IN PARTNERSHIP WITH:
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Ecole normale supérieure de Lyon
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Activity Report 2015

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. Members

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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. Those large scale platforms based on the aggregation of large clusters (Grids), huge datacenters (Clouds), collections of volunteer PC (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 different 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 (maximing 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 Modelization

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.

2.2.4. Application Mapping and Scheduling

Avalon will propose multi-criteria mapping and scheduling algorithms to meet the challenge of automatizing 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 6.9) will be our platform of choice for experiments.

3. Research Program

3.1. Energy Application Profiling and Modelization

International roadmaps schedule to build exascale systems by the 2018 time frame. According to the Top500 list published in November 2013, the most powerful supercomputer is the Tianhe-2 platform, a machine with more than 3,000,000 cores. It consumes more than 17 MW for a maximum performance of 33 PFlops while the Defense Advanced Research Projects Agency (DARPA) has set to 20 MW the maximum energy consumption of an exascale supercomputer [64].

Energy efficiency is therefore a major challenge for building next generation large scale platforms. The targeted platforms will gather hundreds of million 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 the measure, the understanding, and the analysis of the large-scale platform energy consumption. Unlike approaches [65] 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 resources 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 [68], phase detection for specific HPC applications [73], etc.). As a second step, we aim at designing a framework model that allows interactions, dialogues and decisions taken in cooperation between 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 of the time implicitly linked to "analytics" to refer to issues such as 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 infrastructure 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. Resourc-Agnostic Application Description Model

When programming in parallel, users expect to obtain performance improvement, whatever the cost is. For long, parallel machines have been simple enough to let a user program them given a minimal abstraction of their hardware. For example, MPI [67] exposes the number of nodes but hides the complexity of network topology behind a set of collective operations; OpenMP [71] simplifies the management of threads on top of a shared memory machine while OpenACC [70] 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 [66]. 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 [74] 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.

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 others research axis. We plan to consider application mapping and scheduling through 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 propose scheduling algorithms for dynamic and elastic platforms. As the amount 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 can not 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 [72] and several issues have been raised in Clouds. Nowadays virtualization is used as the sole mechanism to secure different users sharing resources on Clouds. But, due to improper virtualization of all the components of Clouds (such as micro-architectural components), 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 [69] for ocean modelization), code-coupling applications (*e.g.,* the OASIS coupler [75] 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 comsunption, 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 volume 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 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 cooperates 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. These collaborations bring scientific applications that are both dynamic and data-intensive.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. VHGw Demo on Green-Touch Final Meeting

GreenTouch was founded five years ago with the ambitious goal to improve energy efficiency of communications and data networks by a factor of 1,000.

Avalon was invited to give one of the 15 demonstration of key technology to reduce power consumption. The VHGW (Virtual Home Gateway) demonstration gives a proof of concept and focuses on the main challenges related to the virtualization of home gateways through dense service aggregation and precise energy management.

5.1.2. Dissemination

Laurent Lefevre has given an invited keynote talk on "Towards energy proportional clouds, data centers and networks: the holy grail of energy efficiency ?", in IEEE Online Greencomm Conference, November 10, 2015

5.1.3. Awards

BEST PAPER AWARD:

[26]
D. Balouek-Thomert, E. Caron, P. Gallard, L. Lefèvre. *Nu@ge: Towards a solidary and responsible cloud computing service*, in "CloudTech'2015", Marrakesh, Morocco, June 2015, Best Paper Award [*DOI :* 10.1109/CloudTech.2015.7337006], https://hal.inria.fr/hal-01196898

6. New Software and Platforms

6.1. Active Data

Participants: Gilles Fedak [correspondant], Anthony Simonet.

Functional Description

Active Data is a free software system that tracks the life cycle of data distributed across heterogeneous software and infrastructures.

As the volume of data grows exponentially, the management of these data becomes more complex in proportion. A key point is to handle the complexity of the Data Life Cycle, i.e. the various operations performed on data: transfer, archiving, replication, deletion, etc. Indeed, data-intensive applications span over a large variety of devices and e-infrastructures which implies that many systems are involved in data management and processing. Active Data is a new approach to automate and improve the expressiveness of data management applications. Active Data consists of a formal model that captures the essential data life cycle stages and properties : creation, deletion, replication, derivation, transient unavailability, uniform naming, and many more. Active Data provides a programming model that simplify the development of data life cycle management applications. Active Data allows code execution at each stage of the data life cycle: routines provided by programmers are executed when a set of events (creation, replication, transfer, deletion) happen to any data.

- URL: http://active-data.gforge.inria.fr

6.2. BitDew

Participants: Gilles Fedak [correspondant], Anthony Simonet.

Functional Description

The BitDew framework is a programmable environment for management and distribution of data for Grid, Desktop Grid and Cloud Systems.BitDew offers programmers a simple API for creating, accessing, storing and moving data with ease, even on highly dynamic and volatile environments.The BitDew programming model relies on 5 abstractions to manage the data : i) replication indicates how many occurrences of a data should be available at the same time on the network, ii) fault-tolerance controls the policy in presence of machine crash, iii) lifetime is an attribute absolute or relative to the existence of other data, which decides the life cycle of a data in the system, iv) affinity drives movement of data according to dependency rules, v) protocol gives the runtime environment hints about the protocol to distribute the data (http, ftp or bittorrent). Programmers define for every data these simple criteria, and let the BitDew runtime environment manage operations of data creation, deletion, movement, replication, and fault-tolerance operation.

- URL: http://www.bitdew.net

6.3. DIET

Participants: Daniel Balouek Thomert, Eddy Caron [correspondant], Maurice Faye, Arnaud Lefray.

Functional Description

Middleware for grids and clouds. Toolbox for the use and porting of intensive computing applications on heterogeneous architectures.

In 2015 we have published a new release of DIET. A short list of the major improvements over the version 2.9 of DIET:

Security: SSL communications are now available.

Cloud: some improvements

More information are provided to the user

OAR binding improvement

QuickStart documentation is provided

- Partners: CNRS - ENS Lyon - UCBL Lyon 1
- URL: http://graal.ens-lyon.fr/diet/

6.4. Kwapi

Participants: Laurent Lefèvre [correspondant], Jean-Patrick Gelas, Laurent Pouilloux.

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 Grid'5000 resources.

- URL: https://launchpad.net/kwapi

6.5. DirectL2C

Participants: Vincent Lanore, Christian Perez [correspondant].

KEYWORDS: HPC, Software Components, Reconfiguration

FUNCTIONAL DESCRIPTION

L2C (http://hlcm.gforge.inria.fr/l2c:start) 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.

In 2015, we have prototyped DirectL2C on top of L2C. DirectL2C enables efficient and consistent reconfiguration of large scale L2C based assemblies. It provides an assembly model enhanced with domains, tranformations, and transformation adapters.

- URL: http://hlcm.gforge.inria.fr/l2c:start

6.6. Sam4C

Participants: Eddy Caron [correspondant], Arnaud Lefray.

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 (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.

- URL: https://gforge.inria.fr/projects/sam4c/

6.7. SimGrid

Participant: Frédéric Suter [correspondant].

KEYWORDS: Large-scale Emulators - Grid Computing - Distributed Applications
FUNCTIONAL DESCRIPTION

Scientific Instrument for the study of Large-Scale Distributed Systems. SimGrid is a toolkit that provides core functionalities for the simulation of distributed applications in heterogeneous distributed environments. In 2015, we published a new release, SimGrid 3.12.

- Partners: CNRS - Ecole Normale Supérieure de Rennes - University of Hawaii - Université de Reims Champagne-Ardenne - Femto-st
- URL: http://simgrid.gforge.inria.fr/

6.8. execo

Participants: Matthieu Imbert [correspondant], Laurent Pouilloux.

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 Grid'5000 testbed. The execo_engine package provides tools to ease the development of computer sciences experiments.

- URL: http://execo.gforge.inria.fr

6.9. Grid'5000 Experimental Platform

Participants: Laurent Lefèvre [correspondant], Simon Delamare, David Loup, Christian Perez, Marc Pinhède, Laurent Pouilloux.

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.

- URL: https://www.grid5000.fr/mediawiki/index.php/Grid5000:Home

7. New Results

7.1. Energy Efficiency of Large Scale Distributed Systems

Participants: Laurent Lefèvre, Daniel Balouek Thomert, Eddy Caron, Radu Carpa, Marcos Dias de Assunçao, Jean-Patrick Gelas, Olivier Glück, Jean-Christophe Mignot, Violaine Villebonnet.

7.1.1. Energy efficient Core Networks

This work [8], [43] seeks to improve the energy efficiency of backbone networks by providing an intra-domain Software Defined Network (SDN) approach to selectively turn off a subset of links. To do this, we designed an energy-aware traffic engineering technique for reducing energy consumption in backbone networks. Energy-efficient traffic engineering was analysed in previous work, but none addressed implementation challenges of their solutions. We showed that ignoring to test the feasibility of techniques can lead to bad estimations and unstable solutions. We proposed the STREETE framework (SegmenT Routing based Energy Efficient Traffic Engineering) that represents an online method to switch some links off/on dynamically according to the network load. We have implemented a working prototype in the OMNET++ simulator. Networks are progressively using centralised architecture, and SDN is increasingly utilised in data centre networks. We believe that SDN may be extended to backbone networks. The implemented solution shows that SDN may also be a good means for reducing the energy consumption of network devices. Compared to previous work, in this work we used the SPRING protocol to improve the stability of energy-efficient traffic engineering solutions. To the best of our knowledge, this is the first work proposing the use of SPRING to improve the energy efficiency of backbone networks. The flexibility of this routing protocol is well suited to frequent route changes that happen when we switch links off and on. Moreover, this protocol can be easily applied to SDN solutions. Using simulations, we showed that as much as 44% of links can be switched off to save energy in real backbone networks. Even greedy techniques can easily approach the maximum reduction in the amount of energy consumed. In fact, the bottleneck in terms of energy efficiency in energy-aware traffic engineering is the connectivity constraint. We performed a stress test of our solution under rapidly increasing traffic patterns and showed that more work must be done in the domain of switching links back on: a field which has received little attention from the research community.

7.1.2. Energy proportionality in HPC systems

Energy savings are among the most important topics concerning Cloud and HPC infrastructures nowadays. Servers consume a large amount of energy, even when their computing power is not fully utilized. These static costs represent quite a concern, mostly because many datacenter managers are over-provisioning their infrastructures compared to the actual needs. This results in a high part of wasted power consumption. In this work [19], [47] , we proposed the BML (“Big, Medium, Little”) infrastructure, composed of heterogeneous architectures, and a scheduling framework dealing with energy proportionality. We introduce heterogeneous power processors inside datacenters as a way to reduce energy consumption when processing variable workloads. Our framework brings an intelligent utilization of the infrastructure by dynamically executing applications on the architecture that suits their needs, while minimizing energy consumption. Our first validation process focuses on distributed stateless web servers scenario and we analyze the energy savings achieved through energy proportionality. This research activity is performed with the collaboration of Sepia Team (IRIT, Toulouse) through the co-advising of Violaine Villebonnet.

7.1.3. Energy-Aware Server Provisioning

Several approaches to reduce the power consump- tion of datacenters have been described in the literature, most of which aim to improve energy efficiency by trading off performance for reducing power consumption. However, these approaches do not always provide means for administrators and users to specify how they want to explore such trade-offs. This work [27] provides techniques for assigning jobs to distributed resources, exploring energy efficient resource provisioning. We use middleware-level mechanisms to adapt resource allocation according to energy-related events and user-defined rules. A proposed framework enables developers, users and system ad- ministrators to specify and explore energy efficiency and perfor- mance trade-offs without detailed knowledge of the underlying hardware platform. Evaluation of the proposed solution under three scheduling policies shows gains of 25% in energy-efficiency with minimal impact on the overall application performance. We also evaluate reactivity in the adaptive resource provisioning This approach has been applied in the Nuage research project [26].

7.1.4. Virtual Home Gateway

About 80-90% of the energy in today's wireline networks is consumed in the access network, , including about 10 to 30W per user being dissipated mostly by the customer premises equipment (CPE). Home gateway is a popular equipment deployed at the end of networks and supporting a set of heterogeneous services (data, phone, television, multimedia, security services). These gateways and associated services can be difficult to deploy and maintain for customers. These gateways are difficult to manage for network operators and consume a lot of energy. We explore the technical solutions to reduce the complexity and energy impact of such equipments by moving services to some external dedicated and shared facilities of network operators. This result is a joint work between Avalon team (J.P. Gelas, L. Lefevre) and Addis Abeba University (M. Tsibie and T. Assefa). This research has been demonstrated in the GreenTouch final celebration event in New York (June 2015).

7.2. MPI Application and Storage System Simulation

Participants: Frédéric Suter, Laurent Pouilloux.

7.2.1. Scalable Off-line Simulation of MPI Applications

Analyzing and understanding the performance behavior of parallel applications on parallel computing platforms is a long-standing concern in the High Performance Computing community. When the targeted platforms are not available, simulation is a reasonable approach to obtain objective performance indicators and explore various hypothetical scenarios. In the context of applications implemented with the Message Passing Interface, two simulation methods have been proposed, on-line simulation and off-line simulation, both with their own drawbacks and advantages.

We proposed in [9] an off-line simulation framework, i.e., one that simulates the execution of an application based on event traces obtained from an actual execution. The main novelty of this work, when compared to previously proposed off-line simulators, is that traces that drive the simulation can be acquired on large, distributed, heterogeneous, and non-dedicated platforms. As a result the scalability of trace acquisition is increased, which is achieved by enforcing that traces contain no time-related information. Moreover, our framework is based on an state-of-the-art scalable, fast, and validated simulation kernel.

Such off-line analysis faces scalability issues for acquiring, storing, or replaying large event traces. Then, in [10], we combined our framework with another, specialized in the production of compact traces, to capitalize on their respective strengths while alleviating several of their limitations. We showed that the combined framework affords levels of scalability that are beyond that achievable by either one of the two individual frameworks.

7.2.2. Simulation of Storage Elements

Storage is a essential component of distributed computing infrastructures, *i.e.,* clusters, grids, clouds, data centers, or supercomputers, to cope with the tremendous increase in scientific data production and the ever-growing need for data analysis and preservation. Understanding the performance of a storage subsystem or dimensioning it properly is an important concern for which simulation can help by allowing for fast, fully repeatable, and configurable experiments for arbitrary hypothetical scenarios. However, most simulation frameworks tailored for the study of distributed systems offer no or little abstractions or models of storage resources.

In [34], we detailed the extension of SimGrid with storage simulation capacities. We first defined the required abstractions and propose a new API to handle storage components and their contents in SimGrid-based simulators. Then we characterized the performance of the fundamental storage component that are disks and derive models of these resources. Finally we listed several concrete use cases of storage simulations in clusters, grids, clouds, and data centers for which the proposed extension would be beneficial.

7.3. MapReduce Computations on Hybrid Distributed Computations Infrastructures

Participants: Gilles Fedak, Julio Anjos, Anthony Simonet.

In this section we report on our efforts to provide MapReduce Computing environments on Hybrid infrastructures, i.e composed of Desktop Grids and Cloud computing environments.

Cloud computing has increasingly been used as a platform for running large business and data processing applications. Although clouds have become extremely popular, when it comes to data processing, their use incurs high costs. Conversely, Desktop Grids, have been used in a wide range of projects, and are able to take advantage of the large number of resources provided by volunteers, free of charge. Merging cloud computing and desktop grids into a hybrid infrastructure can provide a feasible low-cost solution for big data analysis. Although frameworks like MapReduce have been devised to exploit commodity hardware, their use in a hybrid infrastructure raise some challenges due to their large resource heterogeneity and high churn rate.

7.3.1. BIGhybrid - A Toolkit for Simulating MapReduce in Hybrid Infrastructures

In [20], we introduced BIGhybrid, a toolkit that is used to simulate MapReduce in hybrid environments. Its main goal is to provide a framework for developers and system designers that can enable them to address the issues of Hybrid MapReduce. In this paper, we described the framework which simulates the assembly of two existing middleware: BitDew- MapReduce for Desktop Grids and Hadoop-BlobSeer for Cloud Computing. The experimental results that are included in this work demonstrate the feasibility of our approach.

7.3.2. HybridMR: a New Approach for Hybrid MapReduce Combining Desktop Grid and Cloud Infrastructures

In [18], we proposed a novel MapReduce computation model in hybrid computing environment called HybridMR. Using this model, high performance cluster nodes and heterogeneous desktop PCs in Internet or Intranet can be integrated to form a hybrid computing environment. In this way, the computation and storage capability of large-scale desktop PCs can be fully utilized to process large-scale datasets. HybridMR relies on a hybrid distributed file system called HybridDFS, and a time-out method has been used in HybridDFS to prevent volatility of desktop PCs, and file replication mechanism is used to realize reliable storage. A new node priority-based fair scheduling (NPBFS) algorithm has been developed in HybridMR to achieve both data storage balance and job assignment balance by assigning each node a priority through quantifying CPU speed, memory size and I/O bandwidth. Performance evaluation results showed that the proposed hybrid computation model not only achieves reliable MapReduce computation, reduces task response time and improves the performance of MapReduce, but also reduces the computation cost and achieves a greener computing mode.

7.3.3. D^3 -MapReduce: Towards MapReduce for Distributed and Dynamic Data Sets

So far MapReduce has been mostly designed for batch processing of bulk data. The ambition of D^3-MapReduce, presented in [32], is to extend the MapReduce programming model and propose efficient implementation of this model to: i) cope with distributed data sets, i.e. that span over multiple distributed infrastructures or stored on network of loosely connected devices; ii) cope with dynamic data sets, i.e. which dynamically change over time or can be either incomplete or partially available. In this paper, we draw the path towards this ambitious goal. Our approach leverages Data Life Cycle as a key concept to provide MapReduce for distributed and dynamic data sets on heterogeneous and distributed infrastructures. We first reported on our attempts at implementing the MapReduce programming model for Hybrid Distributed Computing Infrastructures (Hybrid DCIs). We present the architecture of the prototype based on BitDew, a middleware for large scale data management, and Active Data, a programming model for data life cycle management. Second, we outlined the challenges in term of methodology and present our approaches based on simulation and emulation on the Grid'5000 experimental testbed. We conducted performance evaluations and compare our prototype with Hadoop, the industry reference MapReduce implementation. We presented our work in progress on dynamic data sets that has lead us to implement an incremental MapReduce framework. Finally, we discussed our achievements and outline the challenges that remain to be addressed before obtaining a complete D 3-MapReduce environment.

7.3.4. Availability and Network-Aware MapReduce Task Scheduling over the Internet.

MapReduce offers an ease-of-use programming paradigm for processing large datasets. In our previous work, we have designed a MapReduce framework called BitDew-MapReduce for desktop grid and volunteer computing environment, that allows nonexpert users to run data-intensive MapReduce jobs on top of volunteer resources over the Internet. However, network distance and resource availability have great impact on MapReduce applications running over the Internet. To address this, an availability and network-aware MapReduce framework over the Internet is proposed in [38]. Simulation results show that the MapReduce job response time could be decreased by 27.15%, thanks to Naive Bayes Classifier-based availability prediction and landmark-based network estimation.

7.4. Managing Big Data Life Cycle

Participants: Gilles Fedak, Anthony Simonet.

7.4.1. Active Data - Enabling Smart Data Life Cycle Management for Large Distributed Scientific Data Sets

The Big Data challenge consists in managing, storing, analyzing and visualizing these huge and ever growing data sets to extract sense and knowledge. As the volume of data grows exponentially, the management of these data becomes more complex in proportion. A key point is to handle the complexity of the data life cycle, i.e. the various operations performed on data: transfer, archiving, replication, deletion, etc. Indeed, data-intensive applications span over a large variety of devices and e-infrastructures which implies that many systems are involved in data management and processing. In [17], we proposed Active Data, a programming model to automate and improve the expressiveness of data management applications. We first define the concept of data life cycle and introduce a formal model that allows to expose data life cycle across heterogeneous systems and infrastructures. The Active Data programming model allows code execution at each stage of the data life cycle: routines provided by programmers are executed when a set of events (creation, replication, transfer, deletion) happen to any data. We implement and evaluate the model with four use cases: a storage cache to Amazon-S3, a cooperative sensor network, an incremental implementation of the MapReduce programming model and automated data provenance tracking across heterogeneous systems. Altogether, these scenarios illustrate the adequateness of the model to program applications that manage distributed and dynamic data sets. We also show that applications that do not leverage on data life cycle can still benefit from Active Data to improve their performances.

7.4.2. Using Active Data to Provide Smart Data Surveillance to E-Science Users

Modern scientific experiments often involve multiple storage and computing platforms, software tools, and analysis scripts. The resulting heterogeneous environments make data management operations challenging, the significant number of events and the absence of data integration makes it difficult to track data provenance, manage sophisticated analysis processes, and recover from unexpected situations. Current approaches often require costly human intervention and are inherently error prone. The difficulties inherent in managing and manipulating such large and highly distributed datasets also limits automated sharing and collaboration. In [37], we study a real world e-Science application involving terabytes of data, using three different analysis and storage platforms, and a number of applications and analysis processes. We demonstrate that using a specialized data life cycle and programming model, Active Data, we can easily implement global progress monitoring, and sharing, recover from unexpected events, and automate a range of tasks.

7.4.3. SMART: An Application Framework for Real Time Big Data Analysis on Heterogeneous Cloud Environments.

The amount of data that human activities generate poses a challenge to current computer systems. Big data processing techniques are evolving to address this challenge, with analysis increasingly being performed using cloud-based systems. Emerging services, however, require additional enhancements in order to ensure their applicability to highly dynamic and heterogeneous environments and facilitate their use by Small & Medium-sized Enterprises (SMEs). Observing this landscape in emerging computing system development, this work presents Small & Medium-sized Enterprise Data Analytic in Real Time (SMART) for addressing some of the issues in providing compute service solutions for SMEs. SMART offers a framework for efficient development of Big Data analysis services suitable to small and medium-sized organizations, considering very heterogeneous data sources, from wireless sensor networks to data warehouses, focusing on service composability for a number of domains. In [62], we presented the basis of this proposal and preliminary results on exploring application deployment on hybrid infrastructure.

7.5. Desktop Grid Computing

Participants: Gilles Fedak, Anthony Simonet.

7.5.1. Multi-Criteria and Satisfaction Oriented Scheduling for Hybrid Distributed Computing Infrastructures

Assembling and simultaneously using different types of distributed computing infrastructures (DCI) like Grids and Clouds is an increasingly common situation. Because infrastructures are characterized by different attributes such as price, performance, trust, greenness, the task scheduling problem becomes more complex and challenging. In [15], we presented the design for a fault-tolerant and trust-aware scheduler, which allows to execute Bag-of-Tasks applications on elastic and hybrid DCI, following user-defined scheduling strategies. Our approach, named Promethee scheduler, combines a pull-based scheduler with multi-criteria Promethee decision making algorithm. Because multi-criteria scheduling leads to the multiplication of the possible scheduling strategies, we proposed SOFT, a methodology that allows to find the optimal scheduling strategies given a set of application requirements. The validation of this method is performed with a simulator that fully implements the Promethee scheduler and recreates an hybrid DCI environment including Internet Desktop Grid, Cloud and Best Effort Grid based on real failure traces. A set of experiments shows that the Promethee scheduler is able to maximize user satisfaction expressed accordingly to three distinct criteria: price, expected completion time and trust, while maximizing the infrastructure useful employment from the resources owner point of view. Finally, we present an optimization which bounds the computation time of the Promethee algorithm, making realistic the possible integration of the scheduler to a wide range of resource management software.

7.5.2. Synergy of Volunteer Measurements and Volunteer Computing for Effective Data Collecting, Processing, Simulating and Analyzing on a Worldwide Scale

The paper [31] concerns the hype idea of Citizen Science and the related paradigm shift: to go from the passive “volunteer computing” to other volunteer actions like “volunteer measurements” under guidance of scientists. They can be carried out by ordinary people with standard computing gadgets (smartphone, tablet, etc.) and the various standard sensors in them. Here the special attention is paid to the system of volunteer scientific measurements to study air showers caused by cosmic rays. The technical implementation is based on integration of data about registered night flashes (by radiometric software) in shielded camera chip, synchronized time and GPS-data in ordinary gadgets: to identify night air showers of elementary particles; to analyze the frequency and to map the distribution of air showers in the densely populated cities. The project currently includes the students of the National Technical University of Ukraine KPI, which are compactly located in Kyiv city and contribute their volunteer measurements. The technology would be very effective for other applications also, especially if it will be automated (e.g., on the basis of XtremWeb or/and BOINC technologies for distributed computing) and used in some small area with many volunteers, e.g. in local communities (Corporative/Community Crowd Computing).

7.5.3. Towards an Environment for doing Data Science that runs in Browsers

In [25], we proposed a path for doing Data Science using browsers as computing and data nodes. This novel idea is motivated by the cross-fertilized fields of desktop grid computing, data management in grids and clouds, Web technologies such as Nosql tools, models of interactions and programming models in grids, cloud and Web technologies. We propose a methodology for the modeling, analyzing, implemention and simulation of a prototype able to run a MapReduce job in browsers. This work allows to better understand how to envision the big picture of Data Science in the context of the Javascript language for programming the middleware, the interactions between components and browsers as the operating system. We explain what types of applications may be impacted by this novel approach and, from a general point of view how a formal modeling of the interactions serves as a general guidelines for the implementation. Formal modeling in our methodology is a necessary condition but it is not sufficient. We also make round-trips between the modeling and the Javascript or used tools to enrich the interaction model that is the key point, or to put more details into the implementation. It is the first time to the best of our knowledge that Data Science is operating in the context of browsers that exchange codes and data for solving computational and data intensive programs. Computational and data intensive terms should be understand according to the context of applications that we think to be suitable for our system.

7.5.4. *E-Fast & CloudPower: Towards High Performance Technical Analysis for Small Investors.*

About 80% of the financial market investors fail, the main reason for this being their poor investment decisions. Without advanced financial analysis tools and the knowledge to interpret the analysis, the investors can easily make irrational investment decisions. Moreover, in- vestors are challenged by the dynamism of the market and a relatively large number of indicators that must be computed. In this paper we propose E-Fast, an innovative approach for on-line technical analysis for helping small investors to obtain a greater efficiency on the market by increasing their knowledge. The E-Fast technical analysis platform proto- type relies on High Performance Computing (HPC), allowing to rapidly develop and extensively validate the most sophisticated finance analysis algorithms. In [36], we aim at demonstrating that the E-Fast im- plementation, based on the CloudPower HPC infrastructure, is able to provide small investors a realistic, low-cost and secure service that would otherwise be available only to the large financial institutions. We describe the architecture of our system and provide design insights. We present the results obtained with a real service implementation based on the Exponential Moving Average computational method, using CloudPower and Grid5000 for the computations' acceleration. We also elaborate a set of interesting challenges emerging from this work, as next steps towards high performance technical analysis for small investors.

7.6. HPC Component Model

Participants: Hélène Coullon, Vincent Lanore, Christian Perez, Jérôme Richard.

7.6.1. *3D FFT and L^2C*

We have completed the work started in 2014. To harness the computing power of supercomputers, HPC application algorithms have to be adapted to the underlying hardware. This is a costly and complex process which requires handling many algorithm variants. In [23], we studied the ability of the component model L^2C to express and handle the variability of HPC applications. The goal is to ease application adaptation. Analysis and experiments are done on a 3D-FFT use case. Results show that L^2C, and components in general, offer a generic and simple handling of 3D-FFT variants while obtaining performance close to well-known libraries

7.6.2. *Multi-Stencil DSL in L^2C*

As high performance architectures evolve continuously to be more powerful, such architectures also usually become more difficult to use efficiently. As a scientist is not a low level and high performance programming expert, Domain Specific Languages (DSLs) are a promising solution to automatically and efficiently write high performance codes. However, if DSLs ease programming for scientists, maintainability and portability issues are transferred from scientists to DSL de- signers. This work [44] has dealt with an approach to improve maintainability and programming productivity of DSLs through the generation of a component-based parallel runtime. To study it, we have designed a DSL for multi-stencil programs, that is evaluated on a real-case of shallow water equations implemented with L^2C.

7.6.3. Reconfigurable HPC component model

High-performance applications whose structure changes dynamically during execution are extremely complex to develop, maintain and adapt to new hardware. Such applications would greatly benefit from easy reuse and separation of concerns which are typical advantages of component models. Unfortunately, no existing component model is both HPC-ready (in terms of scalability and overhead) and able to easily handle dynamic reconfiguration. In [33], we aimed at addressing performance, scalability and programmability by separating locking and synchronization concerns from reconfiguration code. To this end, we propose directMOD, a component model which provides on one hand a flexible mechanism to lock subassemblies with a very small overhead and high scalability, and on the other hand a set of well-defined mechanisms to easily plug various independently-written reconfiguration components to lockable subassemblies. We evaluate both the model itself and a C++/MPI implementation called directL2C .

7.6.4. Towards a Task-Component Model

In [24], we propose a first model that aims at combining both component models and task based models such as StarPU. Component models bring many good software enginering properties such as code re-use while task based models seems to be very efficient to exploit recent hardware such as SMP, manycore, or GPGPUs. This work evaluates a proof-of-concepts only considering SMP nodes.

7.7. Security for Virtualization and Clouds

Participants: Eddy Caron, Arnaud Lefray.

7.7.1. Security and placement

We have proposed a solution for placement-based security and client-centric security. Even with perfect information flow control mechanisms, virtualized environments are still sensitive to silent information leakage, that is covert channels, due to shared hardware ressources. We have proposed a fine-grained placement based on the client's security properties to tackle this issue. The client submits an application i.e., a graph of VMs, and information flow rules defining the acceptable risk. Due to the lack of usable covert channel metric to qualify an acceptable risk, we have proposed a new information leakage metric. As covert channels exploit microarchitecture flaws, we have integrated the specificity of NUMA allocation schemes in our placement algorithm.

7.7.2. Security and logic language

Besides, the main issue with existing security languages is the ability to formally guarantee the required property. On the one hand, security policies described in a natural language have quite ambiguous semantics. On the other hand, a formal language or logic provides clear syntax and semantics. Moreover, existing mechanisms are dedicated to secure specific type of entities (e.g., VM, Service, Data, VNet). Therefore, the problem is to have a formal definition of security properties and proven procedures to transform the end-user's global security properties into multiple local properties enforceable by several local mechanisms. For these reasons, we proposed a logic language called IF-PLTL (Information Flow Past Linear Time Logic). Our logic is dedicated to controlling the propagation of information i.e., direct and indirect information flows. As these information flows cannot be obtained directly, we have explained their construction from low-level observable events. Security decisions are naturally expressed according to past actions. Accordingly, IF-PLTL is based on the past fragment of LTL. In addition to using IF-PLTL to transform properties, we have proposed a dynamic monitor that can enforce the full expressivity of IF-PLTL even if its complexity (in time and space) would incur a high overhead in practice.

7.8. Autonomic Middleware Deployment using Self-Stabilization

Participants: Eddy Caron, Maurice Faye.

Dynamic nature of distributed architecture is a major challenge to avail the benefits of distributed computing. An effective solution to deal with this dynamic nature is to implement a self-adaptive mechanism to sustain the distributed architecture. Self-adaptive systems can autonomously modify their behavior at run-time in response to changes in their environment. This capability may be included in the software systems at design time or later by external mechanisms. We have created a self-adaptive algorithm for the DIET middleware. Once the middleware is deployed, it can detect a set of events which indicate an unstable deployment state. When an event is detected, some instructions are executed to handle the event. We have designed a simulator to have a deeper insights of our proposed self-adaptive algorithm.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. Animerique

One of the goals of the CapRézo company is to provide an original tool to make 2D/3D animation films. This tool is an innovative and distributed numerical platform. This platform is built on software developed by Avalon like DIET. Technologies developed in collaboration between CapRézo and Inria are based on Cloud federation environment. The collaboration, started in 2014, is scheduled for the next 5 years.

8.2. Bilateral Grants with Industry

8.2.1. NewGeneration-SR

We have a collaboration with the company NewGeneration-SR. The aim of this company is to reduce the energy impact through solutions on each layer of the energy consumption (from the data- center design and the production to usage). NewGeneration-SR improve the life cycle (design, production, recycling) in order to reduce the environmental impact of it. NewGeneration-SR was member of the Nu@ge consortium: one of five national Cloud Computing projects with “emprunts d’avenir” funding. With a CIFRE PhD student (Daniel Balouek), we are developing models to reduce the energy consumption for the benefit of data-center

8.2.2. IFPEN

We have collaboration with IFPEN. IFPEN develops numerical code 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 parallel implementation of multi-level decomposition domain on many-core architecture and GPGPU.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. PIA

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

Participants: Hélène Coullon, 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 programming and execution environment. It also aims to validate the relevance of these development 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 Lefevre is the Inria representative in the ELCI technical committee.

9.1.2. French National Research Agency Projects (ANR)

9.1.2.1. ANR EMERGENCE CloudPower, Cloud Service providing HPC on-demand to innovative SME's, 35 months, ANR-12-EMMA-0038

Participant: Gilles Fedak.

High performance computing (HPC) allows scientists and industries to run large numerical application on huge data volumes. The HPC is a key factor in knowledge and innovation in many fields of industry and service, with high economic and social issues: aerospace, finance and business intelligence, energy and environment, chemicals and materials, medicine and biology , digital art and games, Web and social networks, ... Today, acquiring HPC supercomputer is very expensive, making HPC unreachable to SMIs / SMEs for their research and development. The CloudPower project results from the XtremWeb research and development project. Its goal is to offer a low cost Cloud HPC service for small and medium-sized innovative companies. With CloudPower, companies and scientists will run their simulations to design and develop new products on a powerful, scalable, economical, reliable and secure infrastructure.

The project will lead the creation of a new and innovative company operating the platform implemented in the framework of the ANR Emergence. CloudPower will implement SaaS / PaaS portal for customers and develop extensions to allow commercial exploitation of unused resources. Building on the network of SMIs from the competitiveness clusters System@tic and LyonBiopole, we will implement scenarios and/or demonstrators which illustrate the ability of CloudPower to increase competitiveness, research and marketing of innovative SMEs.

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

Participants: Christian Perez, Laurent Lefèvre, 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.

9.1.2.3. ANR INFRA SONGS, Simulation Of Next Generation Systems, 4 years, ANR-12-INFRA-11, 2012-2016

Participant: Frédéric Suter.

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

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

Any sound study of such systems through simulations relies on the following pillars of simulation methodology: Efficient simulation kernel; Sound and validated models; Simulation analysis tools; Campaign simulation management.

9.1.3. Inria Large Scale Initiative

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

Participants: Hélène Coullon, Christian Perez, Laurent Lefèvre, 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 propose algorithms and contribute to generic libraries and core solvers in order to take benefit from all the parallelism levels with the main goal of optimal scaling on very large numbers of computing entities and, numerical mathematicians that are studying numerical schemes and scalable solvers for systems of partial differential equations in view of the simulation of very large-scale problems.

9.1.3.2. DISCOVERY, DIstributed and COoperative management of Virtual Environments autonomousLY, 4 years, 2015-2019

Participants: Christian Perez, Gilles Fedak.

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

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

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

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

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. PaaSage

Participants: Christian Perez, Laurent Pouilloux.

Title: PaaSage: Model-based Cloud Platform Upperware

Type: Seventh Framework Programme

Instrument: Collaborative project

Duration: October 2012 - September 2016 (48 months)

Coordinator: Pierre Guisset (GEIE ERCIM)

Others partners: SINTEF, STFC, HLRS, University of Stuttgart, Inria, CETIC, FORTH, be.wan, EVRY, SysFera, Flexiant, Lufthansa Systems, AG GWDG, Automotive Simulation Center Stuttgart e.V.

See also: http://paasage.eu

Abstract: PaaSage will deliver an open and integrated platform, to support both deployment and design of Cloud applications, together with an accompanying methodology that allows model-based development, configuration, optimization, and deployment of existing and new applications independently of the existing underlying Cloud infrastructures. Specifically it will deliver an IDE (Integrated Development Environment) incorporating modules for design time and execution time optimizations of applications specified in the CLOUD Modeling Language (CLOUD ML), execution-level mappers and interfaces and a metadata database.

9.2.2. Collaborations in European Programs, except FP7 & H2020

9.2.2.1. CHIST-ERA STAR

Participants: Marcos Dias de Assunçao, Radu Carpa, Laurent Lefèvre, Olivier Glück.

Title: SwiTching And tRansmission project

Type: CHIST-ERA (European Coordinated Research on Long-term Challenges in Information and Communication Sciences & Technologies ERA-Net)

Duration: 2013-2015

Coordinator: Jaafar Elmirghani (University of Leeds - UK)

Others partners: Inria ,University of Cambridge (UK), University of Leeds (UK), AGH University of Science and Technology Department of Telecommunications (Poland)

See also: http://www.chistera.eu/projects/star

Abstract: The Internet power consumption has continued to increase over the last decade as a result of a bandwidth growth of at least 50 to 100 times. Further bandwidth growth between 40% and 300% is predicted in the next 3 years as a result of the growing popularity of bandwidth intensive applications. Energy efficiency is therefore increasingly becoming a key priority for ICT organizations given the obvious ecological and economic drivers. In this project we adopt the GreenTouch energy saving target of a factor of a 100 for Core Switching and Routing and believe this ambitious target is achievable should the research in this proposal prove successful. A key observation in core networks is that most of the power is consumed in the IP layer while optical transmission and optical switching are power efficient in comparison, hence the inspiration for this project. Initial studies by the applicants show that physical topology choices in networks have the potential to significantly reduce the power consumption, however network optimization and the consideration of traffic and the opportunities afforded by large, low power photonic switch architectures will lead to further power savings. Networks are typically over provisioned at present to maintain quality of service. We will study optimum resource allocation to reduce the overprovisioning factor while maintaining the quality of service. Protection is currently provided in networks through the allocation of redundant paths and resources, and for full protection there is a protection route for every working route. Avalon is contributing to STAR in terms of software network protocols and services optimizations which will be combined with more efficient photonic switches in order to obtain a factor of 100 power saving in core networks can be realised through this project with significant potential for resulting impact on how core photonic networks are designed and implemented.

9.2.2.2. COST IC1305 : Nesus

Participants: Laurent Lefèvre, Marcos Dias de Assunçao, Violaine Villebonnet.

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 Lefevre is co-chairing the Working on Energy Efficiency (WG5). In 2015, Violaine Villebonnet has been involved in a shirt term scientific mission with Universtity of La Lagune (Spain) on the topic of energy proportionality and profiling of HPC systems (May 18-29, 2015).

9.2.2.3. SEED4C

Program: Celtic-Plus

Project acronym: SEED4C

Project title: Security Embedded Element and Data privacy for the Cloud.

Duration: 2012-2015

Coordinator: Stéphane Betge-Brezetz (Alcatel-Lucent lab)

Other partners: Gemalto, ENSI Bourges, Inria, Wallix, VTT Technical Research centre of Finland, Mikkelin Puhelin Oyj, Cygate, Nokia Siemens Networks, Finceptum OY (Novell), Solacia, Innovalia Association, Nextel, Software Quality Systems, Ikusi, Vicomtech, Biscaytik

Abstract: SEED4C is a Celtic-Plus project: an industry-driven European research initiative to define, perform and finance through public and private funding common research projects in the area of telecommunications, new media, future Internet, and applications and services focusing on a new "Smart Connected World" paradigm. Celtic-Plus is a EUREKA ICT cluster and is part of the inter-governmental EUREKA network.

The cloud security challenge not only reflects on the secure running of software on one single machine, but rather on managing and guaranteeing security of a computer group or cluster seen as a single entity. Seed4C focus is to evolve from cloud security with an isolated point or centralized points of enforcement for security to cloud security with cooperative points of enforcement for security.

9.3. International Initiatives

9.3.1. Inria International Labs

9.3.1.1. Inria-UIUC-NCSA Joint Laboratory for Petascale Computing

Participants: Eddy Caron, Hélène Coullon, Olivier Glück, Vincent Lanore, Laurent Lefèvre, Christian Perez.

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

9.3.1.2. Informal International Partners

- Université Gaston Berger, Saint Louis, Sénégal. Contact: Pr. Ousmane Thiaré.
- École Centrale Mahindra, Hyderabad, India. Contact: Dr. Arya Kumar Bhattacharya.

9.3.2. Participation In other International Programs

9.3.2.1. GreenTouch

Participants: Jean-Patrick Gelas, Laurent Lefèvre.

GreenTouch is a consortium of leading Information and Communications Technology (ICT) industry, academic and non-governmental research experts dedicated to fundamentally transforming communications and data networks, including the Internet, and significantly reducing the carbon footprint of ICT devices, platforms and networks. The GreenTouch project has ended in June 2015 through the dissemination and demonstration of main results during a final celebration in New York. Our activities on designing virtual home gateway at large scale have been demonstrated.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

Dr Dan Emanoil Grigoras. University College Cork (UK). September 16-18 2015.

9.4.2. Visits to International Teams

9.4.2.1. Research stays abroad

9.4.2.1.1. Gilles Fedak visited CAS, Beijing, China

Dates: 15/8/15 - 15/9/15

Local contact: Pr Haiwu He

Gilles Fedak hase been awarded the President's International Fellowship Initiative (PIFI) from the Chinese Academy of Sciences. He visited the CSNET institute in Beijing for one month, working with Pr. Haiwu He on D^3 MapReduce.

9.4.2.1.2. Daniel Balouek Thomert visited Mahindra Ecole Centrale, India

Dates: 10/5/15 - 12/19/15

Local contact: Dr Arya K. Bhattacharya (Arya.Bhattacharya@mechyd.ac.in)

Other avalon researcher involved: Eddy Caron and Laurent Lefevre.

Abstract: Our work synergizes two state-of- the-art technologies by combining Multi-Objective Evolutionary Algorithms (MOEA) with trade-off mechanisms using the DIET toolkit, in a context of cloud computing workflow placement. Evaluation of the proposed solution under different scheduling policies shows significant gains of energy consumption with some improvement on the overall workflow completion time. Following this work, a paper has been submitted.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

L. Lefevre: Co-Workshop chair of ExtremeGreen 2015 : Extreme Green & Energy Efficiency in Large Scale Distributed Systems , Shenzen, China, May 2015

L. Lefevre: Co-organizer of the Green Days Toulouse event: "From energetic to thermic, GreenIT really green ?", Toulouse, March 16-17, 2015

10.1.1.2. Member of the organizing committees

C. Pérez: Program committee member of SUCCES'2015 (*Rencontres Scientifiques des Utilisateurs de Calcul intensif, de Cloud Et de Stockage*

10.1.2. Scientific events selection

10.1.2.1. Chair of conference program committees

- G. Fedak: Program chair of COMPAS'15 (Conférence en Parallélisme, Architecture et Systèmes), Lille, France.
- G. Fedak: co-tracke chair, GECON, Conference on the Economics of Grids, Clouds, Systems, and Services, Track “Economically Efficient Resource Allocation and Service Level Agreements”, Cluj-Napoca, Romania.

10.1.2.2. Member of the conference program committees

E. Caron: CNRIA 2015, SETCAC'15, HCW'2015, CLOSER 2015, CLOUDTECH 2015, Compas'15

C. Pérez: CCGRID 2015, ParCo 2015

F. Suter: CloudCom'15, EuroMPI'15, EuroPar'15, FICloud'15, VTDC'15

G. Fedak: CCGRID'15, CloudCom'15, HPDC'15

O. Glück: PDP 2015, ExtremeGreen 2015

10.1.3. Journal

10.1.3.1. Member of the editorial boards

- G. Fedak: Co-editor of Elsevier Journal of Cluster Computing

10.1.3.2. Reviewer - Reviewing activities

E. Caron: IEEE Transactions on Services Computing (TSC), Cluster Computing

F. Suter: Concurrency and Computation: Practice and Experience, The Computer Journal, Journal of Parallel and Distributed Computing

10.1.4. Invited talks

- G. Fedak, Big Data, Beyond the Data Center, Hunan University of Sciences and Technology, September 2015, Changsha, China, Department Seminary.
- G. Fedak, Active Data, Managing Big Data Lifecycle, Computer Network Information Center, Chinese Academy of Sciences, August 2015, Beijing, China, Seminary
- G. Fedak, Big Data, Beyond the Data Center, Séminaire LIG, 11 Juin 2015, Grenoble, France, Seminary.
- A. Simonet, G. Fedak, M. Ripeanu, S. Al-Kiswany, K. Chard, I. Foster, Active Data: Data Life Cycle Management Across Heterogeneous Systems and Infrastructures. Hot Topics in High-Performance Distributed Computing Workshop, IBM Almaden Research Center, San Jose, California, March 12, 2015, Invited Speaker
- O. Glück, Efficacité énergétique dans les réseaux et centres de calcul haute performance, Journées Scientifiques Inria 2015, 18 Juin 2015, Nancy, France.
- T. Gautier, Le runtime XKAAPI, Ecole Thématique "Signal Images : Architecture et Programmation des GPUs", 17 décembre 2015, Grenoble, France.

10.1.5. Scientific expertise

- G. Fedak: Mission of expertise in Big Data for the French Ambassy in China

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence: Eddy Caron, ASR1, 48h, niveau L3, Ecole Normale Supérieure de Lyon, France.

Licence: Eddy Caron, Projet 1, 48h, niveau L3, Ecole Normale Supérieure de Lyon, France.

Master: Eddy Caron, Syste`mes Distribue´s, 30h, niveau M1, Ecole Normale Supérieure de Lyon, France.

Master: Eddy Caron, Projet Intégré, 42h, niveau M1, Ecole Normale Supérieure de Lyon, France.

Master: Eddy Caron, Gilles Fedak, Laurent Lefèvre, and Christian Perez, Distributed Computing: Models and Challenges, 36h, niveau M2, Ecole Normale Supérieure de Lyon, France.

Licence: Olivier Glück, Initiation Réseaux, 2x9h, niveau L2, Université Lyon 1, France

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

Licence: Olivier Glück, Réseaux, 45h, niveau L3, Université des Sciences de Ho Chi Minh Ville, Vietnam

Master: Olivier Glück, Réseaux par la pratique, 20h, niveau M1, Université Lyon 1, France

Master: Olivier Glück, Services et Protocoles Applicatifs sur Internet, 40h, niveau M2, Université Lyon 1, France

Master: Olivier Glück, Services et Protocoles Applicatifs sur Internet, 24h, niveau M2, IGA Casablanca, Maroc

Master : Olivier Glück, Administration des Systèmes et des Réseaux, 16h, niveau M2, Université Lyon 1, France

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

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

Master: Jean-Patrick Gelas, Analyse de performance, 6h, niveau M2, Université Lyon 1, France

Master: Jean-Patrick Gelas, Réseaux, 48h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Système d'exploitation, 30h, niveau M2 (CCI), Université Lyon 1, France

Master: Jean-Patrick Gelas, Architecture des routeurs, 6h, niveau M2, Université Lyon 1, France

Master: Jean-Patrick Gelas, Systèmes embarqués (GNU/Linux, Android), 85h, niveau M2, Université Lyon 1, France

Master: Jean-Patrick Gelas, Routage et IPv6, 45h, niveau M2, Université Lyon 1, France

Master: Jean-Patrick Gelas, Introduction aux IaaS (Cloud), 5h, niveau M2, Université Lyon 1, France

E-learning

MooC : Jean-Patrick Gelas, MooC Cloud, 7 semaines, Claroline Connect, Université Lyon 1 (http://claco.univ-lyon1.fr/workspaces/7816/open/tool/home)

MooC : Jean-Patrick Gelas, MooC Capps (Conception et valorisation d'applications mobiles), 6 semaines, Claroline Connect, Université Lyon 1 (http://claco.univ-lyon1.fr/workspaces/7812/open/tool/home)

MooC : Jean-Patrick Gelas, Vet4Apps (Conception et valorisation d'applications mobiles), 7 semaines, versal, Nebula European project (https://versal.com/c/jq29wt)

10.2.2. Supervision

PhD in progress: Daniel Balouek-Thomert, *Ordonnancement et éco-efficacité dans les environnements virtualisés*, 09/2013, Eddy Caron (dir), Laurent Lefevre (co-dir), Gilles Cieza (NewGen society, co-dir)

PhD in progress: Radu Carpa, *Efficacité énergétique des échanges de données dans une fédération d'infrastructures distribuées à grande échelle*, 10/2014, Laurent Lefèvre (dir), Olivier Glück (co-dir).

PhD in progress: Hadrien Croubois, *Étude et conception d'un système de gestion de workflow autonomique conçu pour l'animation 3D* , 10/2015, Eddy Caron.

PhD defended: Maurice Djibril Faye, *Déploiement auto-adaptatif d'intergiciel sur plateforme élastique*, **??**/2015, Eddy Caron (dir), Ousmane Thiaré (Université Gaston Berger, St Louis, Sénégal, co-dir)

PhD defended: Sylvain Gault, *Improving MapReduce Performance on Clusters*, Mar 2015, Frédéric Despez (dir), Christian Pérez (co-advisor)

PhD defended: Vincent Lanore, *On Scalable Reconfigurable Component Models for High-Performance Computing*, Dec 2015, Christian Pérez (dir)

PhD defended: Arnaud Lefray, *Mission fonctionnelle et de sécurité dans une informatique en nuage*, Nov. 2015, Eddy Caron (dir), Christian Toinard (ENSIB, co-dir)

PhD canceled nov 2015: Semen Marchuk, *Contribution pour la conception d'algorithmes d'ordonnancement de taches de calcul dans le domaine de l'animation 3D*, 10/2014, Eddy Caron (dir), Pierre Biecher (CapRézo society, co-dir) and Rodolphe De Carini (CapRézo society, co-dir)

PhD in progress: Pedro Silva, *Application model and co-scheduling algorithm for dynamic and evolutive data-intensive application*, 10/2014, Christian Perez (dir), Frédéric Desprez (co-dir).

PhD defended: Anthony Simonet, *Active Data - Enabling Smart Data Life Cycle Management for Large Distributed Scientific Data Sets*, Jul. 2015, Gilles Fedak (dir)

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

PhD in progress: Jérôme Richard, *Conception of a software component model with task scheduling for many-core based parallel architecture, application to the Gysela5D code*, 11/2014, Christian Perez (dir), Julien Bigot (CEA, co-dir).

PhD in progress: Violaine Villebonnet, *Proportionnalité énergétique dans les systèmes distribués à grande échelle*, 9/2013, Laurent Lefevre (dir), Jean-Marc Pierson (IRIT, Toulouse, co-dir)

PhD in progress: Hayri Acar, *Towards a green and sustainable software*, 09/2014, Parisa Ghodous (dir), Gulfem Alptekin (co-dir), Jean-Patrick Gelas (co-dir)

10.2.3. Juries

Eddy Caron has been member of the following PhD Juries:

- Aleila Abidi. “Revisiter les Grilles de PCs avec des technologies du Web et le Cloud Computing ?”. Université Paris 13, March 2015, Reviewer.
- Karine Pirez. “Distribution et Transcodage des Systemes a Grande Echelle de Flux en Direct”. Université Pierre et Marie Curie, March 2015, Reviewer
- Etienne Michon. “Allocation dynamique sur cloud IaaS. Allocation dynamique d’infrastructure de SI sur plateforme de Cloud avec maîtrise du compromis coûts/performances”. Université de Strasbourg, June 2015, Reviewer.

Thierry Gautier has been member of the following PhD Jury:

- Farouk Mansouri : "Modèle de programmation des applications de traitement du signal et de l’image sur cluster parallèle et hétérogène", Université de Grenoble, October 2015, Examinateur

Laurent Lefevre has been member of the following PhD Juries:

- Davide Morelli : "Theory of benchmarking", University of Pisa, Italy, September 2015, Rapporteur
- Richard Ewelle Ewelle : "Adapting Communications in Cloud Games", University of Montpellier, August 2015, Examinateur

Christian Pérez has been member of the following PhD Juries:

- Emmanuel Cieren: "Molecular Dynamics for Exascale Supercomputers", University of Bordeaux, France, Oct 2015, Reviewer
- Quang The Bui: "Criblage virtuel sur grille de composés isolés au Vietnam", University of Blaise Pascal Clermont-Ferrand II, France, Jun 2015, Reviewer
- Matthieu Dreher: "Méthodes In-Situ et In-Transit: vers un continuum entre les applications interactives et offines à grande échelle", University of Grenoble, France, Feb 2015, jury member
- Franços Tessier: "Placement d’applications parallèles en fonction de l’affinité et de la topologie", University of Bordeaux, France, Jan 2015, Reviewer

10.3. Popularization

Eddy Caron has participated to the following interview:

- Interview for NSmag N°9, Editeur: Imaginove. «Pipeline de production: Optimisation des temps de calcul et parallélisme». January 2015.

Laurent Lefevre has participated to the following interviews and publications :

- Interview for Sciences pour tous, "Le numérique écologique, c’est possible ?", "A digital ecological world, is it possible ?", September 2015.
- Interview : "Internet au bord de la saturation ?", Le MAG de la Science, Science et Vie TV, 26 Septembre 2015
- Interview : "Comment Internet pollue (vraiment) la planète", BFM Business, May 29, 2015
- Interview Industrie et Technologies : Un blackout d’Internet en 2023 ? 5 raisons de ne pas y croire", May 13, 2015
- Interview in "Le Monde" NewsPaper : "Internet congestionné d’ici à 2023 ? Pas si vite !", May 12, 2015

- Interview in "#2020 program", "Internet Crunch" : La mort du web est pour 2023", Mouv' Radio, May 12, 2015
- Combined Short papers in "Liberation NewsPaper" and "CNRS Le Journal" : "Le Big Data est il polluant ?", Laurent Lefevre, Jean-Marc Pierson, April 3, 2015
- Interview in Sciences et Avenir Journal : "Coup de chaud sur les data centers", Number 816, February 2015

Olivier Glück has participated to the following interview:

- Interview for Radio France Mouv in LE 20#20 radio broadcasting on "La mort du web & Naruto", 12 mai 2015 20h30. Podcast http://www.mouv.fr/player/reecouter?play=198336

11. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] G. FEDAK. *Contributions to Desktop Grid Computing* , Ecole Normale Supérieure de Lyon, May 2015, Habilitation à diriger des recherches, https://hal.inria.fr/tel-01158462

[2] S. GAULT. *Improving MapReduce Performance on Clusters*, Ecole normale supérieure de lyon - ENS LYON, March 2015, https://tel.archives-ouvertes.fr/tel-01146365

[3] V. LANORE. *On Scalable Reconfigurable Component Models for High-Performance Computing*, Ecole normale supérieure de lyon - ENS LYON, December 2015, https://tel.archives-ouvertes.fr/tel-01257842

[4] A. LEFRAY. *Security for Virtualized Distributed Systems : from Modelization to Deployment*, Ecole normale supérieure de lyon - ENS LYON, November 2015, https://tel.archives-ouvertes.fr/tel-01229874

[5] A. SIMONET. *Active Data - Enabling Smart Data Life Cycle Management for Large Distributed Scientific Data Sets*, Ecole normale supérieure de lyon - ENS LYON, July 2015, https://tel.archives-ouvertes.fr/tel-01218016

Articles in International Peer-Reviewed Journals

[6] A. ANCEL, I. ASSENMACHER, K. I. BABA, J. CISONNI, Y. FUJISO, P. GONÇALVES, M. IMBERT, K. KOYAMADA, P. NEYRON, N. KAZUNORI, O. HIROYUKI, A.-C. ORGERIE, X. PELORSON, B. RAFFIN, N. SAKAMOTO, E. SAKANE, S. WADA, S. SHIMOJO, A. VAN HIRTUM. *PetaFlow: a global computing-networking-visualisation unitwith social impact*, in "International Research Journal of Computer Science", April 2015, vol. 2, n° 4, https://hal.inria.fr/hal-01231826

[7] M. BAGEIN, J. BARBOSA, V. BLANCO, I. BRANDIC, S. CREMER, S. FREMAL, H. KARATZA, L. LEFÈVRE, T. MASTELIC, A. OLEKSIAK, A.-C. ORGERIE, G. L. STAVRINIDES, S. VARRETTE. *Energy Efficiency for Ultrascale Systems: Challenges and Trends from Nesus Project*, in "Supercomputing frontiers and innovations ", September 2015, vol. 2, n° 2, pp. 105-131 [*DOI :* 10.14529/JSFI150206], https://hal.inria.fr/hal-01196798

[8] R. CARPA, O. GLUCK, L. LEFÈVRE, J.-C. MIGNOT. *Improving the energy efficiency of software-defined backbone networks*, in "Photonic Network Communications", December 2015, vol. 30, n° 3, pp. 337-347 [*DOI :* 10.1007/S11107-015-0552-9], https://hal.inria.fr/hal-01246376

[9] H. CASANOVA, F. DESPREZ, G. S. MARKOMANOLIS, F. SUTER. *Simulation of MPI applications with time-independent traces*, in "Concurrency and Computation: Practice and Experience", April 2015, vol. 27, n^o 5, 24 p. [*DOI :* 10.1002/CPE.3278], https://hal.inria.fr/hal-01232776

[10] H. CASANOVA, A. GUPTA, F. SUTER. *Toward More Scalable Off-Line Simulations of MPI Applications*, in "Parallel Processing Letters", September 2015, vol. 25, n^o 3 [*DOI :* 10.1142/S0129626415410029], https://hal.inria.fr/hal-01232787

[11] M. DIAS DE ASSUNCAO, C. CARDONHA, M. NETTO, R. CUNHA. *Impact of User Patience on Auto-Scaling Resource Capacity for Cloud Services*, in "Future Generation of Computing Systems (FGCS)", 2015, pp. 1-10, https://hal.inria.fr/hal-01199207

[12] J.-G. DUMAS, T. GAUTIER, C. PERNET, J.-L. ROCH, Z. SULTAN. *Recursion based parallelization of exact dense linear algebra routines for Gaussian elimination*, in "Parallel Computing", November 2015, https://hal.archives-ouvertes.fr/hal-01084238

[13] F. KOCH, M. DIAS DE ASSUNCAO, C. CARDONHA, M. NETTO. *Optimising resource costs of cloud computing for education*, in "Future Generation Computer Systems", 2015, pp. 1-7 [*DOI :* 10.1016/J.FUTURE.2015.03.013], https://hal.inria.fr/hal-01199188

[14] F. KOCH, M. DIAS DE ASSUNCAO, C. CARDONHA, M. A. NETTO, T. T. PRIMO. *An architecture and algorithm for context-aware resource allocation for Digital Teaching Platforms*, in "Ibm Journal of Research and Development", December 2015, vol. 59, n^o 6, pp. 1-9, https://hal.inria.fr/hal-01205652

[15] M. MOCA, C. LITAN, G. C. SILAGHI, G. FEDAK. *Multi-criteria and satisfaction oriented scheduling for hybrid distributed computing infrastructures*, in "Future Generation Computer Systems", 2016, vol. 55 [*DOI :* 10.1016/J.FUTURE.2015.03.022], https://hal.inria.fr/hal-01239218

[16] L. POUILLOUX, T. HIROFUCHI, A. LEBRE. *SimGrid VM: Virtual Machine Support for a Simulation Framework of Distributed Systems*, in "IEEE Transactions on Cloud Computing", January 2016, forthcoming, https://hal.inria.fr/hal-01197274

[17] A. SIMONET, G. FEDAK, M. RIPEANU. *Active Data: A Programming Model to Manage Data Life Cycle Across Heterogeneous Systems and Infrastructures*, in "Future Generation Computer Systems", December 2015, vol. 55, 17 p. [*DOI :* 10.1016/J.FUTURE.2015.05.015], https://hal.inria.fr/hal-01241491

[18] B. TANG, H. HE, G. FEDAK. *HybridMR: a New Approach for Hybrid MapReduce Combining Desktop Grid and Cloud Infrastructures*, in "Concurrency and Computation: Practice and Experience", May 2015, vol. 27, n^o 16, 16 p. [*DOI :* 10.1002/CPE.3515], https://hal.inria.fr/hal-01239299

[19] V. VILLEBONNET, G. DA COSTA, L. LEFÈVRE, J.-M. PIERSON, P. STOLF. *"Big, Medium, Little": Reaching Energy Proportionality with Heterogeneous Computing Scheduler*, in "Parallel Processing Letters", 2015, vol. 25, n^o 03, 1541006 p. [*DOI :* 10.1142/S0129626415410066], https://hal.archives-ouvertes.fr/hal-01206525

[20] J. C. S. DOS ANJOS, G. FEDAK, C. GEYER. *BIGhybrid: A Simulator for MapReduce Applications in Hybrid Distributed Infrastructures Validated with the Grid5000 Experimental Platform*, in "Concurrency and Computation: Practice and Experience", 2015 [*DOI :* 10.1002/CPE.665], https://hal.inria.fr/hal-01239382

Articles in Non Peer-Reviewed Journals

[21] J. CARRETERO, R. ČIEGIS, E. JEANNOT, L. LEFÈVRE, G. RÜNGER, D. TALIA, Ž. JULIUS. *HeteroPar 2014, APCIE 2014, and TASUS 2014 Special Issue*, in "Concurrency and Computation: Practice and Experience", 2016, 2 p. , https://hal.inria.fr/hal-01253278

Invited Conferences

[22] F. CLOUET, S. DELAMARE, J.-P. GELAS, L. LEFÈVRE, L. NUSSBAUM, C. PARISOT, L. POUILLOUX, F. ROSSIGNEUX. *Kwapi: A Unified Monitoring Framework for Energy Consumption and Network Traffic*, in "4th GENI / FIRE Collaboration Workshop", Washington, DC, United States, September 2015, https://hal.inria.fr/hal-01204618

[23] R. JÉRÔME, C. PÉREZ, V. LANORE. *Towards Application Variability Handling with Component Models: 3D-FFT Use Case Study*, in "UnConventional High Performance Computing 2015", Vienne, Austria, Euro-Par 2015: Parallel Processing Workshops, Springer, August 2015, 12 p. , This papper will be publish soon, https://hal.inria.fr/hal-01192732

[24] J. RICHARD. *Vers un modèle de composants supportant l'ordonnancement de tâches pour le calcul de haute performance*, in "Compas 2015", Lille, France, Romain Rouvoy and Michaël Hauspie and Julien Iguchy-Cartigny and Philippe Marquet and Lionel Seinturier and Thomas Vantroys and Christine Yvoz, June 2015, 10 p. , https://hal.inria.fr/hal-01192661

International Conferences with Proceedings

[25] L. ABIDI, C. CÉRIN, G. FEDAK, H. HE. *Towards an Environment for doing Data Science that runs in Browsers*, in "International Conference on Big Data Intelligence and Computing (DataCom 2015)", Chengdu, China, December 2015, https://hal.inria.fr/hal-01245751

[26] *Best Paper*
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