DISCOVERY Inria Project Lab: midterm summary
Distributed and Cooperative Environment to manage Virtual Environment Autonomously
http://beyondtheclouds.github.io

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  Project lead's team (EP): ASCOLA **Research center (CRI):** IRBA

- **Internal partners (EP/CRI) and external partners currently involved (other laboratories or industriels)** : ASAP (Rennes), AVALON (Lyon), CORSE (Grenoble), MADYNES (Nancy), MYRIADS (Rennes), Orange Labs (Grenoble, Lannion, Paris)

Overview

To satisfy requirements of the Industrial and Tactile Internet applications (such as real-time), academics and industry experts advocate for moving from large-centralized infrastructures to smaller ones massively distributed at the edge of the network. To favor the adoption of this decentralized model (referred to as "Fog/Edge Computing"), the development of a system in charge of turning a complex and diverse network of resources into a global unified infrastructure is critical. While brokering and orchestrating multiple clouds are the first approaches that are considered when it comes to operate and use distinct clouds, DISCOVERY's members target a tightly coupled system leveraging OpenStack, the de-facto open source solution for operating Cloud Computing Infrastructures.

Highlights

- July 2015: First plenary meeting in Paris (10 participants)
- Dec 2015: Second plenary meeting in Nantes (official kickoff, first contact with the OpenStack foundation, 20 participants)
- April 2016:
  - Presentation of a first PoC at the Austin OpenStack Summit (beginning of our official involvement within the OpenStack community).
  - Submission to the H2020 ICT-06-2016 call: EOLE: Blow the clouds to the edge (8 partners, Inria was the coordinator of this proposal)
- July 2016, Third plenary meeting in Rennes (25 participants)
- October 2016
  - Presentation of the EnOS framework at Barcelona OpenStack Summit.
  - Creation of a Fog/Edge/Massively Distributed Cloud OpenStack WG: https://wiki.openstack.org/wiki/Fog_Edge_Massively_Distributed_Clouds
- March 2017: Fourth plenary meeting in Rennes (35 participants)
- May 2017:
  - Organization of the 1st edition of the ICFEC conference (25 participants): http://fec-conf.gforge.inria.fr
  - Boston OpenStack summit
    - OpenStack WANWide: First performance evaluations.
    - The OpenStack foundation advocates the advent of Fog/Edge infrastructures and officially highlights our action.
- September 2017: MidTerm review

Research accomplished and progress on the IPL challenges

By massively adopting OpenStack for operating small to large private and public clouds, the industry has made it one of the largest running software project, overgrowing the Linux kernel. DISCOVERY's objectives consist in (i) studying to what extent the current OpenStack mechanisms can handle fog/edge infrastructures, (ii) proposing revisions/extensions of internal mechanisms when appropriate, and (iii) investigating how current cloud APIs could be extended to take advantage of the geo-distribution (latency-aware applications ...). After conducting an economical analysis of Fog/Edge infrastructures [1iw16], our major activities have been structured around the analysis of the OpenStack ecosystem, a software stack composed of millions of lines of code.

EnOS: Conducting Scientific Evaluations of OpenStack (ASCOLA/MYRIADS) To help researchers and more generally any contributor of the community to conduct scientific analysis on the OpenStack codebase, we have been developing Enos, an integrated framework that relies on container technologies for deploying and evaluating OpenStack on any testbed. The EnoS toolkit[1] allows researchers to easily express different configurations, invoke benchmarks and collect metrics for post-mortem analyses. It is a critical service for DISCOVERY members as it enables us to conduct several experiments on several OpenStack components WANWide. The toolkit has been presented through publications and OpenStack-related events [4ip16, 4ic17, 6ip17, 1tu17]. Moreover, we recently signed a contract with Orange to favour the transfer of EnOS toward the OpenStack community.

From SQL to noSQL DBs and Beyond (ASCOLA/AVALON/CORSE). Although the organization of the OpenStack services respects the *Shared Nothing* principle, the message bus and the fact that objects are persistent in shared databases prevent the distribution of the system across distinct geographical sites. In 2016, we presented a first PoC of the Nova service (the OpenStack compute element) using a decentralized key/value store in place of the centralized SQL DB. This revision enables us to distribute Nova over several sites. The proper functioning of this PoC has been validated via several experiments performed on top of Grid'5000. In addition to tackling both the scalability and distribution issues of the SQL database, our prototype leads to promising performance. More than 80% of the API requests are performed faster than with the SQL backend without doing any modification in the Nova code [1ip16, 2ip16, 3ic17]. We are currently working on a similar study that investigates the relevance of NewSQL DBs for OpenStack.

On-going activities

- The PhD position of Genc Tato (2015/2018, MYRIADS/ASAP) focuses on providing a lazy but efficient routing and discovery mechanism for Fog/Edge infrastructures. The expected outcome is a locality-aware overlay network that will act as a building block for higher-level services, such as message brokering and database distribution. Preliminary evaluations are promising and a first publication is expected soon.
- The PostDoc position of Dimitri Pertin (2016/2017, ASCOLA/AVALON) deals with the deployment of any distributed application or system onto Fog/Edge infrastructures. The main use-case is the deployment of our revised OpenStack. A first contribution has been done and published [6ic17] under the form of a survey of existing deployment tools

[1] https://github.com/BeyondTheClouds/enos

currently used to deploy OpenStack. This survey, which follows a deployment model to compare existing tools, is very useful for our ongoing work on a new deployment model and framework. This work will be consolidated through the new PhD position of Maverick Chardet (2017/2020, ASCOLA/AVALON).

- The PhD position of Jad Darrous (2016/2019, AVALON/KERDATA) focuses on efficient management of Virtual Machine Images (VMIs) in Fog/Edge infrastructures. Traditional ways to distribute these VMIs between data centers are costly in terms of storage requirement and transfer cost. As WAN exhibits high latency and low bandwidth with heterogeneous up/down links, transferring these huge images over the WAN is challenging and should be done efficiently. As a preliminary work, we experimentally evaluated the efficiency of the InterPlanetary File System (IPFS), a storage backend leveraging bittorent protocol to share data WANWide [1nc17].
- the PostDoc position of Ehsan Ahvar (2017/2018, MYRIADS/ASCOLA) is focusing on the energy consumption of different cloud architectures. The goal is to propose a comprehensive, accurate and scalable energy model that can be easily adapted to different cloud architectures in different scales, ranging from centralized to distributed clouds such as Fog/Edge infrastructures. Thanks to such a model and by leveraging the economical study we performed [1iw16], we expect to deliver means to identify where and how micro DCs should be deployed.

We highlight that additional topics are under investigations through PhD positions funded by Orange Labs in the context of the Inria/Orange joint lab (monitoring of Fog/Edge infrastructures, workload placements, Security: Threats and opportunities . . .).

Changes made to the IPL organization

The first change is related to the involvement of RENATER that cannot allocate sufficient resources to the IPL due to internal changes: members still take part to some discussions but rather follow the progress of the IPL instead of performing concrete tasks. Although this is unfortunate, the impact is for the moment negligible as the expected effort was around a use-case that should be addressed on the second part of the project. Regarding the testbed we have planned to deploy within the RENATER infrastructure, we already think about possible backups as discussed later in the document.

The second change is the integration of MADYNES (Inria Nancy Grand Est) in April 2017 in oder to help DISCOVERY members address network challenges. While we expected to integrate DIANA at the creation of the IPL, we finally invited MADYNES due to the involvement of some of their researchers in the Inria/Orange joint lab (some PhD candidates are co-supervised between MADYNES and DISCOVERY members making the integration more natural).

The last change is related to the move of DISCOVERY's members between Inria Project-teams: Frédéric Desprez, initially in AVALON moved to CORSE (Inria Grenoble Rhone-Alpes) in 2016 while Shadi Ibrahim, initially in KERDATA, joined ASCOLA in 2017. Those changes do not have any impact of on-going and future activities.

More generally, ASCOLA, AVALON and MYRIADS are well committed with several members contributing to the DISCOVERY working groups.

Interactions between the IPL teams

In addition to regular discussions between teams involved in PhDs and PostDocs co-supervisions, three working groups have been constituted.

- **P2P Building Blocks, ASCOLA/ASAP/MYRIADS, July 2015-20xx** Leveraging face-to-face quarterly meetings in average, this working group discusses progress achieved within the IPL but also recent achievements in distributed algorithms in order to identify results that can be relevant for the project. Current discussions are related to (i) the use of the lazy overlay network (Genc Tato's PhD) for revising the communication bus of OpenStack and (ii) the use of NewSQL backends (such as cockRoachDB) for storing internal states of OpenStack WANWide. From the expertise viewpoint, ASAP and MYRIADS have a strong background on distributed protocols while ASCOLA is expert on the OpenStack ecosystem. Combining both skills enables us to identify which components of OpenStack should be revised and in which way.
- **Placement (formerly Architecture), ASCOLA, AVALON, CORSE, Orange, MYRIADS, July 2016-20xx**. Leveraging monthly web conferences, this WG initially focused on use-cases in order to identify requirements of our targeted OpenStack. In 2017, we chose to focus this WG on workload placement challenges because it is a key topic for Fog/Edge infrastructures. Generally, these monthly meetings are used to discuss one particular topic in details. Subjects can deal with either a state of the art solution, a specific use-case or a prospective idea. Orange provides use-cases and their expertise around OpenStack production systems. ASCOLA and AVALON bring their expertise around workload placements while MYRIADS provides its deep knowledge related to resource management, in particular from the energy viewpoint.
- **Data management, ASCOLA, AVALON, KERDATA (up to Jan 2017), MADYNES (from April 2017), Oct 2016-20xx**. The goal of this WG is to identify challenges but also opportunities that Fog/Edge infrastructures bring to data management. ASCOLA (KERDATA) and AVALON have strong background on data management at large scale while MADYNES brings its expertise around traffic exchanges at WAN scale. This WG is for the moment less active than the two previous ones. However, the PhD of Jad Darrous (started in Oct 2016) and the ANR Greco (Apr. 2017- Dec. 2020), which deals with data challenges in massively distributed clouds, should quickly lead to interesting exchanges.

In addition to these WGs, we organize twice a year a plenary meeting for all DISCOVERY's members. These two-days meetings are used to present latest results, on-going activities and roadmaps for the next period. The last meeting has been held in Rennes with 35 attendees.

Finally, it is noteworthy that several members of the IPL interact through OpenStack WGs. In addition to the Fog/Edge/Massively Distributed Clouds OpenStack WG, which is chaired by ASCOLA, ASCOLA, MYRIADS and Orange Labs are used to take part to the OpenStack Performance meetings.

Revised objectives for the remainder of the project

The DISCOVERY objectives are to design, implement, demonstrate and promote a resource management system in charge of turning a complex, extremely large-scale and widely distributed infrastructure into a collection of abstracted computing resources which are efficient, reliable, secure, and friendly to operate and use. While they remain the same at coarse-grained, we should underline that the studies we conducted during the first two years showed us the richness, complexity, and velocity of the OpenStack ecosystem. These characteristics make our investigations and progress toward our target of a unified system much more difficult than what we expected.

Although we can achieve Proof-of-Concepts on a component/service basis, the technical changes that are regularly performed by the OpenStack community on the source code make the integration of new mechanisms almost impossible. The OpenStack code is driven by use-cases strongly supported by powerful lobbies. This prevents us to deliver and validate the unified system we target as we have to integrate code changes in our PoC to move forward.

We hope that the recent interest of major actors (AT&T, Verizon, Wallmart, ETSI ...) on Fog/Edge solutions under the OpenStack perspective will enable us to have a bigger impact on the community overall. We highlight that the OpenStack foundation has organized a dedicated meeting[2] to gather experts from industry and academy to collaborate around use cases, reference architectures and gap analysis. ASCOLA and AVALON will take part to this event.

Future possibilities and the choices before you today

As underlined by the external reviewers, the topic addressed within the DISCOVERY framework is timely. The evolution of large Cloud Computing data centers towards smaller infrastructures deployed within and at the edge of the network is no more debated. Fog/Edge Computing has become a hot topic for academics with several dedicated tracks and more recently conferences where latest achievements and next research directions are discussed. While this is a good point for the project, we should highlight the fact that we discovered an important gap between academic proposals and current issues faced by resource management systems of production infrastructures. Most academic works are over-simplified in comparison to the complexity of resource management systems such as OpenStack: they focus on a particular service without considering interactions with the other ones as well as their locations. As an example, several improvements have been proposed for the management of VM images in a geo-distributed context (deduplication, compression ...). However more "production" issues such as where and how should be deployed storage repositories according to all other services have not been addressed yet. As a consequence, an important point to be discussed during our next plenary meeting is the revision of the expected outcomes of the project: instead of focusing

[2] http://www.opendevconf.com.

on the development/improvement of a dedicated mechanism/service like it is heavily investigated by the community, it would probably be more relevant to favor activities that focus on the integration of all services in a Fog/Edge infrastructure. Such a strategy change is also motivated by the fact that complementary resources are now available by the Inria/Orange joint lab in the form of several PhD grants. At this time, three PhDs candidates are conducting research activities that are directly connected to DISCOVERY (addressing monitoring, security and placement challenges reciprocally) and two others should complete these efforts by the end of 2017. On one hand, those grants allow Inria and Orange Labs researchers to move forward on Fog/Edge system mechanisms and on the other hand, they enable DISCOVERY members to use IPL resources to study their integration.

The second change is related to the RENATER strategy for the next years. While several European NRENs have started to deploy academics cloud computing solutions (*e.g.*, GARR Cloud infrastructure in Italy[3], the will of RENATER of delivering IaaS and PaaS platforms is still unclear. In that sense, it is not sure whether the achievements which are done in the DISCOVERY framework will benefit to RENATER. As a backup, it might be interesting to make connections with other institutions such as France Grille (or its in-discussion successor, the Research Instrument "Meso-centres") for instance to see how a representative testbed can be deployed.

[3] https://cloud.garr.it

Appendices

Non-permanent staff funded by the IPL

- CHARDET Maverick, PhD, Oct 2017, Sep. 2020
- AHVAR Ehsan, PostDoc, June 2017, May 2018.
- DARROUS Jad, PhD, Oct. 2016, Sep. 2019
- PERTIN Dimitri, PostDoc, Oct. 2016, Feb. 2018
- CHERRUEAU Ronan-Alexandre, Research Engineer, July 2016, June 2019 (InriaHub Mercury),
- TATO Genc, PhD, Dec. 2015, Nov. 2018
- SIMONET Anthony, PostDoc, Oct 2015, June 2017 (now PostDoc at Rutgers, USA)

Other projects underway and planned (funded outside Inria) connected to the IPL

- EnOS - CRE Orange - Performance Evaluations of AQMP Alternatives for the OpenStack Ecosystem
  - A. Lebre (Inria) / A. Chari (Orange Labs)
  - Sep 2017 / Aug.2018 (12 months)
- GRECO - Resource manager for cloud of things (ANR-16- CE25-0016)
  - Coordinator: Qarnot computing (P. Benoit)
  - List of partners:
    - LIG (DataMove, D. Trystram)
    - Inria (ASCOLA, A. Lebre)
  - April 2017 / Dec 2020 (42 Months).

Publications

(ic: International Conference, iw: International Workshop, nc: National Conference)

[6ic17] H. Coullon, C. Perez and D. Pertin, *Production Deployment Tools for IaaSes: an Overall Model and Survey*, in *Proceedings* of the IEEE International Conference on Future Internet of Things and Cloud (FiCloud) 2017, Prague, Czech Republic, August 2017. 2

[5ic17] M. Abderrahim, M. Ouzzif, K. Guillouard, J. Francois, and A. Lebre, *A Holistic Monitoring Service for Fog/Edge Infrastructures: a Foresight Study*, in *Proceedings* of the IEEE International Conference on Future Internet of Things and Cloud (FiCloud 2017), Czech Republic, August 2017.

[1nc17] J. Darrous, *On the (In)Efficiency of IPFS for Geo-distributed Virtual Machine Images Management*, Conférence d'informatique en Parallélisme, Architecture et Système 2017, Nice, France, June 2017. 3

[4ic17] R-A. Cherrueau, D. Pertin, A. Simonet, M. Simonin, and A. Lebre, *ENOS: a Holistic Framework for Conducting Scientific Evaluations of OpenStack*, short paper in *Proceedings* of the IEEE/ACM Symposium on Cluster, Cloud and Grid Computing (CCGRID 2017), Spain, May 2017. 2

[3ic17] A. Lebre, J. Pastor, A. Simonet, and F. Desprez, *Revising OpenStack to Operate Fog/Edge Computing Infrastructures*, in *Proceedings* of the IEEE Conference on Cloud Engineering (IC2E'17), Canada, April 2017. 2

[2ic16] A. Bousselmi, J-F Peltier and A. Chari, *Experiments Towards an Openstack-based Massively Distributed Cloud Operating System*, in *Proceedings* of the IEEE conference on Standards for Communications and Networking (CSCN 2016), Berlin, Germany, Nov 2016.

[1ip15] F. Desprez, S. Ibrahim, A. Lebre, A-C Orgerie, J. Pastor, and A. Simonet, *Energy-Aware Massively Distributed Cloud Facilities: the DISCOVERY Initiative*, poster in *Proceedings* of the 11th IEEE International Conference on Green Computing and Communications (GreenCom), Sydney, Australia, December 2015.

[1ic15] I. Cuadrado Cordero, A-C Orgerie, and C. Morin, *GRaNADA: A Network-Aware and Energy-Efficient PaaS Cloud Architecture*, in *Proceedings* of the 11th IEEE International Conference on Green Computing and Communications (GreenCom), Sydney, Australia, December 2015.

[1iw16] A. Simonet, A. Lebre and A-C Orgerie, *Deploying Distributed Cloud Infrastructures: Who and at What Cost?*, in Proceedings of the 5th IEEE International Workshop on Cloud Computing Interclouds, Multiclouds, Federations, and Interoperability, (InterCloud), colocated with IC2E'16, Berlin, May 2016. 2, 3

Invited Talks/Communications

(ip: International Presentation, np: National Presentation, tu: Tutorial)

[4np17] A. Lebre, M. Simonin, R-A Cherrueau, *OpenStack@Inria*, Presentation, OpenStack Meetup, Rennes, France, Sept 2017.

[1tu17] R-A Cherrueau and D. Pertin, *Evaluating the OpenStack behavior*, Tutorial, Rescom, Le Croisic, France, June 2017. 2

[7ip17] A. Lebre, *EnoS; a Holistic Framework for Conducting Scientific Evaluations of OpenStack*, Cloud Control Workshop, Enköping, Sweden, June 2017.

[6ip17] A. Lebre, R-A Cherrueau and P. Riteau, *Toward Fog, Edge, and NFV Deployments: Evaluating OpenStack WANwide*, Presentation, OpenStack Summit, Boston, USA, May 2017. 2

[5ip17] C. Collicut, A. Lebre, C. Huang, *When One Cloud is Not Enough: An Overview of Sites, Regions, Edges, Distributed Clouds, and More*, Presentation, OpenStack Summit, Boston, USA, May 2017.

[3np16] A. Simonet, *Conduire OpenStack vers l'Edge Computing* , Presentation, OpenStack Day France Day, Paris, France, Sep 2017.

[2np16] A. Lebre, *Revising OpenStack to operate the next generation of Cloud Computing platforms*, CargoDay - La virtulisation: état des lieux, Nantes, Oct 2016.

[4np16] C. Tedeschi, *The Discovery Project*, Presentation, IRT B-Com working group, Rennes, France, Jan 2016.

[4ip16] M. Simonin, A. Shaposhnikov and D. Belova, *Chasing 1000 nodes Scale*, Presentation, OpenStack Summit, Barcelona, Spain, Oct 2016. 2

[3ip16] A. Simonet, *Design considerations for the next massively distributed Fog/Edge Cloud Controller*, Discussion Chair, Cloud Control Workshop, Friiberghs Herrgard, Sweden, June 2016.

[2ip16] A. Simonet, *Revising OpenStack Internals to Operate Massively Distributed Clouds*, Presentation, Cloud Control Workshop, Friiberghs Herrgard, Sweden, June 2016. 2

[1ip16] A. Lebre, M. Simonin, J. Pastor and T. Carrez, *A Ring to Rull Them All*, Presentation, OpenStack Summit, Austin, USA, May 2016. 2

[1np15] *The Discovery Initiative, Would OpenStack be the solution?*, Journée SUCCESS - France Grille, Paris, Nov 2015.