A Comparative Study of Open Source IaaS Cloud Computing Platforms

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Abstract—Cloud management platforms manage the resources provided by the infrastructure as a service (IaaS) cloud.IaaS represents a new consumption model for the use of IT resources. An IaaS provider offers storage, processing and compute power on an elastic,on-demand basis, over the Internet. With the rapid development of open-source cloud platforms, these have been widely used due to open and free, some of them can substitute commercial clouds. Existing related literature briefly compare only the basic features of open-source platforms, but did not include some new released features in the latest versions. Hence, this paper compares the existing literature along with the updated features.

Keywords - Eucalyptus, OpenNebula, Nimbus, OpenStack, Cloudstack, OpenQRM.

I. INTRODUCTION

In the world of Information Technology, cloud computing [1] become a most popular word in recent year. Cloud means Computing Location independent Online Utility that is available on-Demand which allow users to access that are resides on local, remote and other Internetconnected devices. Since the emergence of the term" cloud computing", major IT companies and academia give different definitions of cloud computing from different views but the definition given by the National Institute of Standards and Technology (NIST) is widely referenced and most comprehensive. NIST defines cloud computing as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". Cloud computing is a new style of computing where the processing power, storage capacity, applications, and other computing resources are moved from user desktops to data centres on the Internet. End users can access the cloud using any internet enabled device. Cloud computing promises to offer infinite, cheap, and scalable computing resources available on demand to users over the network.The cloud offers three kinds of service models IaaS,PaaS and SaaS. But this paper focuses mainly on IaaS. SaaS moves the task of managing software and its deployment to third-party services and reduce the cost of software ownership by removing the need for technical staff to manage install and upgrade software, as well as reduce the cost of licensing software. PaaS functions at a lower level than SaaS and provides a platform on which software can be developed and deployed. It is built on top of virtualization technology.Businesses can requisition resources as they need them, scaling as demand grows, rather than investing in hardware with redundant resources.

IaaS abstracts hardware (server, storage, and network infrastructure) into a pool of computing, storage, and connectivity capabilities owned and hosted by service provider and offered to customers as service for a usage based cost.With IaaS, IT shops don't have to buy, maintain or upgrade software, hardware or operating systems. They don't have to worry about network configurations. That can save big money, both up front and over time. IaaS, like all cloud offerings, is a pay-as-you-go model. So organizations pay only for the resources they use, which is more cost-effective than the traditional method of paying set fees for services and equipment, even when they aren't being used.

The rest of the paper is organized as follows.Section II briefly reviews the related work in the field of cloud architectures. InSection III, an overview of OpenStack, Eucalyptus, Nimbus, Cloudstack, OpenQRM and OpenNebula platforms is provided. In Section IV comparison of above mentioned open source platforms is done by considering various parameters like storage,architecture and virtualization, etc. and paper concludes in section V.

II. RELATED WORK

With the emergence of different open-source cloud platforms, the decision to choose the most suitable one that meets the customers' needs becomes a difficult task, because every platform has its specific characteristics. Therefore, a number of papers begin to research and compare each platform, [3] makes a qualitative overview and compares architecture and different implementation of features, [4] conducts a survey and classification of open-source solutions and compare them from different angles , [5] does an elaborate comparison and analysis and also points out some challengesof further development, [6] gives an object description, compares from some basic aspects and provides specific recommendations for use, [7] discusses an elaborate set of evaluation criteria that can be used to evaluate the stability, performance and features of open-source clouds and compares some available platforms, [8] conducts a survey to help readers choose the best one with their needs and build their own cloud infrastructure.

From what present above, we can get an idea that thesepapers only focus on the basic features such as architecture, service type and virtualization, etc. And they almost present a summary of each platform and don't give a presentation in detail. At the same time, some platforms are developing constantly. Therefore, some new features and functions are not introduced and compared in these papers. None of the research paper has compared more than three open source IaaS platforms. In this paper we compare five open source IaaS platforms.

III. OVERVIEW OF OPEN SOURCE IAAS PLATFORMS

Today, many open source cloud Infrastructure as a Service (IaaS) platforms exist. The following six open source IaaS platforms have been identified for this work:Eucalyptus,OpenNebula, Nimbus, OpenStack, Cloudstack and OpenQRM. A brief description of these platforms highlighting their main characteristics and architecture is discussed below.

a) Eucalyptus: - Eucalyptus [2] stands for Elastic Utility Architecture for Linking Your Program to Useful System. It has five high-level components: Cloud Controller (CLC) that manages the virtualized resources; Cluster Controller (CC) controls the execution of VMs (virtual machines); Walrus is the storage system, Storage Controller (SC) provides block-level network storage including support for Amazon Elastic Block Storage (EBS) semantics; and Node Controller (NC) is installed in each compute node to control VM activities, including the execution, inspection, and termination of VM instances. The network is managed by the component cloud controller and each controller is authenticated by SSH key files and permission to authenticate transactions.

b) OpenNebula: - OpenNebula [12]is a cloudcomputing platform for managing heterogeneous distributed data center infrastructures. The OpenNebula platform manages a data center's virtual infrastructure to build private, public and hybrid implementations of infrastructure as a service.The OpenNebula cloud consists of Front-end (runs all of the OpenNebula services). Host (runs on a server with installed hypervisor). This component interacts with the hypervisor,hosts virtual machine instances and musthave network connectivity to the Front-end. The Cluster(acts as a pool of hosts that share the same data stores and networks). With the forming of clusters of hosts, performances such as load-balancing, high-availabilityand high-performance computing can be reached.Image Repository(acts as a repository of registered virtual machine images in the cloud).

c) Nimbus: - Nimbus [15] [16] is an open-source cloud focused on providing Infrastructure-as-a-Service (IaaS) capabilities to the scientific community. The Nimbus has Workspace service(allows clients to manage and administer VMs by providing two interfaces; One interface is based on the web service resource framework (WSRF) and the other is based on EC2 WSDL). This service communicates with a workspace resource manager or a workspace pilot to manage instances. Workspace resource manager(Implements VM instance creation on a site and management), Workspace pilot(provides virtualization with significant changes to the site configurations), Workspace control (implements VM instance management such as start, stop and pause VM),Context broker (allows clients coordinate large virtual cluster launches automatically and repeatedly) , Workspace client (a complex client that provides full access to the workspace service functionality),Cloud client (a simpler client providing access to selected functionalities in the workspace service) and Storage service (Cumulus providing users with storage capabilities to store image).

d) OpenStack: - OpenStack [13][14] is organized around three main modules i.e. compute, storage and networking. Along with these three, dashboard (Horizon) become an important component in providing interface to administrators and users for provisioning and release of resources. Openstack compute (Nova) is designed for provisioning of virtual machines and its components are designed to interact based on message based architecture. OpenStack storage (Swift) provides objects storage to be used for storing necessary images to run virtual machines or virtual instances. Openstack network (Neutron) provides necessary services which are used for communication with in virtualmachine. OpenStackIdentity Service (Keystone) provide towork across public and private clouds to support hybrid workloads in multi-cloud environments.

e) Cloudstack: - Apache Cloud Stack [9] [10] mainly consists of two parts: Management server and cloud Infrastructure. Management server is Cloudstack software which manages the cloud resources, controls creation and management of virtual machines and also assigns IP addresses to them. Management server also provides APIs for cloud stack. The management servermanages the zones having hosts which contain the virtual machines. Cloud infrastructure has Zone(equivalent to a single datacentre, consists of one or more pods and secondary storage),Pod(one rack of hardware and one or more clusters) ,Cluster(consists of one or more hosts and primary storage),Host(A single compute node within a cluster, the actual cloud services run in the form of guest virtual machines here). Primary storage is associated with a cluster, and it stores the disk volumes for all the VMs running on hosts in that cluster. Secondary storage is associated with a zone, and it stores templates, ISO images, and disk volume snapshots.

f) OpenQRM: - OpenQRM [18] means "open Qlusters Resource Manager". It is the next generation, open-source data-centre management platform. This has fully pluggable architecture focuses on automatic, rapid and appliance-based deployment, monitoring, high-availability, cloud computing and especially on supporting and conforming multiple virtualization technologies.The OpenQRM platform provides an easy way of building private cloud network inside your office organization network.

IV. PROBLEM FORMULATION

Many comparative studies [4, 5, 6, 7] have been presented in the literature. P. Sempolinski [4] did a comparison of Eucalyptus, OpenNebula and Nimbus with eleven parameters such as Disk image options, disk image storage, Hypervisors, DHCP, network issues and unique features etc.S. Wind [5] did a comparison of Abicloud, Eucalyptus, OpenNebula and Nimbus with twelve parameters i.e. architecture, OS licence, Interoperability, cloud types supported, VM memory, compatibility etc. H. Parmar [6] did a comparative study of OpenNebula, Eucalyptus, OpenStack and Cloudstack with ten parameters i.e. scalability, networking, software development, storage, authentication, license, Hypervisors,   interface,   Average   release   frequency.
 X.Wen et al. [7] did a comparison of OpenStack and OpenNebula with ten parameters i.e. open-source license, cloud types, supported OS, Programming Language, Data memory, Commercial model, hypervisors and main purpose.
No survey has been reported in the literature comparing the latest configurations of six IaaS platforms on fourteen parameters which have been considered for this work. Six open source IaaS platforms identified in this paper are-Eucalyptus, OpenNebula, Nimbus, OpenStack, Cloudstack and OpenQRM with parameters- latest release, computing architecture, cloud types, web interface, virtualization machine manager, compatibility, development language, storage, load balancing, fault tolerance, uses with updated information in latest version. Some new features identified are live-migration, monitoring and multilingual management platform.

V. A COMPARATIVE STUDY OF OPEN SOURCE IAAS PLATFORMS

All the IaaS platforms have been designed to allow users to create and manage their own virtual infrastructures. However, these platforms have differences that need to be considered when choosing a platform. Some qualitative features to consider as part of the selection are summarized in Table 1. The following parameters have been identified for the comparison   i.e. Web Interface, virtual machine manager, live migration, Storage, Development Language, Multilingual management platform, Compatibility, fault tolerance, load-balancing and monitoring.

a) Web Interface: It controls a display for theuser and allows user to interact with the cloud.Eucalyptus provides its own set of command line interface (CLI) called Euca2ools, which can be used internally to interact with Eucalyptus private cloud installations or externally to interact with public cloud offerings, including Amazon EC2.OpenNebula provides Unix-like CLI to manage all resources and easy-to-use Sunstone Graphical Interface. Nimbus, OpenQRM provides CLI and self-service cloud portal which enables end-users to request new managed servers and application stacks on-demand.OpenStack provides CLI, euca2tool and NOVA API. Cloudstack provides RichManagement,Brand-ableSelf ServiceUser Interface and CLI.

b) Virtual Machine Manager (VMM): - VMM (hypervisors)[9]is a software layer between the hardware and the operating system that allows the server hardware to be virtualized, so that multiple virtual machines can run on the same hardware, and increase server utilization.All of the IaaS platforms support KVM and XEN, which are the most popular open source hypervisors. OpenNebula, Cloudstack   and OpenStack, OpenQRM also support VMware. VMware is deprecated in eucalyptus latest version. Nimbus also supports Bash and Libvirt.

c) Live Migration: -Live migration(LM) means moving a virtual machine while it is still running.In Eucalyptus, LM is yet not supported. Nimbus has traffic sensitive LM. OpenNebula hasrunning VMs support i.e. ability to importthat allows toautomatically import an existing infrastructure.Open stack has OVF (open virtualizationformat) supported.Cloudstack has Hyper-V that allows migration of volumes (virtual disks) of a virtual machine from one storage to another, while the virtual machine continues to run. OpenQRM supports various migration scenarios,from (Physical to Virtual,Virtual to Physical, Virtual to Virtual) machines.

d) Storage: -Storage is very important in cloud because we have to manage many images and they must be available for users anytime. Therefore, most of theIaaS frameworks decided to provide cloud storage. In the case of Nimbus, it is called Cumulus. OpenStack and Eucalyptus provide more sophisticated storage systems. In OpenStack it is called Swift, and in Eucalyptus it is called Walrus.Eucalyptus also provides expanded SAN support for Elastic Block Store (EBS) storage. Both of them are designed to provide fault tolerance and scalability. OpenNebula do not provide a cloud storage product, but its internal storage system can be configured for storage in different ways. Cloudstack provides pooled, virtualized storage throughNetwork Attached Storage (NAS) and Storage AreaNetwork (SAN) helps in allowing the infrastructure to allocate storage on demand that can be based on policy that is, automated. OpenQRM supports any kind of NAS or SAN Storage.

e) Development Language: - It is one of programming language in which the platform is developed**.** Eucalyptus is written in Java language, C and Python. OpenNebula is written in C++, Ruby and Shell. Nimbus is written in Java, Python .OpenStack is written in Python .Cloudstack is written in Java, Python. OpenQRM is written in PHP, C and Shell script.

f) Multilingual Management Platform: -Itmeans the user can install the platform in multiple languages available according to preference. All of the IaaS platforms are available in English. OpenNebula is available in Russian and Spanish also in the latest version. OpenQRM is available in German, French, Spanish, Dutch and Italian in the latest version.

g) Compatibility: - All of the IaaS platforms are compatible with Amazon EC2 (Elastic compute Cloud) and S3. In Eucalyptus latest release, tech preview implementation of EC2-VPC(virtual private cloud)is added. OpenNebula is compatible with EC2 only.

h) Monitoring: - Monitoring is an ability to monitor running (virtual) machines, eitherwith an internal tool or an external plug-in or program.The latest releaseof Eucalyptus makes a variety of relevant information available which can be used in open source tools like Nagios andGanglia.Nimbus uses OpenTSDB (Time series database) for monitoring VM resources, and can collect performancerelated data from VMs, such as available memory, load, etc. OpenNebula core is a centralised component which managers use to monitorand manage the virtual machines and physical servers.OpenQRMhas fully automatic Nagios configuration (single click) to monitor allsystems and services.

i) Fault Tolerance: -It means the ability of a platform to continue performing its intended function in spite of faults.Eucalyptus has separate clusters which reduce likelihood of correlated errors. OpenNebula has permanent database to store information about hosts,networks and virtual machines.Nimbus provides regular check and backup of worker nodes. OpenStack uses Replication for fault tolerance. Cloudstack uses regions with multiple zones. OpenQRM supports "N to 1" fail-over. This meansthat you only need to have one stand-by server for N servers.

j) Load balancing: - Load balancing is a process of reassigning the total load to the individual nodes of the collective system to the facilitate networks and resources to improve the response time of the job with maximum throughput in the system [11].Eucalyptus has simple load balancing cloud controller. OpenNebula has Nginx server configured as load balancer.Nimbus launches self- configuring virtual cluster (the context broker).OpenStack has the bare metal service, Ironic, for provisioning workloads that require direct access to hardware. In Cloudstack when a VM is powered on in the cluster, DRS(Distributed resource scheduler) attempts to maintain proper load balancing by either placing the VM on an appropriate host or making a recommendation.

Table1. Comparison of open source IaaS cloud computing platforms

Feature	Eucalyptus	OpenNebula	Nimbus	OpenStack	Cloudstack	OpenQRM
Latest release	4.1.0	4.12.1(Cotton Candy)	2.10.1	Kilo	4.4.3	5.2.1(community edition)
Computing Architecture	Hierarchical structure	Modular architecture	Three modules contain all the components	Message based architecture	multi-tenant architecture	Pluggable architecture
Cloud Types	Private, Hybrid cloud	Public, private, Hybrid cloud	Public Cloud	Public, Private & Hybrid Cloud	Public & Private Cloud	Hybrid Cloud
Web Interface	CLI ,euca2tool and Web UI	Unix like CLI, Sunstone graphical interface	WSRF based or Amazon EC2 WSDL web interface	CLI ,euca2tool & NOVA API	CLI	CLI, CloudPortal
Virtual machine manager	Xen, KVM , VMware(deprecated)	Xen, KVM and on-demand access to Amazon EC2	Xen, KVM, Bash, Libvirt	Xen, KVM	Xenserver, KVM, VMware,	KVM, VMware, Xen, Virtualbox
Live Migration	Not supported	Running VMs support	Traffic sensitive live migration.	Open virtualization format (OVF) support	Storage live migration Support for Hyper-V	Supports various migration scenarios
Storage	Walrus (the front end for the storage subsystem), SAN for EBS	Nova, better Ceph support	Cumulus (Grid FTP and SCP)	Swift(Object storage), Cinder(Block storage)	NAS and SAN (on demand storage)	Any kind of NAS or SAN Storage
Development Language	C, Java	C++, C, Ruby, Java, Shell script, lex, yacc	Java, Python	Python	Java, Python	PHP, C, Shell Script,
Multilingual Management platform	English	English, Russian, Spanish	English	English	English	English, German, Spanish, Dutch, French and Italian

Monitoring	With Nagios and Ganglia	Image, Template Repository Subsystem, Showback	Uses OpenTSDB	With Nagios, Zenoss	With Zenoss	Fully automatic Nagios configuration
Compatibility	EC2, S3,VPC	EC2	EC2, S3	EC2, S3	EC2, S3	EC2
Load Balancing	Elastic load balancing(ELB) cloud controller	Nginx Server configured as load balancer	The context broker	Ironic Bare metal provisioning	VMware DRS(Distributed Resource Scheduler)	Dynamic load balancing
Fault Tolerance	Separate clusters reduce the chance of correlated failures	Persistent database backend to store host and VM information	Checking worker nodes periodically and recovery	Use Swift	Using regions with multiple zones	Supports 'N to 1' failover
Uses	Geared toward persons interested in their cloud	Geared toward private company that want their own cloud.	Used in scientific Applications	Mission to produce ubiquitous cloud computing Platform	Used in datacentre virtualization	Ideal for small set-ups, targeting students and private users.

VI.   DISCUSSION

Different platforms are appropriate for different application areas. It is found thatEucalyptus provides industry leading compatibility with popular Amazon Web Services (AWS) APIs including EC2, S3 and Elastic load balancing (ELB)suitable for private company that wants their own cloud for their own use. OpenNebula provides advance control and monitoring of virtual infrastructures, well suitable for persons interested in their own cloud. Nimbus is suitable for more cooperative scientific community whereasOpenStack is the most widely deployed open source software for building clouds. Enterprises use OpenStack to support rapid deployment of new products. Cloudstack issuitable for datacenter virtualization.OpenQRM has high efficiency and flexibility, suitable for small set-ups, aiming students and private users.

VII.   CONCLUSION

Open source cloud platforms provide flexibility, on demand services and allow great amount of customization. This paper compares the six most popular and commonly used open source IaaS platform- Cloudstack, Eucalyptus, Nimbus, OpenStack, OpenQRM and OpenNebula. It is found that Eucalyptus, OpenNebula and OpenQRM are suitable for private company that want their own cloud. OpenStack is suitable for rapid deployment of new products and Nimbus is well suitable for scientific community.

The analysis and summarization done in this paper would help the users to understand the characteristics and would allow users to choose better services according to their requirements and also make more unified decision on the open source cloudplatform according to their compatibility, interfaces anddeployment requirement. By understanding some of the main differences between them, one can decide where and when each solution may be appropriate for its use.

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