Managing IaaS Cloud Using Common Management Services Framework

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Abstract: IaaS model of Cloud Computing increases responsiveness to business needs. But, at the same time it also creates a completely transformed operating environment. The management requirements are compounded because the user’s scope of control on the infrastructure resources is also increased. In such a scenario, a unified framework for management of various activities which ensures operational integrity of IaaS cloud becomes a necessity. This paper presents a Common Management Services Framework for IaaS Cloud (CMSFIC) that organizes essential management functions into layers. Each layer is partitioned into management components that are designed to implement an automated and seamless IaaS cloud that provides agility, cost saving and optimized use of resources to its customer. CMSFIC incorporates the features of the important commercial and open source IaaS platforms. The given framework can make a significant impact on the architecture of IaaS cloud and also helps to compare the capabilities of prevailing IaaS products.

Keywords: Cloud Provider; Service Catalog; Cloud Service Creator; IaaS; Management Layer Function

I. Introduction

In a cloud environment information technology (IT) and computing resources for example, hardware, operating systems, storage, databases and software applications, are available instantly when demanded by a user. Indeed, cloud computing has dramatically transformed the way IT is managed. Clouds are broadly classified as IaaS (Infrastructure as a Service), PaaS (Platform as a service) and SaaS (Software as a Service). The difference in the three classes lies in the infrastructural abstraction for management of virtual resources available to a customer. Figure 1 depicts the scope of control of the user in the IaaS platforms.

Infrastructure as Service [30] model of cloud computing is becoming popular among the business enterprises due to its proven ability to lower upfront costs and optimize resource utilization. A typical IaaS provisioning model offers scalability, location independence, physical security of data center locations, utility style costing and no single point of failure. It is clear that the scope of IaaS clouds is very wide due to which any IT solution that permits the outsourcing of computing resources of all kinds is wrongly considered as an IaaS cloud. Evidently, there is a lack of a standard IaaS reference architecture or model that can be used as roadmap to build an IaaS cloud and alternatively to evaluate the most important

Fig 1. Scope of control between user and IaaS Provider

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commercial and open source IaaS cloud infrastructures and compare their performance.

The objectives of this paper are- (i) to demonstrate a comprehensive overview of cloud computing reference architectures given by authors for research purpose as well as those models that are industry best practices, (ii) with the help of literature reading and relative comparisons of the characteristic features of the given reference architectures, we arrive at a structured framework for managing IaaS clouds in a systematic way. We call our framework Common Management Services Framework for IaaS Cloud (CMSFIC) which provides a complete specification of different management activities involved in IaaS cloud.

CMSFIC is of much importance as IaaS model of cloud computing is the fastest growing field and to the best of our knowledge there is no such integrated reference model that has the ability to describe the important management tasks in IaaS clouds from service request to service retirement. Every resource in IaaS environment undergoes an automated lifecycle that is clearly defined so that IaaS customers may get an experience of a seamless and predictable service environment. We claim that CMSFIC is a ‘one-stop-management-services’ model that integrates essential management functions in one place.

This paper is organized in the following manner. Section II presents the related work. In section III various roles in IaaS cloud and their inter relationship is presented with the help of UML diagram. A sequence diagram is also given to explain the steps involved in-service life cycle. Section IV gives the architecture of Common Services Management Framework for IaaS Clouds and description of its layers and components. In section V, the significance of CSMFIC is discussed. Section VI is devoted to analysis and comparison of open source and commercial IaaS platforms using CSMFIC. The conclusions and future work is presented in section VII.

II. Related Work

In many research papers, IaaS architectures have been compared [1-11]. However a complete description of the management functions has not been addressed. The authors in [3] present a comparative analysis of OpenNebula, cloud toolkits such as Eucalyptus and Nimbus that are well known virtual infrastructure managers but did not present the details of the management layer. Literature survey reveals the evolution of promising cloud reference architectures in the industry as well as different associations. Significant architectures given by IBM [12], Oracle [13], Cisco [14], IETF [15], DMTF [16] are layer based that discuss the mapping of IaaS components to the layers of the architecture. However, very little stress has been put on the management layer [36, 37]. In contrast the CMSFIC focuses on all the essential aspects of the management layer of IaaS clouds including security management and customer relationship management.

OpenCrowd [17], NIST [18], Intel [20] and Riemal et al. [19], presented a general cloud computing taxonomy. An inspiring work by Dukaric [21], presented vital IaaS capabilities but does not address elaboration of such management functions as service catalog management and monitoring the health of customer experience, as included in our work. While a vivid description of resource management for IaaS clouds as given by [22] helped us to design our resource management layer, the Cloud Computing Business Framework given by [23] and BMC [24] cloud life cycle management shaped our view of service layer as given in CMSFIC.

As IaaS cloud is becoming the fastest growing field, business enterprises face the problem of choosing between the better cloud offer that fulfills their specific business needs and building their own cloud infrastructures using open source technologies [38]. To address this problem the linkage between business needs and cloud capabilities must be clearly identified. A list of challenges for an enterprise to 'go
cloud’ includes flexibility, security and interoperability. The need of an enterprise-ready IaaS is mentioned by researchers [34, 35] but very little comprehensive solution has been provided. For understanding the smooth transition of business activities onto IaaS clouds, we referred the benchmark research papers given by [23, 27, 28 and 25]. A reference model for cloud (RMC) [25] presented IaaS as tower architecture and defined the research clouds including use cases. The IT Infrastructure Library (ITIL) Version 3 Service Framework summarizes industry best practices in IT service management. The focus is given on the continuous improvement of the QoS by undergoing five processes, building service strategy, creating service design, defining service transition, managing service operation and continual service improvement. Papazollou [29] presented the overview of SOA and explain the various service layers and their functionalities. Another SOA framework given by IBM [28] has benefits like agility, profit maximization, improved control over processes and integration of different technologies.

The aforementioned papers suggest a top-down relationship between business models and IT services. Such a top down relationship where the top layers present the business requirements to the bottom layers and obtain the services of the lower layers, is difficult to be incorporated in the IaaS cloud architecture. However layered and component based approach seems to be feasible.

III. Various roles in IaaS and the UML representation

Figure 2 presents the generic relationship between the major actors (customer, cloud provider and cloud service creator) in the IaaS cloud. It also shows the basic interactions among the actors. Each actor performs specific tasks in IaaS cloud. The definition of the actors are given as-

1. Customer: An individual or organization that uses service from IaaS provider.

2. IaaS Provider: The organization or entity that makes a service available to the customers.

3. Cloud service creator: An individual or entity that creates services by following the specifications given by the IaaS provider.

![Fig 2. UML diagram showing interactions among the actors](image)

The figure shows that a customer can use many cloud services. A cloud service has many instances so that they can be given to different customers. A cloud service is made up of many runtime and management functions that are managed by the IaaS provider. The provider employs a cloud service creator who develops cloud services. To develop a cloud service, a cloud service creator uses and integrates runtime and management functions in such a way so that IT capabilities can be delivered ‘as-a-service’.

Some other actors such as cloud auditor, cloud broker, cloud carrier are also mentioned in the literature. However we focus only on the three basic roles so as to bring out the essential management activities conducted during a service life cycle. In all the models of cloud computing, service is the common element whose deployment or delivery gives birth to the underlying management tasks.

While the customer interacts only with the IaaS provider, the latter interacts both with the customer as well as the Cloud Service Creator.
Figure 3 shows the sequence diagram of the steps involved in service creation. The steps of service creation are explained as follows:

**Step 1. request service:** A *Customer* requests for a compute or storage resource from the *IaaS Provider*.

**Step 2. specify service description:** The *IaaS Provider* stores the customer’s requirements (configuration options, type of resource, time period for which it will be used) and combines service level agreement guidelines to prepare a service description that is given to the *Cloud Service Creator*.

**Step 3. implement service description:** The *Cloud Service Creator* implements the service description given by the *IaaS Provider*.

**Step 4. return:** The *Cloud Service Creator* creates the service and returns to the *IaaS provider* for additional bindings.

**Step 5. specify delivery description:** The *IaaS Provider* describes the delivery guidelines that includes self service support, usage monitoring, problem management, security management and billing management for the service to the *Cloud Service Creator*.

**Step 6. implement self service:** The *Cloud Service Creator* implements self service support so that user can navigate through various options offered by the *IaaS Provider*.

**Step 7. implement monitoring metrics:** The *Cloud Service Creator* implements monitoring support that tracks availability of resources to the customer as well as the amount used.

**Step 8. implement problem management:** The *Cloud Service Creator* implements problem management support that helps the *Cutomer* overcome unusual incidents while using the service.

**Step 9. implement security function:** The *Cloud Service Creator* implements security measures like authorization and authentication to avoid malusage of resources.

**Step 10. implement billing metrics:** The *Cloud Service Creator* implements the billing metrics for auditing and reporting customer payment information to the *IaaS Provider*.

**Step 11. register service to service catalog:** The *Cloud Service Creator* registers a service with all specifications implemented in the service catalog of the *IaaS Provider*.

**Step 12. present service catalog:** The *IaaS provider* presents the service catalog to the *Customer*.

**Step 13. choose service:** The *Customer* chooses a service offering from the service catalog presented by the *IaaS Provider*.

**Step 14. deploy service:** The *IaaS Provider* deploys the chosen service at the *Customer* site.

**Step 15. consume service:** The *Customer* consumes the service for the required time period.

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Step 16. send bill: The *IaaS Provider* sends billing notifications to the *Customer*.

Step 17. pay bill: The *Customer* pays the bill to the *IaaS Provider*.

The above mentioned steps are studied in detail to understand the important management tasks performed by the IaaS provider and develop the common management services framework.

**IV. Common Management Services Framework for IaaS Cloud (CMSFIC)**

In this section we describe the various layers of the CMSFIC. Each layer contains certain components that are responsible for specific management functions. The layers are arranged in a bottom up manner, from generic to sophisticated tasks. There are two components, orchestration and workflow management that bind together the layers of the framework. Each layer is explained as follows:

(A) The Abstraction Layer

This layer has three components that manage the basic operations of the IaaS cloud. The description of each component is given below-

1. **Virtual Machine Management:** Virtualization allows IaaS consumers to share virtual computers, network accessible storage and other fundamental computing resources in an abstracted manner. The virtual machine management component protects the integrity of guest virtual machines as well as the infrastructure computing resources. This component sits directly on the top of hardware resources and provides the demanded services by allocating virtual machines to user generated requests. It performs essential functions like virtual machine load balancing, virtual machine migration, live migration, managing various hypervisors and optimizing resource utilization. Virtualization plays a central role in both compute and resource clouds and so does the virtual machine management component of CMSFIC.

2. **Resource Management:** Every device connected to a computer system is considered as a resource. Resources can be physical, like CPU, memory, storage, workstation, network elements, sensors, etc. or virtual, like operating systems, energy, network bandwidth, network load, protocols, APIs etc. For both the types of resources, the resource management component is responsible for resource provisioning, resource allocation, resource adaptation, resource mapping, resource modelling, resource estimation, resource discovery and selection, resource brokering and resource scheduling. The resource management ensures the reliability, ease of deployment, QoS, delay and control overhead in all its operations.

3. **Network Infrastructure Management:** This component manages network component like hubs, bridges, switches etc to enable easy and efficient sharing of computers resources and network paths and at the same time minimize energy consumption. This includes putting the

![Diagram of Common Management Services Framework](image_url)
idle components to sleep mode and balancing load on network routers as and when required.

(B) The Business Support Layer
Since cloud is attractive for its utility driven, service oriented mode of computing, the business aspects of IaaS cloud is managed by the business support layer. It consists of three components as described below-

1. IaaS Customer Management: This component takes care of the IaaS customers and performs the tasks such as maintaining and managing various customer accounts, updating customer profiles, market analysis and leveraging opportunities, customer relationship management, enhancing customer satisfaction by resolving problems.

2. Service Contract Management and SLA Definition: This component incorporates the management of service contract life cycle, setting up new contracts, negotiating the terms with the customer, closing and terminating contracts when required, building contract policies and defining SLA terms and conditions that includes various QoS metrics, payment structures as well as discount options.

3. Revenue Management: This component manages billing and payment tracking, invoice generation, sending of notification, resource usage information maintaining, payments and chargebacks collection, reporting, accounting and auditing.

4. Customer Experience Monitoring: Customer feedback is a valuable guide for continuous improvement of the service offering. This component monitors the customers’ experience of the service usage life cycle, ease of use of the offered services and demand pattern as well as customer suggestions.

(C) The Operation Support Layer
This layer manages the core functions involved in the operation of service delivery to the customers. It consists of three components that are explained as follows-

1. Service Management: The service management component takes care of the activities that ensure smooth and seamless services to the IaaS customer. It is responsible for service request management, service provisioning and deployment, monitoring incidents and problems management, changes in users’ requests and configuration management, capacity planning, QoS management, service life cycle management, policy enforcement and monitoring, metering, service decommissioning and elasticity management.

2. Service Catalog Management: A service catalog is a user friendly document that guides the users through the service request process. It gives such information as who can see and use a particular service, constraints of a service and various configuration options. It manages the packaging of the services for the tenants and listing group service offerings. It elaborates the functional description of the services such as operating system, CPU configuration, middleware application stack, available alternatives, service levels, pricing structure, various options of networking and possible customization.

3. Multi-cloud Management: The key function of this component is to manage cloud services composition by unifying services in the federated clouds that involves virtual server migration management and collaboration management among various cloud sites.

(D) The Policy Layer
This policy layer describes the rules, regulations and various guidelines that must be followed during service enforcement.

1. Policy Design Management: Functions like designing policies for service categories, that yield high return on investment are managed by this component. Various enforcement principles and guidelines, market analysis and assessment of self competency, service deployment guidelines and charge back policy are also laid down by this component.

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2. **Policy Repository Management:** Versioning of policy document, maintenance of records, service level agreement documents and various contracts with different the stakeholders are maintained and updated by this component.

(E) **The security layer:**
Cloud customers’ security considerations are managed by the security layer. The tasks performed in this layer encompass all the other layers and components of ICMP.

1. **Security Specifications Management:**
Security specifications are based on the identification of vulnerabilities during service delivery, security of customer accounts, security of hardware and software resources, security of processes, network security, firewalls, risk assessment and various recovery measures. These specifications are laid down and managed by this component.

2. **Authorization and Authentication Management:**
This layer is responsible for authorization and authentication of service users, encryption of user accounts, certificate management, auditing and detecting frauds; it also deals with risk mitigation and preparation of recovery procedures.

**Orchestration and Workflow Management**

The orchestration component monitors the smooth communication among the specified layers and transfers control information among them. The workflow management component monitors transfer of important files and documents among the layers. The orchestration and workflow management make the system automated and self controlled.

**V. Significance of CMSFIC**

Till date, open source as well as commercial cloud companies use internal architecture of their own to build service clouds. As the open cloud computing is growing with a rapid pace, the necessity of structured IaaS clouds that can easily form cloud federations has emerged.

CMSFIC is a unified framework which presents the holistic view of various management functionalities during a service life cycle. The identification and classification of these functionalities into layers and components also helps the cloud service creator to easily implement service description laid down by the IaaS provider.

Thus, by adopting the proposed framework, IaaS cloud companies and cloud service creator would be able to understand the functional dependencies among the management components in a clear and better way. Moreover, CMSFIC can be used to analyse and compare the management capabilities of the leading cloud companies in terms of implementation of the layers as given in the framework. The comparison is presented in the next section.

**VI. Analysis and comparison of IaaS products using CMSFIC**

A number of IaaS platforms exist in the industry, open source as well as commercial. The market leader is Amazon Web Services that is considered as the ‘de facto’ standard in general purpose storage cloud. The other notable commercial platforms are Oracle IaaS, Microsoft Private Cloud and Vmware vCloud. Among the open source products are OpenNebula, OpenStack, Eucalyptus, Citrix and Nimbus. We analysed the feature support and management capabilities of the above mentioned IaaS platforms with the help of literature study and compared them by using the proposed framework. The comparison has been made by mapping the features to the layers and components of the proposed framework. The comparison results are shown in figure 5. The components in each layer are shown by the corresponding number entries. The ‘*’ entry represents that the corresponding component of the framework is present in the platform, the ‘X’ entry represents that the corresponding component is either absent or internally implemented in the platform.

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VII. Conclusion and future work

In this paper a Common Management Services Framework for IaaS Clouds is presented. Infrastructure cloud services are rapidly being adopted by business enterprises for saving upfront costs and increasing return on investment. In the absence of a common and unified framework for management activities in infrastructure clouds, management tasks are implemented differently in all the leading IaaS platforms thereby the deliver services on best effort basis. The proposed framework presents a unified view of essential management tasks in IaaS cloud so that cloud providers can provide seamless service life cycle to their customers. The framework is designed after analysing the service life cycle using UML diagrams as given in section. We used the framework to compare the feature support of leading open source and commercial IaaS platforms and concluded that some of the functionalities specified in the framework are absent from the selected IaaS platforms. Therefore we conclude that the proposed framework is a significant contribution towards the design of uniform management functionalities that must be implemented by the IaaS providers.

As our future work we plan to develop and implement a unified architecture for open IaaS clouds so that interoperability between IaaS clouds can be increased and the cloud customer has a greater ease of use in using the services.

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