REMOTE CONTROL AND TELE-OPERATION IN THE CLOUD

Salvatore F. Pileggi, Carlos Fernandez-Llatas and Vicente Traver

TSB-ITACA, Universidad Politécnica de Valencia, Valencia, Spain

Keywords: Cloud computing, Grid computing, Tele-operation, Remote controls, Distributed systems.

Abstract: Remote controls and tele-operation platforms are object of great commercial interest in several application domains and disciplines. Reliable and effective platforms could completely change the vision at certain environments, as well as novel perspectives for production and business models could be a reality. The cloud environments are constantly increasing their popularity providing competitive and dynamic solutions for distributed computing and systems. In this paper, remote controls and tele-operation platforms are considered as composed of pervasive cloud services.

1 INTRODUCTION

Tele-operation indicates operation of a machine at a distance (Teleoperation, Wikipedia). It is similar in meaning to the phrase "remote control" but is usually encountered in research, academic and technical environments. It is also and most commonly associated with robotics and mobile robots but can be applied to a whole range of circumstances in which a device or machine is operated by a person from a distance (Teleoperation, Wikipedia). Tele-operation can be associated to local environments (clients and machines/devices are connected to a local communication infrastructure) or it can be understood as a low-range distributed environment in which remote client access and operate remote machines or devices through Internet. In the first case (local control), the QoS can be managed and tele-operation platforms can be designed considering a really low response time that positively affect the overall performance. On the other hand, the design of high-scale internet enabled remote controls implies unpredictable performances as well as the need of providing acceptable performances and reliability for time-critical operations.The last generation of internet services and applications is been designed according to a Cloud approach (Mell and Grance, 2009);(Weiss, 2007); (Hayes, 2008). "Cloud computing is a Web-based processing, whereby shared resources, software, and information are provided to computers and other devices on demand over the Internet" (Cloud Computing, Wikipedia).

Details are abstracted from the users that are supported by the technology infrastructure "in the cloud". Cloud computing describes a novel consumption and delivery model for IT services enabling dynamic and scalable environments for the sharing of virtual resources. The term "cloud" is also used as a metaphor for the Internet. Most cloud computing infrastructures consist of services delivered through common centers and built on servers. Clouds often appear as single points of access for consumers' computing needs. The last generation of Cloud Technology allows users to feel remote resource and software remotely running as part of its own computation resource. Cloud vision enables several innovative business scenarios that assume customers do not own the physical infrastructure. Cloud Computing has become a scalable services consumption and delivery platform in the field of Services Computing. At the moment, several classes of cloud services can be identified (Baliga et al., 2011): in a cloud environment, software, storage and processing can be viewed and provided as services. The Cloud vision is affecting the evolution of the great part of systems and platforms. A consistent example is the relatively recent application of cloud technologies to increase the capacity of robots that rely on cloud-computing infrastructure to access vast amounts of processing power and data (Guizzo, 2011). This analysis is easy to be extended to the great part of physical resources (e.g. sensors (Yuriyama and Kushida, 2010)): they are available as virtual resource for high-capable remote processing services that build knowledge on

the basic data provided by physical resources. An exhaustive overview on the last generation cloud technologies, as well as the analysis of current limitation and potential benefits, is really interesting but out of paper scope. In this paper, remote controls and tele-operation is analyzed as cloud services. First of all, a brief analysis about cloud technologies and their relationship with grid computing is proposed (section 3). The section 4 would introduce the tele-operation as cloud service and, finally, in the section 5 some experimental results are proposed in order to provide a first preliminarily overview at current limitations in terms of performance considering realistic scenarios.

2 RELATED WORK

Remote controls and tele-operation platforms are commonly used in the context of several domains and disciplines. An exhaustive analysis in this sense is out of paper scopes. The increasing popularity of cloud environments, supported by high-capable networks, could progressively extend the current view at cloud services, including remote controls, tele-operation and other services potentially affected by time-critical operations. In the section 5, first remote operations will be classified in function of their relationship with the response time; then a qualitative analysis supported by experimental data is provided.

3 GRID AND CLOUD COMPUTING

In the context of this work, the characterization of

the logic and technologic environment can be approached according to several methodologies. The idea is providing a modern and dynamic view at virtual organizations (Foster et al., 2001). In order to archive this goal, an analysis of the relationship between grid and cloud computing (Foster et al., 2008) is proposed in the section.

The Grid approach for the systems development is explained by the following definition:

A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities (Foster, 2002).

Cloud Computing is defined as in the follow:

A large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet (Mell and Grance, 2009).

Evidently the problems are mostly the same in Grids and Clouds as well as the vision is really similar (Foster et al., 2008). On the other hand, there are significant differences between these solutions in terms of both business model (project-oriented for Grid, consumption-based for Cloud) and computation model (resource-centric for Grid, platform-centric for Cloud as showed in Figure 1) (Foster et al., 2008). A deeper analysis of cloud platforms by a business perspective is provided by (Chang et al. 2010); a technical perspective should at least distinguish among:

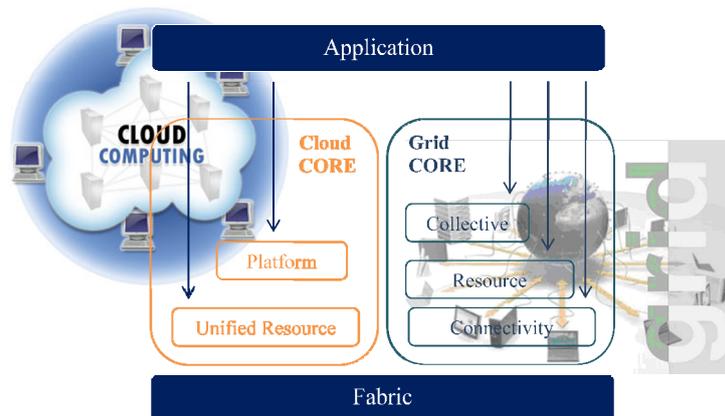- *Infrastructure as a Services (IaaS)* that virtualizes machines according to an approach similar to Grid.

Figure 1: Relationship between Grid and Cloud Computing.

- *Platform as a Service (PaaS)* based on the virtualization of services.
- *Software as a Service (SaaS)* is a software delivery model in which software and its associated data are hosted centrally and are typically accessed by users using a thin client (Software as a service).

Summarizing, Cloud and Grid have a strong convergent point even if they are not the same. In the context of this work, the power of the virtualization (of resources and/or platforms) on large scale is the key issue as well as the pervasive approach to distributed systems.

Clouds and Grids can so referred as the same in this context.

4 REMOTE CONTROL AND TELE-OPERATION AS CLOUD SERVICES

Cloud environments are applied in the context of an increasing number of applications and disciplines. In this section, a short discussion on the platform model that enables remote controls and tele-operations in the cloud is proposed.

4.1 Virtual Organizations in the Cloud Page Setup

Cloud models allow innovative and high-competitive solutions for remote control and tele-operation. The benefits introduced by the cloud vision can be analyzed according to a two-side perspective:

- *Cost/efficiency:* support services can be provided by external and specialized providers. More concretely, a notable number of environments generate and need to store consistent amounts of information. Also high-performance data processing is often required. The clear separation between physical environments and support services could limit the cost of the maintenance.
- *Flexibility*: virtual environments built on the top of cloud technologies (Figure 2) and so composed of pervasive services can be accessed by any kind of devices because lack of the need of local computation. In other word, there is a potential improvement of the capabilities for the reference virtual organizations.

A further interest points are the appliance approach to platforms (Epstein et al., 2010) and the mobile cloud (Kovachev et al., 2010). The resulting Virtual Organization is composed of several interacting actors:

- *Physical Resources*: any class of active (e.g. sensors) or passive (to be controlled) device.
- *Resources/services in the cloud*: common cloud services such as storage, computing and software.

Both infrastructure models assume hybrid final applications (Sotomayor et al. 2009) composed of a
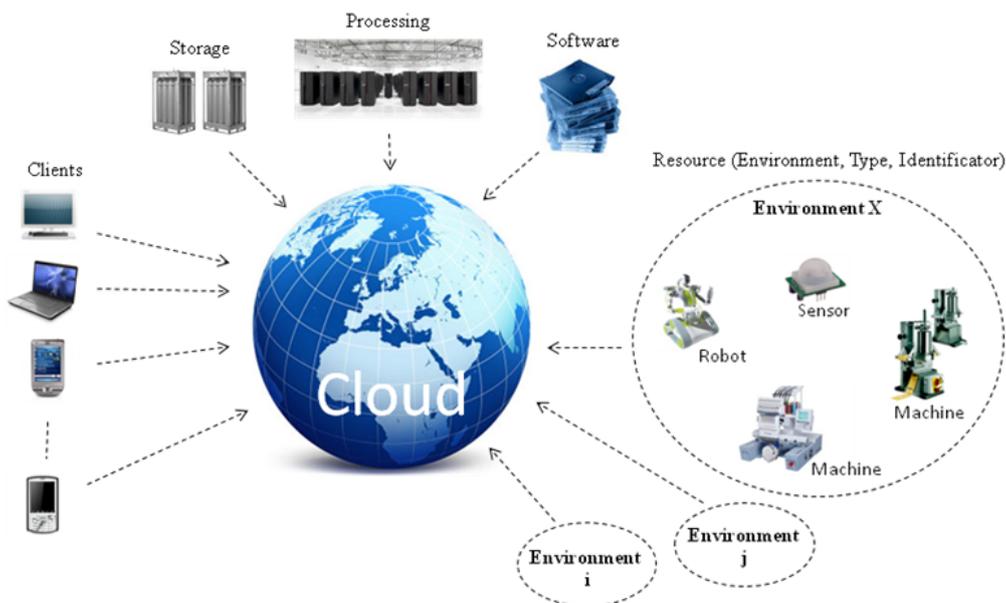

Figure 2: Schematic view of the Cloud Environments for remote control and tele-operation.

set of CORE services (private cloud (Sotomayor et al. 2009)) for tele-operation and controls and of external services that provide support functionalities (data storage, software, computation resource, etc).

- *Cloud Platforms*: orquestration/choreography of complex services.
- *Clients*: support to final users.

The effective relationship between cloud platforms and clients could be quite different in practice and it could depend by several factors such as concrete business models, application requirements and technological factors.

4.2 Remote Control and Tele-operation Model

In order to develop virtual environments able to support effective remote control and tele-operation in the cloud, the background model has to be carefully analyzed. The key issue is the physical infrastructures that enable physical resource in the cloud. There are two main approaches:

- *Centralized Model*: single resources are enabled in the cloud. This model allows improved centralized management models but it could propose a certain decreasing of the performances if the environment (Figure 2) requires internal interaction among single resources.

- *Distributed Model*: only environments are enabled in the Cloud (Figure 3). The resulting management model is intrinsically more limited in terms of interaction of services as well as the background environment needs of its own management.

5 A PRELIMINARY EVALUATION: CURRENT LIMITATIONS

The cloud approach to systems development is concretely applicable under the assumption of high-capable networks. Controlled networks allow the QoS management, on the contrary, consuming remote services through Internet implies an unpredictable response time.

Considering a generic distributed environment, remote operations can be classified in function of their sensibility to the response time as in the follow:

- *No-affected*: operations that are not affected by the response time.
- *QoS-driven*: the response time determines the "quality" of the operation affecting the quality of service and/or the quality of the experience. The operation has not a strict functional requirement in terms of response time. However considering that the response time determines
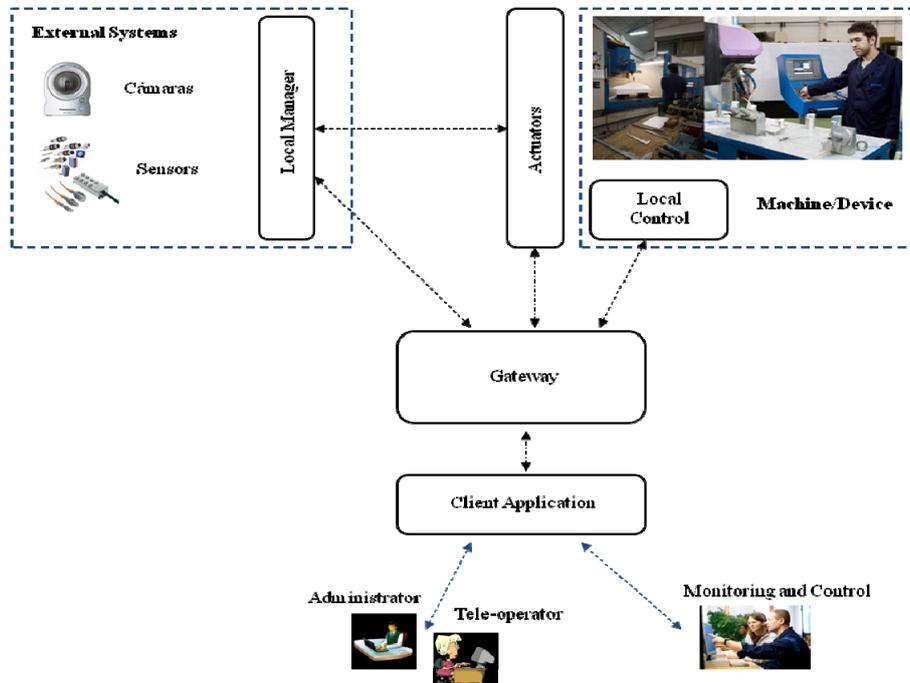

Figure 3: Enabling Remote Control/Tele-operation in the Cloud.

the "goodness" of the operation so that a short response time is expected.

- *Time-critical*: operations that have a strong response time requirements. They can be considered correct operations only if their response time is inferior to the required.

It is interesting to have an experimental view at the effective response time using concrete technologies and environments. This work just proposes a preliminarily evaluation based on the following assumptions:

- Only one technology (Globus Toolkit 4 (Globus Toolkit (GT))) is considered. The evaluation will be extended to more technologies in future works.
- Only IP networks are considered.
- The scenarios represented in Figure 4 are considered: accessing services from local networks (Scenario a) is a good approximation for "private" clouds. At the same time, it provides a key reference for the evaluation of more complex scenarios (Scenario b) in which the access network is Internet.
- Only basic operations (as defined in Table 1) are considered. An evaluation of concrete services is out of paper scope.
- The response time is related to the ping time to assure a relationship with the status of the network during the experiment.
- The proposed analysis is just indicative. An analytic model that allows a deeper evaluation is currently a work in progress. The main assumption is that the overall performance of the services is proportional to the performance of the basic operations.

A number of experimental results referring the Scenario a (Figure 4) are represented in the Figure 5.

As showed, the scenario is characterized by really short average ping-times: response times are a good estimation of the best performance allowed. Obtained results also put in evidence that the considered basic operations have similar response times.

If topologies that propose higher ping-times (scenario b) are considered, performances fundamentally and intrinsically depend by network performance. The Figure 6 represents the response times obtained by random access to services from different networks under variable conditions. As showed, the response times have significant variations respect to the average value and, so, the relation with the ping time is not clearly defined as for the previous scenario.

Table 1: Basic remote operations.

Operation	Description
Class 1	Change remote variable value
Class 1(*)	Read remote variable value
Class 2	Write a value in a remote file system

Summarizing, the preliminary experimentation provided the following issues:

- Basic operations have similar response times. The experimentation on local areas is relatively simple because it allows a direct and consistent relationship with the average ping time. The experimentation considering unpredictable network conditions requires complex models for the analysis.

Remote controls and tele-operation platforms could bring benefit from cloud approach: the next generation of architectures could propose pervasive environments composed of distributed cloud
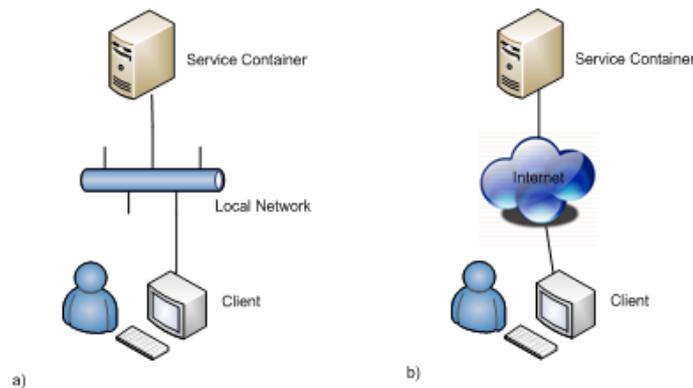

Figure 4: Consuming the service through a local network (Scenario a) and through Internet (Scenario b).
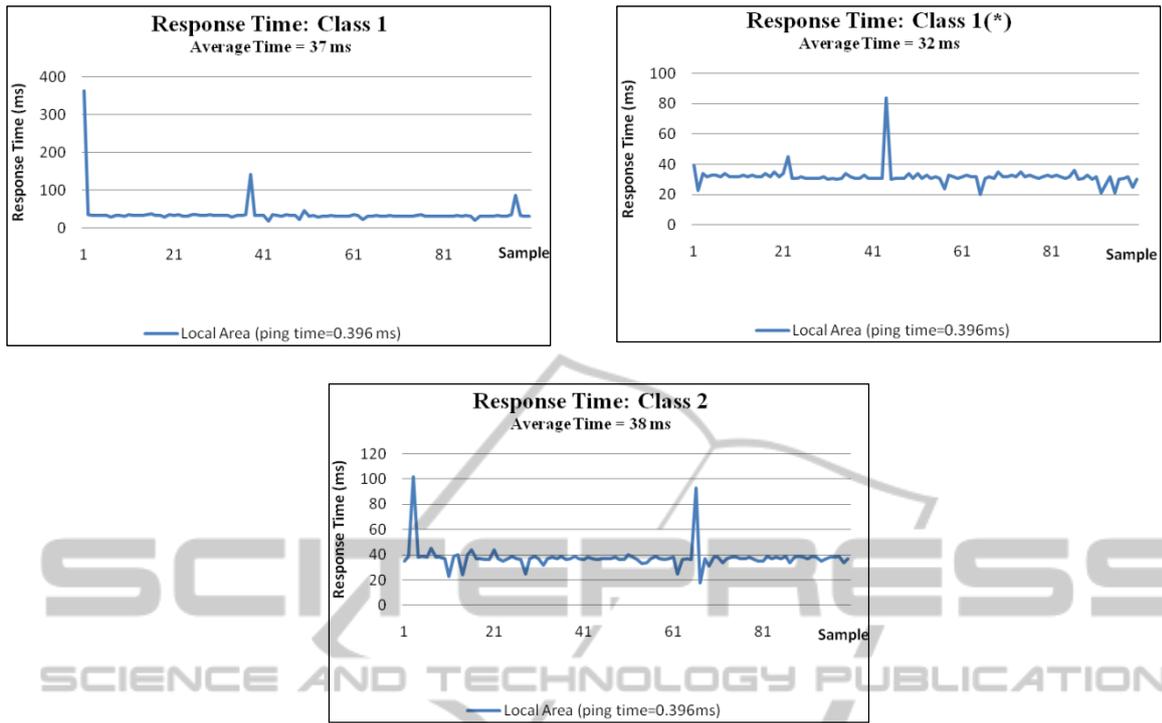
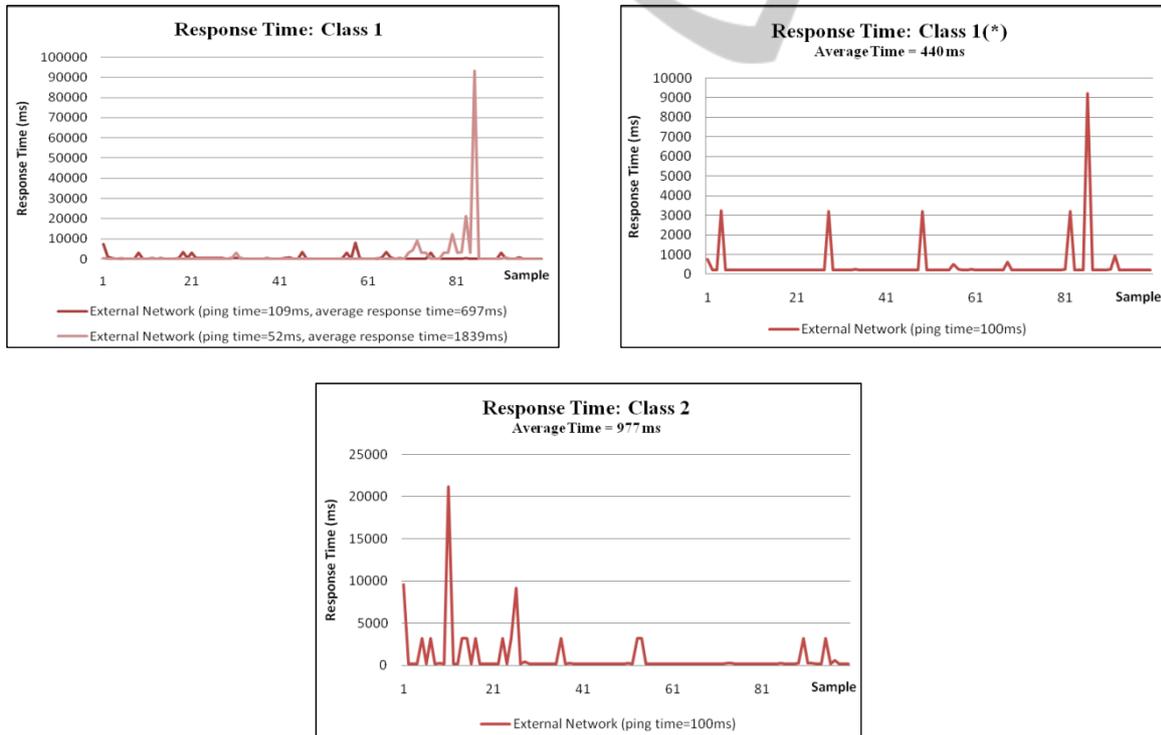Figure 5: Response time within local networks (Scenario a).

Figure 6: Response time accessing resource from Internet (Scenario b).

services able to provide storage, computation and software services resulting in a high-scalable models in which heterogeneous resources are bridged together.

6 CONCLUSIONS

Cloud environments have great possibilities of exploitation as well as constantly increasing perspectives of application.

Cloud models allow innovative and scalable solutions according to high-competitive business models.

The increasing capabilities of networks make the massive migration of local applications to cloud-based architectures next to be a fact.

ACKNOWLEDGEMENTS

REFERENCES

Teleoperation, Wikipedia, http://en.wikipedia.org/wiki/Teleoperation.

I. Foster, Yong Zhao, Ioan Raicu, Shiyong Lu, Cloud Computing and Grid Computing 360-Degree Compared, *Grid Computing Environments Workshop,* 2008. GCE '08.

I. Foster, C. Kesselman, S. Tuecke, The Anatomy of the Grid: Enabling Scalable Virtual Organizations, *Journal of International Journal of High Performance Computing Applications*, Volume 15, Issue 3, August 2001.

I. Foster, What is the Grid? *A Three Point Checklist, GRID today* (2002), Volume 1, Issue 6, Pages: 22–25.

Baliga, J.; Ayre, R. W. A.; Hinton, K.; Tucker, R. S.; Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport, *Proceedings of the IEEE* , vol.99, no.1, pp.149-167, Jan. 2011.

P. Mell and T. Grance, Draft NIST Working Definition of Cloud Computing v14, *Nat. Inst. Standards Technol*, 2009. [Online]. Available: http://csrc.nist.gov/groups/SNS/ cloud-computing/index.html.

Weiss, Computing in the clouds, *netWorker, vol. 11*, no. 4, pp. 16–25, 2007.

B. Hayes, *Cloud computing, Commun. ACM*, vol. 51, no. 7, pp. 9–11, 2008.

Molina, T. E.; Yang, G.; Lin, A. W.; Peltier, S. T.; Ellisman, M. H.; A generalized service-oriented architecture for remote control of scientific imaging instruments, *First International Conference on e-Science and Grid Computing*, 2005.

Xueyu Geng; Shunyao Wu; Jinlong Wang; Peng Li; An Effective Remote Control System Based on TCP/IP, *International Conference on Advanced Computer Theory and Engineering*, 2008.

Manouchehr Ghahramanian Golzar, HamidReza Tajozzakerin, A New Intelligent Remote Control System for Home Automation and Reduce Energy Consumption, *Proceedings of the 2010 Fourth Asia International Conference on Mathematical/Analytical Modelling and Computer Simulation*.

Cloud Computing, Wikipedia, http://en.wikipedia.org/wiki/Cloud_computing.

Guizzo, E.; Robots with their heads in the clouds, Spectrum, *IEEE* , vol.48, no.3, pp.16-18, March 2011.

Globus Toolkit (GT), www.globus.org.

Yuriyama, M.; Kushida, T.; Sensor-Cloud Infrastructure - Physical Sensor Management with Virtualized Sensors on Cloud Computing, 2010 *13th International Conference on Network-Based Information Systems* (NBiS), 14-16 Sept. 2010.

Epstein, A.; Lorenz, D. H.; Silvera, E.; Shapira, I.; Virtual Appliance Content Distribution for a Global Infrastructure Cloud Service, *INFOCOM, 2010 Proceedings IEEE*, 14-19 March 2010.

Dejan Kovachev, Dominik Renzel, Ralf Klamma, Yiwei Cao, "Mobile Community Cloud Computing: Emerges and Evolves," mdm, pp.393-395, 2010 *Eleventh International Conference on Mobile Data Management*, 2010.

Software as a service, http://en.wikipedia.org/wiki/SaaS.

Chang, V.; Wills, G.; De Roure, D.; A Review of Cloud Business Models and Sustainability, 2010 *IEEE 3rd International Conference on Cloud Computing (CLOUD),* 5-10 July 2010.

Sotomayor, B.; Montero, R. S.; Llorente, I. M.; Foster, I., Virtual Infrastructure Management in Private and Hybrid Clouds, *Internet Computing, IEEE* , vol.13, no.5, pp.14-22, Sept.-Oct. 2009.