ONTOLOGICAL MODELING IN CLOUD SERVICES

About Information Sharing to Support Service Composition

Martín Serrano, Lei Shi, Mícheál Ófoghlú and William Donnelly
Waterford Institute of Technology – WIT
Telecommunications Software and Systems Group – TSSG, Co. Waterford, Ireland

Keywords: Information, Modelling, Interoperability, Linked Data, Knowledge Engineering, Semantic Annotation, Ontologies, Ontology Engineering.

Abstract: This paper presents a study about information sharing and domain ontological modeling within the framework of cloud computing services. We have investigated common practices on service oriented architectures design and knowledge engineering to support the composition of services in the cloud. Research results about information sharing and information modeling by using semantic annotations are discussed. Particularly we present how we use ontological models to represent management information and service lifecycle operations and thus control both system management operations and services running onto cloud infrastructure. We support the idea of look information sharing as a mechanism to facilitate the composition of services, thus ontology-based information modelling is used for this purpose. It enables information exchange by using interoperable data framework for different applications running on infrastructure and application layers. Ontologies support this information sharing approach by formalizing the necessary data needs to be shared or exchanged. An introductory application scenario is depicted. We discuss what implications this approach imposes on architectural design terms and also how virtual infrastructures and cloud-based systems can benefit from this ontological modelling approach.

1 INTRODUCTION

In the race for deploying cloud computing solutions (SaaS) academic and ITC's industry communities have realized an important challenge to tackle is the interoperability of the information or information sharing. Unfortunately, cloud infrastructure implementations (IaaS) has not fully run a coordinated course in terms of design and deployed solutions not even middleware approaches (PaaS) where the information exchange is crucial. As result of this, diversity of approaches multiple non-interoperable cloud solutions are in place. Following this problem linked data for information sharing is becoming an accepted best practice to exchange information in an interoperable and reusable fashion way (Kalinichenko, 2003), for example different communities over the Internet use the semantic web standards to enable interoperability and exchange information. This practice is actually being well accepted by other ICT's communities.

When building enterprise solution(s) traditionally a series of combinations to use existing enterprise services (sub-services) is a very common practice, first by economic interest and second by technology restrictions, this practice has become so popular and today is know as service composition. As an important feature service composition can define in other services definition (recursively). Recursive service composition of business services is one of the most important features of Software Oriented Architectures (SOA), however which advantages it offers in cloud services? How SOA architectures influence cloud solutions allowing rapidly build new solutions based on the existing business services? Is this same recursive methodology applicable to cloud environments? As a fact we assume the amount of individual business services and their composed services are a growing tendency (at least in SOA design), and this practice allows a much easier implementation for new enterprise solutions.

Currently cloud computing architectures, as a design conception, enables capabilities for interoperability and information exchange between data and service levels, this feature facilitates service composition processes, a common practice in software oriented architectures (SOA). However

Serrano M., Shi L., Ófoghlú M. and Donnelly W..
ONTOLOGICAL MODELING IN CLOUD SERVICES - About Information Sharing to Support Service Composition.
DOI: 10.5220/0003693103280335
In *Proceedings of the International Conference on Knowledge Engineering and Ontology Development* (KEOD-2011), pages 328-335
ISBN: 978-989-8425-80-5

aware to this requirement this feature is far to be fully implemented, and information exchange can't be done transparently, this fact promotes a race between academic and industry communities to investigate for designing the Cloud Computing architectures and service solutions enabling or facilitating this feature. It is a fact, currently design approaches concentrate on defining individual business services to be implemented for stand alone applications and ad-hoc particular infrastructures.

Design principles in Cloud Computing aligned with composed services practices contributes for transforming from isolated services (some times considered agnostics) to a more awareness services and integrated solutions. In this designs process many active academic and Information and Communications Technology (ICT) industry communities have participated with approaches to enable information interoperability. Mainly proposing the design conception in the area of Future Internet (Clark, 2003), (Blumenthal, 2001), (Feldman, 2007) where virtual infrastructure support design ideas.

Convergence towards Internet technologies for communications networks and application services has been a clear trend in the ICT domain in the past few years. Although widely discussed this exponentially increasing trend involve many issues of non-interoperable aspects where social, economic and political dimensions take place, all these issues a matter of end-user demands and service requirement.

The intention in this paper is not to define what the Knowledge Engineering means, but rather to view study and define a service-oriented design philosophy; coming through a revision about the role linked data and ontological modeling (Kalinichenko, 2003) can play to satisfy part of the mentioned shared information challenges. In Cloud-based systems services and infrastructure follow a common guideline; provide solutions in form of implemented interoperable mechanisms. Communications networks have undergone a radical shift from a traditional physical expansion environment with heavy expensive devises focused on applications-oriented perspective, towards converged service-oriented distributed software applications alike more powerful (shared to increase processing capacity) data centres architecture. In this radical shift Internet applications are the interaction interface between customer as end-user and network operators and service providers.

This paper focuses on information interoperability and Linked Data for controlling communication systems in the Future Internet of network and services. The extensible, reusable, common and manageable information Linked-Data layer is critical for this deployment. The novelty aspect of this approach relies on the fact that high level infrastructure representations do not use resources when they are not being required to support or deploy services. We optimize resources using this approach by classifying and identifying, by semantic descriptions in a knowledge-based fashion way what resources need to be used. Thus dynamically the service composition is executed and service deployed by result of knowledge–based analysis.

Organization of this paper is as follows: Section II presents the analysis about composing services in the Cloud era and the role Software Oriented Architectures and Linked data plays in this ongoing transformation. Section III presents the summary of challenges for an architecture-infrastructure interoperable, where information exchange (linked data processes) occurs to support application and network services. Section IV introduces our data link approach in form of meta-ontologies facilitating information interoperability and a demonstrator in form of functional architecture to support the inference approach. Section V presents the summary and outlook and finally some relevant references used in this paper are listed.

2 SERVICES COMPOSITION IN CLOUD COMPUTING SYSTEMS

The business benefits of the cloud shift significantly reflects cost reduction and increase systems flexibility to react to user demands efficiently and by replacing, in a best practice manner, a plethora of proprietary hardware and software platforms with generic solutions supporting standardised development and scalable stacks.

Research initiatives addressing this cloud-based design trend inspired by SOA requirements argue that the future rely in layers above virtual networks that can meet various requirements whilst keeping a very simplistic, almost unmanaged infrastructure, IP for the underlying Internet for example, GENI NSF-funded initiative to rebuild the Internet (GENI, online Feb 2011) is an example of this. Others argue that the importance of wireless access networks requires a more fundamental redesign of the core Internet Protocols themselves (Clean Slate, Online April 2011), (AKARI, Online May 2011). Whilst this debate races nothing is a clear outcome in terms of information interoperability or data models sharing.

We follow the idea of service agnostic designs (ad-hoc solutions) are not anymore a way to achieve interactive solutions in terms of information sharing capabilities for heterogeneous infrastructure support either to facilitate service composition in complex environments such cloud environments/applications.

A narrow focus on designing optimal networking protocols in isolation is too limited, instead a more holistic and long-term view is required. In this holistic view multiple services representation (e.g. applications, computing processing, distribution of services, networking) are addressed in a manner of various distributed protocols delivering sub-services as part of composed services. In other terms, a more realistic way of seeing what currently is happening with services in the Internet and according changing communities of users needs. However, realistically this new holistic view increasingly stops to become a matter of critical infrastructure, in this sense cloud computing infrastructures with virtualisation as main driver is a promising alternative of solution to this stopping problem. Network operators are today coming to realise lack in the promise of simpler all-IP networks, where new integrated Internet services are easier and quicker to design, deploy and manage.

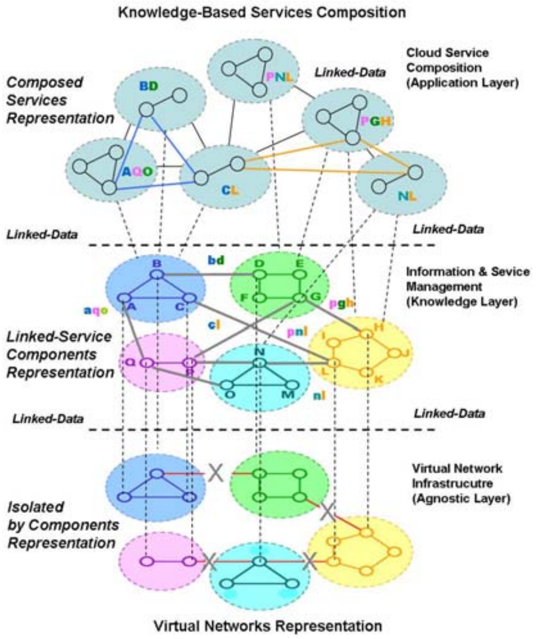

Figure 1: Service Composition by using Linked Data – Information Interoperability.

The figure 1 depicts the mentioned service-aware holistic view and its implementation relies on the inference plane (Strassner, 2007), or knowledge layer where the exchange of information (Linked-Data structures) facilitates knowledge-driven support and generation of composed services with operations by enabling interoperable management information. From down to top and having cloud infrastructures representation as example, isolated components representations are depicted with no capacities of sharing information, linked data mechanisms are missing and "X" represented. In an upper knowledge Layer linked mechanism are represented and used to define services externally. So the migrations towards composed services and networks increases providing solutions to a number of significant technical issues by using more standard information exchange and promoting sharing information. At the upper part of the linked data mechanisms are supported by ontology representations and ontology-based mapping allowing at the same time original services (e.g. ABC) can be managed effectively and most important offering open opportunities for a knowledge-based service-oriented support having a fundamental impact on knowledge-based composition of services (e.g. AQO, PGH) by a complete information sharing and sub-services representation (e.g. BD, CL, PNL, NL).

3 CHALLENGES FOR INFORMATION SHARING IN CLOUD-BASED SYSTEMS

Taking a broad view of state of the art, current development of data link interactions and converging communications, many of the problems present in current Internet about data and information management are generated by interoperability problems; we have identified three persistent problems:

1. Users are offered relatively small numbers of composed services, which they can not *personalise* to meet their *evolving needs*; communities of users can not tailor *services* to help *create*, *improve and sustain* their *social interactions*.
2. The *services* offered are typically *technology-driven* and static, designed to maximise usage of capabilities of underlying technologies and not to satisfy user requirements *per-se*, and thus cannot be *readily adapted* to their changing *operational context*.
3. Service providers cannot *configure* their

> infrastructure to *operate effectively* in the face of changing *service usage patterns* and technology deployment; infrastructure can only be *optimised*, on an *individual basis*, to meet specific low-level objectives, often resulting in sub-optimal operation in comparison to the more important *business and service user objectives*.

As the move towards convergence of communications systems and a more extended service-oriented architecture design and cloud computing gains momentum (VoIP is a clear example of this convergence) the academic research community is increasingly focussing on how to evolve technologies to enable dynamic service composition. In this sense we believe that addressing evolution of networking technologies in isolation is not enough; instead, it is necessary to take a holistic view of the evolution of communications services and the requirements they will place on the heterogeneous physical or virtual infrastructure over which they are delivered (IFIF, Online May 2011), (SRC FAME, Online June 2011), However, communications technology is not part of this research, we concentrate in accessible information sharing features in this convergence of systems.

By addressing sharing information issues, composed systems must be able to exchange information and customize their services. So cloud environments can reflect individual and shared preferences in network and services and can be effectively managed to ensure delivery of critical services in a services-aware design view with general infrastructure challenges.

4 INTEROPERABILITY AND DATA LINK BY USING SEMANTIC ANNOTATION

A current activity, attracting the attention of many research and industrial communities is the formalization of data models (ontology engineering). Enabling information for management of services and control of operations is an example where this formalization is used (Strassner, 2007), (Serrano, 2007). This process focuses in the semantic enrichment task where descriptive references about simple data entries are used to extend data meaning (semantic aggregation), to for example, provide an extensible, reusable, common and manageable linked data plane, also referenced as inference plane (Serrano, 2009). Thus management information described in both enterprise and infrastructure data models (physical or virtual) with ontological data can be used inherently in both domains

The semantic aggregation can be seen as a tool to integrate user data with the management service operations, to offers a more complete understanding of user's contents based on their operational relationships and hence, a more inclusive governance of the management of components in the infrastructure (resources, devices, networks, systems) and or services inclusive. The objective is sharing the integrated management information within different management systems (liked data). This approach is to use ontologies as the mechanism to generate a formal description, which represents the collection and formal representation for network management data models and endow such models with the necessary semantic richness and formalisms to represent different types of information needed to be integrated in network management operations. Using a formal methodology the user's contents represent values used in various service management operations, thus the knowledge-based approach over the inference plane (Strassner, 2007) aims to be a solution that uses ontologies to support interoperability and extensibility required in the systems handling end-user contents for pervasive applications (Serrano, 2009).

4.1 Service and Infrastructure Management by using Ontological Modelling

The meta-ontology approach introduced in this section integrates concepts from the IETF policy standards (Westerinen, 2001), (Moore, 2003) as well as the TM Forum SID model (TMF GB922, 2003), (SID 1684 Online May 2011). In this section important classes originally defined in the IETF, SIM and DEN-ng models, in telecommunications, are cited and implemented as ontologies, some other extended or adapted for communication services adaptability (Serrano, 2008). The meta-model defines a set of interactions between the information models, pervasive management service lifecycle models, and communications systems operations in order to define relationships and interactions between the classes from cited models and from the different knowledge domains. The Ontology mapping and Ontology construction process, which is a four-phase methodology is result of formal study to build up ontologies contained and studied from (Horridge, 2004), (Gruber, 1995).

The formal language used to build the set of ontologies is the web ontology language (OWL) (OWL, 2004), (OWL-s Online May 2011), which has been studied in order to be applied to cloud computing environments; additional formal definitions act as complementary parts of the modelling process. Formal descriptions about the terminology related within infrastructure management domain has been specified to build and enrich the proposal for integrating infrastructure and other service and operation management data within the information models. The objective is to create a more complete information model definition with the appropriate management operations using formal descriptions in OWL. The proposed meta-Ontology model uses concepts from policy-based management systems (Sloman, 1994), (Strassner, 2004) to represent a system ruled by infrastructure policies in cloud environment (virtual infrastructures), which is an innovative aspect of this research work. Figure 2 shows the Ontology representation. The image represents the linked data representation process as result in the integration of classes related to the management operation class through the event class. The Event class interacts with other classes from different domains in order to represent information.

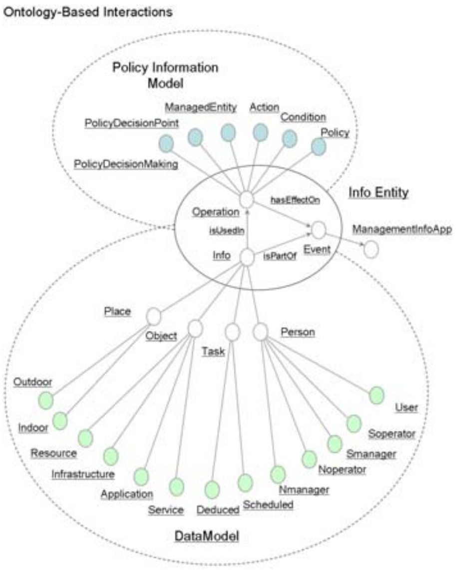

Figure 2: View of InfoEntity Data Links in Service-Oriented Architectures.

This representation simplifies the identification of interactions between the information models. These entity concepts, and their mutual relationships, are represented as lines in the figure. The InfoEntity class forms part of an Event class, and then the Event govern the policy functionality of a Managed Entity by taking into account context information contained in Events. This functionality enables exchange information as part of operations requested from a cloud service, and is represented as interaction between Event and InfoEntity.

The meta-Ontology model is driven by a set of service management operations each as part of the cloud-based service lifecycle. The service composition and its model representation contain the service lifecycle operations, as depicted in figure 3. In figure 3, service management operations, as well as the relationships involved in the management service lifecycle process, are represented as classes. These classes then are used, in conjunction with ontologies, to build the language that allows a *formal* form of English to be used to describe its actions that has effect into events. To do so information (InfoEntity) is underlayed in such relationships, which a correspondence with activities called “*events*” and related to Info Class.

The meta-model is founded on information models principles for sharing information and policy management promoting an integrated management, which is required by both cloud-bases systems as well as service management applications. The combination of data models, ontologies and policy-driven services motivates the use of extensible and scalable frameworks to enable the integration of these three diverse sources of knowledge to realize a scalable management platform we are experimenting with virtual infrastructures to do so.

Form the figure 3 the management operations that are controlled by InfoEntity, the Service Editor is the Service Interface acting as the application that creates the new service. Assume that the service for deploying and updating the service code in certain cloud-based application has been created. This result in the creation of an event named “*aServiceOn*”, which instantiates a relationship between the Application and Maintenance classes. This in turn causes the appropriate policies and service code to be distributed via the Distribution class as defined by the “*aServiceAt*” aggregation. The service distribution phase finds the nearest and/or most appropriate servers or nodes to store the service code and policies, and then deploys them when the task associated with the “*eventFor*” aggregation is instantiated. When a service invocation arrives, as signalled in the form of one or more application events, the invocation phase detects these events as indication of a context variation, and then instantiates the service by instantiating the association “*aServiceStart*”. The next phase to be performed is the execution of the service. Any location-specific parameters are defined by the

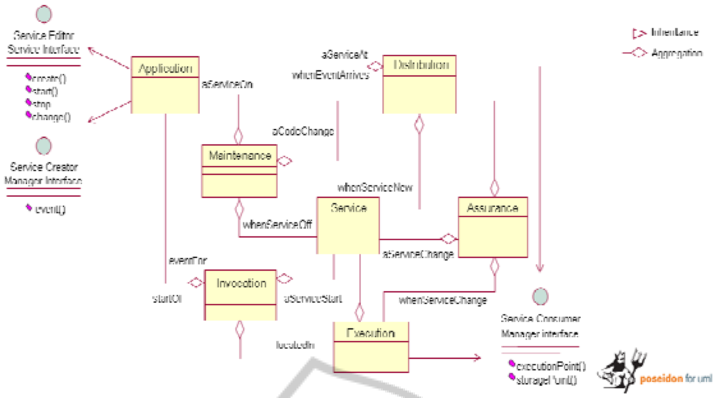

Figure 3: Control and Representation of Service Lifecycle Interactions - UML model.

"locatedIn" aggregation.

The execution phase implies the deployment of service code, as well as the possible evaluation of new policies to monitor and manage the newly instantiated service. Monitoring is done using the service consumer manager interface, as it is the result of associations with execution. If maintenance operations are required, then these operations are performed using the appropriate applications, as defined by the*"aServiceOn"* aggregation, and completed when the set of events corresponding to the association "*whenServiceOff*" is received. Any changes required to the service code and/or polices for controlling the service lifecycle are defined by the events associated with the *"whenServiceNew"* and *"aServiceChange"* associations.

The service management operations are related to each other, and provide the necessary activation of cloud infrastructure to guarantee the monitoring and management of the services over time. The UML operations system design shown in figure 3 captures these relationships, thus the pervasive service provisioning and deployment is on certain manner assured to provide service code and policies supporting such services to the service consumers.

The real sense of this representation defines how the descriptions and concepts contained in InfoEntity and described as Operations and events are used to control virtual infrastructures as part of management operations by suing the proposed ontology. Figure 4 shows the OWL grammar section of the ontology that describes the InfoEntity and its corresponding domain elements. It is a description of an object class for representing an InfoEntity, and represents the simplest definition and relationships in sense of disjointness to the Application, Place, Person and Task classes. The disjoints represent a semantic tool for filtering the seek of information, thus the objects classes including disjoints can be easily identified to be considered or not as part of the control operations that is being seek.

One of the advantages of using OWL to express the ontology is to provide a number of tools for parser and text editors. This enables new adopters to use a tool or set of tools that is best suited to their needs. OWL is used to define the set of concepts and constraints imposed by the information model over which it defines instances.

The RDF-Schema (RDFS) (W3C, Online May 2011) language emerged as a set of extensions to provide increased semantics of RDF by providing basic ontological modelling primitives, like classes, properties, ranges and domains. Finally this extensive use of XML, and the resulting use of RDF extensions, aimed to improve the expressiveness of this ontology.

```
<owl:Class rdf:ID="Event">
    <rdfs:subClassOf rdf:resource="#Policy"/>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#isPartOf"/>
            <owl:someValuesFrom rdf:resource="#DomainConceptPolicy"/>
        </owl:Restriction>
</owl:Class>
    <owl:Class rdf:ID="Condition">
        <rdfs:subClassOf rdf:resource="#DomainConceptPolicy"/>
        <rdfs:label rdf:datatype="&xsd;string">Condition Class</rdfs:label>
        <rdfs:subClassOf rdf:resource="#PolicyModel"/>
        <owl:disjointWith rdf:resource="#PolicySet"/>
        <owl:disjointWith rdf:resource="#PolicyRule"/>
        <owl:disjointWith rdf:resource="#PolicyGroup"/>
        <owl:disjointWith rdf:resource="#Event"/>
        <owl:disjointWith rdf:resource="#Action"/>
        <owl:disjointWith rdf:resource="#PolicyModel"/>
    </owl:Class>
<owl:Class rdf:ID="Action">
        <rdfs:subClassOf>
            <owl:Restriction>
                <owl:onProperty rdf:resource="#isPartOf"/>
                <owl:someValuesFrom rdf:resource="#DomainConceptPolicy"/>
            </owl:Restriction>
        </rdfs:subClassOf>
        <rdfs:subClassOf rdf:resource="#PolicyModel"/>
        <owl:disjointWith rdf:resource="#PolicySet"/>
        <owl:disjointWith rdf:resource="#PolicyRule"/>
        <owl:disjointWith rdf:resource="#PolicyGroup"/>
        <owl:disjointWith rdf:resource="#Event"/>
        <owl:disjointWith rdf:resource="#Condition"/>
        <owl:disjointWith rdf:resource="#PolicyModel"/>
    </owl:Class>
<owl:Class rdf:ID="ManagedEntity">
     <rdfs:subClassOf rdf:resource="#Policy"/>
</owl:Class>
<owl:Class rdf:ID="Obligation">
     <rdfs:subClassOf rdf:resource="#Policy"/>
</owl:Class>
<owl:Class rdf:ID="Authorization">
     <rdfs:subClassOf rdf:resource="#Policy"/>
</owl:Class>
```

Figure 4: Event InfoEntity Description using OWL - RDF Representation.

4.2 Functional Virtual Infrastructure Approach

A functional diagram for functional architecture supporting the meta-Ontology with its functional components as initial approach is depicted in Figure 5. This diagram shows the interactions between the main components. The architecture controls with a certain high level domain-based view, how service composition is performed, thus the control of the behavior is considering like added value functionalities using high level and formal representations expanding operations in other service application domains.

The depicted architecture use monitoring information to manage service operation and instructions with ontology-based information models using linked data mechanisms. Based on previous implementation experience (Serrano, 2007), (Serrano, 2006) this architecture allows adaptability and dynamism to cloud services with the advantages of incorporating performance information from applications and inputs from users in form of events by using InfoEntity Class.

This functional approach offers the advantage in functionality to orchestrate system behaviour using data from business, infrastructure, and other constituencies beyond of the previously defined in the data model. By using this approach the formal models representing data can be translated and integrated as information, machine-based learning and reasoning engines are used to make the correlation between data models. In this particular approach we translate data from application-specific data models into a cloud application- and infrastructure control-neutral forms to facilitate its integration with other types of cloud systems. The key difference in this architecture relies in the usage of *semantics* to perform decision processes.

Performance values are translated into events to be co-related with the system's behaviour and then learned to make the system react when the same events occur. Linked events trigger and control each set of independent related events thus certain level of autonomy is achieved. The service composition process involves analyzing the triggering events expressed in an appropriate interoperable language via service coordination and decision-making integration, and matches them to service management and control level available (Schönwälder, 1999) with the difference of this component using semantic descriptions to co-relate events with particular kind of conflicts that must be identified and evaluated. A detailed Semantic-Based Service Control Engine (S2CE) and its components as part of Functional Architecture is out of the scope of this paper, however implementation results are being analyzed and interaction between different domain events tested successfully, Details can be found in (Keeney, 2011).

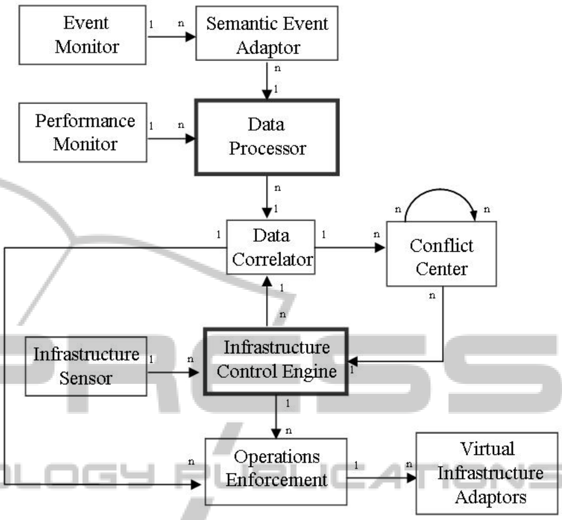

Figure 5: Semantic-Based Service Control Engine - Functional Architecture.

5 CONCLUSIONS

We have demonstrated by use of linked-data, semantic annotation, are good practices for sharing information, alike some semantic web standards has been used to enable this information exchange.

Information sharing is a crucial activity to satisfy the requirement in convergence service and communication systems. Implications for services and infrastructure management are still under research (service composition). We have studied and demonstrated how formal representation of data can be used for modelling service cloud infrastructures.

Remaining research challenges regarding information model extensibility and information dissemination conduct our attention to continue our activity towards virtual infrastructure management, perform more cloud service control experiments and look for full service lifecycle control in cloud infrastructures.

In cloud infrastructures (virtual machines) high demands of information interoperability and of data link are demanded to satisfy service discovering and services composition requirements being controlled by diverse, heterogeneous systems and thus make more dynamic the perform of cloud-based system.

We have demonstrated with this formal representation we can use ontologies to share information between different domains where diversely same information is used to describe systems performance in form of simple data instances or likewise describe management operations in the form of events used to control virtual infrastructures.

The approach presented in this paper emerges as study looking forward alternatives to solve part of the sharing information complex problem. Particular focus has been described into cloud environments as cloud computing is one of the most hot areas not only from a service composition and technology deployment point of view else from a no less important cloud service management perspective.

ACKNOWLEDGEMENTS

This work is a contribution to SFI-FAME SRC (Federated, Autonomic Management of End-to-End Communications Services - Scientific Research Cluster). Partially funded by Science Foundation Ireland (SFI) via grant 08/SRC/I1403.

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