration with **Thomas Watteyne** and Tengfei Chang, 20 November – 19 December 2017.
3. *Pablo Modernell (UOC)*, F-Interop, collaboration with Remy Leone and **Thomas Watteyne**, 20–27 November 2017.

4. *Malisa Vucinic (U Montenegro)*, 6TiSCH Security, collaboration with **Thomas Watteyne**, 06-24 November 2017.
5. *Carlos Oroza (UC Berkeley)*, Machine-Learning Based Placement Strategy, collaboration with **Thomas Watteyne**, 18 October – 06 November 2017.
6. *Prof. Xavi Vilajosana (UOC/OpenMote)*, OpenMote B, the greatest thing since sliced bread, collaboration with **Thomas Watteyne** and Tengfei Chang, 19–20 September 2017.
7. *Felipe Lallane (Inria Chile)*, Exploiring collaboration opportunities with Inria-Chile around IoT, collaboration with **Thomas Watteyne**, 19–20 June 2017.
8. *Cristina Cano (UOC, Barcelona)*, Wireless Coexistence, collaboration with **Thomas Watteyne**, 16 May 2017.
9. *Ryan Grammenos (Univ. College London)*, Machine Learning for 6TiSCH networks, collaboration with Keoma Brun-Laguna and **Thomas Watteyne**, 15–19 May 2017.
10. *Craig Schindler (UC Berkeley)*, Industrial Process Control with 6TiSCH, collaboration with Tengfei Chang and **Thomas Watteyne**, 9–19 May 2017.
11. *Pedro Henrique Gomez (USC)*, Exploiting Diversity in 6TiSCH Networks, collaboration with Tengfei Chang and **Thomas Watteyne**, 5 June – 9 July 2017.
12. *Prof. Diego Dujovne (UDP, Chile)*, Advanced Scheduling in 6TiSCH networks, collaboration with **Thomas Watteyne**, 5–22 July 2017.
13. *Prof. Steven Glaser (UC Berkeley)*, Real-time real-world remote sensing, collaboration with Ziran Zhang, Keoma Brun-Laguna, **Thomas Watteyne**, 27 May – 3 June 2017.
14. *Prof. Xavi Vilajosana (UOC/OpenMote)*, OpenWSN core-team meet-up, collaboration with **Thomas Watteyne** and Tengfei Chang, 3–7 April 2017.

#### 9.4.2. Internships

1. **Felipe Moran Correa Meyer**, sub-100  $\mu$ s synchronization and sub-m RTLS with SmartMesh IP (ENSTA), September 2017 – August 2018.
2. **Fatima Adda**, simulation of active signaling in TDMA networks (Paris VI), March-August 2017.
3. **Nasr Khouaja Mohamed Hassine**, positioning with wireless networks (ENSTA), April-June 2017.

#### 9.4.3. Visits to International Teams

##### 9.4.3.1. Research Stays Abroad

- **Thomas Watteyne** spent the month of August 2017 at UC Berkeley, working with Prof. Glaser on the SnowHow project, and with Prof. Pister on Smart Dust and OpenWSN.
- Keoma Brun-Laguna spent summer 2017 with the Dust Networks product team at Analog Devices in Silicon Valley as part of an internship.

## FUN Project-Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

#### 9.1.1. StoreConnect

**Participants:** Nathalie Mitton [correspondant], Valeria Loscri, Antonio Costanzo, Abdoul Aziz Mbacke.

Title: StoreConnect

Type: FUI

Duration: September 2016 - October 2018

Coordinator: NEOSSENSYS

Others partners: Inria FUN, SPIRALS and STARS, TeVolys, Ubudu, Smile, STIME, Leroy Merlin

The aim of StoreConnect is to provide French large retailers with efficient and powerful tools in the in-store customer interaction. This project has yield to several publications in 2017: [50], [23], [24].

#### 9.1.2. PIPA

**Participants:** Nathalie Mitton [correspondant], Farouk Mezghani.

Title: Partager de l'Info Partout à bas coût

Type: Chercheur citoyen

Duration: Dec 2015 - Dec 2017

Coordinator: Inria FUN

Others partners: SpotTrotter

PIPA project aims to provide an innovative low cost solution to share information in places where communication infrastructure are lacking, insuffisant or not adapted, going beyond technical, economical or political limitations. This project has yield to several publications in 2017: [27], [28], [44].

### 9.2. National Initiatives

#### 9.2.1. Inria Project Lab

##### 9.2.1.1. CityLab@Inria

**Participants:** Valeria Loscri, Abdoul Aziz Mbacke, Nathalie Mitton [correspondant].

- Title: CityLab@Inria
- Type: IPL
- Duration: 2015 - 2019
- Coordinator: Valerie Issarny
- CityLab@Inria studies ICT solutions toward smart cities that promote both social and environmental sustainability. A strong emphasis of the Lab is on the undertaking of a multi-disciplinary research program through the integration of relevant scientific and technology studies, from sensing up to analytics and advanced applications, so as to actually enact the foreseen smart city Systems of Systems. Obviously, running urban-scale experiments is a central concern of the Lab, so that we are able to confront proposed approaches to actual settings. The Lab's research leverages relevant effort within Inria project-teams that is further revisited as well as integrated to meet the challenges of smart cities. Research themes span: energy-efficient wireless communication protocols, urban-scale social and physical sensing, privacy by design, cloud-based urban data management, data assimilation, visual analysis, and urban system software engineering. In addition, CityLab Inria research builds upon collaborative effort at the International level, and especially collaboration in the context of the Inria SiliconValley program. This project has yield to the set up of a full course on Smart Cities via a MOOC [51], [52], [53], [54] and a set of publications [23], [24], [32].

### 9.2.2. ADT

#### 9.2.2.1. RFunID

**Participants:** Ibrahim Amadou, Nathalie Mitton [correspondant], Julien Vandaele.

Duration: September 2015 - December 2017

Coordinator: Inria FUN

The purpose of this project is to deploy a large scale experimental RFID platform that enables remote programming of RFID scenario on heterogeneous devices.

#### 9.2.2.2. Catimex

**Participants:** Matthieu Berthome, Nathalie Mitton [correspondant], Julien Vandaele.

Duration: September 2017 - June 2019

Coordinator: Inria FUN

The purpose of this project is to foster research transfer in IoT from ADT members to their industrial partners by widening experimental features and PoC realization.

### 9.2.3. Equipements d'Excellence

#### 9.2.3.1. FIT

**Participants:** Nathalie Mitton [correspondant], Julien Vandaele, Matthieu Berthome.

Title: Future Internet of Things

Type: EquipEx

Duration: March 2010 - December 2019

Coordinator: UPMC

See also: <http://fit-equipex.fr/>

Abstract: FIT (Future Internet of Things) aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It will provide this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project will give French Internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the Future Internet. FIT is one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Equipements d'Excellence" (Equipex) research grant program. Coordinated by Professor Serge Fdida of UPMC Sorbonne Universités and running over a nine-year period, the project will benefit from a 5.8 million euro grant from the French government. This project has yield to [39].

## 9.3. European Initiatives

### 9.3.1. H2020 Projects

#### 9.3.1.1. VESSEDIA

**Participants:** Simon Duquennoy, Nathalie Mitton [correspondant], Allan Blanchard.

- Title: VERIFICATION ENGINEERING OF SAFETY AND SECURITY CRITICAL DYNAMIC INDUSTRIAL APPLICATIONS
- Program: H2020
- Duration: January 2017 - Dec. 202019
- TECHNIKON FORSCHUNGS UND PLANUNGSGESELLSCHAFT MBH (TEC)

The VESSEDIA project will bring safety and security to many new software applications and devices. In the fast evolving world we live in, the Internet has brought many benefits to individuals, organizations and industries. With the capabilities offered now (such as IPv6) to connect billions of devices and therefore humans together, the Internet brings new threats to the software developers and VESSEDIA will allow connected applications to be safe and secure. VESSEDIA proposes to enhance and scale up modern software analysis tools, namely the mostly open-source Frama-C Analysis platform, to allow developers to benefit rapidly from them when developing connected applications. At the forefront of connected applications is the IoT, whose growth is exponential and whose security risks are real (for instance in hacked smart phones). VESSEDIA will take this domain as a target for demonstrating the benefits of using our tools on connected applications. VESSEDIA will tackle this challenge by 1) developing a methodology that allows to adopt and use source code analysis tools efficiently and produce similar benefits than already achieved for highly-critical applications (i.e. an exhaustive analysis and extraction of faults), 2) enhancing the Frama-C toolbox to enable efficient and fast implementation, 3) demonstrating the new toolbox capabilities on typical IoT (Internet of Things) applications including an IoT Operating System (Contiki), 4) developing a standardization plan for generalizing the use of the toolbox, 5) contributing to the Common Criteria certification process, and 6) defining a label "Verified in Europe" for validating software products with European technologies such as Frama-C.

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

#### 9.4.1.1. Agrinet

**Participants:** Abdoul Aziz Mbacke, Nathalie Mitton [correspondant].

##### **Agrinet**

Title: Agrinet

International Partner (Institution - Laboratory - Researcher):

Type: LIRIMA Associate team

Duration: 2017-2020

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

The current drought and limited water resources in many parts of Southern Africa and beyond, already have a significant impact on agriculture and hence, food production. Sustainable food security depends upon proper plant and crop management respectful of soils and natural resources, such as water. This includes very important South African farming areas, such as the Western Cape and Northern Cape. In France, agriculture is also hugely important. Not just nationally, but also in Europe. The system proposed can be applied to a variety of crops. The economic- and social consequences are profound and any contribution towards more efficient farming within increasingly onerous natural constraints, should be a priority. To address these constraints, we propose to develop a flexible, rapidly deployable, biological/agricultural data acquisition platform and associated machine learning algorithms to create advanced agricultural monitoring and management techniques, to improve crop management and use of natural resources. The project also addresses an industry with very high socioeconomic impact.

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

#### 9.4.2.1. DepIoT

**Participants:** Simon Duquennoy [correspondant], Nathalie Mitton.

Title: DepIoT: Coexistence and Security for Dependable Internet of Things

Type: North-European Inria Associate Team with SICS, Sweden

Duration: Sept 2016 - August 2018

Abstract: In order to foster the adoption of IoT technologies, dependability must be guaranteed. We will tackle this challenge by ensuring operation even in the presence of other networks sharing the same frequency band (coexistence) and by enabling a secure communication.



### 9.4.3. Inria International Partners

#### 9.4.3.1. Declared Inria International Partners

Università Mediterranea di Reggio Calabria (UNIC) (Italy) Objective of this collaboration is the design of an innovative architecture that enables autonomic and decentralized fruition of the services offered by the network of smart objects in many heterogeneous and dynamic environments, in a way that is independent of the network topology, reliable and flexible. The result is an 'ecosystem' of objects, self-organized and self-sustained, capable of making data and services available to the users wherever and whenever required, thus supporting the fruition of an 'augmented' reality thanks to a new environmental and social awareness. This collaboration has allowed students and researchers exchanges and joint publications, among them for 2017: [30].

#### 9.4.3.2. Informal International Partners

##### **Southern University, China**

The purpose of this collaboration is to study the green (or energy-efficient) communication problem in vehicular ad hoc networks (VANETs) and the application of vehicular network communication in green transportation. In this framework, Nathalie Mitton visited the Nanjing University. It gave birth to joint project submission, joint conference organization (WCSP 2017) and joint publications, among them, in 2017 [40].

##### **Arun Sen from Arizona State University, USA**

The purpose of this collaboration is to study the joint scheduling and trajectory of RFID readers in a mobile environment. In this framework, Arun Sen visited the FUN team for 6 months in 2015 and in July 2016. It gave birth to joint project submission, joint conference submission and joint publications, among them in 2017 [12].

##### **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 2017 [14], [15], [20], [35], [47], [48].

### 9.4.4. Participation in Other International Programs

#### 9.4.4.1. CROMO

**Participants:** Valeria Loscri, Nathalie Mitton [correspondant].

**Title:** Crowd Data In the mobile cloud

**Duration:** January 2015 - December 2019

CroMo (Crowd Data In the mobile cloud) is a submission to the CAPES-COFECUB project call lead by Inria from the French side and University of Rio de Janeiro from Brazilian Side. Other partner institutions are Université Pierre et Marie Curie and Université de la Rochelle.

Mobile cloud computing is an emerging paradigm to improve the quality of mobile applications by transferring part of the computational tasks to the resource-rich cloud. The multitude data sources combined with the known difficulties of wireless communications represent an important issue for mobile cloud computing. Therefore, the additional computational power added by the cloud has to deal with the constraints of the wireless medium. One could imagine a situation where different sensors collect data and require intensive computation. This data must be transmitted at high rates before becoming stale. In this case, the network becomes the main bottleneck, not the processing power or storage size. To circumvent this issue, different strategies can be envisioned. As usual alternatives, wireless data rates must be increased or the amount of data sent to the cloud must be reduced. CROMO tackles challenges from all these three components of the mobile clouds (data generation, collect and processing) to then integrate them as a whole enhanced mobile cloud with improved network performances in terms of delay, energy consumption, availability, and reliability. In this context, joint exchanges and crossed visits have been done (Aziz went to Rio, Dianne went to Lille). The project yield to several publications such as [16], [41].

## **9.5. International Research Visitors**

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

Several researchers have visited our group in 2017, mainly from our partner universities but not only:

- Luis Henrique Costa, Brazil, December 2017
- Milan Erdej, UTC, France, December 2017
- Pedro Braconnot Velloso, UFRJ, Brasil, July 2017
- Essia Hamouda, Riverside University, USA, May 2017
- Felipe Lalanne, Inria Chile, June 2017
- Nicola Accettura, CNRS, March 2017
- Jacques Tiberghien, ULB, Brussels, May 2017
- Jens Gerlach, Fraunhofer FOKUS, March 2017
- Virgile Prevosto, CEA, March 2017

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

#### *9.5.2.1. Research Stays Abroad*

- Abdoul Aziz Mbacke visited Stellenbosch university from October to December 2017
- Jad Nassar visited Metropolitan Autonomous University Cuajimalpa Campus, Mexico in September 2017

## GANG Project-Team

## 8. Partnerships and Cooperations

### 8.1. Regional Initiatives

#### 8.1.1. *Laboratory of Information, Networking and Communication Sciences (LINCS)*

Gang is participating to the LINCS, a research centre co-founded by Inria, Institut Mines-Télécom, UPMC and Alcatel-Lucent Bell Labs, dedicated to research and innovation in the domains of future information and communication networks, systems and services. Gang contributes to work on online social networks, content centric networking and forwarding information verification.

### 8.2. National Initiatives

#### 8.2.1. *ANR DESCARTES*

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

Cyril Gavoille (U. Bordeaux) leads this project that grants 1 Post-Doc. H. Fauconnier is the local coordinator (This project began in October 2016).

Despite the practical interests of reusable frameworks for implementing specific distributed services, many of these frameworks still lack solid theoretical bases, and only provide partial solutions for a narrow range of services. We argue that this is mainly due to the lack of a generic framework that is able to unify the large body of fundamental knowledge on distributed computation that has been acquired over the last 40 years. The DESCARTES project aims at bridging this gap, by developing a systematic model of distributed computation that organizes the functionalities of a distributed computing system into reusable modular constructs assembled via well-defined mechanisms that maintain sound theoretical guarantees on the resulting system. DESCARTES arises from the strong belief that distributed computing is now mature enough to resolve the tension between the social needs for distributed computing systems, and the lack of a fundamentally sound and systematic way to realize these systems.

#### 8.2.2. *ANR MultiMod*

**Participants:** Adrian Kosowski, Laurent Viennot.

David Coudert (Sophia Antipolis) leads this project. L. Viennot coordinates locally. The project begins 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.

### 8.2.3. ANR FREDDA

**Participants:** Carole Delporte-Gallet, Hugues Fauconnier, Pierre Fraigniaud.

Arnaud Sangnier (IRIF, Univ Paris Diderot) leads this project that grants 1 PhD. (This project began in October 2017).

Distributed algorithms are nowadays omnipresent in most systems and applications. It is of utmost importance to develop algorithmic solutions that are both robust and flexible, to be used in large scale applications. Currently, distributed algorithms are developed under precise assumptions on their execution context: synchronicity, bounds on the number of failures, etc. The robustness of distributed algorithms is a challenging problem that has not been much considered until now, and there is no systematic way to guarantee or verify the behavior of an algorithm beyond the context for which it has been designed. We propose to develop automated formal method techniques to verify the robustness of distributed algorithms and to support the development of robust applications. Our methods are of two kinds: statically through classical verification, and dynamically, by synthesizing distributed monitors, that check either correctness or the validity of the context hypotheses at runtime.

### 8.2.4. ANR Distancia

**Participants:** Pierre Charbit, Michel Habib, Laurent Viennot.

Victor Chepoi (Univ. Marseille) leads this project. P. Charbit coordinates locally. The project begins 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  $\ell_1$ -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.

### 8.2.5. ANR HOSIGRA

**Participants:** Pierre Charbit, Michel Habib.

This project starting in early-2018, led by Reza Naserasr, explores the connection between minors and colorings, exploiting the notion of signed graphs. With the four colour theorem playing a central role in development of Graph Theory, the notions of minor and coloring have been branded as two of the most distinguished concepts in this field. The geometric notion of planarity has given birth to the theory of minors among others, and coloring have proven to have an algebraic nature through its extension to the theory of graph homomorphisms. Great many projects have been completed on both subjects, but what remains mostly a mystery is the correlation of the two subjects. The four color theorem itself, in slightly stronger form, claims that if a complete graph on five vertices cannot be formed by minor operation from a given graph, then the graph can be homomorphically mapped into the complete graph on four vertices (thus a 4-coloring). Commonly regarded as the most challenging conjecture on graph theory, the Hadwiger conjecture claims that

five and four in this theorem can be replaced with  $n$  and  $n - 1$  respectively for any value of  $n$ . The correlation of these two concepts has been difficult to study, mainly for the following reason: While the coloring or homomorphism problems roots back into intersections of odd-cycles, the minor operation is irrelevant of the parity of cycles. To overcome this barrier, the notion of signed graphs has been used implicitly since 1970s when coloring results on graphs with no odd- $K_4$  is proved, following which a stronger form of the Hadwiger conjecture, known as Odd Hadwiger conjecture, was proposed by P. Seymour and B. Gerards, independently. Being a natural subclass of Matroids and a superclass of graphs, the notion of minor of signed graphs is well studied and many results from graph minor are either already extended to signed graphs or it is considered by experts of the subject. Observing the importance, and guided by some earlier works, in particular that of B. Guenin, we then started the study of algebraic concepts (coloring and homomorphisms) for signed graphs. Several results have been obtained in the past decade, and this project aims at exploring more of this topic.

### 8.3. European Initiatives

#### 8.3.1. FP7 & H2020 Projects

Amos Korman has an ERC Consolidator Grant entitled “Distributed Biological Algorithms (DBA)”, started in May 2015. This project proposes a new application for computational reasoning. More specifically, the purpose of this interdisciplinary project is to demonstrate the usefulness of an algorithmic perspective in studies of complex biological systems. We focus on the domain of collective behavior, and demonstrate the benefits of using techniques from the field of theoretical distributed computing in order to establish algorithmic insights regarding the behavior of biological ensembles. The project includes three related tasks, for which we have already obtained promising preliminary results. Each task contains a purely theoretical algorithmic component as well as one which integrates theoretical algorithmic studies with experiments. Most experiments are strategically designed by the PI based on computational insights, and are physically conducted by experimental biologists that have been carefully chosen by the PI. In turn, experimental outcomes will be theoretically analyzed via an algorithmic perspective. By this integration, we aim at deciphering how a biological individual (such as an ant) “thinks”, without having direct access to the neurological process within its brain, and how such limited individuals assemble into ensembles that appear to be far greater than the sum of their parts. The ultimate vision behind this project is to enable the formation of a new scientific field, called algorithmic biology, that bases biological studies on theoretical algorithmic insights.

#### 8.3.2. LIA Struco

Pierre Charbit is director of the LIA STRUCO, which is an Associated International Laboratory of CNRS between IÚUK, Prague, and IRIF, Paris. The director on the Czech side is Pr. Jaroslav Nešetřil. The primary theme of the laboratory is graph theory, more specifically: sparsity of graphs (nowhere dense classes of graphs, bounded expansion classes of graphs), extremal graph theory, graph coloring, Ramsey theory, universality and morphism duality, graph and matroid algorithms and model checking.

STRUCO focuses on high-level study of fundamental combinatorial objects, with a particular emphasis on comprehending and disseminating the state-of-the-art theories and techniques developed. The obtained insights shall be applied to obtain new results on existing problems as well as to identify directions and questions for future work.

One of the main goals of STRUCO is to provide a sustainable and reliable structure to help Czech and French researchers cooperate on long-term projects, disseminate the results to students of both countries and create links between these students more systematically. The chosen themes of the project indeed cover timely and difficult questions, for which a stable and significant cooperation structure is needed. By gathering an important number of excellent researchers and students, the LEA will create the required environment for making advances, which shall be achieved not only by short-term exchanges of researchers, but also by a strong involvement of Ph. D students in the learning of state-of-the-art techniques and in the international collaborations.

STRUOCO 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.

## 8.4. International Initiatives

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

Carole Delporte-Gallet and Hugues Fauconnier are members of the Inria-MEXICO Equipe Associée LiDiCo (At the Limits of Distributed Computability, <https://sites.google.com/site/lidicoequipeassociee/>).

### 8.4.2. Inria International Partners

#### 8.4.2.1. Informal International Partners

Ofer Feinerman (Physics department of complex systems, Weizmann Institute of Science, Rehovot, Israel), is a team member in Amos Korman's ERC project DBA. This collaboration has been formally established by signing a contract between the CNRS and the Weizmann Institute of Science, as part of the ERC project.

Rachid Guerraoui (School of Computer and Communication Sciences, EPFL, Switzerland) maintains an active research collaboration with Gang team members (Carole Delporte, Hugues Fauconnier).

Pierluigi Crescenzi (University of Florence, Italy) is a frequent visitor to the team and maintains an active research collaboration with Gang team members (Pierre Fraigniaud).

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).

## 8.5. International Research Visitors

### 8.5.1. Visits of International Scientists

[chercheurs invités, profs invités (via université), Les internships sont à mettre dans la subsection suivante.]

Sergio Rajsbaum (UNAM-Mexico) was invited for two months (May-June).

Eli Gafni visited the team for one month (mid-June to mid-July).

Lalla Mouatadid visited the group for 2 weeks in 2017. She is finishing her PhD in computer. Science at University of Toronto, under the supervision of prof. Derek Corneil and Alan Borodin.

### 8.5.2. Visits to International Teams

Carole Delporte-Gallet and Hugues Fauconnier have visited 2x10 days Sergio Rajsbaum at UNAM (Mexico) in September and November 2017.

## INFINE Project-Team

# 8. Partnerships and Cooperations

## 8.1. National Initiatives

### 8.1.1. Equipex FIT

**Participants:** Cedric Adjih, Emmanuel Baccelli, Alexandre Abadie, Philippe Lubrano, Ichrak Amdouni, Alaeddine Weslati, Vincent Ladeveze.

**Partners:** Inria (Lille, Sophia-Antipolis, Grenoble), INSA, UPMC, Institut Telecom Paris, Institut Télécom Evry, LSIT Strasbourg.



*Figure 3. FIT IoT-LAB site in Saclay*

FIT (Future Internet of Things) aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It provides this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project gives french internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the future internet. FIT was one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Équipements d'Excellence" (Equipex) research grant program, in 2011.

One component of the FIT platform is the sets of IoT-LAB testbeds (see [the IoT-LAB web site](#)). These were motivated by the observation that the world is moving towards an "Internet of Things", in which most communication over networks will be between objects rather than people.

The Infine team is more specifically managing the FIT IoT-LAB site formerly at Rocquencourt, which recently moved to Saclay (on-going re-deployment), and is participating in the deployment of an additional IoT-lab testbed in Berlin (at Freie Universitaet Berlin).



## 8.2. European Initiatives

### 8.2.1. FP7 & H2020 Projects

#### 8.2.1.1. AGILE (H2020 project)

**Participants:** Emmanuel Baccelli, Cedric Adjih.

Program: H2020 ICT-30-2015 Topic: Internet of Things and Platforms for Connected Smart Objects

Project acronym: AGILE

Project title: Adoptive Gateways for dIverse muLtipLe Environments

Duration: 2015-2017

Coordinator: Emmanuel Baccelli

Other partners: Canonical (UK), Eclipse IoT Foundation (IE), Mobistar (BE), Libelium (ES), Startupbootcamp IoT (SP), CREATE-NET (IT), iMinds (BE), Atos (SP), Rulemotion (UK), Jolocom (DE), Passau University (DE), Sky-Watch (DN), BioAssist (GR), Graz Technical University (AT), Eurotech (IT), IoTango (US).

Abstract:

The AGILE project is a 3-year H2020 project started in January 2016, which will deliver an integrated framework of open source tools and platforms that interoperate for enabling the delivery of adaptive, self-configurable and secure IoT elements (both software and hardware) that can be utilized in a variety of scenarios. Such tools target actors with heterogeneous skills, including entrepreneurs, researchers, and individuals, aiming to enable the realization of IoT applications respecting user privacy and data ownership.

#### 8.2.1.2. ARMOUR (H2020 project)

**Participants:** Emmanuel Baccelli, Cedric Adjih.

Program: H2020 ICT-12-2015 Topic: Integrating experiments and facilities in FIRE+

Project acronym: ARMOUR

Project title: Large-Scale Experiments of IoT Security Trust

Duration: 2016-2018

Coordinator: Serge Fdida (UPMC)

Other partners: UPMC (France), Synelixis (Greece), SMA (France), UI (Portugal), JRC (Belgium), EGM (France), OdinS (Spain).

Abstract: The ARMOUR project is a 2-year H2020 project started in February 2016. The ARMOUR project is aimed at providing duly tested, benchmarked and certified Security & Trust technological solutions for large-scale IoT using upgraded FIRE large scale IoT/Cloud testbeds properly-equipped for Security & Trust experimentations. To this, ARMOUR will: (1) Enhance two outstanding FIRE testbeds (> 2700 nodes; 500 users) with the ARMOUR experimentation toolbox for enabling large-scale IoT Security & Trust experiments; (2) Deliver six properly experimented, suitably validated and duly benchmarked methods and technologies for enabling Security & Trust in the large-scale IoT; and (3) Define a framework to support the design of Secure & Trusted IoT applications as well as establishing a certification scheme for setting confidence on Security & Trust IoT solutions.

### 8.2.2. Collaborations with Major European Organizations

#### 8.2.2.1. EU CHIST-ERA MACACO

**Participants:** Aline Carneiro Viana, Emmanuel Baccelli, Eduardo Mucelli.

Program: EU CHIST-ERA, topic Context- and Content-Adaptive Communication Networks

Project acronym: MACACO

Project title: Mobile context-Adaptive CAching for COntent-centric networking

Duration: 2013-2017 (extended until December 2017)

Coordinator: Aline Carneiro Viana

Other partners: INPT-ENSEEIH at University of Toulouse, University of Birmingham (UK), SUPSI (Switzerland), CNR (Italy) and Federal University of Minas Gerais (Brazil)

Abstract:

MACACO (Mobile context-Adaptive CACHing for Content-centric networking ) is a 3-year CHIST-ERA European Project addressing the topic Context- and Content-Adaptive Communication Networks. Due to delay in funding access and data collection campaign we got an extension until December 2017. It is funded by ANR in France, SNSF in Switzerland, and ESRC in UK. It focus on data offloading mechanisms that take advantage of context and content information. Our intuition is that if it is possible to extract and forecast the behaviour of mobile network users in the three dimensional space of time, location and interest (i.e. what, when and where users are pulling data from the network), it is possible to derive efficient data offloading protocols. Such protocols would pre-fetch the identified data and cache it at the network edge at an earlier time, preferably when the mobile network is less charged, or offers better quality of service. This project has officially started in November 2013.

## 8.3. International Initiatives

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

#### 8.3.1.1. EMBRACE

Title: Leveraging Human Behavior and Uncertainty in 5G Networks to Build Robust Resource Allocation and Services Orchestration Models

International Partners (Institution - Laboratory - Researcher):

UTFPR (Brazil) - Departamento Academico de Informatica (DAINF) Curso de Pos-Graduacao em Engenharia Eletrica e Informatica Industrial (CPGEI) - Anelise Munaretto

UFG (Brazil) - Institute of Computational Mathematics and Scientific / Engineering Computing - Kleber Vieira Cardoso

UFMG (Brazil) - Dpt of Statistics - Antonio A. F. Loureiro

Start year: 2017

See also: <https://team.inria.fr/infine/embrace/>

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.

### 8.3.2. Inria International Partners

#### 8.3.2.1. Declared Inria International Partners

1. Renewed IOTPUSH collaboration with Freie Universitaet Berlin around the long-term stay of Emmanuel Baccelli in Berlin, on research topics about the Internet of Things, RIOT and Information-Centric Networking.

#### 8.3.2.2. Informal International Partners

1. On-going collaboration with Freie Universitaet Berlin and Hamburg University of Applied Science around RIOT.
2. Informal collaborations with UIUC and UMass.

3. Informal collaborations with ENSI Tunis and Sesame Tunis.
4. On-going strong collaboration with Sapienza University of Rome, Italy.
5. On-going strong collaboration with CNR Torino, Italy.
6. On-going collaboration with University of Porto, Portugal.
7. On-going collaboration with ENSAE/CNRS, France.
8. On-going collaboration with University of Edinburgh, UK.

### 8.3.3. Participation in Other International Programs

#### 8.3.3.1. Indo-French project

The Inria teams Infine and Eva are part of the "D2D Communication for LTE Advanced Cellular Network", a project funded by the Indo-French Centre for the Promotion of Advanced Research (CEFIPRA). With industrial partners, and also with Indian partners, this project is focusing on the evolution of cellular networks towards 5G: this includes exploration of device-to-device (D2D) communication, and more generally IoT communication in a cellular context. Research directions include efficient access for IoT devices (massive numbers of devices with low volume communication); combination of random access protocols/error coding/physical layer ; efficient neighbor discovery, ....

#### 8.3.3.2. STIC AmSud MOTIf 2017

**Participant:** Aline Carneiro Viana.

Program: STIC AmSud

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

Duration: 2017-2019

Coordinators: Marton Karsai (ENS/Inria) and Jussara M. Almeida (UFMG) and Alejo Salles (Univ. of Buenos Aires)

**Abstract:** Information and Communication Technology (ICT) is becoming increasingly social, as demonstrated by the multitude of emerging technologies and technology platforms that facilitate social interactions, taking place as communication via telephone, text message, email, online social networks etc. At the same time, our social activities are increasingly embedded in the ICT environments that enable and enhance our ability to transact, share experiences, and maintain social relationships. One of the best ways to explore these developments is through the mining and analysis of data, which are collected through mobile phones and allow us to investigate how individuals act when embedded in a technology-enabled environment. The MOTIf project builds on the analysis and modeling of geo-localized temporally detailed but fully anonymised mobile phone call networks. These datasets allow us to address the two scientific objectives about spatiotemporal patterns of service usage of anonymised individuals to learn when, where, and what people are doing; and about the fine-grained sociodemographic structure of society and its effect on the individual social behaviour. In other words our goal in general is to understand how individuals behave in a dynamic techno-social environment.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

**Rik Sarkar** was Visiting Researcher at Infine for 3 days. He worked with Aline C. Viana and the internship Maria Astefanoaei on predicting new places to visit in human mobility decision.

**Julinda Stefa** was Visiting Researcher at Infine for 3 months. She worked with Aline C. Viana and the internship Adriano Di Luzio on the inference of human personality from mobile phones datasets.

**Ana Aguiar** was Visiting Researcher at Infine for 3 days. She worked with Aline C. Viana and the internship Emanuel Lima on data offloading decision via mobile crowdsensing.

#### 8.4.1.1. Internships

**Panagiota Katsikouli** did an internship of 5 months at Infine working with Aline C. Viana and Marco Fiore on sampling frequency of human mobility.

**Maria Astefanoaei** did an internship of 5 months at Infine working with Aline C. Viana and Rik Sarkar on predicting new places to visit in human mobility decision.

**Adriano Di Luzio** did an internship of 4 months at Infine working with Aline C. Viana and Julinda Stefa on the inference of human personality from mobile phones datasets.

**Emanuel Lima** did an internship of 3 months at Infine working with Aline C. Viana and Ana Aguiar on data offloading decision via mobile crowdsensing.

**Ayat Zaki Hindi** did an internship of 6 months at Infine working with Cedric Adjih, Michel Kieffer and C. Weidmann on synchronization strategy in Information-Centric Networks.

#### 8.4.2. Visits to International Teams

##### 8.4.2.1. Research Stays Abroad

**Emmanuel Baccelli** is Visiting Professor at Freie Universitaet (FU) Berlin, within the context of the formal collaboration IOTPUSH with this university on research topics about the Internet of Things, RIOT and Information-Centric Networking.

## MADYNES Team

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

#### 9.1.1. 6PO Research Region Lorraine and UL project

**Participants:** Emmanuel Nataf, Ye-Qiong Song, Laurent Ciarletta [contact].

*Funded by Region Lorraine and Université de Lorraine since 2013. Adel Belkadi (CRAN & LORIA) is co-directed by L. Ciarletta and Didier Theilliol (CRAN correspondant).*

6PO (“Systèmes Cyber-Physiques et Commande Coopérative Sûre de Fonctionnement pour une Flotte de Véhicules sans Pilote”) is a joint research project between the Loria and CRAN laboratories. As a part of the Aetournos ecosystem, it also aims at researching solutions for safe formation flying of collaborative UAVs seen as part of a collection of Cyber Physical Systems mixing computer science and automation solutions.

It is reinforced by a PhD grant from this federation that started in october 2014 (*Conception de méthodes de diagnostic et de tolérance aux fautes des systèmes multi-agents: Application à une flotte de véhicules autonomes*, Adel Belkadi) and has been successfully defended in october 2017.

This led to common publications, notably on the subjects of the robust control of a fleet or flock of UAVs (with or without leader, using agents paradigms and particle swarm optimisation [10] and [31]).

The project provides common use cases and scientific challenges that serve as catalysts for collaboration between teams from different research topics :

- Cyber Physical Systems, Real Time, Quality of service, Performance and Energy in Wireless Sensors and Activator Networks
- Collaborative, communicating autonomous systems and Unmanned Vehicles
- Safety, Dependability, Reliability, Diagnosis, Fault-Tolerance

#### 9.1.2. Hydradrone FEDER Région Lorraine project

**Participants:** Zhixiang Liu, Laurent Ciarletta [contact].

*Feder funding*

The Madynes team has been working on the Hydradrone project since July 2014. It started as a collaborative R&D initiative funded by *Région Lorraine* and is now FEDER funded. This project started as a joint work between Madynes and PEMA (*Pedon Environnement et Milieux Aquatiques*), an SME/VSE (small and medium size Entreprise, PME/TPE). The consortium now includes Alerion another VSE, a spinoff from Loria/UL.

It consists in developing a new solution for the surveillance of aquatic environment, the Hydradrone:

- starting with an actual need for automated and remote operation of environmental sensing expressed by PEMA
- based on an hybrid UxV (Unmanned Air, Surface... Vehicle),
- some Cyber Physical bricks in coherence with the Alerion’s concepts (ease of use, safety, autonomy)
- and an integration in the Information System of the company

PEMA, as an environmental company, provides the use cases and terrain (and business) validation, while Alerion is working on the integration and engineering of the solution.

This third year has been dedicated to the development of the surface controller for the Hydradrones along with the development of a new small version, and the integration of environmental sensors. The project has been extended towards the summer 2018 in order to finish the integration and tests.

### 9.1.3. Satelor AME Lorraine regional project

**Participants:** François Despaux, Bernardetta Addis, Evangelia Tsiontsiou, Ye-Qiong Song [contact].

The Madynes team is involved in Satelor, a regional research and development project funded by the AME (Agence de Mobilisation Economique) of Lorraine (October 2013 – September 2017). The consortium includes academic (Univ. of Lorraine, Inria), medical (OHS) and industrial (Diatelic-Pharmagest (lead), ACS, Kapelse, Salendra, Neolinks) partners. It aims at developing innovative and easily deployable ambient assisted living solutions for their effective use in the tele-homecare systems. The Madynes team is mainly involved in the data collection system development based on wireless sensors networks and IoT technology. The first topic consists in defining the basic functions of the future SATEBOX – a gateway box for interconnecting in-home sensors to the medical datacenter, based on our previously developed MPIGate software. A beta-version prototype of the future Satebox gateway has been achieved. It now includes Zigbee wireless sensors, EnOcean battery-free sensors and Bluetooth Low Energy sensors. It provides a low-cost and easily deployable solution for the daily activity monitoring. After its first real-world deployment at a OHS hospital room, a second prototype testbed has been realized at one EHPAD including several rooms. The second topic is related to improve the data transfer reliability while still keep minimum energy consumption. This has led us to focus on the multi-hop mesh network topology with multi-constrained QoS routing problem (PhD thesis of Evangelia Tsiontsiou). The third topic is UWB-based indoor localization and its use for tracking and detecting falls of the elderlies. Experiments have shown a great benefice of multi-sensor fusion (e.g. localization + accelerometer) for increasing the detection accuracy.

## 9.2. National Initiatives

### 9.2.1. ANR

#### 9.2.1.1. ANR BottleNet

**Participants:** Isabelle Chrisment [contact], Thibault Cholez, Vassili Rivron.

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 user's 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 cause 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 experienced issues. The result can then be used by users, network and service operators or regulators to improve the QoE.

The ANR BottleNet project (<https://project.inria.fr/bottlenet>) started in February 2016. It involves many partners in the field of computer networks and QoE: Inria Muse and Diana teams, Lille1 University, Telecom Sud-Paris, Orange, IP-Label. The objective of BottleNet is to deliver methods, algorithms, and software systems to measure Internet 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 them with user perception to model Internet QoE, and to correlate measurements across users and devices to diagnose poor Internet QoE. This data-driven approach is essential to address the challenging problem of modeling user perception and of diagnosing sources of bottlenecks in complex Internet services. BottleNet will lead to new solutions to assist users, network and service operators as well as regulators in understanding Internet QoE and the sources of performance bottleneck.

#### 9.2.1.2. ANR Doctor

**Participants:** Thibault Cholez [contact], Xavier Marchal, Daishi Kondo, Olivier Festor.

The DOCTOR project <http://www.doctor-project.org> is an applied research project funded by the French National Research Agency (ANR), grant <ANR-14-CE28-000>, and supported by the French Systematic cluster. The project started on December 2014 for three years plus one year of extension (2018) to align the scientific production with the budget consumption. It involves five partners specialized in network monitoring and security: Orange Labs (lead), Thales, Montimage, Université de technologie de Troyes and LORIA/CNRS. The DOCTOR project advocates the use of virtualized network equipment (Network Functions Virtualization), to enable the co-existence of new Information-Centric Networking stacks (e.g.: Named-Data Networking) with IP, and the progressive migration of traffic from one stack to the other while guaranteeing the good security and manageability of the network. Therefore in DOCTOR, the main goals of the project are: (1) the efficient deployment of NDN as a virtualized networking environment; (2) the monitoring and security of this virtualized NDN stack.

This year, we focused on the second workpackage dedicated to security. We did a joint work with UTT investigating the impact on the Content Poisoning Attack on the NDN architecture [21]. We also wrote a book chapter about our use of NDN and NFV technologies to deploy an NDN network while providing advanced monitoring and security functions [35].

We also improved our HTTP/NDN gateway that will be soon released for the community and which design and evaluation will be submitted in a journal.

The next (and last) year of the project will be dedicated to the orchestration of our virtualized NDN architecture to manage its performance and security, and to the deployment of a testbed carrying real user traffic.

#### 9.2.1.3. FUI HUMA (01/09/2015-31/08/2018)

**Participants:** Giulia de Santis, Soline Blanc, Sofiane Lagraa, Jérôme François [contact], Abdelkader Lahmadi, Isabelle Chrisment.

The HUMA project (*L'HUmain au cœur de l'analyse de données MAssives pour la sécurité*) is funded under the national FUI Framework (Fonds Unique Interministeriel) jointly by the BPI (Banque Publique d'Investissement) and the Région Lorraine. It has been approved by two competitive clusters: Systematic and Imaginove. The consortium is composed of three academic (ICube, Citi, Inria) and five industrial (Airbus Defence and Space, Intrinsec, Oberthur, Wallix, Sydo) partners. The leader is Intrinsec.

This project targets the analysis of Advanced Persistent Threat. APT are long and complex attacks which thus cannot be captured with standard techniques focused on short time windows and few data sources. Indeed, APTs may last for several months and involve multiple steps with different types of attacks and approaches. The project will address such an issue by leveraging data analytics and visualization techniques to guide human experts, which are the only one able to analyze APT today, rather than targeting a fully automated approach.

In 2017, our contribution focused on defining a graph-mining technique to discover dependencies among security events clustering techniques in order to group individual events into a common one. We applied our technique to darknet data as shown in section 7.2.1. In addition, we also start the modeling of an attacker process by considering the first phase of APT, *i.e.* the reconnaissance phase by analyzing scanning activities using Hidden Markov Model (7.2.1). We also technically contribute to the definition of APT scenarios by providing a very stealthy scanning approach (Wiscan described in 7.1.2). Finally, from a project management point of view, Inria is in charge of leading the work-package related to data analytics technique for analyzing security probe events.

#### 9.2.1.4. Inria-Orange Joint Lab

**Participants:** Jérôme François [contact], Rémi Badonnel, Olivier Festor, Maxime Compastie, Paul Chaignon.

The challenges addressed by the Inria-Orange joint lab relate to the virtualization of communication networks, the convergence between cloud computing and communication networks, and the underlying software-defined infrastructures. This lab aims at specifying and developing a GlobalOS (Global Operating System) approach as a platform or a software infrastructure for all the network and computing resources required by the Orange network operator. Our work, started in November 2015, concerns in particular monitoring methods for

software-defined infrastructures, and management strategies for supporting software-defined security in multi-tenant cloud environments. We have specified a management framework dedicated to cloud software-defined security. It relies on on-the-fly generation and execution of unikernels in order to build highly-constrained configurations. The solution has been evaluated through extensive series of experiments, based on a proof-of-concept prototype using MirageOS. Results show that the costs induced by security mechanisms integration are relatively limited, and unikernels are well suited to minimize risk exposure.

#### 9.2.1.5. ANR FLIRT

**Participants:** Olivier Festor [contact], Rémi Badonnel, Thibault Cholez, Jérôme François, Abdelkader Lahmadi, Laurent Andrey.

FLIRT (Formations Libres et Innovantes Réseaux & Télécom) is an applied research project led by the Institut Mines-Télécom, for a duration of 4 years. It includes 14 academic partners (engineering schools including Telecom Nancy), 3 industrial partners (Airbus, Nokia Group and Orange), 2 innovative startups (the MOOC agency, and Isograd), as well as 3 professional or scientific societies (Syntec Numérique, Unetel, SEE). The project objective is to build a collection of 10 MOOCs (Massive Open Online Courses) in the area of networks and telecommunications, 3 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 Madynes team is leading a working group dedicated to the building of a MOOC on network and service management. This MOOC, whose first session will open end of 2018, covers the fundamental concepts, architectures and protocols of the domain, as well as their evolution in the context of future Internet, and includes practical labs and exercises using widely-used tools and technologies.

### 9.2.2. Technological Development Action (ADT)

#### 9.2.2.1. ADT UASS

The goal of this ADT provides assistance in developing the Aetournos platform to help in the UAV Challenge Medical Express. Through this ADT, funded by Inria, Raphaël Cherfan has coordinated students work on the platform and tutored the Aetournos team for the 2016 Outback Joe Search and Rescue / Medical Express Challenge, and help in the design and building of a novel Hybrid UAV.

#### 9.2.2.2. ADT VERTEX

This ADT started in 2016 and will end on 2018. The Madynes project is a major partner funded at the level of 120k€. ADT VERTEX built upon the foundations of the Grid'5000 testbed aims to reinforce and extend it towards new use cases and scientific challenges. Several directions are being explored: networks and Software Defined Networking, Big Data, HPC, and production computation needs. Previously developed prototypes are also being consolidated, and the necessary improvements to user management and tracking are also being performed.

#### 9.2.2.3. ADT SDT

Built on the Distem emulator, that enables the creation of virtual experimental environments from clusters of homogeneous machines, this project aims at enlarging the scope of use of Distem to additional fields: *Software Defined Networking, Named Data Networking, Big Data*. In addition, we will explore *temporal dilation* as a technique to study future infrastructures.

The project started in 2017 and will end in 2019.

#### 9.2.2.4. ADT RIOT

RIOT ADT is a multi-site project with Infine and Madynes teams, which started in December 2016 for a duration of two years. The high-level objective is to (1) contribute open source code, upstream, to the RIOT code base, (2) coordinate RIOT development within Inria, with other engineers and researchers using/developing RIOT, (3) coordinate RIOT development outside Inria, help maintain the RIOT community at large (see <http://www.riot-os.org> and <http://www.github.com/RIOT-OS/RIOT>) which aims to become the equivalent of Linux for IoT devices that cannot run Linux because of resource constraints.



This year MADYNES team has mainly contributed to the efficient MAC layer protocol implementation issues. We have built a general MAC protocol module (gnrc mac module) for providing critical development tools for MAC protocol developers in the RIOT community. Based on these generic functions, we have developed two duty-cycled MAC protocols lw-MAC and GoMacH which are above IEEE802.15.4. lw-MAC is a single channel MAC protocol that has similar principle of X-MAC and ContikiMAC. GoMacH [26] is a traffic-adaptive multi-channel MAC protocol for IoT which exhibits low power consumption and high throughput performance. Both are integrated into the RIOT IoT protocol stack and merged into RIOT master branch. They are publically available in RIOT open source github.

#### 9.2.2.5. ATT AMICS

The ATT AMICS is run in cooperation with the High Security Lab (HSL). The goal is to develop a customizable security analytics stack as a service. The added value of the HSL is to cross-correlate customer data with Internet probes hosted at HSL collecting tons of security data. Indeed, the basic service provided to potential customer is a VPN on top of which custom modules can be added. In 2017, we setup the VPN elements and also developed a flexible framework for security analysis. Different moddules have already been defined and implemented: blacklists aggregators to gather continuously information from third parties providing blacklists, real-time verification of traffic going through the VPN using blacklists, real-time detection of IP spoofing by correlating user traffic with HSL darknet traffic and real-time detection of customer hosts infected by a malware.

### 9.2.3. Inria Project Lab

#### 9.2.3.1. IPL BetterNet

**Participants:** Isabelle Chrisment [contact], Thibault Cholez, Vassili Rivron, Lakhdar Meftah [University of Lille].

The Inria Project Lab BetterNet (<https://project.inria.fr/betternet>) has been launched in October 2016. Its 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 original 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 a valuable service to scientists, stakeholders and civil society.

The Madynes team leads this IPL and in particular Isabelle Chrisment who coordinates the project.

In 2017, the main activities of the project focused on federating Inria's monitoring tools (APISENSE, Fathom, Hostview, ACQUA) and building our open measurement platform for acquiring data.

Lakhdar Meftah, a shared PhD student with the SPIRALS team (Inria/University of Lille) has worked on a privacy preservation scheme using data dissemination that introduces an a priori data anonymization and improves user privacy without compromising the overall quality of the crowdsourced dataset.

#### 9.2.3.2. IPL Discovery

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

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 (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.

MADYNES contributes to the DISCOVERY IPL on the networking axis. A CIFRE PhD with Orange is expected to start at the beginning of 2018.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

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

Title: Federation for FIRE Plus

Program: H2020

Duration: January 2017 - December 2021

Coordinator: Interuniversitair Micro-Electronicacentrum Imec VZW

Partners:

Universidad de Malaga

National Technical University of Athens - NTUA

The Provost, Fellows, Foundation Scholars & the other members of board of the College of the Holy & Undivided Trinity of Queen Elizabeth Near Dublin

Ethniko Kentro Erevnas Kai Technologikis Anaptyxis

GEANT Limited

Institut Jozef Stefan

Mandat International Alias Fondation Pour la Cooperation Internationale

Universite Pierre et Marie Curie - Paris 6

Universidad De Cantabria

Fundacio Privada I2CAT, Internet I Innovacio Digital A Catalunya

EURESCOM-European Institute For Research And Strategic Studies in Telecommunications GMBH

Nordunet A/S

Technische Universitaet Berlin

Instytut Chemii Bioorganicznej Polskiej Akademii Nauk

Fraunhofer Gesellschaft zur Foerderung Der Angewandten Forschung E.V.

Universiteit Van Amsterdam

University of Southampton

Martel GMBH

Atos Spain SA

Institut National de Recherche en Informatique et automatique

Inria contact: David Margery (for MADYNES: Lucas Nussbaum)

Fed4FIRE+ is a successor project to Fed4FIRE. In Fed4FIRE+, we more directly integrate Grid'5000 into the wider eco-system of experimental platforms in Europe and beyond using results we developed in Fed4FIRE. We will also provide a generalised proxy mechanisms to allow users with Fed4FIRE identities to interact with services giving access to different testbeds but not designed to support Fed4FIRE identities. Finally, we will work on orchestration of experiments in a federation context. Fed4FIRE+ was prepared in 2016, and has started January 1st, 2017.

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

#### **9.3.2.1. RETINA**

Program: Eurosatrs-2

Project acronym: RETINA

Project title: Real-Time support for heterogenous networks in automotive applications

Duration: April 2016 - March 2018

Coordinator: TCN (Time critical networks)

Other partners: TCN (Sweden), Alkit (Sweden), Viktoria (Sweden), TNO (Netherlands), Scuola Superiore Sant'Anna (Italy), Evidence (Italy), University of Lorraine (France)

Abstract: The project will develop integrated software tools to predict, simulate, test and support real-time communication in heterogeneous vehicular networks. The tool set will allow SMEs and larger industry to design, develop and evaluate time-critical applications such as advanced safety systems and autonomous vehicles. This will put high requirements on both in-vehicle infrastructure, as well as vehicle-to-vehicle and vehicle-to infrastructure utilizing the next generation of mobile networks for ITS.

## **9.4. International Initiatives**

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

#### **9.4.1.1. IoT4D**

Title: Internet of Things for Developing countries

International Partner (Institution - Laboratory - Researcher):

UY (Cameroon) - MASECNeSS - Thomas DJOTIO NDIE

Start year: 2016

See also: <https://team.inria.fr/iot4dc/>

Our goal is to connect wireless sensors networks (WSN) to the Internet through gateways. WSN should have several accessible gateways (depending on the size and quality of service needed) and gateways should be used by several wireless sensors networks. This is an optimization problem in a peculiar context featuring unreliable communications and equipments that are easily disturbed by environment .

#### **9.4.1.2. Masdin**

Title: MAnagement of Software-Defined INfrastructure

International Partner (Institution - Laboratory - Researcher):

University of Luxembourg (Luxembourg) - SnT (Interdisciplinary Centre for Security, Reliability and Trust) - Radu State

Joint publications: [25], [12], [16]

Start year: 2016

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

Networking is deeply evolving with the advent of new paradigms making the network more configurable and more dynamic. In particular, SDN (Software-Defined Network) consists in splitting the control plane and the data plane. A SDN-enabled switch is so only viewed as a specialized device in forwarding data traffic while a logically centralized controller exposes interfaces to services and applications strengthening their coupling. Hence, network is not only a medium of communication but a software component. In the same context, NFV (Network Function Virtualization) promotes the virtualization of all kinds of network functions (router, load-balancer, firewall. . . ) on commodity server, a server in a cloud. These technologies are deeply changing networking principle by allowing a high flexibility in network management. The new features provided by these concepts will thus allow to reinvent the network management in all its areas, especially for network monitoring and provisioning. In addition, even more recent propositions argue for a finer granularity applying the programmability idea of SDN (working at flow level) to packet processing level by promoting the definition of a common language like P4 to reconfigure any switch at low level (vendor independent). The original goal of the associate team is to explore co-jointly this research area through four directions: Monitoring of NFV- and SDN-enabled networks, investigating the integration of data analytics as virtualized functions in virtual networks, security of SDN networks, service chain composition, programming packet processing with P4 and other equivalents. ICN (Information Centric Networking) is also an important topic which is addressed in the team, especially regarding performance (with SDN) and security.

Furthermore, management of blockchain has been set as a new research topic to be focused in the team at the end of 2016. In the scope of network management, our objective is to design monitoring and orchestration methods for blockchain. In particular, we want to assess the relationships and impact between blockchain and network performance. We will have to define proper metrics to catch meaningful data to be analyzed. Moreover, a blockchain technology is by nature without authority (except in the private case), configuration requires thus to enforce some collaboration between nodes.

## NEO Project-Team

## 9. Partnerships and Cooperations

### 9.1. National Initiatives

#### 9.1.1. ANR Marmote

**Participants:** Alain Jean-Marie, Eleni Vatamidou.

ANR Program: Modèles Numériques (MN) 2012, number ANR-12-MONU-0019

Project title: MARKovian MOdeling Tools and Environments

Duration: January 2013 - June 2017

Coordinator: Alain Jean Marie (Inria)

Partners: Inria (project-teams DYOGENE, NEO and POLARIS), Univ. Versailles-Saint-Quentin (DAVID lab.), Telecom SudParis (SAMOVAR lab.), Univ. Paris-Est Créteil (LACL), and Univ. Pierre-et-Marie-Curie (LIP6)

Abstract: ANRMARMOTE aimed, among other goals, at realizing the prototype of a software environment dedicated to modeling with Markov chains. It brought together seven partner teams, expert in Markovian analysis, who developed advanced solution algorithms and applications in different scientific domains: reliability, distributed systems, physics and economics. See Section 6.1, Section 7.1.2 . Related publications: [26],[33],[37].

<https://wiki.inria.fr/MARMOTE/Welcome>

### 9.2. European Initiatives

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

**Participant:** Konstantin Avrachenkov.

Program: EU COST

Project acronym: **ACROSS**

Project title: Autonomous Control for a Reliable Internet of Services

Duration: November 2013 - November 2017

Coordinator: Rob Van Der Mei (CWI) and J.L. Van Den Berg (TNO), The Netherlands

Other partners: see <http://www.cost-across.nl/>

Abstract: Currently, we are witnessing a paradigm shift from the traditional information-oriented Internet into an Internet of Services (IoS). This transition opens up virtually unbounded possibilities for creating and deploying new services. Eventually, the ICT landscape will migrate into a global system where new services are essentially large-scale service chains, combining and integrating the functionality of (possibly huge) numbers of other services offered by third parties, including cloud services. At the same time, as our modern society is becoming more and more dependent on ICT, these developments raise the need for effective means to ensure quality and reliability of the services running in such a complex environment. Motivated by this, the aim of this Action is to create a European network of experts, from both academia and industry, aiming at the development of autonomous control methods and algorithms for a reliable and quality-aware IoS.

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.

## 9.3. International Initiatives

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

#### 9.3.1.1. MALENA

Title: Machine Learning for Network Analytics

International Partner (Institution - Laboratory - Researcher):

Indian Institute of Technology Bombay (India) - Electrical Communication Engineering - Vivek Borkar

Start year: 2017

See also: <http://www-sop.inria.fr/members/Konstantin.Avratchenkov/MALENA.html>

In the past couple of decades network science has seen an explosive growth, enough to be identified as a discipline of its own, overlapping with engineering, physics, biology, economics and social sciences. Much effort has gone into modelling, performance measures, classification of emergent features and phenomena, etc, particularly in natural and social sciences. The algorithmic side, all important to engineers, has been recognised as a thrust area (e.g., two recent Nevanlinna Prize (J. Kleinberg 2006 and D. Spielman 2010) went to prominent researchers in the area of network analytics). Still, in our opinion the area is yet to mature and has a lot of uncharted territory. This is because networks provide a highly varied landscape, each flavour demanding different considerations (e.g., sparse vs dense graphs, Erdős-Rényi vs planted partition graphs, standard graphs vs hypergraphs, etc). Even adopting existing methodologies to these novel situations is often a nontrivial exercise, not to mention many problems that cry out for entirely new algorithmic paradigms. It is in this context that we propose this project of developing algorithmic tools, drawing not only upon established as well as novel methodologies in machine learning and big data analytics, but going well beyond, e.g., into statistical physics tools.

#### 9.3.1.2. THANES

Title: THEory and Application of NEtwork Science

International Partner (Institution - Laboratory - Researcher):

Universidade Federal do Rio de Janeiro (Brazil) - Department of Computer and Systems Engineering - Daniel Ratton Figueiredo

Purdue University (USA) - Department of Computer Science - Bruno Ribeiro

Start year: 2017

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

During the 3-year lifetime of this joint team we plan to move beyond the study of a single network and focus on multiplex networks, i.e. multiple interacting networks. Multiplex networks have recently raised as “one of the newest and hottest themes in the statistical physics of complex networks.” They originate from the observation that many complex systems, ranging from living organisms to critical infrastructures, operate through multiple layers of distinct interactions among their constituents. In particular work on the co-evolution of the different layers of a multiplex network and on how epidemics spread in such setting.

### 9.3.2. Inria International Partners

#### 9.3.2.1. Informal International Partners

NEO has continued collaborations with researchers from GERAD, Univ. Montreal (Canada), Flinders Univ. (Australia), National Univ. of Rosario (Argentina), Technion - Israel Institute of Technology (Israel), Univ. of Arizona (USA), Univ. of Illinois at Urbana-Champaign (USA), Univ. of Liverpool (UK), Univ. of Massachusetts at Amherst (USA), Univ. of Florence (Italy), Univ. of Palermo (Italy), Univ. of Twente (The Netherlands), Petrozavodsk State Univ. (Russia) and Ghent Univ. (Belgium).

### 9.3.3. Participation in Other International Programs

#### 9.3.3.1. SticAmSud project DyGaMe

Title: Dynamic Games Methods: theory, algorithmics and application

International Partners (Institution - Laboratory - Researcher):

Univ. de Chile (Chile) - Department of Industrial Engineering - Fernando Ordóñez

Univ. Nacional de Rosario (Argentina) - Facultad de Ciencias Exactas, Ingeniería y Agrimensura - Eugenio Della Vecchia

CNRS (France) - LIP6 - Emmanuel Hyon

Duration: 2016 - 2017

Start year: 2016

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

Stochastic Dynamic Game Theory is developing in Engineering sciences and is in need of more theoretical results, algorithms and applications. This project brings together researchers from Applied Mathematics, Operations Research and Economics, with the objective of contributing to these aspects. It will more specifically concentrate on agent rationality and the game structure, look for efficient solution algorithms by crossing Applied Mathematics and Operations Research techniques, and apply the results to problems originating from, on the one hand, security/conservation concerns, and on the other hand, sustainable development problems.

#### 9.3.3.2. CEFIPRA Grant Monte Carlo, no.5100-ITI

Title: Monte Carlo and Learning Schemes for Network Analytics

International Partners (Institution - Laboratory - Researcher):

IIT Bombay (India) - Department of Electrical Engineering - Prof. V.S. Borkar;

IIS Bangalore (India) - Department of Electrical Engineering - Prof. R. Sundaresan.

Duration: 2014 - 2017

Start year: 2014

The project aims to approach various computation problems in network analytics by means of Markov Chain Monte Carlo (MCMC) and related simulation techniques as well as machine learning algorithms such as reinforcement learning, ant colony optimization, etc. This will include network diagnostics such as ranking, centrality measures, computation on networks using local message passing algorithms, resource allocation issues pertaining to networks and network-based systems such as the internet, peer-to-peer networks, social networks. The work will involve both development of analytical tools and extensive validation thereof using simulation studies. The research will draw upon techniques from graph theory, probability, optimization, and distributed computation.

## 9.4. International Research Visitors

### 9.4.1. Visits of International Scientists

#### 9.4.1.1. Professors / Researchers

Damiano Carra

Date: 6-8 December 2017

Institution: Univ. of Verona (Italy)

Koen de Turck

Date: 13-17 November 2017

Institution: CentraleSupélec (France)

Eugene Feinberg

Date: 1 June 2017

Institution: Stony Brook Univ. (USA)

Daniel Figueiredo

Date: 17-21 July 2017

Institution: UFRJ (Brazil)

Giulio Iacobelli

Date: 21-25 August 2017

Institution: UFRJ (Brazil)

Emilio Leonardi

Date: 21 February 2017 - 3 March 2017

Date: 9-20 October 2017

Institution: Politecnico di Torino (Italy)

Nelly Litvak

Date: 23 May 2017 - 2 June 2017

Institution: Twente Univ. (The Netherlands)

Vladimir Mazalov

Date: 19-17 March 2017

Institution: Karelian Institute of Applied Mathematical Research (Russia)

Fernando Ordóñez

Date: 15-19 May 2017

Institution: Univ. of Chile (Chile)

Pawel Pralat

Date: 2 July 2017 - 4 August 2017



Institution: Ryerson Univ. (Canada)

Bruno Ribeiro

Date: 17-21 July 2017

Institution: Purdue Univ. (USA)

Isaac Sonin

Date: 1-13 April 2017

Institution: Dept. of Mathematics and Statistics, UNC Charlotte (USA)

Rajesh Sundaresan

Date: 13-25 February 2017

Institution: IIS Bangalore (India)

Uri Yechiali

Date: 24 April 2017 - 5 May 2017

Institution: Tel Aviv Univ. (Israel)

#### *9.4.1.2. Post-doc / Ph.D. students*

Víctor Bucarey López

Date: 15-19 May 2017

Institution: Univ. of Chile (Chile)

Akhil Padinhare Thalasseryveetil

Date: 20 February 2017 - 20 August 2017

Institution: IIT Bangalore (India)

Berksan Serbetci

Date: 20 September 2017 - 20 December 2017

Institution: Univ. of Twente (The Netherlands)

Ranbir Singh

Date: 18 September 2017 - 26 October 2017

Institution: IIT Mumbai (India)

Gayane Vardoyan

Date: 16 May 2017 - 10 August 2017

Institution: Univ. of Massachusetts (USA)

Geetika Verma

Date: 20-30 June 2017

Institution: Univ. of South Australia (Australia)

#### *9.4.1.3. Internships*

Ilya Bogdanov

Date: 3 July 2017 - 18 September 2017

Institution: Moscow High School of Economics (Russia)

Supervisor: Konstantin Avrachenkov

Konstantinos Dermentzis

Date: 20 November 2017 - 19 May 2018

Institution: National Technical Univ. of Athens (Greece)

Supervisor: Giovanni Neglia

Srishti Jain

Date: 9 May 2017 - 26 Jul 2017

Institution: IIT Kampur (India)

Supervisor: Eitan Altman

Sarath Pattathil

Date: 3 May 2017 - 3 July 2017

Institution: IIT Bombay (India)

Supervisor: Konstantin Avrachenkov

Dmytro Rubanov

Date: 1 March 2017 - 31 August 2017

Institution: Master IFI Ubinet, UNS

Supervisor: Konstantin Avrachenkov

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

#### *9.4.2.1. Research Stays Abroad*

Konstantin Avrachenkov

Date: 1 - 9 February 2017

Institution: IIT Bombay and IIS Bangalore (India)

Date: 11 - 19 March 2017

Institution: Novosibirsk State Univ. (Russia)

Date: 18 - 25 April 2017

Institution: Univ. of Liverpool (UK)

Date: 18 - 19 September 2017

Institution: Univ. of Warsaw (Poland)

Date: 30 October - 4 November 2017

Institution: IIT Bombay (India)

Alain Jean-Marie

Date: 2 - 20 November 2017

Institution: Univ. of Montreal (Canada)

Date: 28 October - 27 November 2017

Institution: National Univ. of Rosario (Argentina)

Giovanni Neglia

Date: 8 - 11 November 2017

Institution: Northeastern Univ., Boston and Univ. of Massachusetts, Amherst (USA)

Date: 13 - 18 November 2017

Institution: Purdue Univ. (USA)

Date: 14 - 15 December 2017

Institution: Florence Univ. (Italy)

## **RAP2 Team**

# **6. Partnerships and Cooperations**

## **6.1. International Research Visitors**

### ***6.1.1. Visits of International Scientists***

- Louigi Addario-Berri (McGill)
- Gabor Lugosi (ICREA and Pompeu Fabra)
- Cyril Marzouk (Paris Sud)
- Minmin Wang (Buenos Aires)
- S. Foss (Heriot-Watt University, UK)
- V. Gupta (University of Chicago, USA)

### ***6.1.2. Visits to International Teams***

- *Nicolas Broutin* visited the computer science department of McGill University (Canada), the CRM in Montreal, the mathematics institute in Nice and the university Aix-Marseille.
- *Wen Sun* has visited the Division of Applied Mathematics in Brown University to work with Kavita Ramanan, 07-16 Nov. 2017.

## SOCRATE Project-Team

## 8. Partnerships and Cooperations

### 8.1. National Initiatives

#### 8.1.1. Equipex FIT- Future Internet of Things

The FIT project is a national equipex (*équipement d'excellence*), headed by the Lip6 laboratory. As a member of Inria, Socrate is in charge of the development of an Experimental Cognitive Radio platform that is used as test-bed for SDR terminals and cognitive radio experiments. This has been operational since 2014 and is maintained for a duration of 7 years. To give a quick view, the user will have a way to configure and program through Internet several SDR platforms (MIMO, SISO, and baseband processing nodes).

#### 8.1.2. Insa-Spie IoT Chair

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

#### 8.1.3. Inria Project Lab: ZEP

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

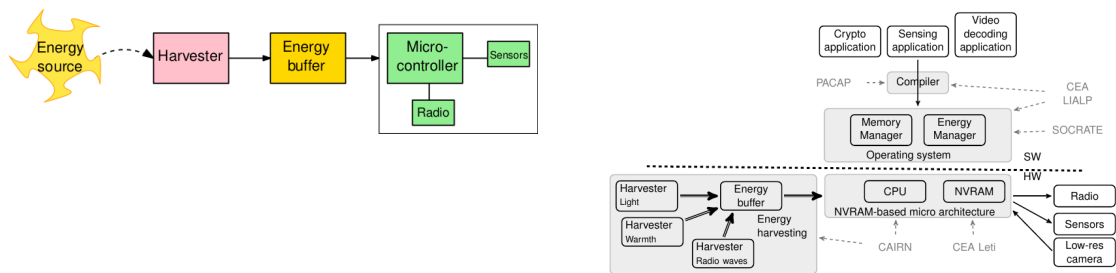


Figure 6. Example of system targeted by the ZEP project on the left, and on the right: the ZEP research program.

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

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

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

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

#### 8.1.4. ANR - MetalibM

The goal of the MetalibM - “Automatic Generation of Function and Filters” (2014-2017, 200 keuros) project is to provide a tool for the automatic implementation of mathematical (libm) functions. A function  $f$  is automatically transformed into machine-proven C code implementing an polynomial approximation in a given domain with given accuracy. This project is led by Inria, with researchers from Socrate and AriC; PEQUAN team of Laboratoire d’Informatique de Paris 6 (LIP6) at Université Pierre et Marie Curie, Paris; DALI team from Université de Perpignan Via Domitia and Laboratoire d’Informatique, Robotique et Microélectronique de Montpellier (LIRMM); and SFT group from Centre Européen de Recherche Nucléaire (CERN).

#### 8.1.5. ADT Sytare

The SYTARE project (Développement d’un SYStème embArqué faible consommation à mémoiRE persistante - ADT Inria 2015-2017) aims to develop and study novel operating system mechanisms for NVRAM-based embedded systems. The term NVRAM collectively describes an emerging generation of memory technologies which are both non-volatile and byte-addressable. These two properties together make the classical RAM+ROM memory architecture obsolete, and enable the design of embedded systems running on intermittent power. This is very attractive in the context of energy-constrained scenarios, for instance systems harvesting their power from the environment. But working with NVRAM also poses novel challenges in terms of software programming. For instance, application state consistency must be guaranteed accross reboots, even though the system includes both NVRAM and volatile elements (e.g. CPU, hardware peripherals). The SYTARE project is funded by Inria via the ADT program.

#### 8.1.6. ADT CorteXlab

The Socrate project-team is in charge of the FIT/CorteXlab platform (section 5.6). This platform (ADT Inria 2015-2017) makes use of many complex technologies from signal processing to computer science through micro-electronics and FPGA. The objective of the CorteXlab ADT is to maintain a support to the user of the FPGA-based platform of CorteXlab and to provide tutorial and running experiment that will help them in building experimentation using the PicoSDR machines.

#### 8.1.7. ANR - Ephyl

The general objective of the project EPHYL - “Enhanced PHY for Cellular Low Power Communication IoT” (2016-2019, 183 keuros) is to investigate coming and future LPWA technologies with the aim to improve coverage, data rate and connectivity while keeping similar level of complexity and power consumption at the node for the access. New waveforms enablers will be investigated and trialled in order to increase the efficiency of future systems and to provide efficient and fair access to the radio resource. The proposed new waveforms should comply with system constraints and with the coexistence of multiple communications.

#### 8.1.8. ANR - Arburst

In this project Arburst - “Achievable region of bursty wireless networks” (2016-2020, 195 KEuros), we propose an original approach complementary to other existing projects. Instead of proposing one specific technical solution, our objective is to define a unified theoretical framework devoted to the study of IoT networks fundamental limits. We aim at establishing the fundamental limits for a decentralized system in a bursty regime which includes short packets of information and impulsive interference regime. We are targeting the fundamental limits, their mathematical expression (according to the usual information theory framework capturing the capacity region by establishing a converse and achievability theorems). We will use the recent results relative to finite block-length information theory and we will evaluate the margin for improvement between existing approaches and these limits and we will identify the scientific breakthrough that may bring

significant improvements for IoT/M2M communications. This project will contribute to draw the roadmap for the development of IoT/M2M networks and will constitute a unified framework to compare existing techniques, and to identify the breakthrough concepts that may afford the industry the leverage to deploy IoT/M2M technical solutions.

## 8.2. European Initiatives

### 8.2.1. FP7 & H2020 Projects

#### 8.2.1.1. CYBERNETS

Title: Cybernetic Communication Networks: Fundamental Limits and Engineering Challenges

Programm: H2020

Duration: June 2015 - June 2017

Coordinator: Inria

Inria contact: Samir M. Perlaza

This Reintegration Panel proposal, CYBERNETS, focuses on the study of Cybernetic Communication Networks (CCN). CCNs are wireless networks that are context-aware, possess learning capabilities and artificial intelligence to guarantee reliability, efficiency and resilience to changes, failures or attacks via autonomous, self-configuring and self-healing individual and network behavior. Typical examples of CCNs are beyond-5G cellular systems and critical communication systems, e.g., law enforcement, disaster relief, body- area, medical instruments, space, and indoor/outdoor commercial applications. A practical implementation of a CCN requires extending classical communication systems to embrace the dynamics of fully decentralized systems whose components might exhibit either cooperative, non-cooperative or even malicious behaviors to improve individual and/or global performance. In this context, CYBERNETS aims to develop a relevant understanding of the interactions between information theory, game theory and signal processing to tackle two particular problems from both theoretical and practical perspectives: (I) use of feedback and (II) behavior adaptation in fully decentralized CCNs. In the former, the main objectives are: (i) to determine the fundamental limits of data transmission rates in CCNs with feedback; and (ii) to develop and test in real-systems, transmit-receive configurations to provide a proof-of-concept of feedback in CCNs. For the achievement of these practical objectives, CYBERNETS relies on the world-class testbed infrastructure of Inria at the CITI Lab for fully closing the gap between theoretical analysis and real-system implementation. In the latter, the main objectives are: (i) to identify and explore alternatives for allowing transmitter-receiver pairs to learn equilibrium strategies in CCNs with and without feedback; (ii) to study the impact of network-state knowledge on scenarios derived from the malicious behavior of network components.

#### 8.2.1.2. COM-MED

Title: COMMunication systems with renewable Energy micro-grid

Programm: H2020

Duration: October 2016 - October 2019

Coordinator: Inria

Inria contact: Samir M. Perlaza

A smart micro-grid is a small-scale power-grid system consisting of a number of distributed energy sources and loads which is responsible to ensure power sufficiency in a small area. The effectiveness of a smart micro-grid depends on the proper implementation of a communications and networking system which monitors, controls and manages the grid's operations. Due to the ever growing worldwide energy consumption, the need of an efficient framework for managing the way power is distributed and utilized has increased. The main objective of the project COM-MED is to study the

fundamental interplay between communications and power networks in the context of smart micro-grids and renewable energy sources. On one hand, we study advanced signal processing techniques and communications methods to optimize the operation of smart micro-grid systems. On the other hand, we focus on mobile communications networks with renewable energy base-stations (BSs) and we investigate communications and networking techniques that take into account both data traffic and energy profiles to support high quality-of-service (QoS). The objectives of each technical WP have been assigned in such a way as to ensure that the project's target is realized during the project's time period. The theoretical results derived from the WPs 3, 4 and 5 will be tested using the telecommunication network of MTN in Cyprus but also the state-of-the-art equipment of the CITI/Inria research lab in France. The outcome of this project will provide a theoretical framework for the optimal cooperation between communications networks and power networks in the context of smart micro-grids and renewable energy sources. This is in line with the objectives of the call's theme "Renewable Energy" and is of paramount importance for the Mediterranean area. The consortium of the project has the expertise and the infrastructure to implement the objectives set and to bring the project to a successful end.

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

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

## 8.3. International Initiatives

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

#### 8.3.1.1. CoWIN

Title: Cognitive Wireless Networks from Theory to Implementation

International Partner (Institution - Laboratory - Researcher):

Princeton (United States) - electrical engineering department - H. Vincent Poor

Start year: 2015

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

The objective of this team is to strengthen the research efforts on emerging software radio and cognitive radio technologies. The team will count on: first, the cognitive radio test-bed CorteXlab recently set up by the Socrate team within the FIT Equipex, second the leading position of Vincent Poor's team in the field of network information theory and third the Orbit Platform of Rutgers university. The goal is to lead research in both the information theory community and the applied research community so as to reinforce the link between both communities. This work will concern architecture and programs of software radio equipments, distributed and cognitive algorithms for radio resource allocation, cognitive radio scenario experimentations, fundamental limits of cooperative wireless channels and the set up of common experimental infrastructure and protocols for research on cognitive wireless networks.

### 8.3.2. Inria International Partners

#### 8.3.2.1. Informal International Partners

Socrate has strong collaborations with several international partners.

- **Princeton University**, School of Applied Science, Department of Electrical Engineering, NJ. USA. This cooperation with Prof. H. Vincent Poor is on topics related to decentralized wireless networks. Samir M. Perlaza has been appointed as Visiting Research Collaborator at the EE Department for the academic period 2016-2017. Scientific-Leaders at Inria: Samir M. Perlaza and Jean-Marie Gorce.
- **Technical University of Berlin**, Dept. of Electrical Engineering and Computer Science, Germany. This cooperation with Prof. Rafael Schaffer is on secrecy and covert communications. Scientific-Leaders at Inria: Samir M. Perlaza.

- **National University Singapore (NUS)**, Department of Electrical and Computer Engineering, Singapore. This collaboration with Prof. Vincent Y. F. Tan is on the study of finite block-length transmissions in multi-user channels and the derivation of asymptotic capacity results with non-vanishing error probabilities. Scientific-Leaders at Inria: Samir M. Perlaza
- **University of Sheffield**, Department of Automatic Control and Systems Engineering, Sheffield, UK. This cooperation with Prof. Inaki Esnaola is on topics related to information-driven energy systems and multi-user information theory. Scientific-in-charge at Inria: Samir M. Perlaza.
- **Rutgers University**, Winlab, Orbit testbed. This cooperation with Ivan Seskar is related to experimental wireless testbed. Orbit has been one of the first wireless testbeds of its type. Tanguy Risset and Leonardo Sampaio-Cardoso have visited Winlab and I. Seskar visited the Socrate team for one week. Their collaboration is on the development of tools to ease experiment handling on wireless testbeds: visualisation, synchronization etc. Scientific-Leader at Inria: Tanguy Risset
- **University of Arizona**, Department of Electrical and Computer Engineering, Tucson, AZ, USA. This cooperation with Prof. Ravi Tandon is on topics related to channel-output feedback in wireless networks. Scientific-Leader at Inria: Samir M. Perlaza.
- **University of Cyprus**, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, Cyprus. This cooperation with Prof. Ioannis Krikidis is on topics related to energy-harvesting and wireless communications systems. Scientific-Leaders at Inria: Guillaume Villemaud and Samir M. Perlaza.
- **Universidade Federal do Ceará**, GTEL, Departamento de Teleinformática, Fortaleza, Brazil. This recently started cooperation with Prof. Tarcisio Ferreira Maciel is on topics related to the optimization of radio resources for massive MIMO in 5G and 5G-like wireless communications systems. Scientific-in-charge at Inria: Leonardo Sampaio-Cardoso.
- **Universidad Nacional del Sur**, LaPSyC laboratory, Bahía Blanca, Argentina. This cooperation with Prof. Juan Cousseau is on topics related to Full-Duplex communications and Interference Alignment. Scientific-in-charge at Inria: Guillaume Villemaud.
- **Bell Labs New Jersey, USA**, This cooperation with Prof. Antonia Tulino (affiliated to Bell Labs and to University of Napoli, Italy) is on caching in wireless networks. The objective is to demonstrate the efficiency of caching at the edge of wireless networks through experimentations on CorteXlab. This work will be published in 2017 in a special issue of IEEE Communication magazine (Yasser Fadlallah, Antonia M. Tulino, Dario Barone, Giuseppe Vettigli, Jaime Llorca and Jean-Marie Gorce: Coding for caching in 5G networks, IEEE Communication Magazine, 2017, accepted for publication). Scientific leader at Inria : Jean-Marie Gorce.
- **Technical University "Gh. Asachi" of Iasi, Romania**, Department of Electronics, Telecommunications and Information Technology. This recent collaboration has started on topics related on the theoretical aspects of the ultra-low power radio communications. Scientific-in-charge at Inria: Florin Hutu

## 8.4. International Research Visitors

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

### 8.4.1. Visits to International Teams

#### 8.4.1.1. Sabbatical programme

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



**8.4.2. Internship**

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