Beyond The Clouds,
How Should Next Generation Utility Computing Infrastructures Be Designed?

DIStributed and COoperative management of Virtual EnviRonments autonomously DISCOVERY

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Proposal Abstract:
The DISCOVERY initiative aims at exploring a new way of operating Utility Computing (UC) resources.
Instead of the current trend consisting of building larger and larger data centers in few strategic locations, the discovery consortium proposes to leverage any facilities available through the Internet in order to deliver widely distributed UC platforms that can better match the geographical dispersal of users. Although it involves radical changes in the way resources are managed, leveraging computing resources close to the end-users is the only solution to deliver a new generation of UC platforms, highly efficient and sustainable. Critical to the emergence of such locality-based UC (LUC) platforms is the availability of appropriate operating mechanisms. The DISCOVERY initiative aims at designing and implementing of a unified system driving the use of resources at an unprecedented scale by turning a complex and diverse infrastructure into a collection of abstracted computing facilities that is both easy to operate and reliable.
Internet Service Providers (ISPs) as well as academic and private institutions in charge of operating a part of the internet network will be able to build competitive LUC platforms with a limited additional cost and a relatively short delay by simply deploying the DISCOVERY system through their infrastructure. In addition to opening new opportunities for critical applications (health, smart-cities, education), the emergence of LUC infrastructures in Europe will greatly contribute to break the current lock-in of US cloud providers.

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1 Scientific and/or technical quality

The success of Cloud Computing has driven the advent of Utility Computing (UC). However, Cloud Computing is a victim of its own success: In order to answer the escalating demand for computing resources, Cloud Computing providers must build data centers (DCs) of ever-increasing size. As a consequence, besides facing the well-known issues of large-scale platforms management, large-scale DCs have now to deal with energy considerations that limit the number of physical resources that one location can host.

Instead of investigating alternative solutions that could tackle the aforementioned concerns, the current trend consists in deploying Mega DCs (i.e. composed of more than 15K servers) in few strategic locations presenting energy advantages. For example, Western North Carolina, USA, is an attractive area due to its abundant capacity of coal and nuclear power brought about the departure of the textile and furniture industry [23]. More recently, several proposals suggested building next generation DCs close to the polar circle in order to leverage free cooling techniques, considering that cooling is accounting for a big part of the electricity consumption [25].

Inherent Limitations of Mega DCs

Although building large scale DCs enables to cope with the actual demand, it is far from delivering sustainable and efficient UC infrastructures. In addition to requiring the construction and the deployment of a complete network infrastructure to reach each Mega DC, it exacerbates the inherent limitations of the Cloud Computing model:

- The externalization of private applications/data often faces legal issues that restrain companies from outsourcing them on external infrastructures, especially when located in other countries.
- The overhead implied by the unavoidable use of the Internet to reach distant platforms is wasteful and costly in several situations: Deploying a broadcasting service of local events or an online service to order pizzas at the edge of the polar circle, for instance, leads to important overheads since most of the users are a priori located in the neighborhood of the event/the pizzeria.
- The connectivity to the application/data cannot be ensured by centralized dedicated centers, especially if they are located in a similar geographical zone. The only way to ensure disaster recovery is to leverage distinct sites[1].

The two first points could be partially tackled by hybrid or federated Cloud solutions [9], that aim at extending the resources available on one Cloud with those of another one; however, the third one requires a disruptive change in the way UC resources are managed.

Another issue is that, according to some projections of a recent IEEE report [26], the network traffic continues to double roughly every year. Consequently, bringing the IT services closer to the end-users is becoming crucial to limit the energy impact of these exchanges and to save the bandwidth of some links. Similarly, this notion of locality is critical for the adoption of the UC model by applications that need to deal with a large amount of data as getting them in and out actual UC infrastructures may significantly impact the global performance [20].

The concept of micro/nano DCs at the edge of the backbone [25] may be seen as a complementary solution to hybrid platforms in order to reduce the overhead of network exchanges. However, operating multiple small DCs breaks somehow the idea of mutualization in terms of physical resources and administration simplicity, making this approach questionable.

Ubiquitous and Oversized Network Backbones

One way to partially solve the mutualization concern enlightened by the defenders of Mega DCs is to directly deploy the concept of micro/nano DCs upon the Internet backbone. People are (and will be) more and

[1] "Netflix / Amazon outages", http://gigaom.com/2013/12/02/netflix-is-balancing-its-streaming-traffic-across-

more surrounded by computing resources, especially those in charge of interconnecting all IT equipments. Even though these small and medium-sized facilities include resources that are barely used [8, 12], they can hardly be removed (e.g. routers). Considering this important aspect, we claim that a new generation of UC platforms can be delivered by leveraging existing network centers, starting from the core nodes of the back-bone to the different network access points in charge of interconnecting public and private institutions. By such a mean, network and UC providers would be able to mutualize resources that are mandatory to operate network/data centers while delivering widely distributed UC platforms able to better match the geographical dispersal of users. Figure 1 allows to better capture the advantages of such a proposal. It shows a snapshot of the network weather map of RENATER[2], the backbone dedicated to universities and research institutes in France. It reveals several important points:

- As mentioned before, most of the resources are underutilized (only two links are used between 45% and 55%, a few between 25% and 40%, and the majority below the threshold of 25%).
- The backbone was deployed and is renewed to match the demand: The density of points of presence (PoP, *i.e.* a small or medium-sized network center) as well as the bandwidth of each link are more important on the edge of large cities such as Paris, Lyon or Marseille.
- The backbone was designed to avoid disconnections, since 95% of the PoPs can be reached by at least two distinct routes.

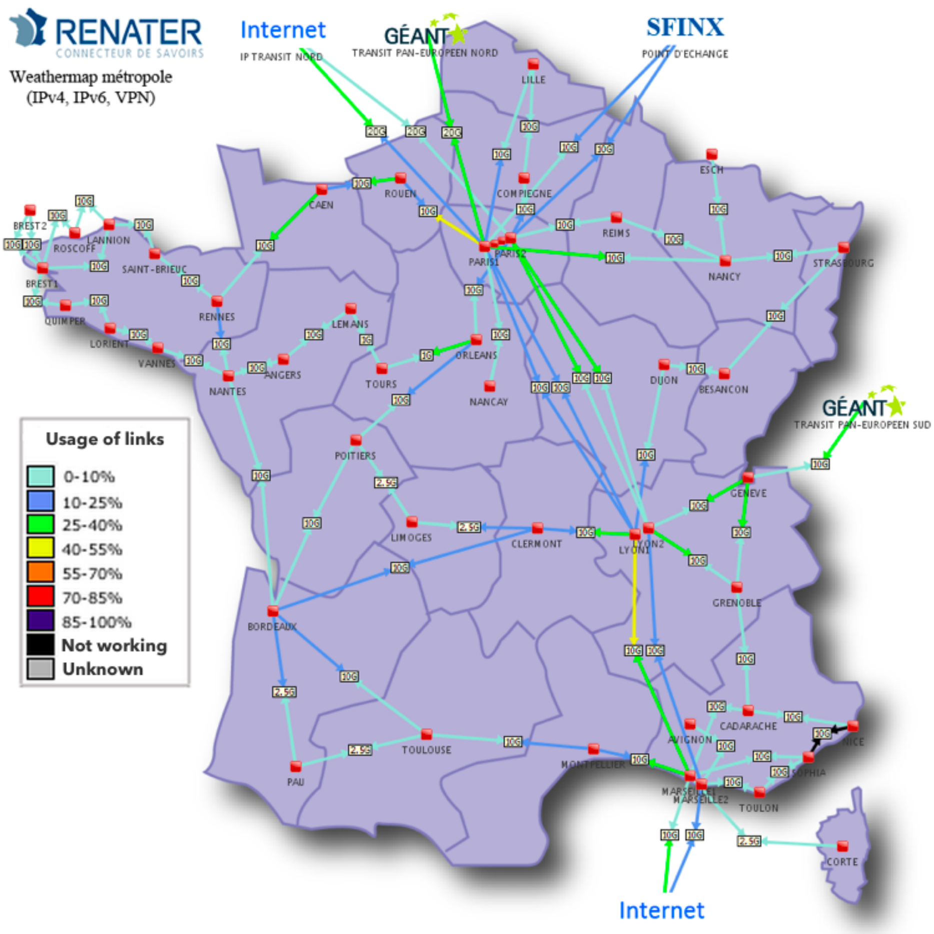

Figure 1 - The Renater Wheater Map
Each red square corresponds to a particular point of presence (PoP) of the network. The map is available in real-time at http://www.renater.fr/raccourci?lang=en

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[2] http://www.renater.fr

1.1 Targeted breakthrough and long-term vision

The DISCOVERY consortium proposes to investigate Locality-based UC (LUC) infrastructures, a new generation of UC platforms that solves inherent limitations of the Cloud Computing paradigm relying on Mega DCs. Although it involves radical changes in the way physical and virtual resources are managed, leveraging network centers is a promising way to deliver highly efficient and sustainable UC services.

From the physical point of view, network backbones provide appropriate infrastructures, *i.e.,* reliable and efficient enough to operate UC resources spread across the different PoPs. Ideally, UC resources would be able to directly take advantage of computation cycles available on network active devices, *i.e.* those in charge of rout- ing packets. However, leveraging network resources to make external computations may lead to important security concerns. Hence, we propose to extend each PoP with a number of servers dedicated to hosting virtual machines (VMs). Because it is natural to assume that the network traffic and UC demands are proportional, more UC resources will be deployed in the largest network centers. Moreover, by deploying UC services on relevant PoPs, a LUC infrastructure will be able to natively confine network exchanges to a minimal scope, minimizing altogether the energy footprint of the network, the impact on latency and the congestion phenomena that may occur on critical paths (for instance Paris and Marseille on the RENATER topology).

From the software point of view, the main challenge is to design a comprehensive distributed system in charge of turning a complex and diverse network of resources into a collection of abstracted computing facilities that is both reliable and easy to operate.

The design of the *LUC Operating System* (OS), an advanced system being able to unify many UC resources distributed on distinct sites, would enable Internet service providers (ISPs) and other institutions in charge of operating a network backbone to build an extreme-scale LUC infrastructure with a limited additional cost. Instead of redeploying a complete installation, they will be able to leverage IT resources and specific devices such as computer room air conditioning units, inverters or redundant power supplies already present in each center of their backbone.

In addition to considering *locality* as a primary concern, the novelty of the LUC OS proposal is to consider the VM as the basic object it manipulates. Unlike existing research on distributed operating systems designed around the process concept, a LUC OS will manipulate VMs throughout a federation of widely distributed physical machines. Virtualization technologies abstract out hardware heterogeneity, and allow transparent deployment, preemption, and migration of virtual environments (VEs), *i.e.* a set of interconnected VMs. By dramatically increasing the flexibility of resource management, virtualization allows to leverage state-of-the-art results from other distributed systems areas such as autonomous and decentralized systems. Our goal is to build a system that allows end-users to launch VEs over a distributed infrastructure as simply as they launch processes on a local machine, *i.e.* without the burden of dealing with resources availability or location.

1.2 Novelty and foundational character

Several generations of UC infrastructures have been proposed and still co-exist [21]. However, neither Desktop, nor Grid, nor Cloud Computing platforms provide a satisfying UC model. Contrary to the current trend that promotes large offshore-centralized DCs as the UC platform of choice, we claim that the only way to achieve sustainable and highly efficient UC services is to target a new infrastructure that better matches the Internet structure. Because it aims at gathering an unprecedented amount of widely distributed computing resources into a single platform providing UC services close to the end-users, a LUC infrastructure is fundamentally different from existing ones. Keeping in mind the aforementioned objectives, recycling UC resource management solutions developed in the past is doomed to failure.

To avoid possible confusion and as previously mentioned, our vision significantly differs from hybrid Cloud Computing solutions that aim at extending the available resource delivered by one cloud (either public or private) with another one. These concerns are investigated by several EU projects. For instance, the FP7 CONTRAIL IP project[3] aims at providing standardized interfaces for supporting cooperation and resource sharing over Cloud federations. The FP7 OPTIMIS IP project[4] aims at enabling organizations to automatically externalize services and applications through the use of hybrid cloud computing systems. The FP7 MOSAIC STREP project[5] focuses on the design and the implementation of an open-source platform that enables applications to negotiate Cloud services between several cloud providers. Although these research activities address important concerns related to the use of federated Cloud platforms, such as interface standardization for supporting cooperation and resource sharing, their propositions are incremental improvements of existing UC models. Recent investigations on hybrid Clouds and Cloud federation are comparable in some ways to previous works done on Grids, since the purpose of a Grid middleware is to interact with each resource management system composing the Grid [15, 47, 52].

By taking into account network issues, in addition to traditional computing and storage concerns in Cloud Computing systems, the FP7 SAIL IP project[6] is probably the one that targets the biggest advances with regard to previous works on Grid systems. More concretely, this project investigates new network technologies to provide end-users of hybrid/federated Clouds with the possibility to configure and virtually operate the network backbone interconnecting the different sites they use [38].

More recently, the *Fog Computing* concept has been proposed as a promising solution to applications and services that cannot be put into the Cloud due to locality issues (mainly latency and mobility concerns) [14]. Although it might look similar to our vision as they propose to extend the Cloud Computing paradigm to the edge of the network, *Fog Computing* does not target a unified system but rather proposes to add a third party layer (i.e. the *Fog)* between Cloud vendors and end-users. Although such an approach is interesting and might be comparable in some points to our proposal, it does not target to reduce the dependence with major US cloud providers.

In our vision, UC resources (i.e. Cloud Computing ones) should be repacked in the different points of presence of backbones and operated through a unified system, the LUC OS. As far as we know, the only system that investigated whether a widely distributed infrastructure can be operated by a single system, was the FP6 XtreemOS IP Project[7]. Although this project shared some of the goals of the LUC OS, it did not investigate how the geographical distribution of resources can be leveraged to deliver more efficient and sustainable UC infrastructures.

To sum up, the novelty of the DISCOVERY proposal lies in a new way of designing systems to operate UC resources. DISCOVERY can be viewed as a distributed OS, manipulating VEs instead of processes and considering locality as a primary concern. Referred to as a LUC OS, such a system will include most of the mechanisms that are common to current UC management systems [2, 4, 5, 6, 33, 36]. However, each of them will have to be rethought in order to leverage peer-to- peer algorithms. While largely unexplored for building operating systems, peer-to-peer/decentralized mechanisms have the potential to achieve the scalability required to manage LUC infrastructures.

Using such design principles for establishing the foundation mechanisms of a massive-scale LUC OS will be a major breakthrough compare to current centralized (Sotomayor, Montero, Llorente, & Foster, 2009) (Sempolinski & Thain, Dec 2010) or hierarchical (Feller, Rilling, & Morin, May 2012) management solutions. Considerable research needs to be conducted to provide core operating systems services in a fully decentralized way and without centrally maintained comprehensive knowledge of system's resources. However, we believe that conducting investigations on this area make sense for the following reasons. First, distributed, self-* and autonomous mechanisms are now robust as well as efficient enough to design scalable and reliable systems. Second, the capabilities offered by VMs (and, by transitivity, by Virtual Environments) will enable us to manage LUC resources in the same way traditional OSes manage processes (start/stop, suspend/resume, migrate). Finally, the workloads hosted by cloud platforms are less restrictive than the historical HPC ones (a significant number of independent small-scale VEs running simultaneously in contrast to large tightly-coupled applications), which will allow us to have a more dynamic infrastructure without impacting too much the execution of the VEs.

[3] Grant Agreement no. 257439 - http://contrail-project.eu
[4] Grant Agreement no. 257115 - http://www.optimis-project.eu
[5] Grant Agreement no. 256910 - http://www.mosaic-cloud.eu
[6] Grant Agreement no. 257448 - http://www.sail-project.eu
[7] Grant Agreement no. 033576 - http://www.xtreemos.eu/

We expect the DISCOVERY project to open a new direction in the area of operating systems and resource management research. It will lay the foundation for the design of fully distributed operating systems based on virtualization that could operate an extreme scale distributed platform such as a LUC. Investigating right now how it can be possible to deliver and operate such an infrastructure, would lead to a significant advantage for European companies and public bodies as deeper described in Section 2.1. The participation of internationally recognized researchers of Utility Computing as well as the involvement of network backbone key operators throughout Europe in the Discovery Initiative assures prime scientific results as well as excellent opportunities for the adoption of the LUC model.

Finally, looking one step ahead and considering that large part of the Internet may be seen as computing services hosted by UC platforms, the question might be extended to: Will DISCOVERY make possible to host/operate a large part of the Internet by its internal structure itself? Similarly to the interconnection of academics and private networks and the use of the TCP/IP standard that resulted in the Internet, the deployment and the use of the DISCOVERY system through the different networks might lead to a global UC platform, i.e. the DISCOVERY infrastructure: A scalable and nearly infinite 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-user.

1.3 S/T methodology

1.3.1 Overall strategy of the work plan

The design of a LUC OS requires a clear organization of the work, as there are strong dependencies between the different mechanisms of the system. To help readers understanding the overall strategy as well as the work packages organization, we present a brief overview of the system we envision.

The core of the DISCOVERY system is a multi-agent peer-to-peer system deployed on the physical resources, which compose the LUC platform. Agents are autonomous entities that collaborate to efficiently use the LUC resources. In our context, efficiency means that a good trade-off is found between satisfying user's expectations, ensuring reliability, reactiveness as well as availability of the services while limiting the energy consumption of the system and providing scalability. We propose thus to leverage epidemic and gos-sip-based techniques, that allow self-* properties, such as self-adaptation, self-repairing of overlays. We think that relying on a multi-agent peer-to-peer system is the best solutions to cope with the scale as well as the network disconnections that may create temporary partitions in a LUC platform.

Each DISCOVERY agent has two purposes: (i) maintaining knowledge base on the LUC platform composition (ii) ensuring the correct execution of the VEs (each VE being potentially composed of several VMs). Concretely, the knowledge base will consist of overlays that will be used for the autonomous management of the VEs life cycle. This include the configuration, deployment and monitoring of VEs as well as the dynamic allocation or relocation of VMs to adapt to changes in VEs requirements and physical resources availability. To this end, agents will need to rely on dedicated mechanisms. Most of them are common to UC management systems but they have to be rethought to meet the characteristics of the targeted LUC platform. They can be classified in four main categories:

- Mechanisms related to physical resource localization and monitoring,
- Mechanisms related to VEs management,
- Mechanisms related to the VM images management,
- Mechanisms related to reliability.

TO BE COMPLETED

1.4 Consortium as a whole

The DISCOVERY consortium is composed of 3 research centers, 3 NRENs operators, one major telecom company and one SME from 6 countries (France, Italy, Greece, Poland, Spain, Sweden) distributed as shown in Figure 2. This geographic pluralism coupled with the privileged relationships the participants in the project enjoy with industrial actors secures a wide possible dissemination and exploitation impact.

Figure 2: Geographic distribution of DISCOVERY Consortium partners.

From the scientific point of view, the consortium gathers the expertise of well-recognized research groups dealing for several years with Cluster/Grid/Cloud and P2P Computing challenges as well as the potentials of young researchers who have clearly demonstrated their ability in their respective areas (virtualization, large-scale systems, data management or reliability). This association of strong research groups and high potential young researchers leading the different work packages assures prime scientific results to the DISCOVERY project.

Finally, it is worth nothing that most of the members are used to collaborate directly around formal or informal collaborations. From the industrial point of view, Inria and Orange Labs have been collaborating for several years around different projects such as ANR Selfware, ANR SelfXL and more recently the OpenCloudware FSN project. Regarding RENATER, several members of the consortium are used to interact with the main technical leaders through the Grid'5000 project. At the European level, ASCOLA and BSC have been taking part the European Marie Curie Initial Training Network SCALUS, SCALing by means of Ubiquitous Storage since 2009. In (L`ebre, et al. March 2011), ASCOLA with CRS4 conducted a prospective study that sketch out the premises of the current DISCOVERY proposal. All these fruitful collaborations are excellent indicators for the successfully achievement of the DISCOVERY project.

1.5 Relevance to the ICT-7-a Call

Identified Themes	*Relevance of DISCOVERY*
High performance heterogeneous cloud infrastructures. *The focus is on development, deployment and management of cloud-based infrastructures and services (IaaS, PaaS, SaaS) over large-scale, distributed, heterogeneous, dynamic computing and storage environments.*	The Discovery initiative aims at designing and implementing a unified system, i.e. the LUC OS, driving the use of resources at an unprecedented scale by turning a complex and diverse infrastructure into a collection of abstracted computing facilities that is both easy to operate and reliable.
Federated cloud networking*: Techniques for the deployment and management of federated and decentralised cloud infrastructures, in particular cloud networking techniques (within software-defined data centres and across wide-area networks) and mechanisms to enable incorporation of resources and services independent of their location across distributed computing and storage infrastructures. Approaches, including standards, to increase interoperability between cloud services and infrastructure providers to enable efficient interworking and migration of services, applications and data.*	The Discovery initiative proposes to investigate a new generation of UC infrastructures that will be physically distributed on top of point of presences of network backbones, tackling the limitations of current cloud computing offers. From the provider point of view, the deployment of the LUC OS proposal within a network backbone will enable to deliver a highly controllable UC infrastructure where computing, storage and network resources will be tightly integrated and operated in a unified manner. From the user point of view, the LUC system will extend current *defacto* APIs of IaaS systems by offering the opportunity to benefit from the locality aspects of UC resources in order to locate services, applications and data on the most appropriated area according to the demand.
Dynamic configuration, automated provisioning and orchestration of cloud resources: *Tools for automatic and dynamic deployment, configuration and management of services to enhance availability, flexibility, elasticity and to meet targeted performance constraints; techniques for managing big data taking into account integrity, consistency and maintenance aspects. Tools to facilitate the coherent deployment of distributed applications over heterogeneous infrastructures and platforms from multiple providers. Mechanisms to off-load computation and storage tasks from mobile devices onto the cloud at both design and execution time.*	At coarse-grained, the DISCOVERY initiative can be summarized by a simple idea: redistributing large-scale DCs such as the mega ones (i.e. DCs composed of tens of thousands resources) into several micro/nano DCs operated WANwide in a unified manner. Hence, the number of resources that a LUC infrastructure will operate is not going to reduce and the autonomic mechanisms that are used to operate mega DCs will have to be revisited/extended to consider additional constraints imposed by the WAN scale. For instance, if the mean time between failure (MTBF) will be quite similar, the mean time between repair will be much more important due to the natural distribution of the UC resources and the impossibility to have a human presence on each network PoPs.
Automated discovery and composition of services: Innovative ways to facilitate collaboration between public administrations, users and other stakeholders as to produce, discover, mix and re-use different service components and create new public services through pooling and sharing of resources, data, content and tools, even across national borders. The research will build on the "cloud of public services” concept that requires interoperable, reusable modules for public	By offering the possibility to turn a network backbone as a UC infrastructure and by considering that NRENs are national institutions, the DISCOVERY initiative will contribute to the deployment of e-governmental cloud infrastructures/services nationwide, avoiding to leverage public offers operated by private companies such as Amazon or Google. Moreover, thanks to the design of the LUC OS, managing a virtual environment (i.e. a cloud

service functionalities. These are likely to be cross-institutional, cross-sector, easily used, re-used and combined dynamically to address specific needs.	service) through distinct network backbones will be totally transparent technically speaking. In other words, similarly to the peering agreements that link network operators and enable to exchange data worldwide through the Internet, it will be possible to deploy cross-institutional cloud systems/services once mutual agreements between institutions will be in placed. What about's cloud services Discovery ?
Cloud security: Mechanisms, tools and techniques to increase trust, security and transparency of cloud infrastructures and services, including data integrity, localisation and confidentiality, also when using third party cloud resources.	In addition to the localisation aspects that are the foundations of the Discovery Initiative, the implementation of the LUC OS will be driven by security concerns. We classified the challenges in three categories: - Authentication/Trustability of LUC OS components and their behaviour. - Authentication/trustability of peers joining the LUC infrastructure - User security policies (i) Providing end-users with a way to define their own security and privacy policies (ii) Ensuring that these policies are enforced thanks to distributed security and privacy decision and enforcement points (SPDEPs).

1.6 *Resources to be committed*

TO BE COMPLETED

2 Impact

Preliminary DRAFT (coming from a previous proposal)

2.1 *Transformational impact on science, technology and/or society*

While a lot of progress has already been made in cloud technologies, there are several concerns that limit the complete adoption of the Cloud Computing paradigm. Amongst others, resource management as well as scale and heterogeneity of modern IT environments are two of the research issues identified in the ICT-7 call and already highlighted in the *Advance in Clouds* report (European Commission, 2012). With the DISCOVERY project, we propose to investigate an innovative approach that will tackle and go beyond these limitations. By leveraging the investments already made by the EU in Cloud Computing research and the generated know-how of the last five years in resource management system design for Infrastructure as a Service platforms, the objective of DISCOVERY is to pave the way for a new generation of utility computing closer to the end-users. By offering the possibility to tightly couple UC servers and network backbones throughout distinct sites, the DISCOVERY technology may lead to major changes in the design of IaaS infrastructures as well as in their environmental impact.

2.1.1 *Opportunities related to the DISCOVERY internal mechanisms*

The DISCOVERY initiative promotes a new way of managing a large-scale infrastructure through a single integrated resource management system, i.e. the LUC OS. Nonetheless, we would like to emphasize that all investigations performed on the internal mechanisms bring contribution opportunities in the domain of virtualized infrastructures management. Besides the contributions to the scientific community, technology transfers of these mechanisms to the EU as well as to international companies may occur at the end of the project. As highlighted in the letters of support (See Annex 1 – letters of support), industrials are especially interested in:

- Advances in the dynamic management of VE (autonomous reconfiguration/relocations) involving distinct sites (taking into account network as well as persistent state concerns);
- Advances in VE Reliability;
- Advances in energy reduction techniques.

To maximize the opportunities for technological transfers, the DISCOVERY members gathered major industrials actors in the Advisory Board. They also plan to leverage the privileged partnerships of each participant.

2.1.2 Opportunities of a new field of investigations thanks to LUC OS

The Cloud Computing paradigm is changing the way applications are designed. In order to benefit from the elasticity capability of cloud systems, applications integrate or leverage mechanisms to provision resources, i.e. starting or stopping VMs, according to their fluctuating needs (the term ''autoscaling'' is usually employed). Contribution of the FP7 Contrail IP project, ConPaaS (Pierre & Stratan, 2012) is one of the promising systems for elastic cloud applications. At the same time, a few projects have started investigating distributed/collaborative way of hosting famous applications such as Wikipedia[8] or Facebook-like[9] systems by leveraging volunteer computing techniques. This research area has been mainly investigated in the context of desktop computing. Resources provided by end-users were not considered because they were assumed not reliable enough to host such applications.
By providing a system that will enable to operate widely spread but more reliable resources closer to the end-users (such as Internet Points of Presence, hubs and DSLAMs), the DISCOVERY project may lead to a new research area that aims at investigating the benefit of locality provisioning (i.e. combining elasticity and distributed/collaborative hosting). Such provisioning strategies taking into account locality could benefit to several web services. Images sharing system such as Google Picasa[10] or Flickr[11] are examples of applications where leveraging locality will enable to limit network exchanges: Users could upload their images on a peer close to them and images would be transferred to other locations only when required (pulling vs. pushing model). This concern has been recently highlighted in an article of the NewYork times [12] *"…The complexity of a basic transaction is a mystery to most users: Sending a message with photographs to a neighbor could involve a trip through hundreds or thousands of miles of Internet conduits and multiple data centers before the e-mail arrives across the street…"*

LUC infrastructures operated by the DISCOVERY system will allow envisioning a wider range of services that may answer specific SMEs requests such as data archiving or backup solutions while significantly reducing the network overhead as well as legal concerns. Of course, this will require software engineering and middleware advances to easily take advantage of locality but the DISCOVERY project is the mandatory step before investigating such applications.

Finally and similarly to the FP7 SAIL IP project that has been trying to leverage the expertise of the cloud computing community on one hand and of the network community on the other hand, we believe that the DISCOVERY investigations may also contribute to fill the gap between these two areas. This may result in the long view in a new community dealing with UC concerns where network and computational concerns are fully integrated. Such a new community may leverage the background of both areas to propose new systems that are more suitable to accommodate the needs of our modern societies.

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[8] Decentralized Wikipedia - http://www.globule.org/?page_id=72
[9] Diaspora - https://joindiaspora.com
[10] http://picasa.google.com
[11] http://www.flickr.com
[12] http://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html (valid on Sept. 2012, the 25th).

2.1.3 Opportunities to reinforce the competitiveness of the EU IT sector

A recent post of Ignacio M. Llorente on the cloud computing journal website[13] aimed at explaining, "why is Europe behind the US on Cloud Computing?". In his post he states that Europe *"…does not have large suppliers who may compete in public provision with the major US suppliers. Only the European Telecoms are big and powerful enough to compete, but they still have to become big players in this space."*
By supporting the Open Source community in the design of a LUC OS, the DISCOVERY initiative will provide European Telecom companies with opportunities to deliver competitive UC platforms to their customers. Adopting new recommendations to design/extend and setup their network infrastructure, by adding for instance a few servers dedicated to host the UC services in each Point of Presence, Telecom companies such as Orange will be able to simply leverage the DISCOVERY system to operate their own backbone as a LUC platform.

Furthermore, to conclude his post on the strength of the EU telecom industry, I. M. Llorente also underlines the "*many hosting and small cloud providers developing innovative cloud offerings*". The AoTerra SME, which strongly supports the DISCOVERY proposal (See Annex 1 – Letters of support), is such a company. Based on the concept of data furnaces (Lui, Goraczko, James, & Belady, June 2011), AoTerra proposes to take advantage of computing facilities in medium and large institutions in order to heat their buildings. Thanks to the LUC OS, they will be able to extend their model to much smaller computing facilities, hosted in small buildings as well as houses and to operate them remotely through the DISCOVERY system as a large LUC platform.

More generally, by delivering the premises of a LUC OS and with the support of SMEs as well as key players of UC, the discovery project may be a starting point for a new Open Source community. The goal of this new community would be to develop and maintain a system that would allow anyone, from end-users to larger companies, to easily build and operate its own UC infrastructure. Indeed, since DISCOVERY can deal with the geographical distribution of resources, it would not be required to build dedicated facilities to host a UC platform.

2.1.4 Opportunities for the society

As mentioned at the beginning of this proposal, there are several limitations that are intrinsic to the current way of providing UC through actual cloud computing platforms. In addition to the legal concerns, the energy impact of IT is a primary concern for modern societies. According to some projections of a recent IEEE report (IEEE 802.3 Ethernet Working Group, July 2012), the network traffic continues to double roughly each year. Bringing the IT services closer to the end-users will become soon crucial to limit the energy impact of these exchanges. The integration of UC servers and network facilities can significantly reduce the energy footprint of both UC platforms and network exchanges. Concretely, following the smart city recommendations[14] (i.e. delivering efficient as well as sustainable ICT services), the construction of new districts in metropolises can leverage both models envisioned in the previous paragraphs: deploying UC computing power throughout the network backbone and using each Point of Presence to heat buildings. Furthermore, these ideas might be extended by taking into account recent results about passive data centers, such as solar-powered micro-datacenters[15] (Bianchini, Goiri, Le, & Nguyen, April 2012). The idea behind passive computing facilities is to limit has much as possible the energy footprint of major hubs and DSLAMS by taking advantage of renewable energies to power them and by using the heat they product as a source of energy. Combining such ideas with the LUC approach promoted by the DISCOVERY project would allow reaching an unprecedented level of energy efficiency for UC platforms.

Finally and to conclude this section, we would like to emphasize once again the long term vision of the DISCOVERY initiative: Will DISCOVERY make possible to host/operate a large part of the Internet by its internal structure itself? Similarly to the interconnection of academics and private networks and the use of the TCP/IP standard that resulted in the Internet, the deployment and the use of the DISCOVERY system

[13] http://cloudcomputing.sys-con.com/node/2342251 (valid on Sept. 2012, the 25th)
[14] http://setis.ec.europa.eu/about-setis/technology-roadmap/european-initiative-on-smart-cities
[15] http://parasol.cs.rutgers.edu

through the different networks might lead to a global UC platform, i.e. the DISCOVERY infrastructure: A scalable and nearly infinite 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-user.

2.2 Expected impacts listed in the work program

Expected impact (quoted)	***Relevance of DISCOVERY to the expected impact***
*"Significantly **higher quality of user experience and trust in clouds** through stronger security and data protection, including **open and auditable solutions for data** **security**."*	The PRISM issue has definitely raised the jurisdiction concerns of the UC paradigm and hence has strongly motivated the deployment of European UC solutions. By delivering UC capabilities close to end-users, the DISCOVERY model ensures that local jurisdiction rules will be applied to end-users. From the technical point of view, and as emphasized several times in the document, the design and the implementation of the LUC OS will be driven by security concerns. Our solution based on pluggable security components at every level of the software stack will enable to deliver on demand security functionalities both at the system and the user levels.
"Demonstration - *of cloud-based services in federated, heterogeneous and multi-layered (IaaS, PaaS, SaaS) cloud environments;* - *of the dynamic provisioning of interoperable applications and services over heterogeneous resources and devices;* - *of high level of performance and quality of service even in highly secure solutions.*	The Discovery initiative aims at delivering a unified system operating a huge number of virtualized environments throughout a federation of diverse and widely distributed resources. Such a system will be the cornerstone of next generations of UC platforms delivering a building block on which, IaaS PaaS or SaaS environments can be deployed. By directly leveraging their own backbone, EU network operators will be able to deliver new UC platforms where Quality of Service can be completely controlled letting the user to define his best trade-off between high performance security expectations.
Increased innovation opportunities for service providers, including SMEs and public administrations, evidenced through implementations of advanced cloud infrastructures and services. Promotion of the reuse of open source software solutions in cloud environments, in particular, involving SMEs and public administrations."	The main objective of the Discovery initiative is to design and implement a new system, i.e. the LUC OS that will allow any institution operating a backbone to easily and quickly set up its own UC infrastructure by leveraging existing facilities. In addition to delivering competitive UC offers in comparison to the defacto solutions provided by US actors such as Amazon or Google, EU network operators such as NRENs or telcos will have the opportunities to take a remarkable advance by deploying the next generation of UC. This new generation that will tackle the limitations of current solutions will enable the complete adoption of the UC paradigm by European enterprises as well as public administrations including education and health institutions. Finally, by its design, the LUC OS will provide to UC infrastructures the elasticity concept that made the strength of current cloud computing models. In other words, the intrinsic distribution of LUC infrastructures will lead to the creation of a new kind of web applications taking locality of UC resources as a considerable advantage, enabling for instance the on demand deployment of IT services in a particular area and for a specific period.

" Demonstration through appropriate use cases of the potential to improve the competitive position of the European cloud sector."

To prove the feasibility and the advantage of a LUC infrastructure, we will delvier at the end of the project a representative testbed of a LUC infrastructure by leveraging few network point of presences (PoP) of the RENATER, PSNC and GRNET backbones. On top of this, we will illustrate elementary use cases (i.e. outsourcing basic Information Systems SI on one area) as well as more advanced applications using the DISCOVERY API in order to take the advantage of the LUC platform distribution.

2.3 Dissemination and/or use of project results

2.3.1 Dissemination

The dissemination efforts will aim at making the DISCOVERY project and related results visible to the widest possible audience. To achieve this goal, we will leverage the following instruments:

- A web site, describing in details the project with information for researchers, policy makers, the media and the general public;
- A leaflet presenting the main objectives of the project and its expected results will be prepared to be distributed during conferences, workshops or to journalists of specialized media.
- Local press releases in national and regional newspapers.
- Publications (in scientific journals and conferences);

These instruments are described in more detail in the description of the *Dissemination* work package, WP6.

Moreover the DISCOVERY consortium may take part, when relevant, to national and international exhibitions. Taking part to such events will be particularly important during the last months of the project in order to showcase the interests of other research teams, industries and public bodies to the results and outcomes of the project.

The consortium will pay attention to mention in any official communication the financial support of the European Commission.

2.3.1.1 Dissemination to the research community in the field

The contributions to the project will be presented in high-level peer-reviewed conferences in the field of distributed systems, cloud-computing, distributed data management, dependable systems, operating systems and networks, and any other relevant cross-domain field (e.g. green computing). In particular, we will target following conferences and journals. Of course, the list is rather exhaustive and we will not aim at publishing in all these events. However, they are all good places to disseminate the objectives and the main results of DISCOVERY.

- Data management / Data storage**:** USENIX Conference on File and Storage technologies (FAST), EuroSys Conference, IEEE International Conference on Data Engineering (ICDE), International Systems and Storage Conference (SYSTOR)
- Distributed systems design and implementation**:** USENIX Symposium on Network Systems Design and Implementation (NSDI), ACM Symposium on Operating Systems Principles (SOSP), USENIX Symposium Operating Systems Design and Implementation (OSDI), International Conference on Distributed Computing Systems (ICDCS), Annual International Conference on Computer Communications (INFOCOM), IEEE International Parallel and Distributed Symposium (IPDPS), ACM Transactions on Computer Systems (TOCS), IEEE Transactions on Parallel and Distributed Systems (TPDS), Journal of Parallel and Distributed Computing (JPDC), Journal of Future Generation Computer Systems (FGFS)
- Virtualization technologies and Cloud Computing**:** ACM Virtual Execution Environments (VEE), IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGRID), ACM Sym-

posium on Cloud Computing (SOCC), IEEE/ACM Conference on Utility and Cloud Computing (UCC), IEEE International Conference on Cloud Computing Technology and Science (CloudCom), International Conference on Cloud Computing and Services Science (CLOSER)

- Dependable systems**:** Dependable Systems and Networks (DSN), Symposium on Reliable Distributed Systems (SRDS), IEEE Transactions on Software Engineering (TSE),
- Performance, scalability, networking aspects: ACM Symposium on High Performance Distributed Computing (HPDC), ACM SIGCOMM Conference, IEEE/ACM Transactions on Networking (TON),
- Evaluations and demonstrations: International Conference on Cooperative Information Systems (CoopIS), International Conference on Objects, Models, Components and Patterns (TOOLS), ACM Symposium On Applied Computing (SAC).
- Green computing and power-awareness: International Green Computing conference (IGCC), International Conference on Green Computing (ICGREEN),

These publications will be completed by external talks whenever possible (especially invited talk in satellite workshops of the aforementioned conferences). Also poster presentations, lectures on national or European conferences will be given.

2.3.1.2 Dissemination to IT stakeholders, potential Users' Group and general public

In addition to the dissemination to the scientific community, we will make strong efforts to make the results of this project visible to the IT stakeholders as well as the general public, through:

- The dissemination of the DISCOVERY results in European events or IT professionals interested by Utility and Cloud Computing services. In particular, we will target events gathering the European scientific and industrial communities. Examples include, but are not limited to, Internet of Services and Cloud Computing meetings from the Europe's Information Society, ISC Cloud Computing, etc. Moreover, we will carefully follow the press releases as well as the events organized by the EU SIENA initiative[16] that aims at coordinating the adoption and the evolution of interoperable distributed computing infrastructures.

- The Web site and the open source repositories; in addition to an electronic version of the leaflet, we will provide general information about the project including pictures and figures illustrating the target and the scenarios envisioned by the project. When appropriate and accessible to the general public, some architecture details about the DISCOVERY systems and details on the major specificities will be also presented. Finally, all resulting codes of the project will be freely downloadable to maximize the evaluation and the adoption of the system by general users.

- The relation to the media; joint press releases will be prepared at M4 and M23 to present the project and its main results (significant publications, demonstrators, etc.).

2.3.2 Management of Knowledge and Intellectual Property (Use of Results)

For the success of the DISCOVERY project it is essential that all project partners agree on explicit rules concerning IP ownership, access rights to any background and foreground IP for the execution of the project and the protection of intellectual property rights (IPRs) and confidential information before the project starts.
Therefore, the management of knowledge and intellectual property rights will be established via the Consortium Agreement and will include modalities of communication among the Partners as well as establish management procedures regarding the results generated by the project (Foreground).
It will define the conditions of allocation among the Partners of ownership, use and protection of the Foreground. As agreed each partner shall retain ownership of its knowledge, know-own, patent, copyright, etc. acquired and/or developed prior to the project and generated independently to the project (Background). An

[16] Grant Agreement no. 261575 - http://www.sienainitiative.eu

improvement of a partner's Background shall also remain the property of this partner.
Each partner shall specify Background, which will be needed by another partner to perform its work package and indicate any third party's rights affecting the Background, which may limit the access rights as well as Background expressly excluded.
The policy of protection of the Foreground will be further detailed insofar as the strategy together with the conditions and activities for dissemination and exploitation will be detailed in the consortium agreement. In case of joint ownership, one of the consortium bodies shall assist the partners in evaluating their contribution to the jointly owned Foreground and establishing their respective shares.
The partners will specify in the Consortium Agreement the terms for the exploitation of the Foreground and the envisaged dissemination activities (including Foreground management, publication, training, forum, conferences, etc.) to ensure and enlarge to the greater extent the communication of results and any foreseen subsequent application and activities such as commercial and/or industrial exploitation. Software Foreground generated within the DISCOVERY project will be freely available as Open Source code. The Open Source licence will be chosen at the beginning of the project and approved by all participants within the consortium agreement.

3 Ethical Issues

<u>**ETHICAL ISSUES TABLE**</u>

	YES	**PAGE**
Informed Consent		
• Does the proposal involve children?		
• Does the proposal involve patients or persons not able to give consent?		
• Does the proposal involve adult healthy volunteers?		
• Does the proposal involve Human Genetic Material?		
• Does the proposal involve Human biological samples?		
• Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?		
• Does the proposal involve Human Foetal Tissue / Cells?		
• Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
• Does the proposal involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Does the proposal involve tracking the location or observation of people?		
Research on Animals		
• Does the proposal involve research on animals?		
• Are those animals transgenic small laboratory animals?		
• Are those animals transgenic farm animals?		
• Are those animals cloned farm animals?		
• Are those animals non-human primates?		
Research Involving Developing Countries		
• Use of local resources (genetic, animal, plant etc)		
• Impact on local community		
Dual Use		
• Research having direct military application		
• Research having the potential for terrorist abuse		
ICT Implants		
• Does the proposal involve clinical trials of ICT implants?		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	

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