Towards Semantic Resources in the Cloud

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Abstract. During the past years, the cloud vision at distributed systems progressively became the new trend for the next generation platforms. The advance in the technology, both with the broadband availability and the explosion of mobile computing, make the massive migration to cloud solution next to be a fact. The Cloud model assures a new technologic and business environment for services and applications where competitiveness, scalability and sustainability converge. On the other hand, next generation applications have to be able to pervasively meet the needs and requirements deeply different among them. Applications involving complex virtual organizations require a higher level of flexibility. An effective approach is based on the convergence between migration and virtualization. The resource-centric model assumes file systems, DBs, services and any other class of resources available in the "cloud" as Virtual Resources. These heterogeneous resources can be managed in a unique virtual context regardless by the infrastructures on which they are deployed. Semantics play a critical role in order to assure advanced and open solutions in a technologic context featured by a fundamental lack of standardization.

Keywords: Cloud Computing, Semantic Technologies, Virtual Organization, Virtualization.

1 Introduction

The popularity of Cloud technologies is constantly increasing as well as the interest on this emerging market from specialized companies that are already able to offer several solutions based on different models such as IaaS, PaaS and SaaS [1].

Even if there are several concerns from involved customers and stakeholders and open issues (e.g. privacy [2], security [3] and standardization [4]) concerning the massive migration to the cloud, both private and enterprise cloud solutions are unanimously considered the "future" of the computation [5].

In practice, the cloud approach is actually referred as the most competitive, scalable and sustainable solution on the market under the always more realistic conditions of constantly decreasing bandwidth price and of always connected users. An exhaustive analysis of technical [1] and business [6] aspects of cloud solutions is out of paper scope.

This business scenario could quickly change in the next future if the cloud will not provide high flexible solutions able to meet the needs of complex Virtual Organizations

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(VOs). Analyzing VOs, it is evident that not all resources normally involved are suitable for the migration to the Cloud. The level of flexibility of cloud solutions could be further increased if the platforms are the result of the convergence between migration and virtualization. The key idea is that resources deployed using cloud infrastructures (migrated resources) and resources deployed according to conventional solution could be merged in a unique virtual environment.

This paper proposes a resource-centric model for cloud infrastructure in which virtual resources are provided with a semantic description/specification able to assure a potential high level of interoperability among platforms as well as a set of facilities for the integration of pre-existent or new resources. As detailed in the following sections, semantics play a critical role in the proposed model especially considering the fundamental lack of standardization the cloud is experimenting [4].

As any cloud model, it is potentially independent from any application domain even if, inevitably, domain-specific semantic representations could be required in certain contexts/applications.

A potential application domain for the model is the Spanish health system. In Spain, the National Health System follows a decentralized model where each autonomous community manages all the centres, services and establishments of the Community Councils, Town Councils and any other intra-regional governments. An autonomous community is the first-level political division of the Kingdom of Spain, established in accordance with the current Spanish Constitution. Each autonomous community has many hospital systems of very different natures, being independent of each other.

When a patient must go to different health centres should generally answer the same questions in order to open his/her medical records in each of them. This generates an overall lack of coordination regarding the interoperability between systems, redundant data, basic services, etc.

There is a current trend, which aims to unify those different systems to autonomous community level. At the moment, interconnection between all hospital systems is unapproachable, being applied to European context.

With this purpose, the proposed model aims to provide interoperability through cloud-based environments, giving support and tools for the virtualization, migration of already existing systems formed by data, apps and/or infrastructure and creation of new generation services, in order to make available basic and composite services to consumers (patients, services,…) and for development and management of customized e-health services to all users.

The core part of the paper is structured in 3 main sections: the section 2 is the natural extension of the introduction (it provides a detailed description of approach and scope); in the section 3 the model is deeply described; finally, in the section 4 a brief analysis to next generation resources is provided.

2 Approach and Scope

The scope of enabling semantic resources in the cloud is the interconnection of heterogeneous systems providing the coexistence of different kinds of heterogeneous resources (Figure 1):

- *Internal Resources*: they are the result of the common migration process to the cloud. Resources are hosted by internal infrastructures and they are available as virtual resource in the platform.
- *External Resources*: they are hosted by external infrastructures but they are pervasively available into the platform as virtual resources (Virtualization).
- *Next Generation Resources*: can be designed and implemented directly over the virtualized layer provided by the platform.

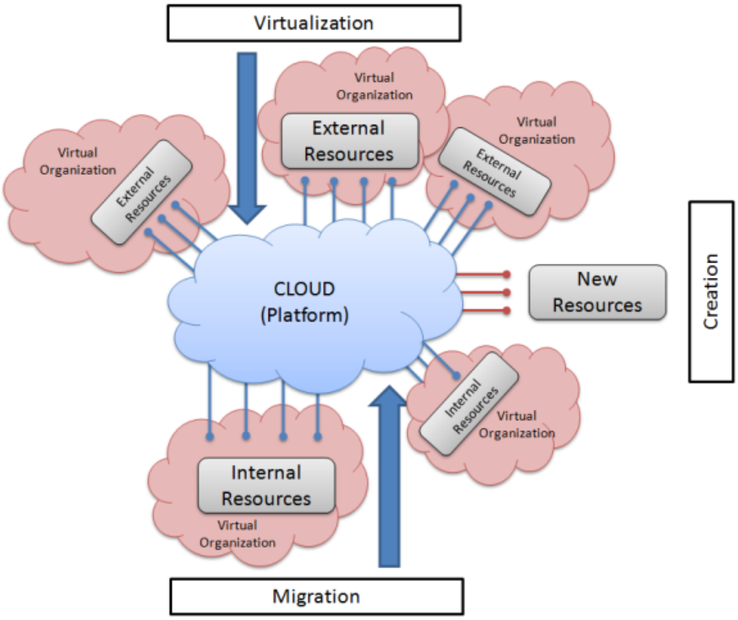

Fig. 1. Interconnecting resources in the Cloud

The platform model assures a flexible and shared infrastructure mainly featured by the following points:

- It enables *ecosystems* among heterogeneous systems.
- It provides a pervasive *virtual environment*: resources are managed at virtual levels assuring high-interoperable capabilities.
- *Cloud Approach*: scalable, competitive and sustainable solutions.
- *Open Semantic Support*: the core semantic support can be integrated/extended with domain-specific interoperability capabilities (e.g. health/medical).
- *Cross-domain Platform*: the core infrastructure of the platform is not domain-specific; the potential application range increases with the expressivity of the semantics.

The diagram represented in the figure 2 shows the platform conceptualization. The free software IHMC CmapTools [7] is adopted for specifying this compact model as a concept map. IHMC CmapTools proposes an approach for knowledge representation similar to semantic networks that build semantic relations among concepts through a directed or undirected graph consisting of vertices, which represent concepts, and edges.

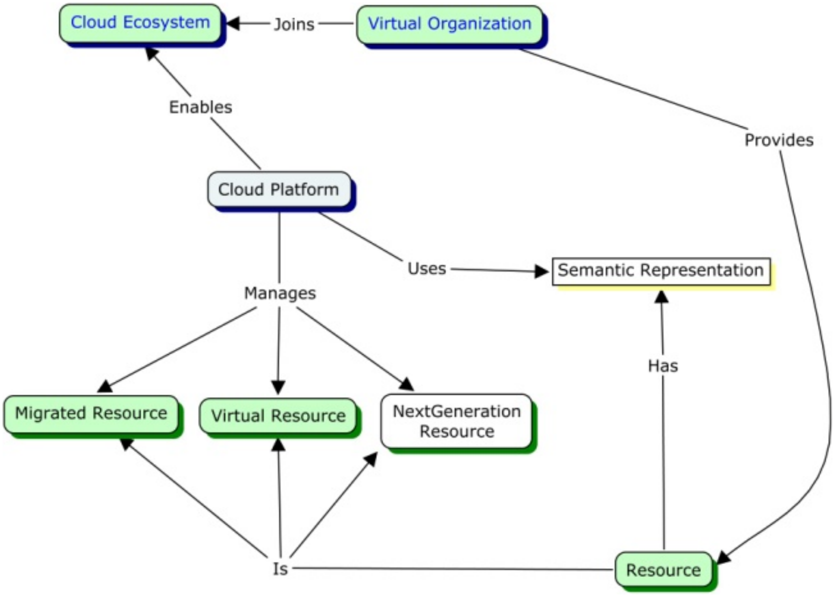

Fig. 2. Platform conceptualization

As showed, pre-existing VOs join the common cloud ecosystem enabled by the platform. Each VO provides a set of resources. These resources can be public (available in the ecosystem for any other VO), protected (available just for authorized actors) or private (available only inside of owner VO or under payment). The platform is able to manage any kind of resource regardless by the infrastructures on which they are deployed. This interoperable layer is assured by the semantic representation of resource.

2.1 A Practical Use Case: Health Systems Interconnection

Several medical systems (e.g. ORION and IANUS) are currently coexisting in Spain providing similar data and services. They are solutions developed in different times in order to meet different requirements and needs from different end-users (e.g. hospitals) that are progressively converging.

Integrated services as well as the need of a stronger level of collaboration require a high level of interoperability. This requirement is completely missed in current systems that are designed to work according to stand-alone behaviors.

The interoperability among health systems is normally solved through ad-hoc solutions (e.g. an interoperable layer between ORION and IANUS). This class of solution is expensive and has several limitations in terms of flexibility because it does not solve a generic problem but just a concrete/local problem. Details about will be provided in the section 3.1.

The health systems interconnection is probably an extreme case from several points of view. But it is a significant example of the impact that virtual (or real) organizations have or can have on the development of systems and platforms operating in the real world. Business scenarios, constraints and restrictions advise an increased level of flexibility in order to assure sustainable and effective environments.

3 Platform Model

The convergence between cloud-based solution and virtualization is not an absolute novelty. An exhaustive analysis [8,9] is out of paper scope but, recently, this approach was used in order to reach different goals in the context of different domains.

The last generation of virtual platforms [10], virtual organizations [11], virtual services [12], techniques for virtual resources management [13]/optimization [14] and virtual infrastructure [15] are, implicitly or explicitly, referred to the cloud model.

Also a semantic specification of resources is a well known topic for both general purpose and specific (e.g. industrial resources [16]) purpose.

The proposed model is composed of three converging perspectives:

- *Interoperability model* (Section 3.1)
- *Business model* (Section 3.2)
- *Technical perspective* (Section 3.3)

3.1 Interoperability Model: Vertical Approach

One of the critical and key issues for the improvement of the current interoperability model is the conceptual evolving from a “horizontal” to a “vertical” approach.

Actually medical systems are logically part of virtual organizations characterized by different complexity in terms of structure and distribution. Each virtual organization has its own technological environment.

During the last few years, a progressive convergence among these environments was aimed (see introduction). The problem is normally approached trying to provide added (or improved) capabilities among existent systems (Figure 3). This “direct” solution is effective and efficient but it is just a local solution: the “integration” of a new system (or resource) implies the need of a “new” solution.

Furthermore, if a new system/resource is integrated in the ecosystem and it has to be interoperable with the existent ones, an ad-hoc component (proxy) that assures the interoperability has to be provided for interfacing each existent system/resource.

This last situation is expressed by (1) where n is the number of independent systems/resources and k is the number of proxies. As showed, if a new resource or system is integrated, a full-interoperable solution implies the deployment of O(n) proxies.

$$\underset{n>2}{k(i) = k(i\text{-}1) + n(i\text{-}1) \rightarrow O(n\text{-}1) = O(n)} \quad (1)$$

The virtualization of resource enables a model of interoperability based on a vertical approach (Figure 3): resources are available at virtual level and the interoperability among systems is approached at this abstracted level.

A solution based on the vertical approach for the interoperability is intrinsically simplest because the integration of a new system/resource just implies the interfacing with the abstract layer (2).

$$k(i) = k(i-1) + 1 \rightarrow O(1) \quad n>2 \tag{2}$$

In practice the vertical approach can be assured according to two different approaches:

1) Standards. Solutions based on shared layers that impose resources to be described according to a well defined set of standards. This is the simplest solution by a technical and conceptual point of view but, unfortunately, is not always easy to be applied in the context of complex virtual organization. This is mainly because standards are hard to be imposed and the data/knowledge from systems can be hard to be converged in well defined standards even considering domain-specific solutions.

2) Open models. Dynamic solutions based on open models (e.g. semantics). Semantic representations guarantee the definition of local knowledge environments that can be centrally managed without the need to share standards. Furthermore, resources could interact among them interchanging semantic data. A completely open model is complex to be proposed and managed. As explained in the section 4, realistic solutions can be designed according to hybrid approaches based on core ontologies that can be extended and/or particularized.

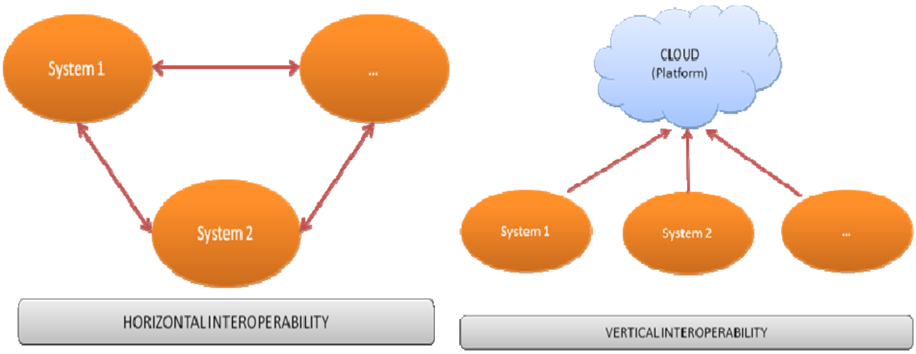

Fig. 3. Horizontal (up) vs vertical (down) approach for interoperability

3.2 Business Model: Merging Migration and Virtualization

Merging migrated and virtualized resources provides a high level of flexibility respect to both technologic and business perspectives. Migration assures a scalable environment, the potential reduction of maintenance costs, as well as the other advantages typical of the cloud approach.

Virtualization allows a further degree of flexibility for resources that owners cannot migrate or do not want to migrate: resources are available into the ecosystems but they are not migrated to the cloud. Motivations for preferring a virtualized resource can be related to law restrictions, business constraints or any other real situation that does not match a full cloud approach.

Regardless from the deployment aspects, a platform that allows the enablement and integration of heterogeneous resources significantly improves the business opportunities and capabilities around shared resources. This is mainly because the virtual resources repository provided by the platform allows a central understanding and management of distributed and heterogeneous environments. The exploitation model of available resources is conceptually similar to services exploitation model. An exhaustive analysis is out of paper scope.

3.3 Technical Overview: Functional and Semantic Support

Platform designed according to the proposed approach should include at least a set of core functionalities, as well as a full semantic support. A reference model can be logically structured as in the follow (Figure 4):

- *CORE Infrastructure/Functional support*: infrastructures and any other functional support to the ecosystem.
- *Management support*: set of functionalities for the management of the platform.
- *Semantic support*: models for knowledge representation.

An exhaustive overview at the architecture design (as well as a detailed analysis of functional layers) is out of the paper scope. The most interesting functional component is probably the *Enabler*.

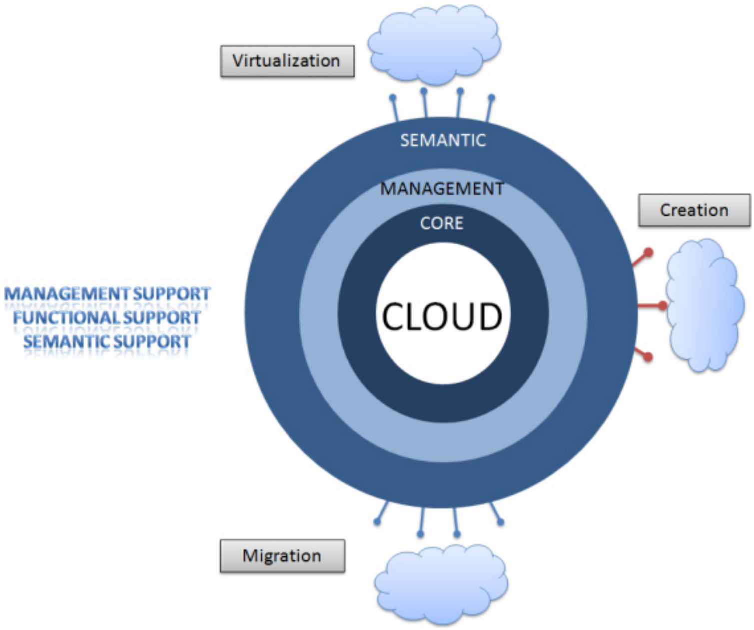

Fig. 4. Technical overview at the platform

Enablers have the critical role of allowing the access to the resources and/or to the modules information. In practical cases, a refinement of the enablers could be required: the information related to a single module could not be atomic and so the enabler could allow the access to a part of the fields, denying the access to other fields; from a resource point of view, also resources could be not managed as atomic components since complex access and consuming policies (similar to services) could be applied. A concrete combination of the enablers defines, at the same time, the rights of a concrete application on the resources and on the information, the role of the application user as well as the privacy contract between the resource owner and the application.

Furthermore, in order to assure a realistic exploitation plan a support for developers is required: a set of APIs and interfaces that support the developer to migrate and virtualize existing resources as well as the design and implementation of new resources.

The platform is evidently the result of the convergence among cloud technologies, virtualization techniques and semantics.

4 Next Generation Resources

A pervasive virtual environment designed according to a cloud approach can provide a solid support for the development of a new generation of resources (e.g. services and applications).

These resources can be developed directly on the top of the virtual layer provided by platforms supporting a high level of abstraction (e.g. role-driven development).

As introduced in the section 3.1, the key issue is the efficient and effective application of open models for the knowledge specification and representation.

The use of "standard" ontologies could be the most immediate solution: rich data models could be enough expressive to represent the knowledge as well as to assure inferred knowledge and an interesting set of interoperability capabilities. But it could limit the advantages and benefits provided by open solutions as well as the problems related to the knowledge convergence could not be solved or skipped.

On the other hand, a completely open model that assumes each local system/resource described according its own ontologies could be hard to be applied in real systems. Typical problems in multi-ontology computation (e.g. correctness and ambiguities) both with the objective difficulty to provide a centralized management for resources advise more realistic approaches.

The current idea is the use of shared vocabularies. These vocabularies should provide the basic concepts making possible the definition of independent local knowledge environments that can be globally linked and processed. In practice, shared concepts have to be used in order to link local ontologies to the platform. Further concepts, as well as rules and relations among them, can be provided by local ontologies. This approach is equivalent to object extension in object-oriented environments.

At the moment of designing a new resource, developers could have a full functional support provided by the platform and a dynamic semantic support. The developer can choose the deployment model (migration or virtualization) that better matches the business needs, link the resource to the platforms through concepts from the shared vocabulary and make available the knowledge required (local ontologies). Further advantages are provided at the moment to design resources that assume the coordinated/uncoordinated use of other resources that can be directly managed at high level.

5 Conclusions

The convergence between cloud and virtualized solutions in a semantic context provides improved interoperability capabilities as well as a competitive environment for resources integration.

The flexibility assured by open models for the knowledge definition and representation could play a key role in several concrete environments (e.g. Spanish health system) involving complex virtual organizations.

The power of integrating existent resources (as well as the design of new ones) directly on the top of an abstracted layer provides a new vision at the cloud and its exploitation model.

Finally, a semantic layer able to link resources to the global environment (platform) and to support, at the same time, local knowledge representations could provide a dynamic support for the effective convergence of dynamic resources in the cloud.

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