

The logo for Inria, featuring the word "Inria" in a stylized, red, cursive font.

IN PARTNERSHIP WITH:  
**Sorbonne Université**

Activity Report 2019

**Project-Team DELYS**

DistributEd aLgorithms and sYStems

IN COLLABORATION WITH: Laboratoire d'informatique de Paris 6 (LIP6)

RESEARCH CENTER  
**Paris**

THEME  
**Distributed Systems and middleware**



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## Project-Team DELYS

*Creation of the Team: 2018 January 01, updated into Project-Team: 2019 January 01*

### Keywords:

#### Computer Science and Digital Science:

- A1.1.1. - Multicore, Manycore
- A1.1.9. - Fault tolerant systems
- A1.2.5. - Internet of things
- A1.3.2. - Mobile distributed systems
- A1.3.3. - Blockchain
- A1.3.4. - Peer to peer
- A1.3.5. - Cloud
- A1.3.6. - Fog, Edge
- A1.5.2. - Communicating systems
- A2.6. - Infrastructure software
  - A2.6.1. - Operating systems
  - A2.6.2. - Middleware
  - A2.6.3. - Virtual machines
  - A2.6.4. - Ressource management
- A3.1.8. - Big data (production, storage, transfer)
- A7.1.1. - Distributed algorithms

#### Other Research Topics and Application Domains:

- B6.4. - Internet of things

## 1. Team, Visitors, External Collaborators

### Research Scientists

- Mesaac Makpangou [Inria, Researcher, HDR]
- Marc Shapiro [Inria, Senior Researcher, HDR]
- Pascale Vicat - Blanc [Inria, Senior Researcher, from Apr 2019 until Oct 2019, HDR]

### Faculty Members

- Pierre Sens [Team leader, Sorbonne Univ., Professor, HDR]
- Luciana Bezerra Arantes [Sorbonne Univ., Associate Professor]
- Philippe Darche [Univ. René Descartes, Associate Professor]
- Swan Dubois [Sorbonne Univ., Associate Professor]
- Jonathan Lejeune [Sorbonne Univ., Associate Professor]
- Franck Petit [Sorbonne Univ., Professor, HDR]
- Julien Sopena [Sorbonne Univ., Associate Professor]

### Post-Doctoral Fellows

- Sara Hamouda [Inria, from Feb 2019]
- Sébastien Bouchard [Sorbonne Univ., Oct. – Dec. 2019]

### PhD Students

- Sébastien Bouchard [Inria, until Sep 2019]
- Marjorie Bournat [Sorbonne Univ., until Aug 2019]

Gabriel Le Bouder [Sorbonne Univ., from Oct. 2019]  
Arnaud Favier [Inria]  
Denis Jeanneau [Sorbonne Univ., until Jun 2019]  
Francis Laniel [Sorbonne Univ.]  
Sreeja Nair [Sorbonne Univ.]  
Laurent Prospero [Inria, from Oct 2019]  
Benoît Martin [Sorbonne-Univ., from Oct 2019]  
Jonathan Sid Otmane [Orange Labs]  
Ilyas Toumlilt [Sorbonne Univ., until Apr 2019]  
Dimitrios Vasilas [Sorbonne Univ.]

**Technical staff**

Ilyas Toumlilt [Inria, Engineer, from Sep 2019]

**Interns and Apprentices**

Yves Kone [Inria, from Jun 2019 until Aug 2019]  
Guillaume Rakotomalala [Inria, from Jun 2019 until Jul 2019]  
Daniel Wilhelm [Inria, from Mar 2019 until Aug 2019]

**External Collaborator**

Sébastien Monnet [Univ Savoie Mont-Blanc]

## 2. Overall Objectives

### 2.1. Overall Objectives

The research of the Delys team addresses the theory and practice of distributed systems, including multicore computers, clusters, networks, peer-to-peer systems, cloud and fog computing systems, and other communicating entities such as swarms of robots. It addresses the challenges of correctly communicating, sharing information, and computing in such large-scale, highly dynamic computer systems. This includes addressing the core problems of communication, consensus and fault detection, scalability, replication and consistency of shared data, information sharing in collaborative groups, dynamic content distribution, and multi- and many-core concurrent algorithms.

Delys is a joint research team between LIP6 (Sorbonne University/CNRS) and Inria Paris.

## 3. Research Program

### 3.1. Research rationale

DELYS addresses both theoretical and practical issues of *Computer Systems*, leveraging our dual expertise in theoretical and experimental research. Our approach is a “virtuous cycle,” triggered by issues with real systems, of algorithm design which we prove correct and evaluate theoretically, and then implement and test experimentally feeding back to theory. The major challenges addressed by DELYS are the sharing of information and guaranteeing correct execution of highly-dynamic computer systems. Our research covers a large spectrum of distributed computer systems: multicore computers, mobile networks, cloud computing systems, and dynamic communicating entities. This holistic approach enables handling related problems at different levels. Among such problems we can highlight consensus, fault detection, scalability, search of information, resource allocation, replication and consistency of shared data, dynamic content distribution, and concurrent and parallel algorithms.

Two main evolutions in the Computer Systems area strongly influence our research project:

(1) Modern computer systems are **increasingly distributed, dynamic** and composed of multiple devices **geographically spread over heterogeneous platforms**, spanning multiple management domains. Years of research in the field are now coming to fruition, and are being used by millions of users of web systems, peer-to-peer systems, gaming and social applications, cloud computing, and now fog computing. These new uses bring new challenges, such as *adaptation to dynamically-changing conditions*, where knowledge of the system state can only be partial and incomplete.

(2) **Heterogeneous architectures and virtualisation are everywhere**. The parallelism offered by distributed clusters and *multicore* architectures is opening highly parallel computing to new application areas. To be successful, however, many issues need to be addressed. Challenges include obtaining a consistent view of shared resources, such as memory, and optimally distributing computations among heterogeneous architectures. These issues arise at a more fine-grained level than before, leading to the need for different solutions down to OS level itself.

The scientific challenges of the distributed computing systems are subject to many important features which include scalability, fault tolerance, dynamics, emergent behaviour, heterogeneity, and virtualisation at many levels. Algorithms designed for traditional distributed systems, such as resource allocation, data storage and placement, and concurrent access to shared data, need to be redefined or revisited in order to work properly under the constraints of these new environments. Sometimes, classical “*static*” problems, (*e.g.*, Election Leader, Spanning Tree Construction, ...) even need to be redefined to consider the unstable nature of the distributed system. In particular, DELYS will focus on a number of key challenges:

Consistency in geo-scale systems. Distributed systems need to scale to large geographies and large numbers of attached devices, while executing in an untamed, unstable environment. This poses difficult scientific challenges, which are all the more pressing as the cloud moves more and more towards the edge, IoT and mobile computing. A key issue is how to share data effectively and consistently across the whole spectrum. Delys has made several key contributions, including CRDTs, the Transactional Causal Consistency Plus model, the AntidoteDB geo-distributed database, and its edge extension EdgeAnt.

Rethinking distributed algorithms. From a theoretical point of view the key question is how to adapt the fundamental building blocks to new architectures. More specifically, how to rethink the classical algorithms to take into account the dynamics of advanced modern systems. Since a recent past, there have been several papers that propose models for dynamic systems: there is practically a different model for each setting and currently there is no unification of models. Furthermore, models often suffer of lack of realism. One of the key challenge is to identify which assumptions make sense in new distributed systems. DELYS’s objectives are then (1) to identify under which realistic assumptions a given fundamental problem such as mutual exclusion, consensus or leader election can be solved and (2) to design efficient algorithms under these assumptions.

Resource management in heterogeneous systems. The key question is how to manage resources on large and heterogeneous configurations. Managing resources in such systems requires fully decentralized solutions, and to rethink the way various platforms can collaborate and interoperate with each other. In this context, data management is a key component. The fundamental issue we address is how to efficiently and reliably share information in highly distributed environments.

Adaptation of runtimes. One of the main challenge of the OS community is how to adapt runtime supports to new architectures. With the increasingly widespread use of multicore architectures and virtualised environments, internal runtime protocols need to be revisited. Especially, memory management is crucial in OS and virtualisation technologies have highly impact on it. On one hand, the isolation property of virtualisation has severe side effects on the efficiency of memory allocation since it needs to be constantly balanced between hosted OSs. On the other hand, by hiding the physical machine to OSs, virtualisation prevents them to efficiently place their data in memory on different cores. Our research will thus focus on providing solutions to efficiently share memory between OSs without jeopardizing isolation properties.

## 4. Highlights of the Year

### 4.1. Highlights of the Year

#### 4.1.1. Awards

In 2019, DELYS obtained a best paper award at ICDCN 2019 (distributed computing track) .

Alejandro Tomsic, former PhD student of the Delys group, was awarded the Prize for Best French PhD in Systems and Networking 2019 for his thesis titled “Exploring the design space of highly-available distributed transactions” . The prize is awarded yearly by ASF (the French chapter of ACM Sigops) and by RSD (the French research network in Networked and Distributed Systems). The award ceremony and presentation of Alejandro’s work took place at the COMPAS 2019 conference in Anglet, France.

The US patent, titled “Distributing computing system implementing a non-speculative hardware transactional memory and a method for using same for distributed computing,” was awarded to inventors Julien Peeters, Nicolas Ventroux, Tanguy Sassolas and Marc Shapiro in April 2019, with number US 10 416 925 B2 [4].

#### BEST PAPERS AWARDS:

[28]

E. MAUFFRET, D. JEANNEAU, L. ARANTES, P. SENS. *The Weakest Failure Detector to Solve the Mutual Exclusion Problem in an Unknown Dynamic Environment*, in "20th International Conference on Distributed Computing and Networking (ICDCN 2019)", Bangalore, India, January 2019, Extended version: <https://hal.archives-ouvertes.fr/hal-01661127v3>, <https://hal.archives-ouvertes.fr/hal-01929224>

[7]

A. Z. TOMSIC. *Exploring the design space of highly-available distributed transactions*, Université Pierre et Marie Curie, Paris, France, April 2018

## 5. New Results

### 5.1. Distributed Algorithms for Dynamic Networks and Fault Tolerance

**Participants:** Luciana Bezerra Arantes [correspondent], Sébastien Bouchard, Marjorie Bournat, João Paulo de Araujo, Swan Dubois, Laurent Feuilloley, Denis Jeanneau, Jonathan Lejeune, Franck Petit, Pierre Sens, Julien Sopena.

Nowadays, distributed systems are more and more heterogeneous and versatile. Computing units can join, leave or move inside a global infrastructure. These features require the implementation of *dynamic* systems, that is to say they can cope autonomously with changes in their structure in terms of physical facilities and software. It therefore becomes necessary to define, develop, and validate distributed algorithms able to managed such dynamic and large scale systems, for instance mobile *ad hoc* networks, (mobile) sensor networks, P2P systems, Cloud environments, robot networks, to quote only a few.

The fact that computing units may leave, join, or move may result of an intentional behavior or not. In the latter case, the system may be subject to disruptions due to component faults that can be permanent, transient, exogenous, evil-minded, etc. It is therefore crucial to come up with solutions tolerating some types of faults.

In 2019, we obtained the following results.



### 5.1.1. Failure detectors

Mutual exclusion is one of the fundamental problems in distributed computing but existing mutual exclusion algorithms are unadapted to the dynamics and lack of membership knowledge of current distributed systems (e.g., mobile ad-hoc networks, peer-to-peer systems, etc.). Additionally, in order to circumvent the impossibility of solving mutual exclusion in asynchronous message passing systems where processes can crash, some solutions include the use of  $(\mathcal{T} + \Sigma^l)$ , which is the weakest failure detector to solve mutual exclusion in known static distributed systems. In [28], we define a new failure detector  $\mathcal{T} \Sigma^l r$  which is equivalent to  $(\mathcal{T} + \Sigma^l)$  in known static systems, and prove that  $\mathcal{T} \Sigma^l r$  is the weakest failure detector to solve mutual exclusion in unknown dynamic systems with partial memory losses. We consider that crashed processes may recover.

Assuming a message-passing environment with a majority of correct processes, the necessary and sufficient information about failures for implementing a general state machine replication scheme ensuring consistency is captured by the  $\Omega$  failure detector. We show in [19] that in such a message-passing environment,  $\Omega$  is also the weakest failure detector to implement an eventually consistent replicated service, where replicas are expected to agree on the evolution of the service state only after some (a priori unknown) time.

### 5.1.2. Scheduler Tolerant to Temporal Failures in Clouds

Cloud platforms offer different types of virtual machines which ensure different guarantees in terms of availability and volatility, provisioning the same resource through multiple pricing models. For instance, in Amazon EC2 cloud, the user pays per hour for on-demand instances while spot instances are unused resources available for a lower price. Despite the monetary advantages, a spot instance can be terminated or hibernated by EC2 at any moment. Using both hibernation prone spot instances (for cost sake) and on-demand instances, we propose in [31] a static scheduling for applications which are composed of independent tasks (bag-of-task) with deadline constraints. However, if a spot instance hibernates and it does not resume within a time which guarantees the application's deadline, a temporal failure takes place. Our scheduling, thus, aims at minimizing monetary costs of bag-of-tasks applications in EC2 cloud, respecting its deadline and avoiding temporal failures. Performance results with task execution traces, configuration of Amazon EC2 virtual machines, and EC2 market history confirms the effectiveness of our scheduling and that it tolerates temporal failures. In [30], we extend our approach for dynamic scheduling.

### 5.1.3. Gathering of Mobile Agents

Gathering a group of mobile agents is a fundamental task in the field of distributed and mobile systems. It consists of bringing agents that initially start from different positions to meet all together in finite time. In the case when there are only two agents, the gathering problem is often referred to as the rendezvous problem.

In [14] we show that rendezvous under the strong scenario is possible for agents with asynchrony restricted in the following way: agents have the same measure of time but the adversary can impose, for each agent and each edge, the speed of traversing this edge by this agent. The speeds may be different for different edges and different agents but all traversals of a given edge by a given agent have to be at the same imposed speed. We construct a deterministic rendezvous algorithm for such agents, working in time polynomial in the size of the graph, in the length of the smaller label, and in the largest edge traversal time.

### 5.1.4. Perpetual self-stabilizing exploration of dynamic environments

In [15], we deal with the classical problem of exploring a ring by a cohort of synchronous robots. We focus on the perpetual version of this problem in which it is required that each node of the ring is visited by a robot infinitely often. We assume that the robots evolve in ring-shape TVGs, *i.e.*, the static graph made of the same set of nodes and that includes all edges that are present at least once over time forms a ring of arbitrary size. We also assume that each node is infinitely often reachable from any other node. In this context, we aim at providing a self-stabilizing algorithm to the robots (*i.e.*, the algorithm must guarantee an eventual correct behavior regardless of the initial state and positions of the robots). We show that this problem is deterministically solvable in this harsh environment by providing a self-stabilizing algorithm for three robots.

### 5.1.5. Torus exploration by oblivious robots

In [17], we deal with a team of autonomous robots that are endowed with motion actuators and visibility sensors. Those robots are weak and evolve in a discrete environment. By weak, we mean that they are anonymous, uniform, unable to explicitly communicate, and oblivious. We first show that it is impossible to solve the terminating exploration of a simple torus of arbitrary size with less than 4 or 5 such robots, respectively depending on whether the algorithm is probabilistic or deterministic. Next, we propose in the SSYNC model a probabilistic solution for the terminating exploration of torus-shaped networks of size  $\ell \times L$ , where  $7 \leq \ell \leq L$ , by a team of 4 such weak robots. So, this algorithm is optimal *w.r.t.* the number of robots.

### 5.1.6. Explicit communication among stigmergic robots

In [18], we investigate avenues for the exchange of information (explicit communication) among deaf and mute mobile robots scattered in the plane. We introduce the use of movement-signals (analogously to flight signals and bees waggle) as a mean to transfer messages, enabling the use of distributed algorithms among robots. We propose one-to-one deterministic movement protocols that implement explicit communication among semi-synchronous robots. Our protocols enable the use of distributed algorithms based on message exchanges among swarms of stigmergic robots. They also allow robots to be equipped with the means of communication to tolerate faults in their communication devices.

### 5.1.7. Gradual stabilization

In [13], we introduce the notion of *gradual stabilization under  $(\tau, \rho)$ -dynamics* (gradual stabilization, for short). A gradually stabilizing algorithm is a self-stabilizing algorithm with the following additional feature: after up to  $\tau$  *dynamic steps* of a given type  $\rho$  occur starting from a legitimate configuration, it first quickly recovers to a configuration from which a specification offering a minimum quality of service is satisfied.

It then gradually converges to specifications offering stronger and stronger safety guarantees until reaching a configuration (1) from which its initial (strong) specification is satisfied again, and (2) where it is ready to achieve gradual convergence again in case of up to  $\tau$  new dynamic steps of type  $\rho$ . A gradually stabilizing algorithm being also self-stabilizing, it still recovers within finite time (yet more slowly) after any other finite number of transient faults, including for example more than  $\tau$  arbitrary dynamic steps or other failure patterns such as memory corruptions. We illustrate this new property by considering three variants of a synchronization problem respectively called *strong*, *weak*, and *partial* unison. We propose a self-stabilizing unison algorithm which achieves gradual stabilization in the sense that after one dynamic step of a certain type *BULCC* (such a step may include several topological changes) occurs starting from a configuration which is legitimate for the strong unison, it maintains clocks almost synchronized during the convergence to strong unison: it satisfies partial unison immediately after the dynamic step, then converges in at most one round to weak unison, and finally re-stabilizes to strong unison.

## 5.2. Distributed systems and Large-scale data distribution

**Participants:** Guillaume Fraysse, Saalik Hatia, Mesaac Makpangou, Sreeja Nair, Jonathan Sid-Otmane, Pierre Sens, Marc Shapiro, Ilyas Toumlilt, Dimitrios Vasilas.

### 5.2.1. Proving the safety of highly-available distributed objects

To provide high availability in distributed systems, object replicas allow concurrent updates. Although replicas eventually converge, they may diverge temporarily, for instance when the network fails. This makes it difficult for the developer to reason about the object's properties, and in particular, to prove invariants over its state. For the sub-class of state-based distributed systems, we propose a proof methodology for establishing that a given object maintains a given invariant, taking into account any concurrency control. Our approach allows reasoning about individual operations separately. We demonstrate that our rules are sound, and we illustrate their use with some representative examples. We automate the rule using Boogie, an SMT-based tool.

This work is accepted for publication at the 29th European Symposium on Programming (ESOP), April 2020, Dublin, Ireland [34]. Preliminary results were presented at the Workshop on Principles and Practice of Consistency for Distributed Data (PaPoC), March 2019, Dresden, Germany [29].

### 5.3. Resource management in system software

**Participants:** Jonathan Lejeune, Marc Shapiro, Julien Sopena, Francis Laniel.

#### 5.3.1. MemOpLight: Leveraging applicative feedback to improve container memory consolidation

The container mechanism supports consolidating several servers on the same machine, thus amortizing cost. To ensure performance isolation between containers, Linux relies on memory limits. However these limits are static, but application needs are dynamic; this results in poor performance. To solve this issue, MemOpLight reallocates memory to containers based on dynamic applicative feedback. MemOpLight rebalances physical memory allocation, in favor of under-performing ones, with the aim of improving overall performance. Our research explores the issues, addresses the design of MemOpLight, and validates it experimentally. Our approach increases total satisfaction by 13% compared to the default.

It is standard practice in Infrastructure as a Service to *consolidate* several logical servers on the same physical machine, thus amortizing cost. However, the execution of one logical server should not disturb the others: the logical servers should remain *isolated* from one another.

To ensure both consolidation and isolation, a recent approach is “containers,” a group of processes with sharing and isolation properties. To ensure *memory performance isolation*, *i.e.*, guaranteeing to each container enough memory for it to perform well, the administrator limits the total amount of physical memory that a container may use at the expense of others. In previous work, we showed that these limits impede memory consolidation [26]. Furthermore, the metrics available to the kernel to evaluate its policies (*e.g.*, frequency of page faults, I/O requests, use of CPU cycles, *etc.*), are not directly relevant to performance as experienced from the application perspective, which is better characterized by, for instance, response time or throughput measured at application level.

To solve these problems, we propose a new approach, called the Memory Optimization Light (MemOpLight). It is based on application-level feedback from containers. Our mechanism aims to rebalance memory allocation in favor of unsatisfied containers, while not penalizing the satisfied ones. By doing so, we guarantee application satisfaction, while consolidating memory; this also improves overall resource consumption.

Our main contributions are the following:

- An experimental demonstration of the limitations of the existing Linux mechanisms.
- The design of a simple feedback mechanism from application to the kernel.
- An algorithm for adapting container memory allocation.
- And implementation in Linux and experimental confirmation.

This work is currently under submission at a major conference. Some preliminary results are published at NCA 2019 [26].

## 6. Bilateral Contracts and Grants with Industry

### 6.1. Bilateral Contracts with Industry

DELYS has a CIFRE contract with Scality SA:

- Dimitrios Vasilas is advised by Marc Shapiro and Brad King. He works on secondary indexing in large-scale storage systems under weak consistency.

DELYS has three contracts with Orange within the I/O Lab joint laboratory:

- Guillaume Fraysse is advised by Jonathan Lejeune, Julien Sopena, and Pierre Sens. He works on distributed resources allocation in virtual network environments.
- Jonathan Sid-Otmane is advised by Marc Shapiro. He studies the applications of distributed databases to the needs of the telco industry in the context of 5G.
- José Alves Esteves Jurandir is advised by Pierre Sens. He works on network slice placement strategies.

## 7. Partnerships and Cooperations

### 7.1. National Initiatives

#### 7.1.1. ANR

##### 7.1.1.1. AdeCoDS (2019–2023)

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

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

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

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

##### 7.1.1.2. ESTATE - (2016–2021)

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

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

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

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

The coordinator of ESTATE is Franck Petit.

##### 7.1.1.3. RainbowFS - (2016–2020)

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

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

Objectives: RainbowFS proposes a “just-right” approach to storage and consistency, for developing distributed, cloud-scale applications. Existing approaches shoehorn the application design to some pre-defined consistency model, but no single model is appropriate for all uses. Instead, we propose tools to co-design the application and its consistency protocol. Our approach reconciles the conflicting requirements of availability and performance vs. safety: common-case operations are designed to be asynchronous; synchronisation is used only when strictly necessary to satisfy the application’s

integrity invariants. Furthermore, we deconstruct classical consistency models into orthogonal primitives that the developer can compose efficiently, and provide a number of tools for quick, efficient and correct cloud-scale deployment and execution. Using this methodology, we will develop an enterprise-grade, highly-scalable file system, exploring the rainbow of possible semantics, and we demonstrate it in a massive experiment.

The coordinator of RainbowFS is Marc Shapiro.

## 7.1.2. LABEX

### 7.1.2.1. SMART - (2012–2019)

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

Funding: Sorbonne Universités, ANR.

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

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

## 7.2. European Initiatives

### 7.2.1. FP7 & H2020 Projects

#### 7.2.1.1. LightKone

Title: Lightweight Computation for Networks at the Edge

Programm: H2020-ICT-2016-2017

Duration: January 2017 - December 2019

Coordinator: Université Catholique de Louvain

Partners:

Université Catholique de Louvain (Belgium)

Technische Universitaet Kaiserslautern (Germany)

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

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

Universitat Politecnica De Catalunya (Spain)

Scality (France)

Gluk Advice B.V. (Netherlands)

Inria contact: Marc Shapiro

The goal of LightKone is to develop a scientifically sound and industrially validated model for doing general-purpose computation on edge networks. An edge network consists of a large set of heterogeneous, loosely coupled computing nodes situated at the logical extreme of a network. Common examples are networks of Internet of Things, mobile devices, personal computers, and points of presence including Mobile Edge Computing. Internet applications are increasingly running on edge networks, to reduce latency, increase scalability, resilience, and security, and permit local decision making. However, today’s state of the art, the gossip and peer-to-peer models, give no solution for defining general-purpose computations on edge networks, i.e., computation with shared

mutable state. LightKone will solve this problem by combining two recent advances in distributed computing, namely synchronisation-free programming and hybrid gossip algorithms, both of which are successfully used separately in industry. Together, they are a natural combination for edge computing. We will cover edge networks both with and without data center nodes, and applications focused on collaboration, computation, and both. Project results will be new programming models and algorithms that advance scientific understanding, implemented in new industrial applications and a startup company, and evaluated in large-scale realistic settings.

## 7.3. International Initiatives

### 7.3.1. Participation in Other International Programs

#### 7.3.1.1. Spanish research ministry project

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

French Partners: Labri, Irisa, LIP6

International Partners (Institution - Laboratory - Researcher):

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

Duration: 2017–2019

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

#### 7.3.1.2. Spanish research ministry project

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

French Partners: Labri, Irisa, LIP6

International Partners (Institution - Laboratory - Researcher):

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

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

#### 7.3.1.3. STIC Amsud

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

International Partners (Institution - Laboratory - Researcher):

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

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

Universidad de la Republica (Uruguay)

Duration: 2019 - 2020

Start year: 2019

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

## 7.4. International Research Visitors

### 7.4.1. Visits of International Scientists

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

### 7.4.2. Visits to International Teams

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

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

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

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

## 8. Dissemination

### 8.1. Promoting Scientific Activities

#### 8.1.1. Scientific Events: Organisation

##### 8.1.1.1. Chair of Conference Steering Committees

- Marc Shapiro is a member of the steering committee of the yearly Workshop on Principles and Practice of Consistency (PaPoC), co-located with EuroSys.

#### 8.1.2. Scientific Events: Selection

##### 8.1.2.1. Member of the Conference Program Committees

Marc Shapiro, member of PC of the European Conference on Computer Systems (EuroSys) 2020, in Heraklion (Greece).

Marc Shapiro, member of PC of the European Conference on Computer Systems (EuroSys) 2019, in Dresden (Germany).

Marc Shapiro, member of Programme Committed of the ACM Symposium on Principles of Distributed Computing (PODC) 2019, in Salerno, Italy.

Marc Shapiro, member of the PC of the Workshop on Planetary-Scale Distributed Systems (W-PSDS) 2019, in Lyon.

Marc Shapiro, member of the Technical Program Committee of the Workshop on Advanced tools, programming languages, and PLatforms for Implementing and Evaluating algorithms for Distributed systems (ApPLIED) 2019, in Budapest, Hungary.

Pierre Sens, 29th International Symposium on Software Reliability Engineering (ISSRE 2019), 19th IEEE International Symposium on Network Computing and Applications (NCA 2019), 38th IEEE International Symposium on Reliable Distributed Systems (SRDS 2019), Gestion de Données – Principes, Technologies et Applications (BDA 2019).

Swan Dubois, 21st International Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS 2019), 21èmes Rencontres Francophones pour les Aspects Algorithmiques des Télécommunications (AlgoTel'18).

Jonathan Lejeune, 22nd Innovation in Clouds, Internet and Networks (ICIN 2019)

#### 8.1.2.2. Reviewer

Swan Dubois, 26th International Colloquium on Structural Information and Communication Complexity (SIROCCO'19).

### 8.1.3. Journal

#### 8.1.3.1. Member of the Editorial Boards

Pierre Sens, International Journal of High Performance Computing and Networking (IJHPCN)

#### 8.1.3.2. Reviewer - Reviewing Activities

Swan Dubois, Distributed Computing, Theoretical Computer Science.

Luciana Arantes, Journal of Parallel and Distributed Computing.

Pierre Sens, Journal of Parallel and Distributed Computing

### 8.1.4. Invited Talks

Marc Shapiro gave the keynote presentation titled “Living on the edge, safely; or: Life without consensus” at the 7th International Conference on Networked Systems, in Marrakech, Morocco, June 2019.

Marc Shapiro gave an invited talk on “The programming continuum, from core to edge,” at the Workshop on Verification of Distributed Systems (VDS), June 2019, Marrakech, Morocco.

Marc Shapiro gave two invited talks at the Dagstuhl Seminar on “Programming Languages for Distributed Systems and Distributed Data Management,” October 2019.

Marc Shapiro was invited to speak about “Living Without Consensus,” at the seminar “Taking Stock of Distributed Computing,” at Collège de France, April 2019. The seminar was organised in conjunction with the *Chaire informatique et sciences numériques* of Rachid Guerraoui.

Pierre Sens, *Probabilistic Byzantine Tolerance Scheduling in Hybrid Cloud Environments*. Research Seminar, University of Fluminense, Brazil, October 2019

Pierre Sens, *Fault tolerance in large and dynamic distributed systems*. Research Seminar, University of Fluminense, Brazil, October 2019

Luciana Arabtes, *A Communication-Efficient Causal Broadcast Protocol*. Research Seminar, University of Fluminense, PUC-Rio, Brazil, October 2019

### 8.1.5. Leadership within the Scientific Community

- Marc Shapiro is Vice-Chair for Research of Société informatique de France, the French learned society in Informatics.



### 8.1.6. Research Administration

Pierre Sens, since 2016: Member of Section 6 of the national committee for scientific research CoNRS

Franck Petit, Pierre Sens, since 2012: Member of the Executive Committee of Labex SMART, Co-Chairs of Track 4, Autonomic Distributed Environments for Mobility.

## 8.2. Teaching - Supervision - Juries

### 8.2.1. Teaching

Julien Sopena is Member of “Directoire des formations et de l’insertion professionnelle” of Sorbonne Université, France

Master: Julien Sopena is responsible of Computer Science Master’s degree in Distributed systems and applications (in French, SAR), Sorbonne Universités, France

Master: Luciana Arantes, Swan Dubois, Jonathan Lejeune, Franck Petit, Pierre Sens, Julien Sopena, Advanced distributed algorithms, M2, Sorbonne Université, France

Master: Jonathan Lejeune, Designing Large-Scale Distributed Applications, M2, Sorbonne Université, France

Master: Maxime Lorrillere, Julien Sopena, Linux Kernel Programming, M1, Sorbonne Université, France

Master: Luciana Arantes, Swan Dubois, Jonathan Lejeune, Pierre Sens, Julien Sopena, Operating systems kernel, M1, Sorbonne Université, France

Master: Luciana Arantes, Swan Dubois, Franck Petit, Distributed Algorithms, M1, Sorbonne Université, France

Master: Franck Petit, Autonomic Networks, M2, Sorbonne Université, France

Master: Franck Petit, Distributed Algorithms for Networks, M1, Sorbonne Université, France

Master: Jonathan Lejeune, Julien Sopena, Client-server distributed systems, M1, Sorbonne Université, France.

Master: Julien Sopena, Marc Shapiro, Ilyas Toumlilt, Francis Laniel. Kernels and virtual machines (*Noyaux et machines virtuelles*, NMV), M2, Sorbonne Université, France.

Licence: Pierre Sens, Luciana Arantes, Julien Sopena, Principles of operating systems, L3, Sorbonne Université, France

Licence: Swan Dubois, Initiation to operating systems, L3, Sorbonne Université, France

Licence: Swan Dubois, Multi-threaded Programming, L3, Sorbonne Université, France

Licence: Jonathan Lejeune, Oriented-Object Programming, L3, Sorbonne Université, France

Licence: Franck Petit, Advanced C Programming, L2, Sorbonne Université, France

Licence: Swan Dubois, Jonathan Lejeune, Julien Sopena, Introduction to operating systems, L2, Sorbonne Université, France

Licence: Mesaac Makpangou, C Programming Language, 27 h, L2, Sorbonne Université, France

Ingénieur 4ème année : Marc Shapiro, Introduction aux systèmes d’exploitation, 26 h, M1, Polytech Sorbonne Université, France.

Licence : Philippe Darche (coordinator), Architecture of Internet of Things (IoT), 2 × 32h, L3, Institut Universitaire Technologique (IUT) Paris Descartes, France.

Engineering School: Philippe Darche (coordinator), Solid-State Memories, 4th year, ESIEE, France.

DUT: Philippe Darche (coordinator), Introduction to Computer Systems - Data representation, 60h, Institut Universitaire Technologique (IUT) Paris Descartes, France.

DUT: Philippe Darche (coordinator), Computer Architecture, 32h, Institut Universitaire Technologique (IUT) Paris Descartes, France.

DUT: Philippe Darche (coordinator), Computer Systems Programming, 80h, Institut Universitaire Technologique (IUT) Paris Descartes, France.

### 8.2.2. Supervision

PhD: João Paulo de Araujo, “L’exécution efficace d’algorithmes distribués dans les réseaux véhiculaires”, funded by CNPq (Brésil), Sorbonne Univ, Apr. 2019. Advised by Pierre Sens and Luciana Arantes.

PhD: Sébastien Bouchard, “Gathering with faulty robots”, Sorbonne Univ., Sep. 2019. Advised by Swan Dubois, Franck Petit, Yoann Dieudonné (University of Picardy Jules Verne)

PhD: Marjorie Bournat, “Speculation and Graceful Degradability for Robots in Highly Dynamic Environments”, Sorbonne Univ., Jun. 2019. Advised by Swan Dubois, Franck Petit, Yoann Dieudonné (University of Picardy Jules Verne)

PhD: Damien Carver, “HACHE : Horizontal Cache cHorEgraphy - Toward automatic resizing of shared I/O caches.”, Sorbonne Univ., May 2019. Advised by Sébastien Monnet, Julien Sopena, Dimitri Refauvelet (Magency).

CIFRE PhD in progress: José Alves Esteves, “Adaptation dynamique en environnements répartis contraints”, Sorbonne Univ., since Sep. 2019. Advised by Pierre Sens and Amina Boubendir Orange Labs.

PhD in progress: Arnaud Favier, “Algorithmes de coordination répartis dans des réseaux dynamiques”, Sorbonne Univ., since Sep. 2018. Advised by Pierre Sens and Luciana Arantes.

PhD in progress: Saalik Hatia, “Efficient management of memory and storage for CRDTs”, Sorbonne Univ., since Oct. 2018. Advised by Marc Shapiro.

CIFRE PhD in progress: Guillaume Fraysse, Orange Lab - Inria, “Ubiquitous Resources for Service Availability”, since Jul. 2017. Advised by Pierre Sens, Imen Grida Ben Yahia (Orange-Lab) , Jonathan Lejeune, Julien Sopena.

PhD in progress: Francis Laniel, “Vers une utilisation efficace de la mémoire non volatile pour économiser l’énergie.” Sorbonne Univ., since Sept. 2017. Advised by Marc Shapiro, Julien Sopena, Jonathan Lejeune.

PhD in progress: Gabriel Le Boudier, “Autonomic synchronization”, Sorbonne Univ., since Sep. 2019. Advised by Franck Petit.

PhD in progress: Benoît Martin, “Protocol de cohérence hybride: de la cohérence causal à la cohérence forte”, Sorbonne Univ., since Sep. 2019. Advised by Mesaac Makpangou and Marc Shapiro.

PhD in progress: Sreeja Nair, “Just-Right Consistency for massive geo-replicated storage”, Sorbonne Univ., since Apr. 2018. Advised by Marc Shapiro.

PhD in progress: Laurent Prosper, “Abstractions, langage et runtime pour les systèmes distribués”, Sorbonne Univ., since Sep. 2019. Advised by Marc Shapiro.

CIFRE PhD in progress: Jonathan Sid-Otmane. “Étude des critères de distribution et de l’usage d’une base de données distribuée pour un OS Telco”, since Dec. 2017. Advised by Marc Shapiro, with Sofiane Imadali and Frédéric Martelli, Orange Labs.

PhD in progress: Ilyas Toumlilt, “Bridging the CAP gap, all the way to the edge”, Sorbonne Univ., since Sep. 2016. Advised by Marc Shapiro.

CIFRE PhD in progress: Dimitrios Vasilas, “Indexing in large-scale storage systems”, Sorbonne Univ., since Sep. 2016. Advised by Marc Shapiro, with Brad King, Scalify.

PhD in progress: Daniel Wladdimiro, “Adaptation dynamique en environnements répartis contraints”, Sorbonne Univ., since Sep. 2019. Advised by Pierre Sens and Luciana Arantes.

PhD in progress: Daniel Wilhelm, “Algorithmes de diffusion causale dans les systèmes répartis dynamique”, Sorbonne Univ., since Oct. 2019, Pierre Sens and Luciana Arantes.

### 8.2.3. *Juries*

Franck Petit was the reviewer of:

- David Ilcinkas, HDR, LaBRI, Bordeaux

Pierre Sens was the reviewer of:

- Heithem Abbes, HDR, LIPN, Villetaneuse
- Xavier Etchevers, HDR, LIG, Univ. Grenoble
- Nicolas Aussel, PhD, SAMOVAR, Telecom Sud Paris
- Paul Chaignon, PhD, LORIA, Nancy
- Jad Darrous, PhD, LIP, ENS-Lyon
- Umar Ozeer, PhD, LIG, Univ. Grenoble
- Bharati Sinha, PhD, National Institute of Technology Kurukshetra, India
- Amir Teshome Wonjiga, PhD, IRISA, Rennes

Pierre Sens was Chair of

- Julien Loudet, PhD, DAVID, UVSQ
- Asma Berriri, PhD, SAMOVAR, Telecom Sud Paris

Marc Shapiro was a reviewer for the CSD (mid-thesis committee) for Khaled Zaouk, PhD student of Yanlei Diao at École Polytechnique.

## 8.3. Popularization

### 8.3.1. *Articles and contents*

- Swan Dubois and Franck Petit coauthored the book entitled “*Introduction to Distributed Self-Stabilizing Algorithms*” [35], that aims at being a comprehensive and pedagogical introduction to the concept of *self-stabilization*.
- Marc Shapiro co-authored two entries for the Encyclopedia of Big Data Technologies (published by Springer, 2019):
  - “Database Consistency Models” [38].
  - “Conflict-Free Replicated Data Types CRDTs” [37].
- Marc Shapiro contributed the post “Living at the edge, safely” to the LightKone blog [6].

## 9. Bibliography

### Major publications by the team in recent years

- [1] V. BALEGAS, N. PREGUIÇA, R. RODRIGUES, S. DUARTE, C. FERREIRA, M. NAJAFZADEH, M. SHAPIRO. *Putting Consistency back into Eventual Consistency*, in "Euro. Conf. on Comp. Sys. (EuroSys)", Bordeaux, France, April 2015, pp. 6:1–6:16, <https://doi.org/10.1145/2741948.2741972>
- [2] L. GIDRA, G. THOMAS, J. SOPENA, M. SHAPIRO, N. NGUYEN. *NumaGiC: a garbage collector for big data on big NUMA machines*, in "Int. Conf. on Archi. Support for Prog. Lang. and Systems (ASPLOS)", Istanbul, Turkey, Assoc. for Computing Machinery, March 2015, pp. 661–673, <http://dx.doi.org/10.1145/2694344.2694361>

- [3] A. GOTSMAN, H. YANG, C. FERREIRA, M. NAJAFZADEH, M. SHAPIRO. *'Cause I'm Strong Enough: Reasoning about Consistency Choices in Distributed Systems*, in "Symp. on Principles of Prog. Lang. (POPL)", St. Petersburg, FL, USA, 2016, pp. 371–384, <http://dx.doi.org/10.1145/2837614.2837625>
- [4] J. PEETERS, N. VENTROUX, T. SASSOLAS, M. SHAPIRO. *Distributing computing system implementing a non-speculative hardware transactional memory and a method for using same for distributed computing*, United States Patent and Trademark Office (USPTO), September 2019, n<sup>o</sup> US 10 416 925 B2
- [5] M. SHAPIRO, N. PREGUIÇA, C. BAQUERO, M. ZAWIRSKI. *Conflict-free Replicated Data Types*, in "Int. Symp. on Stabilization, Safety, and Security of Dist. Sys. (SSS)", Grenoble, France, X. DÉFAGO, F. PETIT, V. VILLAIN (editors), Lecture Notes in Comp. Sc., Springer-Verlag, October 2011, vol. 6976, pp. 386–400, [http://lip6.fr/Marc.Shapiro/papers/CRDTs\\_SSS-2011.pdf](http://lip6.fr/Marc.Shapiro/papers/CRDTs_SSS-2011.pdf)
- [6] M. SHAPIRO. *Living at the edge, safely*, LightKone European Project, May 2019
- [7] *Best Paper*  
A. Z. TOMSIC. *Exploring the design space of highly-available distributed transactions*, Université Pierre et Marie Curie, Paris, France, April 2018.

- [8] M. ZAWIRSKI, N. PREGUIÇA, S. DUARTE, A. BIENIUSA, V. BALEGAS, M. SHAPIRO. *Write Fast, Read in the Past: Causal Consistency for Client-side Applications*, in "Int. Conf. on Middleware (MIDDLEWARE)", Vancouver, BC, Canada, ACM/IFIP/Usenix, December 2015, pp. 75–87

## Publications of the year

### Doctoral Dissertations and Habilitation Theses

- [9] S. BOUCHARD. *On the Deterministic Gathering of Mobile Agents*, Sorbonne Université, September 2019, <https://tel.archives-ouvertes.fr/tel-02320156>
- [10] M. BOURNAT. *Graceful Degradation and Speculation for Robots in Highly Dynamic Environments*, Sorbonne Université, June 2019, <https://hal.inria.fr/tel-02177304>
- [11] D. CARVER. *Advanced Consolidation for Dynamic Containers*, EDITE de Paris, May 2019, <https://tel.archives-ouvertes.fr/tel-02393773>
- [12] J. P. DE ARAUJO. *A communication-efficient causal broadcast publish/subscribe system*, Sorbonne Université ; LIP6 - Laboratoire d'Informatique de Paris 6, April 2019, <https://tel.archives-ouvertes.fr/tel-02105743>

### Articles in International Peer-Reviewed Journals

- [13] K. ALTISEN, S. DEVISMES, A. DURAND, F. PETIT. *Gradual stabilization*, in "Journal of Parallel and Distributed Computing", January 2019, vol. 123, pp. 26-45 [DOI : 10.1016/J.JPDC.2018.09.002], <https://hal.archives-ouvertes.fr/hal-02420362>
- [14] S. BOUCHARD, M. BOURNAT, Y. DIEUDONNÉ, S. DUBOIS, F. PETIT. *Asynchronous approach in the plane: a deterministic polynomial algorithm*, in "Distributed Computing", August 2019, vol. 32, n<sup>o</sup> 4, pp. 317-337 [DOI : 10.1007/s00446-018-0338-2], <https://hal.inria.fr/hal-02413273>

- [15] M. BOURNAT, A. K. DATTA, S. DUBOIS. *Self-stabilizing robots in highly dynamic environments*, in "Theoretical Computer Science", June 2019, vol. 772, pp. 88-110 [DOI : 10.1016/j.tcs.2018.11.026], <https://hal.inria.fr/hal-02413327>
- [16] A. CASTEIGTS, S. DUBOIS, F. PETIT, J. ROBSON. *Robustness: A new form of heredity motivated by dynamic networks*, in "Theoretical Computer Science", August 2019 [DOI : 10.1016/j.tcs.2019.08.008], <https://hal.archives-ouvertes.fr/hal-02420608>
- [17] S. DEVISMES, A. LAMANI, F. PETIT, S. TIXEUIL. *Optimal torus exploration by oblivious robots*, in "Computing", September 2019, vol. 101, n<sup>o</sup> 9, pp. 1241-1264 [DOI : 10.1007/s00607-018-0595-8], <https://hal.archives-ouvertes.fr/hal-02420598>
- [18] Y. DIEUDONNÉ, S. DOLEV, F. PETIT, M. SEGAL. *Explicit Communication Among Stigmergic Robots*, in "International Journal of Foundations of Computer Science", March 2019, vol. 30, n<sup>o</sup> 02, pp. 315-332 [DOI : 10.1142/S0129054119500072], <https://hal.archives-ouvertes.fr/hal-02420394>
- [19] S. DUBOIS, R. GUERRAOU, P. KUZNETSOV, F. PETIT, P. SENS. *The weakest failure detector for eventual consistency*, in "Distributed Computing", December 2019, vol. 32, n<sup>o</sup> 6, pp. 479-492 [DOI : 10.1007/s00446-016-0292-9], <https://hal.inria.fr/hal-02413314>
- [20] M. S. MOSLI BOUSIAA, F. TRAHAY, A. LESCOUET, G. VORON, R. DULONG, A. GUERMOUCHE, E. BRUNET, G. THOMAS. *Using differential execution analysis to identify thread interference*, in "IEEE Transactions on Parallel and Distributed Systems", December 2019, vol. 30, n<sup>o</sup> 12, pp. 2866-2878 [DOI : 10.1109/TPDS.2019.2927481], <https://hal.archives-ouvertes.fr/hal-02179717>

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- [21] K. ALTISEN, S. DEVISMES, A. DURAND. *Silence dans la forêt !*, in "ALGOTEL 2019 - 21èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Saint Laurent de la Cabrerisse, France, June 2019, <https://hal.archives-ouvertes.fr/hal-02118549>
- [22] S. BOUCHARD, Y. DIEUDONNÉ, A. PELC, F. PETIT. *Trouver un trésor plus rapidement avec des conseils angulaires*, in "ALGOTEL 2019 - 21èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Saint Laurent de la Cabrerisse, France, June 2019, <https://hal.inria.fr/hal-02118362>
- [23] D. CARVER, R. GOUCEM, J.-P. LOZI, J. SOPENA, B. LEPERS, W. ZWAENPOEL, N. PALIX, J. L. LAWALL, G. MULLER. *Fork/Wait and Multicore Frequency Scaling: a Generational Clash*, in "10th Workshop on Programming Languages and Operating Systems", Huntsville, Canada, ACM Press, October 2019, pp. 53-59 [DOI : 10.1145/3365137.3365400], <https://hal.inria.fr/hal-02349987>
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- [27] L. LE FRIOUX, S. BAARIR, J. SOPENA, F. KORDON. *Modular and Efficient Divide-and-Conquer SAT Solver on Top of the Painless Framework*, in "TACAS 2019 - 25th International Conference on Tools and Algorithms for the Construction and Analysis of Systems", Prague, Czech Republic, T. VOJNAR, L. ZHANG (editors), Lecture Notes in Computer Science, April 2019, vol. 11427, pp. 135-151 [DOI : 10.1007/978-3-030-17462-0\_8], <https://hal.archives-ouvertes.fr/hal-02093520>
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E. MAUFFRET, D. JEANNEAU, L. ARANTES, P. SENS. *The Weakest Failure Detector to Solve the Mutual Exclusion Problem in an Unknown Dynamic Environment*, in "20th International Conference on Distributed Computing and Networking (ICDCN 2019)", Bangalore, India, January 2019, Extended version: <https://hal.archives-ouvertes.fr/hal-01661127v3>, <https://hal.archives-ouvertes.fr/hal-01929224>.
- [29] S. S. NAIR, G. PETRI, M. SHAPIRO. *Invariant Safety for Distributed Applications*, in "Workshop on Principles and Practice of Consistency for Distributed Data (PaPoC)", Dresden, Germany, Workshop on Principles and Practice of Consistency for Distributed Data (PaPoC), March 2019, <https://arxiv.org/abs/1903.02759>, <https://hal.inria.fr/hal-02052012>
- [30] L. TEYLO, L. ARANTES, P. SENS, L. M. DE A. DRUMMOND. *A Hibernation Aware Dynamic Scheduler for Cloud Environments*, in "ICCP 2019 - 48th International Conference on Parallel Processing - Workshop", Kyoto, Japan, ACM Press, August 2019, pp. 1-10 [DOI : 10.1145/3339186.3339205], <https://hal.inria.fr/hal-02391614>
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