IN PARTNERSHIP WITH:
CNRS

Ecole normale supérieure de Lyon

Université Claude Bernard (Lyon 1)

Activity Report 2017

Project-Team AVALON

Algorithms and Software Architectures for Distributed and HPC Platforms

IN COLLABORATION WITH: Laboratoire de l'Informatique du Parallélisme (LIP)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Distributed and High Performance Computing

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Creation of the Team: 2012 February 01, updated into Project-Team: 2014 July 01

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1. Personnel

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2. Overall Objectives

2.1. Presentation

The fast evolution of hardware capabilities in terms of wide area communication, computation and machine virtualization leads to the requirement of another step in the abstraction of resources with respect to parallel and distributed applications. These large scale platforms based on the aggregation of large clusters (Grids), huge datacenters (Clouds), collections of volunteer PCs (Desktop computing platforms), or high performance machines (Supercomputers) are now available to researchers of different fields of science as well as to private companies. This variety of platforms and the way they are accessed also have an important impact on how applications are designed (*i.e.,* the programming model used) as well as how applications are executed (*i.e.,* the runtime/middleware system used). The access to these platforms is driven through the use of multiple services providing mandatory features such as security, resource discovery, virtualization, load-balancing, monitoring, etc.

The goal of the Avalon team is to execute parallel and/or distributed applications on parallel and/or distributed resources while ensuring user and system objectives with respect to performance, cost, energy, security, etc. Users are not interested in the resources used during the execution. Instead, they are interested in how their application is going to be executed: in which duration, at which cost, what is the environmental footprint involved, etc. This vision of utility computing has been strengthened by the cloud concepts and by the short lifespan of supercomputers (around three years) compared to application lifespan (tens of years). Therefore, a major issue is to design models, systems, and algorithms to execute applications on resources while ensuring user constraints (price, performance, etc.) as well as system administrator constraints (maximizing resource usage, minimizing energy consumption, etc.).

2.2. Objectives

To achieve the vision proposed in Section 2.1, the Avalon project aims at making progress to four complementary research axes: energy, data, component models, and application scheduling.

2.2.1. Energy Application Profiling and Modeling

Avalon will improve the profiling and modeling of scientific applications with respect to energy consumption. In particular, it will require to improve the tools that measure the energy consumption of applications, virtualized or not, at large scale, so as to build energy consumption models of applications.

2.2.2. Data-intensive Application Profiling, Modeling, and Management

Avalon will improve the profiling, modeling, and management of scientific applications with respect to CPU and data intensive applications. The challenges are to improve the performance prediction of parallel regular applications, to model and simulate (complex) intermediate storage components, and data-intensive applications, and last to deal with data management for hybrid computing infrastructures.

2.2.3. Resource-Agnostic Application Description Model

Avalon will design component-based models to capture the different facets of parallel and distributed applications while being resource agnostic, so that they can be optimized for a particular execution. In particular, the proposed component models will integrate energy and data modeling results. Avalon in particular targets OpenMP runtime as a specific use case.

2.2.4. Application Mapping and Scheduling

Avalon will propose multi-criteria mapping and scheduling algorithms to meet the challenge of automating the efficient utilization of resources taking into consideration criteria such as performance (CPU, network, and storage), energy consumption, and security. Avalon will in particular focus on application deployment, workflow applications, and security management in clouds.

All our theoretical results will be validated with software prototypes using applications from different fields of science such as bioinformatics, physics, cosmology, etc. The experimental testbed GRID'5000 (cf Section 5.8) will be our platform of choice for experiments.

3. Research Program

3.1. Energy Application Profiling and Modeling

Despite recent improvements, there is still a long road to follow in order to obtain energy efficient, energy proportional and eco-responsible exascale systems by 2022. Energy efficiency is therefore a major challenge for building next generation large-scale platforms. The targeted platforms will gather hundreds of millions of cores, low power servers, or CPUs. Besides being very important, their power consumption will be dynamic and irregular.

Thus, to consume energy efficiently, we aim at investigating two research directions. First, we need to improve measurement, understanding, and analysis on how large-scale platforms consume energy. Unlike approaches [34] that mix the usage of internal and external wattmeters on a small set of resources, we target high frequency and precise internal and external energy measurements of each physical and virtual resource on large-scale distributed systems.

Secondly, we need to find new mechanisms that consume less and better on such platforms. Combined with hardware optimizations, several works based on shutdown or slowdown approaches aim at reducing energy consumption of distributed platforms and applications. To consume less, we first plan to explore the provision of accurate estimation of the energy consumed by applications without pre-executing and knowing them while most of the works try to do it based on in-depth application knowledge (code instrumentation [37], phase detection for specific HPC applications [42], etc.). As a second step, we aim at designing a framework model that allows interaction, dialogue and decisions taken in cooperation among the user/application, the administrator, the resource manager, and the energy supplier. While smart grid is one of the last killer scenarios for networks, electrical provisioning of next generation large IT infrastructures remains a challenge.

3.2. Data-intensive Application Profiling, Modeling, and Management

Recently, the term "Big Data" has emerged to design data sets or collections so large that they become intractable for classical tools. This term is most time implicitly linked to "analytics" to refer to issues such as data curation, storage, search, sharing, analysis, and visualization. However, the Big Data challenge is not limited to data-analytics, a field that is well covered by programming languages and run-time systems such as Map-Reduce. It also encompasses data-intensive applications. These applications can be sorted into two categories. In High Performance Computing (HPC), data-intensive applications leverage post-petascale infrastructures to perform highly parallel computations on large amount of data, while in High Throughput Computing (HTC), a large amount of independent and sequential computations are performed on huge data collections.

These two types of data-intensive applications (HTC and HPC) raise challenges related to profiling and modeling that the Avalon team proposes to address. While the characteristics of data-intensive applications are very different, our work will remain coherent and focused. Indeed, a common goal will be to acquire a better understanding of both the applications and the underlying infrastructures running them to propose the best match between application requirements and infrastructure capacities. To achieve this objective, we will extensively rely on logging and profiling in order to design sound, accurate, and validated models. Then, the proposed models will be integrated and consolidated within a single simulation framework (SIMGRID). This will allow us to explore various potential "what-if?" scenarios and offer objective indicators to select interesting infrastructure configurations that match application specificities.

Another challenge is the ability to mix several heterogeneous infrastructures that scientists have at their disposal (*e.g.,* Grids, Clouds, and Desktop Grids) to execute data-intensive applications. Leveraging the aforementioned results, we will design strategies for efficient data management service for hybrid computing infrastructures.

3.3. Resource-Agnostic Application Description Model

With parallel programming, users expect to obtain performance improvement, regardless its cost. For long, parallel machines have been simple enough to let a user program them given a minimal abstraction of their hardware. For example, MPI [36] exposes the number of nodes but hides the complexity of network topology behind a set of collective operations; OpenMP [40] simplifies the management of threads on top of a shared memory machine while OpenACC [39] aims at simplifying the use of GPGPU.

However, machines and applications are getting more and more complex so that the cost of manually handling an application is becoming very high [35]. Hardware complexity also stems from the unclear path towards next generations of hardware coming from the frequency wall: multi-core CPU, many-core CPU, GPGPUs, deep memory hierarchy, etc. have a strong impact on parallel algorithms. Hence, even though an abstract enough parallel language (UPC, Fortress, X10, etc.) succeeds, it will still face the challenge of supporting distinct codes corresponding to different algorithms corresponding to distinct hardware capacities.

Therefore, the challenge we aim to address is to define a model, for describing the structure of parallel and distributed applications that enables code variations but also efficient executions on parallel and distributed infrastructures. Indeed, this issue appears for HPC applications but also for cloud oriented applications. The challenge is to adapt an application to user constraints such as performance, energy, security, etc.

Our approach is to consider component based models [43] as they offer the ability to manipulate the software architecture of an application. To achieve our goal, we consider a “compilation” approach that transforms a resource-agnostic application description into a resource-specific description. The challenge is thus to determine a component based model that enables to efficiently compute application mapping while being tractable. In particular, it has to provide an efficient support with respect to application and resource elasticity, energy consumption and data management. OpenMP runtime is a specific use case that we target.

3.4. Application Mapping and Scheduling

This research axis is at the crossroad of the Avalon team. In particular, it gathers results of the three other research axis. We plan to consider application mapping and scheduling addressing the following three issues.

3.4.1. Application Mapping and Software Deployment

Application mapping and software deployment consist in the process of assigning distributed pieces of software to a set of resources. Resources can be selected according to different criteria such as performance, cost, energy consumption, security management, etc. A first issue is to select resources at application launch time. With the wide adoption of elastic platforms, *i.e.,* platforms that let the number of resources allocated to an application to be increased or decreased during its execution, the issue is also to handle resource selection at runtime.

The challenge in this context corresponds to the mapping of applications onto distributed resources. It will consist in designing algorithms that in particular take into consideration application profiling, modeling, and description.

A particular facet of this challenge is to propose scheduling algorithms for dynamic and elastic platforms. As the number of elements can vary, some kind of control of the platforms must be used accordingly to the scheduling.

3.4.2. Non-Deterministic Workflow Scheduling

Many scientific applications are described through workflow structures. Due to the increasing level of parallelism offered by modern computing infrastructures, workflow applications now have to be composed not only of sequential programs, but also of parallel ones. New applications are now built upon workflows with conditionals and loops (also called non-deterministic workflows).

These workflows cannot be scheduled beforehand. Moreover cloud platforms bring on-demand resource provisioning and pay-as-you-go billing models. Therefore, there is a problem of resource allocation for non-deterministic workflows under budget constraints and using such an elastic management of resources.

Another important issue is data management. We need to schedule the data movements and replications while taking job scheduling into account. If possible, data management and job scheduling should be done at the same time in a closely coupled interaction.

3.4.3. Security Management in Cloud Infrastructure

Security has been proven to be sometimes difficult to obtain [41] and several issues have been raised in Clouds. Nowadays virtualization is used as the sole mechanism to allow multiple users to share resources on Clouds, but since not all components of Clouds (such as micro-architectural components) can be properly virtualized, data leak and modification can occur. Accordingly, next-generation protection mechanisms are required to enforce security on Clouds and provide a way to cope with the current limitation of virtualization mechanisms.

As we are dealing with parallel and distributed applications, security mechanisms must be able to cope with multiple machines. Our approach is to combine a set of existing and novel security mechanisms that are spread in the different layers and components of Clouds in order to provide an in-depth and end-to-end security on Clouds. To do it, our first challenge is to define a generic model to express security policies.

Our second challenge is to work on security-aware resource allocation algorithms. The goal of such algorithms is to find a good trade-off between security and unshared resources. Consequently, they can limit resources sharing to increase security. It leads to complex trade-off between infrastructure consolidation, performance, and security.

4. Application Domains

4.1. Overview

The Avalon team targets applications with large computing and/or data storage needs, which are still difficult to program, maintain, and deploy. Those applications can be parallel and/or distributed applications, such as large scale simulation applications or code coupling applications. Applications can also be workflow-based as commonly found in distributed systems such as grids or clouds.

The team aims at not being restricted to a particular application field, thus avoiding any spotlight. The team targets different HPC and distributed application fields, which bring use cases with different issues. This will be eased by our various collaborations: the team participates to the INRIA-Illinois Joint Laboratory for Petascale Computing, the Physics, Radiobiology, Medical Imaging, and Simulation French laboratory of excellence, the E-Biothon project, the INRIA large scale initiative Computer and Computational Sciences at Exascale (C2S@Exa), and to BioSyL, a federative research structure about Systems Biology of the University of Lyon. Moreover, the team members have a long tradition of cooperation with application developers such as CERFACS and EDF R&D. Last but not least, the team has a privileged connection with CC IN2P3 that opens up collaborations, in particular in the astrophysics field.

In the following, some examples of representative applications we are targeting are presented. In addition to highlighting some application needs, they also constitute some of the use cases we will use to valide our theoretical results.

4.2. Climatology

The world's climate is currently changing due to the increase of the greenhouse gases in the atmosphere. Climate fluctuations are forecasted for the years to come. For a proper study of the incoming changes, numerical simulations are needed, using general circulation models of a climate system. Simulations can be of different types: HPC applications (*e.g.,* the NEMO framework [38] for ocean modelization), code-coupling applications (*e.g.,* the OASIS coupler [44] for global climate modeling), or workflows (long term global climate modeling).

As for most applications the team is targeting, the challenge is to thoroughly analyze climate-forecasting applications to model their needs in terms of programing model, execution model, energy consumption, data access pattern, and computing needs. Once a proper model of an application has been set up, appropriate scheduling heuristics could be designed, tested, and compared. The team has a long tradition of working with CERFACS on this topic, for example in the LEGO (2006-09) and SPADES (2009-12) French ANR projects.

4.3. Astrophysics

Astrophysics is a major field to produce large volumes of data. For instance, the Large Synoptic Survey Telescope (http://www.lsst.org/lsst/) will produce 15 TB of data every night, with the goals of discovering thousands of exoplanets and of uncovering the nature of dark matter and dark energy in the universe. The Square Kilometer Array (http://www.skatelescope.org/) produces 9 Tbits/s of raw data. One of the scientific projects related to this instrument called Evolutionary Map of the Universe is working on more than 100 TB of images. The Euclid Imaging Consortium (https://www.euclid-ec.org/) will generate 1 PB data per year.

Avalon collaborates with the *Institut de Physique Nucléaire de Lyon* (IPNL) laboratory on large scale numerical simulations in astronomy and astrophysics. Contributions of the Avalon members have been related to algorithmic skeletons to demonstrate large scale connectivity, the development of procedures for the generation of realistic mock catalogs, and the development of a web interface to launch large cosmological simulations on GRID'5000.

This collaboration, that continues around the topics addressed by the CLUES project (http://www.clues-project.org), has been extended thanks to the tight links with the CC-IN2P3. Major astrophysics projects execute part of their computing, and store part of their data on the resources provided by the CC-IN2P3. Among them, we can mention SNFactory, Euclid, or LSST. These applications constitute typical use cases for the research developed in the Avalon team: they are generally structured as workflows and a huge amount of data (from TB to PB) is involved.

4.4. Bioinformatics

Large-scale data management is certainly one of the most important applications of distributed systems in the future. Bioinformatics is a field producing such kinds of applications. For example, DNA sequencing applications make use of MapReduce skeletons.

The Avalon team is a member of BioSyL (http://www.biosyl.org), a Federative Research Structure attached to University of Lyon. It gathers about 50 local research teams working on systems biology. Moreover, the team cooperated with the French Institute of Biology and Chemistry of Proteins (IBCP http://www.ibcp.fr) in particular through the ANR MapReduce project where the team focuses on a bio-chemistry application dealing with protein structure analysis. Avalon has also started working with the Inria Beagle team (https://team.inria.fr/beagle/) on artificial evolution and computational biology as the challenges are around high performance computation and data management.

5. New Software and Platforms

5.1. Kwapi

FUNCTIONAL DESCRIPTION: Kwapi is a software framework dealing with energy monitoring of large scale infrastructures through heterogeneous energy sensors. Kwapi has been designed inside the FSN XLCloud project for Openstack infrastructures. Through the support of Hemera Inria project, kwapi has been extended and deployed in production mode to support easy and large scale energy profiling of the Grid5000 resources.

- Participants: François Rossigneux, Jean-Patrick Gelas, Laurent Lefèvre and Laurent Pouilloux
- Contact: Laurent Lefèvre
- URL: https://launchpad.net/kwapi

5.2. DIET

Distributed Interactive Engineering Toolbox
KEYWORDS: Scheduling - Clusters - Grid - Cloud - HPC - Middleware - Data management.
FUNCTIONAL DESCRIPTION: Middleware for grids and clouds. Toolbox for the use and porting of intensive computing applications on heterogeneous architectures.

RELEASE FUNCTIONAL DESCRIPTION: - Upgrade to support Cmake 3.3 and later - Update workflow unit tests to take the results of the execution into account - DIET workflow engine was improved
NEWS OF THE YEAR: New release (DIET 2.10) DIET at SC'17 Rutgers University Collaboration

- Participants: Joel Faubert, Hadrien Croubois, Abdelkader Amar, Arnaud Lefray, Aurélien Bouteiller, Benjamin Isnard, Daniel Balouek, Eddy Caron, Eric Bois, Frédéric Desprez, Frédéric Lombart, Gaël Le Mahec, Guillaume Verger, Huaxi Zhang, Jean-Marc Nicod, Jonathan Rouzaud-Cornabas, Lamiel Toch, Maurice Faye, Peter Frauenkron, Philippe Combes, Philippe Laurent, Raphaël Bolze and Yves Caniou
- Partners: CNRS - ENS Lyon - UCBL Lyon 1 - Sysfera
- Contact: Eddy Caron
- URL: http://graal.ens-lyon.fr/diet/

5.3. Sam4C

Security-Aware Models for Clouds
SCIENTIFIC DESCRIPTION: This editor is generated in Java from an EMF -Eclipse Modeling Framework- metamodel to simplify any modifications or extensions. The application model and the associated security policy are compiled in a single XML file which serves as input for an external Cloud security-aware scheduler. Alongside with this editor, Cloud architecture models and provisioning algorithms are provided for simulation (in the current version) or real deployments (in future versions).
FUNCTIONAL DESCRIPTION: Sam4C (https://gforge.inria.fr/projects/sam4c/) -Security-Aware Models for Clouds- is a graphical and textual editor to model Cloud applications (as virtual machines, processes, files and communications) and describe its security policy. Sam4C is suitable to represent any static application without deadline or execution time such as n-tiers or parallel applications.

- Participants: Arnaud Lefray, Eddy Caron and Jonathan Rouzaud-Cornabas
- Contact: Eddy Caron
- URL: https://gforge.inria.fr/projects/sam4c/

5.4. L2C

Low Level Components
KEYWORDS: Software Components - HPC

FUNCTIONAL DESCRIPTION: L2C (http://hlcm.gforge.inria.fr) is a Low Level Component model implementation targeting at use-cases where overhead matters such as High-Performance Computing. L2C does not offer network transparency neither language transparency. Instead, L2C lets the user choose between various kinds of interactions between components, some with ultra low overhead and others that support network transport. L2C is extensible as additional interaction kinds can be added quite easily. L2C currently supports C++, FORTRAN 2013, MPI and CORBA interactions.

- Participants: Christian Pérez, Hélène Coullon, Jérôme Richard and Vincent Lanore
- Partner: Maison de la simulation
- Contact: Christian Pérez
- URL: http://hlcm.gforge.inria.fr/l2c:start

5.5. Halley

KEYWORDS: Software Components - HPC
SCIENTIFIC DESCRIPTION: Halley is an implementation of the COMET component model that enable to efficiently compose independent parallel code using task graph for multi-core shared-memory machines.
NEWS OF THE YEAR: First operational version.

- Participants: Jérôme Richard and Christian Pérez
- Contact: Christian Pérez
- Publications: Conception of a software component model with task scheduling for many-core based parallel architecture, application to the Gysela5D code - Combining Both a Component Model and a Task-based Model for HPC Applications: a Feasibility Study on GYSELA - COMET: A High-Performance Model for Fine-Grain Composition

5.6. SimGrid

KEYWORDS: Large-scale Emulators - Grid Computing - Distributed Applications
SCIENTIFIC DESCRIPTION: SimGrid is a toolkit that provides core functionalities for the simulation of distributed applications in heterogeneous distributed environments. The simulation engine uses algorithmic and implementation techniques toward the fast simulation of large systems on a single machine. The models are theoretically grounded and experimentally validated. The results are reproducible, enabling better scientific practices.

Its models of networks, cpus and disks are adapted to (Data)Grids, P2P, Clouds, Clusters and HPC, allowing multi-domain studies. It can be used either to simulate algorithms and prototypes of applications, or to emulate real MPI applications through the virtualization of their communication, or to formally assess algorithms and applications that can run in the framework.

The formal verification module explores all possible message interleavings in the application, searching for states violating the provided properties. We recently added the ability to assess liveness properties over arbitrary and legacy codes, thanks to a system-level introspection tool that provides a finely detailed view of the running application to the model checker. This can for example be leveraged to verify both safety or liveness properties, on arbitrary MPI code written in C/C++/Fortran.

RELEASE FUNCTIONAL DESCRIPTION:

- Four releases in 2017. Major changes:
  - S4U: many progress, toward SimGrid v4.0. About 80% of the features offered by SimDag and MSG are now integrated, along with examples. Users can now write plugins to extend SimGrid.
  - SMPI: Support MPI 2.2, RMA support, Convert internals to C++.
  - Java: Massive memleaks and performance issues fixed.
  - New models: Multi-core VMs, Energy consumption due to the network
  - All internals are now converted to C++, and most of our internally developped data containers were replaced with std::* constructs.
  - (+ bug fixes, cleanups and documentation improvements)
- Participants: Adrien Lèbre, Arnaud Legrand, Augustin Degomme, Florence Perronnin, Frédéric Suter, Jean-Marc Vincent, Jonathan Pastor, Jonathan Rouzaud-Cornabas, Luka Stanisic, Mario Südholt and Martin Quinson
- Partners: CNRS - ENS Rennes
- Contact: Martin Quinson
- URL: http://simgrid.gforge.inria.fr/

5.7. execo

KEYWORDS: Toolbox - Deployment - Orchestration - Python
FUNCTIONAL DESCRIPTION: Execo offers a Python API for asynchronous control of local or remote, standalone or parallel, unix processes. It is especially well suited for quickly and easily scripting workflows of parallel/distributed operations on local or remote hosts: automate a scientific workflow, conduct computer science experiments, perform automated tests, etc. The core python package is execo. The execo_g5k package provides a set of tools and extensions for the Grid5000 testbed. The execo_engine package provides tools to ease the development of computer sciences experiments.

- Participants: Florent Chuffart, Laurent Pouilloux and Matthieu Imbert
- Contact: Matthieu Imbert
- URL: http://execo.gforge.inria.fr

5.8. Grid'5000

Participants: Laurent Lefèvre, Simon Delamare, David Loup, Christian Perez.

FUNCTIONAL DESCRIPTION

The Grid'5000 experimental platform is a scientific instrument to support computer science research related to distributed systems, including parallel processing, high performance computing, cloud computing, operating systems, peer-to-peer systems and networks. It is distributed on 10 sites in France and Luxembourg, including Lyon. Grid'5000 is a unique platform as it offers to researchers many and varied hardware resources and a complete software stack to conduct complex experiments, ensure reproducibility and ease understanding of results. In 2016, a new cluster financially supported by Inria has been deployed on the Grid'5000 Lyon site.

- Contact: Laurent Lefèvre
- URL: https://www.grid5000.fr/

5.9. Leco

Participants: Thierry Gautier, Laurent Lefèvre, Christian Perez.

FUNCTIONAL DESCRIPTION

The LECO experimental platform is a new medium size scientific instrument funded by DRRT to investigate research related to BigData and HPC. It is located in Grenoble as part of the the HPCDA computer managed by UMS GRICAD. The installation starts in December 2017.

- Contact: Thierry Gautier

6. New Results

6.1. Energy Efficiency in HPC and Large Scale Distributed Systems

Participants: Mathilde Boutigny, Radu Carpa, Marcos Dias de Assunção, Thierry Gautier, Olivier Glück, Laurent Lefèvre, Jean-Christophe Mignot, Issam Rais.

6.1.1. Combining Shutdown Policies with Multiple Constraints

Large scale distributed systems (high performance computing centers, networks, data centers) are expected to consume huge amounts of energy. In order to address this issue, shutdown policies constitute an appealing approach able to dynamically adapt the resource set to the actual workload. However, multiple constraints have to be taken into account for such policies to be applied on real infrastructures: the time and energy cost of switching on and off, the power and energy consumption bounds caused by the electricity grid or the cooling system, and the availability of renewable energy. We propose models translating these various constraints into different shutdown policies that can be combined for a multi-constraint purpose. Our models and their combinations are validated through simulations on a real workload trace [4], [13]. This work is done through the PhD of Issam Rais in the FSN ELCI Project with the collaboration of Anne Benoit (Roma team) and Anne-Cécile Orgerie (Myriads team).

6.1.2. Evaluating the Impact of SDN-Induced Frequent Route Changes on TCP Flows

Traffic engineering technologies such as MPLS have been proposed to adjust the paths of data flows according to network availability. Although the time interval between traffic optimisations is often on the scale of hours or minutes, modern SDN techniques enable reconfiguring the network more frequently. It is argued, however, that changing the paths of TCP flows too often could severely impact their performance by incurring packet loss and reordering. This work analyses and evaluates the impact of frequent route changes on the performance of TCP flows. Experiments carried out on a network testbed show that rerouting a flow can affect its throughput when reassigning it a path either longer or shorter than the original path. Packet reordering has a negligible impact when compared to the increase of RTT. Moreover, constant rerouting influences the performance of the congestion control algorithm. Designed to assess the limits on SDN-induced reconfiguration, a scenario where the traffic is rerouted every 0.1s demonstrates that the throughput can be as low as 35% of that achieved without rerouting.[7], [14].

6.1.3. Evaluating Energy Consumption of OpenMP Runtime

In a joint-work with J.V. Lima from UFSM, Santa Maria, Brazil [26], we analyse performance and energy consumption of four OpenMP runtime systems over a NUMA platform. We present an experimental study to characterize OpenMP runtime systems on the three main kernels in dense linear algebra algorithms (Cholesky, LU and QR) in terms of performance and energy consumption. Our experimental results suggest that OpenMP runtime systems can be considered as a new energy leverage. For instance, a LU factorization with concurrent write extension from libKOMP achieved up to 1.75 of performance gain and 1.56 of energy decrease.

6.2. Modeling and Simulation of Parallel Applications and Distributed Infrastructures

Participant: Frédéric Suter.

6.2.1. Simulating MPI Applications: the SMPI Approach

Predicting the behavior of distributed algorithms has always been a challenge, and the scale of next-generation High Performance Computing (HPC) systems will only make the situation more difficult. Performance modeling and software engineering for these systems increasingly require a simulation-based approach, and this need will only become more apparent with the arrival of Exascale computing by the end of the decade. In [6] we summarized our recent work and developments on SMPI, a flexible simulator of MPI applications. In this tool, we took a particular care to ensure our simulator could be used to produce fast and accurate predictions in a wide variety of situations. Although we did build SMPI on SimGrid whose speed and accuracy had already been assessed in other contexts, moving such techniques to a HPC workload required significant additional effort. Obviously, an accurate modeling of communications and network topology was one of the key to such achievements. Another less obvious key was the choice to combine in a single tool the possibility to do both offline and online simulation.

6.2.2. Modeling Distributed Platforms from Application Traces

Simulation is a fast, controlled, and reproducible way to evaluate new algorithms for distributed computing platforms in a variety of conditions. However, the realism of simulations is rarely assessed, which critically questions the applicability of a whole range of findings.

In [15], we present our efforts to build platform models from application traces, to allow for the accurate simulation of file transfers across a distributed infrastructure. File transfers are key to performance, as the variability of file transfer times has important consequences on the dataflow of the application. We present a methodology to build realistic platform models from application traces and provide a quantitative evaluation of the accuracy of the derived simulations. Results show that the proposed models are able to correctly capture real-life variability and significantly outperform the state-of-the-art model.

6.3. Data Stream Processing and Edge Computing

Participants: Eddy Caron, Marcos Dias de Assunção, Alexandre Da Silva Veith, Laurent Lefèvre, Felipe Rodrigo de Souza.

6.3.1. Resource Elasticity and Edge Computing for Data Stream Processing

We carried out an extensive survey on techniques for enabling resource elasticity for data stream processing applications. Moreover we have been investigating algorithms for placing stream processing tasks onto environments that comprise both cloud and edge computing resources [29].

We are currently working on modelling the placement scenario as a constraint programming problem as well as measuring the energy consumption of constrained devices, such as Raspberry Pi's. The power consumption information is being used for creating a model on power consumption model.

6.4. Large-Scale Cloud Resource Management

Participants: Yves Caniou, Eddy Caron, Marcos Dias de Assunção, Christian Perez, Pedro de Souza Bento Da Silva.

6.4.1. An Efficient Communication Aware Heuristic for Multiple Cloud Application Placement

To deploy a distributed application on the cloud, cost, resource and communication constraints have to be considered to select the most suitable Virtual Machines (VMs), from private and public cloud providers. This process becomes very complex in large scale scenarios and, as this problem is NP-Hard, its automation must take scalability into consideration. In this work [21], we propose a heuristic able to calculate initial placements for distributed component-based applications on possibly multiple clouds with the objective of minimizing VM renting costs while satisfying applications' resource and communication constraints. We evaluate the heuristic performance and determine its limitations by comparing it to other placement approaches, namely exact algorithms and meta-heuristics. We show that the proposed heuristic is able to compute a good solution much faster than them.

6.4.2. Production Deployment Tools for IaaSes: an Overall Model and Survey

Emerging applications for the Internet of Things (IoT) are complex programs which are composed of multiple modules (or services). For scalability, reliability and performance, modular applications are distributed on infrastructures that support utility computing (*e.g.,* Cloud, Fog). In order to simply operate such infrastructures, an Infrastructure-as-a-Service (IaaS) manager is required. OpenStack is the de-facto open-source solution to address the IaaS level of the Cloud paradigm. However, OpenStack is itself a large modular application composed of more than 150 modules that make it hard to deploy manually. To fully understand how IaaSes are deployed today, we propose in [16] an overall model of the application deployment process which describes each step with their interactions. This model then serves as the basis to analyse five different deployment tools used to deploy OpenStack in production: Kolla, Enos, Juju, Kubernetes, and TripleO. Finally, a comparison is provided and the results are discussed to extend this analysis.

6.4.3. Communication Aware Task Placement for Workflow Scheduling on DaaS-based Cloud

We proposed a framework for building an autonomous workflow manager and developped the different components that are required for this design to work. We believe that this design will help solve current issues with workflow deployment and scalling in the context of shared IaaS Cloud platforms. In that regard, our first contribution is the modelization of network topology [24], which is a key factor in predicting communication patterns and should therefore be considered by clustering algorithms. By designing a generic network model, we managed to improve the results of static scheduling in the context of DaaS-based Cloud platforms. In fact, the resulting clusters are both more efficient in terms of makespan (primary objective) and in terms of deployment cost compared to previous non-network-aware clustering algorithms.

6.4.4. Communication Aware Stochastic Tasks Scheduling Composing Scientific Workflows on a Cloud

In order to study the scheduling of workflows composed of stochastic tasks on a set of resources managed as a cloud, we firstly proposed a new execution model taking into account data transfers, heterogeneity, billing of used resources as close to reality based to a great extend on the offers of three big cloud providers: Google Cloud, Amazon EC2 and OVH [25]. We then studied new scheduling heuristics on a set of worflows taken from the Pegasus benchmark suite [23]. During the mapping process, the budget-aware algorithms make conservative assumptions to avoid exceeding the initial budget; we further improve our results with refined versions that aim at re-scheduling some tasks onto faster virtual machines, thereby spending any budget fraction leftover by the first allocation. These refined variants are much more time-consuming than the former algorithms, so there is a trade-off to find in terms of scalability. We report an extensive set of simulations. Most of the time our budget-aware algorithms succeed in achieving efficient makespans while enforcing the given budget, and despite the uncertainty in task weights.

6.5. HPC Component Models and Domain Specific Languages

Participants: Thierry Gautier, Christian Perez, Jérôme Richard.

6.5.1. Combining Both a Component Model and a Task-based Model for HPC Applications: a Feasibility Study on GYSELA

In [12], we studied the feasibility of efficiently combining both a software component model and a task-based model. Task based models are known to enable efficient executions on recent HPC computing nodes while component models ease the separation of concerns of application and thus improve their modularity and adaptability. This paper describes a prototype version of the COMET programming model combining concepts of task-based and component models, and a preliminary version of the COMET runtime built on top of StarPU and L2C. Evaluations of the approach have been conducted on a real-world use-case analysis of a subpart of the production application GYSELA. Results show that the approach is feasible and that it enables easy composition of independent software codes without introducing overheads. Performance results are equivalent to those obtained with a plain OpenMP based implementation.

6.5.2. Extensibility and Composability of a Multi-Stencil Domain Specific Framework

As the computation power of modern high performance architectures increases, their heterogeneity and complexity also become more important. One of the big challenges of exascale is to reach programming models that give access to high performance computing (HPC) to many scientists and not only to a few HPC specialists. One relevant solution to ease parallel programming for scientists is domain specific language (DSL). However, one problem to avoid with DSLs is to mutualize existing codes and libraries instead of implementing each solution from scratch. For example, this phenomenon occurs for stencil-based numerical simulations, for which a large number of languages has been proposed without code reuse between them. The Multi-Stencil Framework (MSF) presented in this paper [5] combines a new DSL to component-based programming models to enhance code reuse and separation of concerns in the specific case of stencils. MSF can easily choose one parallelization technique or another, one optimization or another, as well as one back-end implementation or another. It is shown that MSF can reach same performances than a non component-based MPI implementation over 16,384 cores. Finally, the performance model of the framework for hybrid parallelization is validated by evaluations.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

7.1.1. IFPEN

We have a collaboration with IFPEN (http://ifpenergiesnouvelles.com/). IFPEN develops numerical codes to solve PDE with specific adaption of the preconditioning step to fit the requirement of their problems. With a PhD student (Adrien Roussel) we are studying the parallel implementation of multi-level decomposition domains on many-core architecture and GPGPU.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. PIA

8.1.1.1. PIA ELCI, Environnement Logiciel pour le Calcul Intensif, 2014-2017

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

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

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

8.1.2. French National Research Agency Projects (ANR)

8.1.2.1. ANR INFRA MOEBUS, Multi-objective scheduling for large computing platforms, 4 years, ANR-13-INFR-000, 2013-2016

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

The ever growing evolution of computing platforms leads to a highly diversified and dynamic landscape. The most significant classes of parallel and distributed systems are supercomputers, grids, clouds and large hierarchical multi-core machines. They are all characterized by an increasing complexity for managing the jobs and the resources. Such complexity stems from the various hardware characteristics and from the applications characteristics. The MOEBUS project focuses on the efficient execution of parallel applications submitted by various users and sharing resources in large-scale high-performance computing environments.

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.

8.1.3. Inria Large Scale Initiative

8.1.3.1. C2S@Exa, Computer and Computational Sciences at Exascale, 4 years, 2013-2017

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 that 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 an 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 leaded 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 30th 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 5th to June 31th). 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 25th September to 7th 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.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. General Chair, Scientific Chair

Laurent Lefèvre was

- co-chair of the colloquium : "Towards a sustainable digital society : from Clouds to Connected Objects", with Centre Jacques Cartier and Concordia University, Montreal, Canada, October 2017
- co-chair of the PEAC 2017 Workshop on "Power and Energy Aspects of Computations", held in conjunction with the 12th International Conference on Parallel Processing and Applied Mathematics, PPAM 2017, Lublin, Poland, September 2017
- track co-chair of the ICA3PP 2017 conference: 17th International Conference on Algorithms and Architectures for Parallel Processing, for the track Distributed and Network-based Computing, Helsinki, Finland, August 2017

9.1.1.2. Member of the Organizing Committees

Laurent Lefèvre was

- co-organizer of the GreenDays@Sophia, SophiaTech, Nice, June 2017
- co organizer of the Ecoinfo conference on "Edge Datacenters, a leverage for innovation - Edge datacenters, un levier pour l’innovation", Paris, March 2017 and the Ecoinfo conference on "Eco-design of software", Grenoble, February 2017

- co-chair of the Special Session on Energy Efficient Management of Parallel Systems, Platforms, and Computations during PDP2017 : 25th Euromicro International Conference on Parallel, Distributed and Network based Processing, St Petersburg, Russia, March 2017

Christian Perez served on the Organizing Committee of the 2017 International Conference on High Performance Computing & Simulation (HPCS 2017) as Conference Awards and Recognitions Co-Chair.

9.1.2. Scientific Events Selection

9.1.2.1. Chair of Conference Program Committees

Eddy Caron was the chair of the Chair Parallelism for Compas'2017 (Conférence d'informatique en Parallélisme, Architecture et Système). June 27-30, 2017.

Laurent Lefèvre was co-chair of the Poster and Research Demos of CCGrid 2017 : 17th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing, Madrid, Spain, May 2017

9.1.2.2. Member of the Conference Program Committees

Eddy Caron was member of the program committees of 6th International Conference on Advances in Computing, Commnications and Informatics (ICACCI-2017), Conférence Nationale (en Afrique) sur la Recherche en Informatique et ses Applications (CNRIA 2017), The 3rd International Conference on Cloud Computing Technologies and Applications (CloudTech'17), 7th International Conference on Cloud Computing and Service Science (CLOSER 2017), Third Symposium on Emerging Topics in Computing and Communications (SETCAC'17), The 10th International Conference on Security, Privacy and Anonymity in Computation, Communication and Storage (SpaCCS 2017).

Marcos Dias de Assunção was member of the program committees of the International Conference on Cloud Computing Technology and Science (CloudCom 2017) and Workshop on Clouds and Applications (WCGA 2017).

Olivier Glück was a member of the program committees of PDP 2017 (25th Euromicro International Conference on Parallel, Distributed, and Network-Based Processing) and ICA3PP-2017 (17th International Conference on Algorithms and Architectures for Parallel Processing).

Laurent Lefèvre was member of the program committees of The 3rd IEEE International Conference on Data Science and Systems (DSS 2017), The 23nd IEEE International Conference on Parallel and Distributed Systems (ICPADS 2017), 9th International Conference on Cloud Computing Technology and Science (CloudCom 2017), International Symposium on Computer Architecture and High Performance Computing (SBACPAD 2017), 46th International Conference on Parallel Processing (ICPP2017) and the Conférence d'informatique en Parallélisme, Architecture et Système (Compas'17).

Christian Perez was member of the program committees of the IEEE International Conference on Cluster Computing 2017 (Cluster 2017), the 17th IEEE/ACM International Symposium on Cluster, Cloud and Grid (CCGRID 2017), the 25th annual High Performance Computing Symposium 2017 (HPC '17), the 9th International Conference on Cloud Computing Technology and Science (IEEE CloudCom 2017) and of the 2017 International Conference on Parallel Computing (ParCo 2017). He was a member of the Tutorials Committee of ISC High Performance 2018.

Frédéric Suter was member of the program committees of the European MPI Users' Group Meeting (EuroMPI'17), the International Conference on Algorithms and Architectures for Parallel Processing (ICA3PP'17), the IEEE / ACM International Symposium on Cluster, Cloud, and Grid Computing (CCGrid 2017), the International Workshop on Algorithms, Models and Tools for Parallel Computing on Heteroge- neous Platforms (HeteroPar'17), and the Conférence d'informatique en Parallélisme, Architecture et Système (Compas'17). He was a member of the Posters Committee of the IEEE International Conference on Cluster Computing (Cluster'17).

9.1.2.3. Reviewer

Eddy Caron reviewed a paper for the 23rd International European Conference on Parallel and Distributed Computing (Euro-Par 2017).

Christian Perez reviewed a paper for the 23rd International European Conference on Parallel and Distributed Computing (Euro-Par 2017).

9.1.3. Journal

9.1.3.1. Member of the Editorial Boards

Laurent Lefèvre is associate editor of IEEE Transactions on Sustainable Computing

9.1.3.2. Reviewer - Reviewing Activities

Eddy Caron reviewed articles for Journal of Cloud Computing, Journal FGCS, Transaction on Service Computing, Concurrency and Computation (Practice and Experience), Information Security Journal: A Global Perspective.

Marcos Dias de Assunção reviewed articles for the ACM Computing Surveys, Computer Networks, IEEE Cloud Computing, Software Practice and Experience, Sustainable Computing Journal, Parallel Computing, Cluster Computing Journal, Future Generation Computer Systems Journal (FGCS), Transactions on Cloud Computing, and IEEE Transactions on Network and Service Management.

Thierry Gautier reviewed articles for the ACM Transactions on Architecture and Code Optimization journal.

Christian Perez reviewed articles for the IEEE's Transactions on Big Data journal.

Frédéric Suter reviewed articles for the IEEE's Transactions on Parallel and Distributed Systems and ParallelComputing.

9.1.4. Invited Talks

Marcos Dias de Assunção gave the following talk:

- “Challenges on Resource Elasticity”, University of Umea, Sweden, March 29, 2017.

Laurent Lefèvre has been invited to give the following talk:

- "L'impact environnemental des nouvelles technologies de l'information et de la communication / Environmental impact of ICT", Ville de Vincennes : "Au coeur des savoirs", Vincennes, March 2017
- "Améliorer l'efficacité énergétique de l'informatique et des réseaux de communications / Improving energy efficiency of computing and networking", Assemblée Nationale, Audition publique sur les enjeux de la recherche en énergie, Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques (OPECST), Paris, February 2017
- "Eco-design of software : conclusion of the day - Eco-conception logicielle : conclusion de la journée", Journée EcoInfo sur "Impact des logiciels sur l'environnement quid de l'éco-conception ?", IMAG, Grenoble, February 2017
- "Impacts environnementaux des TICs : constats et pistes d'améliorations (sans green washing) / Environmental impact of ICT : overview and improvements (without green washing)", ENSIMAG, Grenoble, January 2017

Christian Perez has been invited to give the following talk:

- "HPC Component Models", 2017 JLESC Summer School, NCSA, Urbana, Illinois, July 21, 2017.

9.1.5. Leadership within the Scientific Community

Eddy Caron is animator and co-chair for the FIL (Fédération Informatique de Lyon) on the theme IDCHP (Informatique Distribuée et Calcul Haute Performance).

Laurent Lefèvre is animator and chair of the transversal action on "Energy" of the French GDR RSD ("Réseaux et Systèmes Distribués")

Christian Perez is co-leader of the pole Distributed Systems of the French GDR RSD ("Réseaux et Systèmes Distribués").

9.1.6. Scientific Expertise

Eddy Caron reviewed 3 projects for the French National Research Agency (ANR).

Thierry Gautier and Christian Perez were member of the programming environment working group of ETP4HPC in order to define the Strategic Research Agenda (SRA). The SRA identifies the principal challenges in HPC and is used by the European Commission for writing their work programme. The EC is currently working on the WP2018-2020. The SRA -3 was released in November 2017.

Olivier Glück is member of the CNU (Conseil National des Universités) section 27 (Computer Science). He participated to the 2017 "Qualifications" session and "Promotions/CRCT" session.

Christian Perez was a member of the HCERES evaluation committes fot the Laboratoire d'Informatique Fondamentale d'Orléans (LIFO) and for the *Mathématiques et Systèmes* unit of Mines ParisTech. He reviewed projects for the French National Research Agency (ANR), for the *Comité Français d'Évaluation de la Coopération Scientifique et Universitaire avec le Brésil* (COFECUB), and for the Région Pays de la Loire (France).

9.1.7. Research Administration

Eddy Caron is a member of the CDT (Commission de Développement Technologique) de l'Inria Rhône-Alpes. He is deputy director in charge of call for projects, research transfert and international affairs since September 2017 for the LIP laboratory.

Olivier Glück is member of the "Conseil Académique" of Lyon 1 University and Lyon University.

Laurent Lefèvre is a member of the executive board and the sites committee of the Grid'5000 Scientific Interest Group. Laurent Lefèvre leads the PhD commitee and is member of the councill of LIP Laboratory (ENS Lyon). He is elected memeber of the council of Federation Informatique of Lyon. He is a scientific member of the Digital League enterprise cluster of Rhône-Alpes Auvergne Region. He is member of the direction committee of the GDS Ecoinfo group.

Christian Perez represents Inria in the overview board of the France Grilles Scientific Interest Group. He is a member of the executive board and the sites committee of the Grid'5000 Scientific Interest Group. He a member of the committee selection of the project call from the Rhône-Alpes region ARC6 (France). He is also a member of the Inria Grenoble Rhône-Alpes Strategic Orientation Committee.

Frédéric Suter is a member of the Direction Committee of the IN2P3 Computing Center (USR 6402).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: Eddy Caron, Projet 1, 48h, L3, ENS de Lyon. France.

Master: Eddy Caron, Projet Intégré, 42h, M1, ENS de Lyon. France.

Master: Eddy Caron, Système distribués, 30h, M1, ENS de Lyon. France.

Master: Eddy Caron, Advanced Topics in Scalable Data Management, 18h, M2, ENS de Lyon. France.

Licence: Yves Caniou, Algorithmique programmation impérative, initiation, 24h, niveaux L1, Université Lyon 1, France

Licence: Yves Caniou, Unix, 3h, niveaux L1, Université Lyon 1, France

Licence: Yves Caniou, Système d'Exploitation, 42h, niveaux L2, Université Lyon 1, France

Licence: Yves Caniou, Programmation Concurrente, 33h, niveaux L3, Université Lyon 1, France

Licence: Yves Caniou, Réseaux, 54h, niveaux L3, Université Lyon 1, France

Master: Yves Caniou, Sécurité, 36h, niveaux M2, Université Lyon 1, France

Master: Yves Caniou, Systèmes avancés, 4.5h, niveaux M2, Université Lyon 1, France

Master: Yves Caniou, Projet, Bibliographie, Certification, 10h, niveaux M2, Université Lyon 1, France

Master: Yves Caniou, Suivi d'un étudiant en introduction à la recherche, 3h, M1, Université Lyon 1, France

Master: Yves Caniou, Suivi d'étudiants (apprentissage, stage), 33h, niveaux M1 et M2, Université Lyon 1, France

Master: Yves Caniou, Responsible of professional Master SRIV (Systèmes Réseaux et Infrastructures Virtuelles), 42h, Université Lyon 1, France

Master: Yves Caniou, Sécurité, 20h, niveau M2, IGA Casablanca, Maroc

Master: Jean-Patrick Gelas, Programmation embarquée et mobile des objets, 17h, niveau M1, Université Lyon 1, France

Master: Jean-Patrick Gelas, Introduction au Cloud Computing, 24h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Système d'exploitation, 52h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Projet en Informatique en Anglais, 10h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Réseaux Avancés, 27h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Sécurité et Admin des infra résx, 37h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Technologies embarquées, 19h, niveau M2 (Image), Université Lyon 1, France

Master: Jean-Patrick Gelas, Routage (BGP), Routeurs et IPv6, 15h, niveau M2, Université Lyon 1, France

Master: Jean-Patrick Gelas, Systèmes embarqués (GNU/Linux, Android, ARM, Arduino), 34h, niveau M2, Université Lyon 1, France

Master: Jean-Patrick Gelas, Analyse de performance, 3h, niveau M2 (TIW), Université Lyon 1, France

Master: Jean-Patrick Gelas, Cloud Computing, 17h, niveau M2 (TIW), Université Lyon 1, France

Master: Jean-Patrick Gelas, Développement informatique, 23h, niveau M2 (Data science), Université Lyon 1, France

Licence: Olivier Glück, Licence pedagogical advisor, 30h, niveaux L1, L2, L3, Université Lyon 1, France.

Licence: Olivier Glück, Introduction Réseaux et Web, 90h, niveau L1, Université Lyon 1, France.

Licence: Olivier Glück, Algorithmique programmation impérative initiation, 37h, niveau L1, Université Lyon 1, France.

Licence: Olivier Glück, Réseaux, 2x70h, niveau L3, Université Lyon 1, France.

Master: Olivier Glück, Responsible of professional Master SIR (Systèmes Informatiques et Réseaux) located at IGA Casablanca, 20h, niveau M2, IGA Casablanca, Maroc

Master: Olivier Glück, Réseaux par la pratique, 14h, niveau M1, Université Lyon 1, France.

Master: Olivier Glück, Réseaux et protocoles, 33h, niveau M1, Université Lyon 1, France.

Master: Olivier Glück, Applications systèmes et réseaux, 30h, niveau M2, Université Lyon 1, France.

Master: Olivier Glück, Applications systèmes et réseaux, 24h, niveau M2, IGA Casablanca, Maroc

Master Informatique: Laurent Lefèvre, "Parallelism", Université Claude Bernard, France. (18h), M1

Master Systèmes Informatique et Réseaux: Laurent Lefèvre, "Advanced Networks", IGA Casablanca, Maroc (20h), M2

9.2.2. Supervision

PhD: Radu Carpa, *Efficacité énergétique des échanges de données dans une fédération d'infrastructures distribuées à grande échelle*, 26/10/2017, Laurent Lefèvre (dir), Olivier Glück (co-dir).

PhD : ACAR Hayri, Software development methodology in a Green IT environment, Université Claude Bernard Lyon 1, 22/11/2017, Parisa Ghodous (dir), Jean-Patrick Gelas (co-dir), Gulfem Isiklar Alptekin (co-dir).

PhD: Jérôme Richard, *Conception of a software component model with task scheduling for many-core based parallel architecture, application to the Gysela5D code*, 6/12/2017, Christian Perez (dir), Julien Bigot (CEA, MdlS, co-dir).

PhD: Pedro De Souza Bento Da Silva, *Application model and co-scheduling algorithm for dynamic and evolutive data-intensive application*, 11/12/2017, Christian Perez (dir), Frédéric Desprez (Inria, CORSE team, co-dir).

PhD in progress: Dorra Boughzala, *Simulating Energy Consumption of Continuum Computing between Heterogeneous Numerical Infrastructures in HPC*, IPL Hac-Specis Inria, Laurent Lefèvre (dir) , Martin Quinson and Anne-Cécile Orgerie (Myriads, Rennes, co-dir) (since december 2017)

PhD in progress: Anchen Chai: *Simulation of the Distributed Execution of a Medical Imaging Simulator*, Hugues Benoit-Cattin (co-dir, CREATIS, INSA Lyon), Frédéric Suter (co-dir).

PhD in progress: Arthur Chevalier, *Optimisation du placement des licences logiciel des fonctions réseau dans le Cloud pour un déploiement économique et efficace*, Eddy Caron (dir), Noëlle Baillon (co-dir, Orange) (since october 2017).

PhD in progress: Hadrien Croubois, *Étude et conception d'un système de gestion de workflow autonomique*, 10/2015, Eddy Caron (dir).

PhD in progress: Jad Darrous : *Geo-distributed storage for distributed Cloud*, Gilles Fedak (dir) until Aug. 2017 then Christian Perez (dir), Shadi Ibrahim (co-dir)

PhD in progress: Aurélie Kong-Win-Chang: *Techniques de résilience pour l'ordonnancement de workflows sur plates-formes décentralisées (cloud computing) avec contraintes de sécurité*, Yves Robert (dir, ROMA, ÉNS-Lyon), Eddy Caron (co-dir) et Yves Caniou (co-dir).

PhD in progress: Valentin Lorentz : *Energy traceability of data*, Gilles Fedak (dir), Laurent Lefèvre (co-dir) (2016-2019)

PhD in progress: Issam Rais, *Multi criteria scheduling for exascale infrastructures*, 10/2014, Laurent Lefèvre (dir), Anne Benoit (Roma Team, LIP, ENS Lyon, co-dir) and Anne-Cécile Orgerie (CNRS, Myriads team, Irisa Rennes, co-dir).

PhD in progress: Felipe Rodrigo de Souza, *Networking Provisioning Algorithms for Highly Distributed Data Stream Processing*, École Doctorale, Eddy Caron (dir), Marcos Dias de Assunção (co-dir) (2017-2020).

PhD in progress: Alexandre Veith : *Elastic Mechanisms for Big-Data Stream Analytics*, Labex MiLyon, Laurent Lefèvre (dir), Marcos Dias de Assunção (co-dir) (2016-2019).

9.2.3. Juries

Laurent Lefèvre was reviewer and member of the Ph.D. defence committee of Ronnie Muthada Pottaya, University of Bourgogne Franche-Comté (December 8, 2017), Ines de Courchelle, University of Toulouse (November 20, 2017), Nicolas Huin, Nice-Sophia Antipolis University (September 28, 2017), Atefeh Khosravi, University of Melbourne, Australia (July 2017) and Loris Belcastro , University of Calabria, Italy (May 2017). Laurent Lefèvre was a member of the Ph.D. defence committee of Yunbo Li, Université Bretagne Loire (June 2017)

Frédéric Suter was a member of the Ph.D. defence committee of Fernando Mendonca, Ph.D. student of Université de Grenoble held on May 23, 2017.

9.3. Popularization

Laurent Lefèvre has been:

- Participating to the "Nuit européenne des chercheurs - European night of researchers" : talk in the dark "Let's talk about Green IT in the dark" - Interview by Lyon Capitale and Radio Brume, Villeurbanne, September 29, 2017
- Interviewed for the paper "Réseaux, data centers et terminaux, sur les traces de notre empreinte environnementale numérique", Inriality, Pierre Guyot, February 14,2017
- Interviewed for the paper "Surfing is bad for the planet / Surfer nuit gravement à la planète", 01 Net, Number 859, February 15, 2017

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Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] R. CARPA. *Energy Efficient Traffic Engineering in Software Defined Networks*, Université de Lyon, October 2017, https://tel.archives-ouvertes.fr/tel-01650148

[2] J. RICHARD. *Conception of a software component model with task scheduling for many-core based parallel architecture, application to the Gysela5D code*, Université de Lyon, December 2017, https://tel.archives-ouvertes.fr/tel-01663718

Articles in International Peer-Reviewed Journals

[3] F. ALMEIDA, M. DIAS DE ASSUNCAO, J. BARBOSA, V. BLANCO, I. BRANDIC, G. DA COSTA, M. F. DOLZ, A. C. ELSTER, M. JARUS, H. KARATZA, L. LEFÈVRE, I. MAVRIDIS, A. OLEKSIAK, A.-C. ORGERIE, J.-M. PIERSON. *Energy Monitoring as an Essential Building Block Towards Sustainable Ultrascale Systems*, in "Sustainable Computing : Informatics and Systems", 2017, forthcoming, https://hal.inria.fr/hal-01627757

[4] A. BENOIT, L. LEFÈVRE, A.-C. ORGERIE, I. RAÏS. *Reducing the energy consumption of large scale computing systems through combined shutdown policies with multiple constraints*, in "International Journal of High Performance Computing Applications", January 2018, vol. 32, n^{o} 1, pp. 176-188 [*DOI :* 10.1177/1094342017714530], https://hal.inria.fr/hal-01557025

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[7] M. DIAS DE ASSUNCAO, R. CARPA, L. LEFÈVRE, O. GLÜCK, P. BORYLO, A. LASON, A. SZYMANSKI, M. RZEPKA. *Designing and Building SDN Testbeds for Energy-Aware Traffic Engineering Services*, in "Photonic Network Communications", December 2017, vol. 34, n^{o} 3, pp. 396–410 [*DOI :* 10.1007/S11107-017-0709-9], https://hal.inria.fr/hal-01539656

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[10] S. LAMBERT, P. ANANTH, P. VETTER, K.-L. LEE, J. LI, X. YIN, H. CHOW, J.-P. GELAS, L. LEFÈVRE, D. CHIARONI, B. LANNOO, M. PICKAVET. *The road to energy efficient optical access: GreenTouch final results*, in "Journal of Optical Communications and Networking", March 2017, https://hal.inria.fr/hal-01369267

[11] A. N. TOOSI, C. QU, M. DIAS DE ASSUNCAO, R. BUYYA. *Renewable-aware Geographical Load Balancing of Web Applications for Sustainable Data Centers*, in "Journal of Network and Computer Applications", February 2017, vol. 83, pp. 155–168 [*DOI :* 10.1016/J.JNCA.2017.01.036], https://hal.inria.fr/hal-01456789

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[13] A. BENOIT, L. LEFÈVRE, A.-C. ORGERIE, I. RAÏS. *Shutdown Policies with Power Capping for Large Scale Computing Systems*, in "Euro-Par: International European Conference on Parallel and Distributed Computing", Santiago de Compostela, Spain, F. F. RIVERA, T. F. PENA, J. C. CABALEIRO (editors), Lecture Notes in Computer Science, springer, August 2017, vol. 10417, pp. 134 - 146 [*DOI :* 10.1109/COMST.2016.2545109], https://hal.archives-ouvertes.fr/hal-01589555

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[17] P.-F. DUTOT, Y. GEORGIOU, D. GLESSER, L. LEFÈVRE, M. POQUET, I. RAÏS. *Towards Energy Budget Control in HPC*, in "17th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing", Madrid, Spain, Proceedings of the 17th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing, CCGRID 2017, Madrid, Spain, May 14-17, 2017, May 2017, n° 17, pp. 381-390, https://hal.archives-ouvertes.fr/hal-01533417

[18] T. N 'TAKPÉ, F. SUTER. *Don't Hurry be Happy: a Deadline-based Backlling Approach*, in "JSSPP 2017 - 21st Workshop on Job Scheduling Strategies for Parallel Processing", Orlando, FL, United States, June 2017, pp. 1-20, https://hal.inria.fr/hal-01672484

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[22] S. DELAMARE, P. MORILLON, L. NUSSBAUM. *Réalisation d'expériences avec Grid'5000*, in "JRES2017 - Journées Réseaux de l'enseignement et de la recherche", Nantes, France, November 2017, https://hal.inria.fr/hal-01639524

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