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An ontological specification of a Computational Cloud

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Abstract: Ontologies have gained popularity in recent times as the next generation data representation technique that allows for mapping of semantics of data in addition to its content. They have been proposed as a superior data representation technique as compared to its relational counterpart. This paper introduces an Ontology named 'The Cloud Ontology' (CoOn) which classifies data of the Cloud services providers. CoOn will also assist researchers in gaining a better understanding of the Cloud's IaaS (Infrastructure as a Service) layer. It allows data to be organized in a manner which represents the meaning of contents of the Cloud service providers in a format that is machine independent and intelligible. As a proof of concept three popular Cloud providers has been described using the proposed Ontology. CoOn relates similar Cloud services offered by the providers and represents their data in a simplified manner. CoOn was evaluated using SPARQL queries, CoOn is a simplified solution to the deficiencies of the relational model for representing the same data

Keywords: Cloud Computing, Infrastructure as a Service, Ontology, Semantic Web,

1 INTRODUCTION

Data has much evolved recently necessitating new data representation mechanisms that facilitate the usage and storage of data. Traditionally data has been stored in relational format. Relational database schemas have proven to be simple, efficient and secure, however due to recent changes in the way data is processed by both man and machines has raised questions about the effectiveness of the relational schema. The change in technology has led to the need of understanding the semantics of the data being represented and as a result relational database formats leave much to be demand for in that context (Martinez-Cruz, *et al.,* 2012) Several approaches have been proposed to provide an effective mechanism for handling today's data. One such technique involves representing data in the form of a graph called Ontology. Ontologies allow us to map the meaning (semantics) of the data along with its content.

Cloud Computing has been a prominent and an evolving technology for the past few years. Due to which the Cloud market is incredibly vibrant i.e. new Cloud infrastructure services are frequently emerging and the number of Cloud Providers are also rapidly increasing. This variety leads to problems like,the Cloud providers use non standardized naming schemes and proprietary terms .Due to which understanding the similarities between cloud services has become challenging (Li, *et al.,* 2010). Amazon Web Services (AWS) refers to its compute services as Elastic Compute Cloud (EC2) while in contrast the RackSpace Cloud calls it Cloud Servers. Further on Cloud Providers possess different implementation models so from the storage point of view it's not feasible to store Cloud Provider's data within a database considering their heterogeneous forms of information. Therefore such fertility in providers and their services lands the need to represent semantic relations of Cloud Infrastructure Service concepts i.e. we need a Cloud Ontology for representing Cloud concepts and their interrelationships. The ontology provided as a part of this research not only describes the core concepts of infrastructure services but is also capable of storing Cloud Provider's data.

The prime benefactions of the paper include:

- Identifying the basic concepts of the cloud infrastructure services and their relations including functional and non functional configurations.
- Modeling of service descriptions published by Cloud providers according to the developed ontology. By doing so, we validate the expressiveness of ontology against the most commonly available infrastructure services providers including Amazon, Rackspace, GoGrid, etc.
- Gathering the some data from the aforementioned Cloud providers and storing them within the ontology and lastly retrieving the stored data through SPARQL queries.

2 STATE OF THE ART

Semantic Web is an evolving technology that deals with making the web intelligent and to serve this Ontologies act as the corner stone (Cabral, *et al.,* 2004)**.** Much work has been done on Cloud ontologies in the past years starting from using ontologies to classify the Cloud layers/systems and understanding their interrelations and dependencies on their predecessor technologies [9]. Design of a ontology supported cloud service discovery system was proposed in (Claus, *et al.,*

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2011) (Segev, *et al.,* 2012) (Zhao, *et al.,* 2012) (Androcec, *et al.,* 2012). (Hilley, 2009). (Youseff, *et al.,* 2008). Zhang, *et al.,* 2012). Storage architecture of ontology was proposed in (AlFeel, *et al.,* 2011) this included techniques for data acquisition and file storage. The authors in (Claus, *et al.,* 2011) (Segev, *et al.,* 2012) have used ontology to define the schema of the database that stores providers data and is used by the discovery systems but the database underneath it is still Relational. Although Relational Database (RDB) is efficient and secure, but unlike other offerings the relationship between cloud products are complicated. In another research work Hilley states "The products offered by cloud service providers are not mutually interchangeable and such services are not directly comparable on orthogonal dimensions" (Hilley, 2009). Therefore it does not seem efficient to store such heterogeneous data into a RDB due to its nature. CoOn not only focuses on classifying the Cloud's Iaas layer in detail along with Qos aspects involved but to exercise the same ontology to store the data of three popular cloud providers and also querying the stored data.

3 THE CLOUD ONTOLOGY

The Cloud Ontology (CoOn) expresses the domain model of the IaaS layer. CoOn is comprised on two parts; the first one is Functional Cloud configurations and the second one being Non functional Quality of Service (QoS) Cloud configurations. The details of each are given in following sections.

3.1 Functional Cloud Configurations:

The main concept in the Cloud Functional configuration is the Cloud_Resource which can be of the type Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) or Software-as-a-Service (SaaS). The CoOn focuses only on IaaS layer.

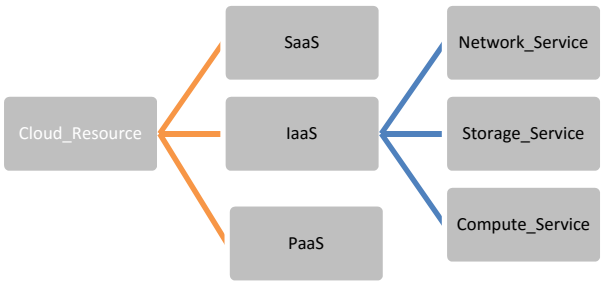


Fig. 1: Fundamental Concepts of IaaS Layer

Services on the Iaas layer are categorized into: Compute_ Service, Storage_ Service and Network_ Service, each of which has been implemented as a separate class in the CoOn **(see the Fig. 2)**

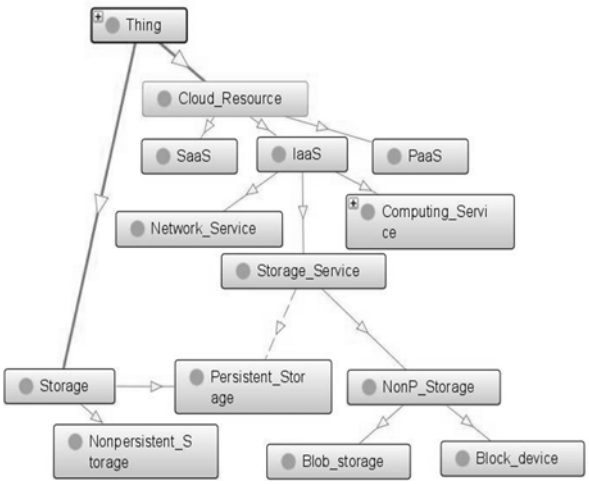


Fig. 2: Cloud Resource Taxonomy

Besides the Cloud Resource there are other concepts which also a part of the Thing Class **(see Fig. 3).**

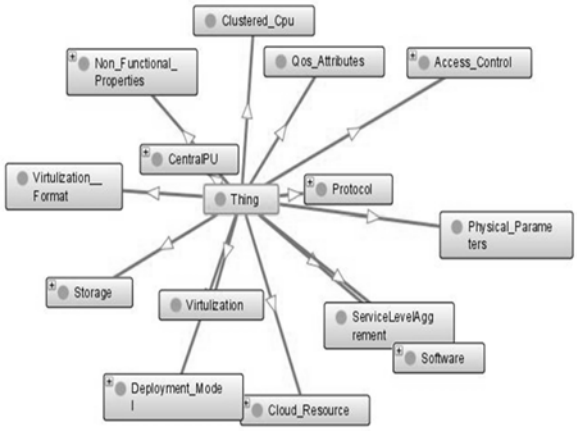


Fig.3: The Big Picture

Each class in **(Fig. 3)** has some object and data properties which are listed in the tables below.

Table 1: Object Properties of the Classes in CoOn

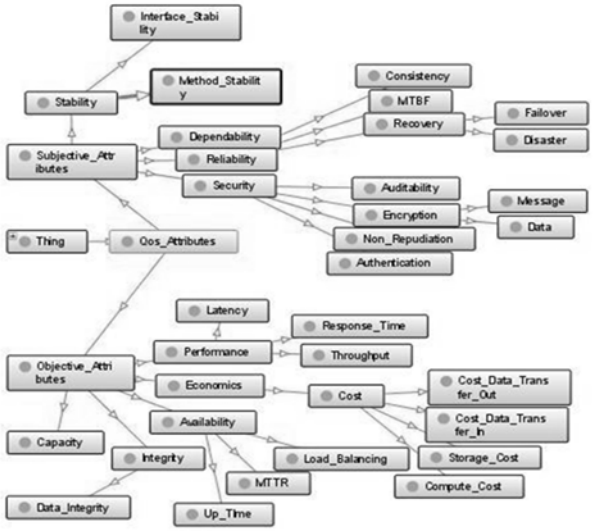
Object Property	Domain	Range
Has_bandwidth	Network _Service	Physical_Parameters
Has_benchmark	CentralPU	Physical_Parameters
Has_Capacity	localStorage,NonP_Storage	Physical_Parameters
Has_ClockRate	CentralPU	Physical_Parameters
Has_Credential	Cloud_Resource	Credential
Has_DeploymentModel	Cloud_Resource	Deployment_Model
Has_Functionality	Software	
Has_LocalStorage	CentralPU	Local_Storage
Has_Location	Cloud_Resource	Location
Had_Memory	CentralPU	Physical_Parameters
Has_MemoryAdressSize	Computing_Service	Physical_Parameters
Has_Provider	Cloud_Resource	Provider
Has_ResourceRecord	CentralPU	Host_Name,IP_Address
Has_SupportedProtocol	Network _Service	Protocol
Has_Virtulization	Computing_Service	Virtulization
Is_A	Storage_service	Persistent_Storage
Is_AvailableIn	Cloud_Resource	Location
Is_SoftwareType	Software	Sw_Type

Table 2: Data Properties of the Classes in CoOn

Data Property	Domain	Range
Access_Number	Access_Control	String
Bandwidth	Network_Service	String
CPU_Family	CentralPU	String
Description	Cloud_Resource	String
Latency	Network_Service	String
No_of_Cores	CentralPU	Decimal
Np_Storage	Non_Persistent_Storage	String
Numeric_Value	Physical_Parameters	Double
Password	Credential	String
Protocol_Version	Protocol	String
Provider_Description	Provider	Literal
Provider_Name	Provider	Name
R_A_M	CentralPU	String
Service_Name	Computing_Service	String
Service_Type	Computing_Service	String
Service_Size	Computing_Service	String
Ssd_Rating	Storage	String
StorageSize_Max	Storage	Decimal
StorageSize_Min	Storage	Decimal

3.2 NonFunctional Cloud Configurations:

From the Nonfunctional Cloud configuration perspective the paper focuses only on Quality of Service Attributes.



4 EVALUATION OF COON

Evaluating Ontology has become a challenging task. Evaluating ontologies is a tricky as they need to be checked for the purpose they are created for i.e. the conceptual understanding and implementation of relations and how the ontology overcomes the shortcomings of traditional information representation mechanisms such as relational etc) Due to their declarative nature one cannot simply compile and run them like other software artifacts. Therefore two approaches have been used to evaluate Ontologies i.e. Qualitative Approach and Quantitative Approach. A qualitative approach involves domain experts to evaluate an ontology based on certain criteria's. While in quantitative approach observations are made using scientific tools. As our ontology is designed to overcome the shortcomings of the relational model, therefore the quantitative approach has been chosen to validate its effectiveness. The evaluation involves executing SPARQL queries on the ontology to retrieve data from the ontology.

4.1 Retrieving The Taxonomy:

CoOn represents all the concepts within the IaaS Provider's domain in the form of classes and its subclasses with is depicted through the snapshot.

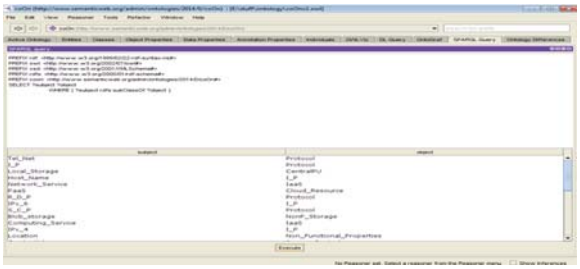


Fig. 5: Snapshot No: 1

4.2 Retrieving The Individuals:

CoOn stocks data from three prominent Cloud Providers through the individuals. The provider class has several individuals for providers based on the classification of the service type offered within each. The snapshot below shows the list of individuals of the class Provider.

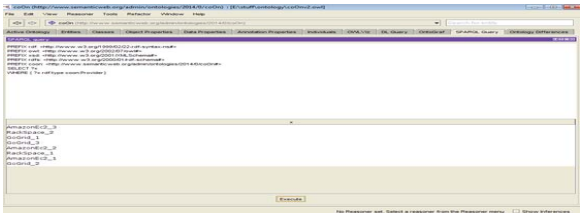


Fig. 6: Snapshot No: 2

4.3 Sorting the data

As Coon houses data of several Providers, which offer different sizes in terms to CPU and RAM. The snapshot shows the number of cores provided by each provider in descending order.

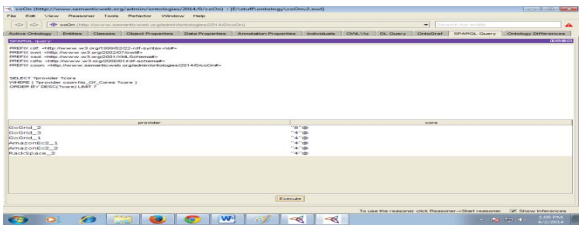


Fig. 7: Snapshot No: 3

4.4 Retrieving Data within Individuals:

The data in CoOn has been stored within the data properties of the individuals, every individual has several data properties that are shown in table no: 2 and each of which is populated with the corresponding data as show in the snapshot below.

Fig. 8: Snapshot No: 4

4.5 Retrieving Maximum

The Cloud Providers offer different RAM sizes based on the service type selected by their clients. The snapshot below shows the maximum RAM offered among the Providers.

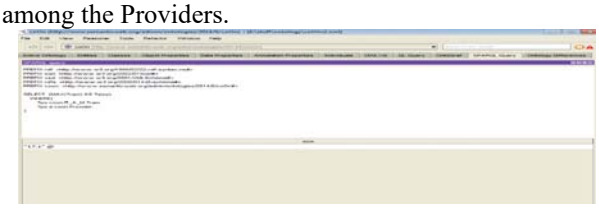


Fig. 7: Snapshot No: 3

5 ANALYSIS

Due to a lack of standardization in the IaaS industry, providers freely use unique terminology to describe their Virtual Machine (VM) resource allocations. How does one compare an ECU to a Virtualized CPU (vCPU)? Moreover Amazon's ECU has CPU capacity of 1.0-1.2Ghz while Gogrid's Cloud Server has CPU capacity of 1.3 GHz. Therefore not only the terminologies but also the underlying units differ in structure.AWS has a bunch of features that other providers don't offer. Storing such kind of a data within a Relational Database is not recommended as it will involve dealing with issues regarding joining of tables, with null values that will occur in columns etc.

6 CONCLUSION

The Cloud Ontology (CoOn) that has been presented as a part of this research work helps to categorize and depict the configuration information related to Cloud based IaaS services including compute, network and storage. The ontology is capable of storing Cloud Provider's service configurations. The Ontology will benefit researchers in gaining better understanding of the core IaaS layer Cloud computing concepts and interrelationships between different service types. The Cloud ontology overcomes the shortcoming of RDBMS by allowing us to group similar proprietary terms of different cloud service providers which would be a complex task to achieve from a Relational Database Management System (RDBMS).

In future the ontology can be extended with the capability to represent SaaS and PaaS configurations also. Due to time constraints, we were unable to investigate the effects of storing the same data in RDBMS whose structure is defined by Ontology. Therefore we plan to migrate the infrastructure definitions to an Ontology Enabled Database (OED) such as Oracle 12c and then use JENA API's for communication

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