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Cloud Service Tools: State of the Art

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Abstract *– cloud computing is not a newly developed technology. It is an evolutionary paradigm evolved from parallel computing, distributed computing, grid computing and utility computing. It has been one of the hot research topics in Information Technology circle. In the present scenario, many industries are involved in cloud computing related techniques. There are many Cloud Service Tools (CST) used in industries as well as in institutions. So, researchers and others need to have an adequate knowledge of these tools in order to use them appropriately. So, this is the right time to acquire knowledge about the tools available for cloud computing related techniques. Understanding the uses of these tools is the main focus of this paper. This paper presents a detailed comparison of CST available for different cloud services, like Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS). The characteristics, architectures and applications of several popular cloud computing service tools are analyzed and discussed in detail. From the comparison of these tools, users can better understand the different CST available and more reasonably choose the appropriate tool for their requirements.*

Keywords: **Cloud Computing, CST, SaaS, PaaS, IaaS**.

I. INTRODUCTION

Cloud computing is a developing computing technology that makes use of the internet and multiple servers to maintain data and software applications [1]. Cloud computing allows users to use robust software applications without installing them on a local computer. Cloud service is acknowledged by the following test, "*If you can walk into any library or internet café and sit down at any computer without preference for operating system or browser and access a service, that service is cloud-based".* End-user pays a subscription fee for using cloud software service. The software is hosted directly from the software providers' servers and is accessed by the end user over the internet. This technology increases computing efficiency by multiple storage, memory, processing and bandwidth. Cloud computing is developed through technologies and business approaches that emerged over a number of years [2].

Cloud Computing is a broad term that describes about many services. In order to understand how cloud can value the organization, it is first important to know what the cloud really is about and its different components and tools available in the market for providing cloud services. Since the cloud has wide collection of services, organizations can choose where, when and how they can use Cloud Computing [3].

This paper explains in detail the different types of tools for cloud services commonly referred to as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) and gives some of the examples for comparison among them. Cloud computing consists of three levels of service offerings which is shown in following Figure.1.

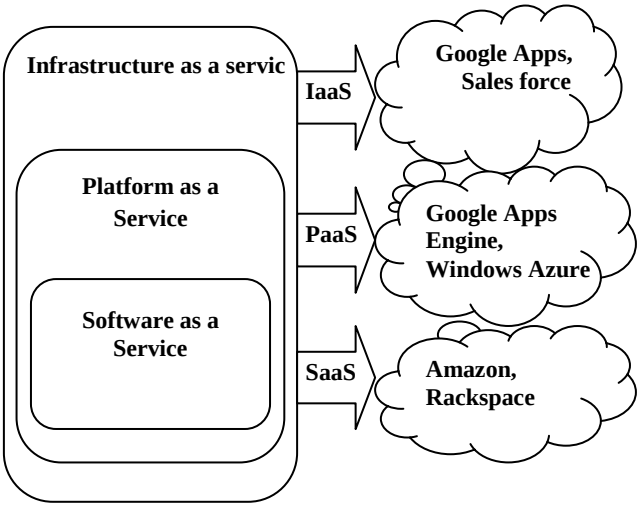

Fig. 1 the layers of Cloud Computing

A. Software as a Service (SaaS)

In this service model, consumers purchase the ability to access and use an application or service that is hosted in the cloud. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings. An example of this is Salesforce.com where necessary information for the interaction between the consumer and the service is hosted as part of the service in the cloud. The following providers such as GoogleApps, salesforce, face book are mainly in SaaS. Some defining characteristics [4] of SaaS include easy usage of commercial software, software is controlled and monitored from centralized manner, software delivered in one-to-many model, software upgrades are done by providers and Application Programming Interfaces (API) are used for integration between different pieces of software. This service model has some benefits. Users get benefit from SaaS in five major ways [5]. When users subscribe for a software service instead of purchasing a software license, they can save money, save time, focus technology budgets on competitive advantage rather than infrastructure, gain immediate access to the latest innovations and join a community of interest.

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B. Platform as a Service (PaaS)

In this service model, consumers purchase access to the platforms, enabling them to deploy their own software and applications in the cloud. The consumers do not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage. But they can control over the deployed applications and possibly application hosting environment configurations in which there might be some constraints in deploying applications, *i.e.* consumer can deploy applications created using programming languages and tools supported by the provider. Among providers, following are the key players in PaaS: Google Apps Engine, Windows Azure. There are a number of different tasks which constitute PaaS, but some basic characteristics [4] include Services to develop, test, deploy, host and maintain applications in the same integrated development environment. Web based user interface (UI) creation tools help to create, modify, test and deploy different UI scenarios, Multi-tenant architecture where multiple concurrent users utilize the same development application, Built-in scalability of deployed software including load balancing and failover environment. PaaS has been shown to speed development of complex software, while making it easier to deploy and manage applications on the cloud. It shields developers from the underlying complexities of installing and configuring applications on low-level operating systems. As a result, IT stakeholders' benefit [6] in several ways that is Lower Costs, Faster Time to Market, Lower Risks, Rapid Prototyping and Higher Security and Interoperability.

C. Infrastructure as a Service (IaaS)

The foundation of any cloud computing stack begins with its infrastructure. Infrastructure as a Service (IaaS) cloud computing is the delivery of computing on demand as a shared service, avoiding the cost of investing in, operating and maintaining the hardware. In this service model, the ability provided to the consumer is for provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which includes operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems; storage, deployed applications, and perhaps limited control of selected networking components (e.g., host firewalls). Among providers, main actors of IaaS are Amazon EC2, Rackspace, GoGrid. IaaS is generally accepted to comply with some important characteristics [4] that are Lower total cost of ownership, full scalability; eliminate the need for administration and maintenance of hardware, enterprise grade infrastructure for all subscribers. IaaS gives more benefits [7] to cloud providers as well as cloud customer. The benefits of Infrastructure as a Service (IaaS) model allows IT to Shift Focus, Hassle free Service, Dynamic Scaling, Multiple Tenets, Investment Cap, Reduces TCO (Total Cost of Ownership), Metered Service and Flexible offering. Thus, benefits of IaaS are numerous. IaaS is especially great for small and medium scale enterprises that are looking for quick and cheaper scale up option.

II. NEED FOR THE TOOLS

Software tool [8] is a program or an application that software developers use to create, debug, maintain, or otherwise to support other programs and applications. Software tools are necessary to keep technology running without a hitch. Software tools are usually relatively simple programs that can be combined together to perform more than one task. They protect computers from crashing and keep them running accurately. Computers store extremely important data, whether they are business computers or personal computers, and often people forget to save their data to other removable storage disks [9]. Software tools decrease the potential of losing important information and increase the performance of the computer itself. Cloud computing uses many software tools based on its services. Cloud tools are particularly used for cloud related services like SaaS, PaaS and IaaS. Each service uses different cloud tools for efficient usage. This paper describes some of the cloud tools which are currently used for different cloud services.

III. CLOUD SERVICE TOOLS

Nowadays Cloud Service Tools (CST) are increasing in number and are used for different organizations to satisfy the computing needs. This article focuses and highlights the main usage and purpose of CST.

A. Amazon EC2

Amazon Elastic Compute Cloud (Amazon EC2) [10] is a web service tool that provides resizable compute capacity in the cloud. It provides a complete control of computing resources that users can run on Amazon's proven computing environment. EC2 allows users to rent virtual computers [11] on which users can run their own computer applications. EC2 allows scalable deployment of applications by providing a web service through which a user can boot an Amazon Machine Image (AMI) to create a virtual machine, which is called an instance, containing any software desired. Time needed to obtain and boot new server instance from Amazon EC2 reduced to minutes. It allows users to quickly scale capacity of the launched server instance, both for up and down, as with computing requirements of user. Amazon EC2 allows users to pay only for the capacity that actually used by the user. Amazon EC2 presents a true virtual computing environment, allowing users to use web service interfaces tool to launch instances with a variety of operating systems, load them with custom application environment, manage network's access permissions, and run image using as many or few systems as desire.

Steps to access Amazon EC2 tool:

- Initially, create an account with Amazon using credit card. Open console URL (http://console.aws.amazon.com/ec2) of Amazon EC2.
- Select a pre-configured, template image to get up and running immediately or create an Amazon Machine Image (AMI) containing user applications, libraries, data, and associated configuration settings.

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- Configure security and network access on Amazon EC2 instance.
- Choose which instance type(s) and operating system user want, then start, terminate, and monitor as many instances of user AMI as needed, using the web service APIs or the variety of management tools provided.
- Determine whether user want to run in multiple locations, utilize static IP endpoints, or attach persistent block storage to user instances.
- When the work is over for a particular running instance, instances can be terminated by the user.

B. Eucalyptus

The Eucalyptus works in IaaS [12]. It offers services to create a private cloud as well as public cloud services. Eucalyptus (Elastic Utility Computing Architecture for Linking Your Programs to Useful Systems) project began from California University, Santa Barbara, and mainly used to build open-source private cloud platform [13, 14]. Now it has been run by Eucalyptus System Company. Eucalyptus is an open-source implementation of Amazon EC2 and compatible with business interfaces. It also implements virtualization depending on Linux and Xen as EC2 does. Eucalyptus is an elastic computing structure that can be used to connect the users' programs to the useful systems. It is an open-source infrastructure using clusters or workstation implementation of elastic, utility, cloud computing and a popular computing standard based on service level protocol that permits users to lease network for computing capability. Eucalyptus uses Amazon's Web Services APIs to support public cloud services. Through a partnership with Amazon Web Services (AWS), Eucalyptus has made itself particularly interesting for companies wanting to implement a hybrid cloud. Amazon partnered with Eucalyptus by providing the company with access to its AWS APIs. This means that an organization that develops a private cloud using Eucalyptus has built-in compatibility with AWS offerings. This allows companies to more easily create and move workloads between their private cloud and public cloud. Figure.2 demonstrates the architecture of Eucalyptus [12].

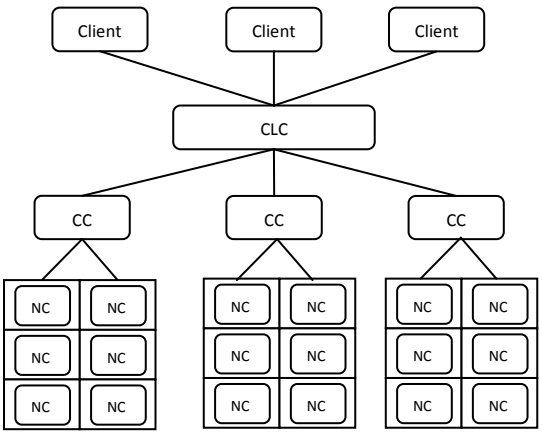

Fig.2 Eucalyptus Architecture

In figure.2, the Node Controller (NC) is the component that executes on the physical resources that host VM (Virtual Machine) instances and it is responsible for instance start up, inspection, shutdown, and cleanup. There are typically many NCs in a Eucalyptus installation, but only one NC needs to execute per physical machine, since a single NC can manage multiple virtual machine instances on a single machine. A collection of NCs that logically bound together to report a single Cluster Controller (CC), that typically executes on a cluster head node or server that has access to both private and public networks. The CC is responsible for gathering state information from its collection of NCs, scheduling incoming VM instance execution requests to individual NCs, and managing the configuration of public and private instance networks. When a CC receives a *run Instances* request, it performs a simple scheduling task of determining which NCs can support the incoming instance by querying each NC through describing resource and choosing the first NC that has enough free resources. Cloud Controller (CLC) is the core of the manager of cloud platform, a component answering for global decision-making which is transparent to users. A Eucalyptus cloud has only one cloud controller. In Eucalyptus, client interface is the pathway of communication and connection between the inside and the outside of Eucalyptus, through which users can access all kinds of resources on the cloud computing environment.

C. Open Nebula

Open Nebula has integration with various environments [13]. It can be worked through command line interface and web services. In addition, it applies administration for resources through virtual machine. Open Nebula is an open and flexible virtual infrastructure management tool [14], which can use to synchronize the storage, network and virtual techniques, and let users dynamically deploy services on the distributed infrastructure according to the allocation strategies at data center and remote cloud resources. Through the interior interfaces and Open Nebula data center environment, users can easily deploy any types of clouds. Open Nebula is mainly used to manage the data center of private cloud and infrastructure of cluster. It also supports hybrid cloud to connect the local and public infrastructure. This is very useful to build highly scalable cloud computing environment. Besides, Open Nebula also supports public cloud platform by providing interfaces and functions to virtual machines, storage and network management and so on. Figure.3 represents the Architecture of Open Nebula [14]. The OpenNebula architecture is based on three basic technologies to enable the provision of services on a distributed infrastructure: virtualization, storage and network. As OpenNebula is an open source, it has flexible cloud with extensible interfaces, structure and components. This makes it suit to be used in any kinds of data center. Compared with Eucalyptus, OpenNebula has more features to support the private cloud platform and dynamic management of the scalability of the virtual machines on clusters. It provides on-demand access and an elastic mechanism as Amazon EC2 does in hybrid cloud. OpenNebula supports heterogeneous execution

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environments with multiple, even conflicting, software requirements on the same shared infrastructure with full control of the lifecycle of virtualized services management [15].

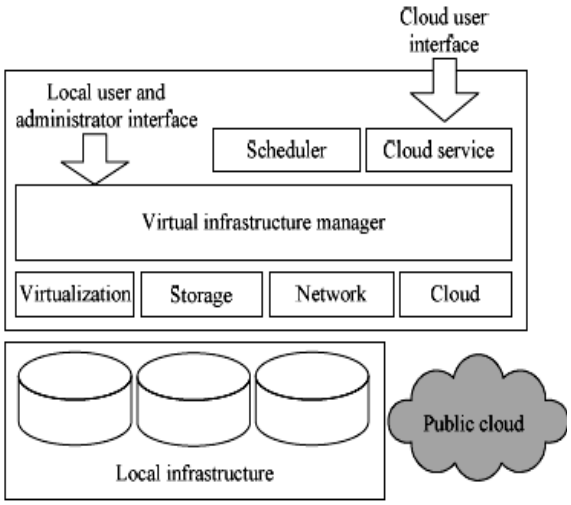

Fig.3 Architecture of Open Nebula

D. Nimbus

Nimbus is an open-source tool focused on providing Infrastructure-as-a-Service (IaaS) cloud to its client via WSRF (Web Services Resource Framework) based or Amazon EC2 WSDL web service APIs [13]. Nimbus supports the Xen hypervisor and virtual machine schedulers PBS (Portable Batch System) and SGE (Sun Grid Engine). It allows deployment of self-configured virtual clusters via contextualization. It is configurable with respect to scheduling, networking leases, and usage accounting [15]. Figure.4 demonstrates the Nimbus Architecture [16].

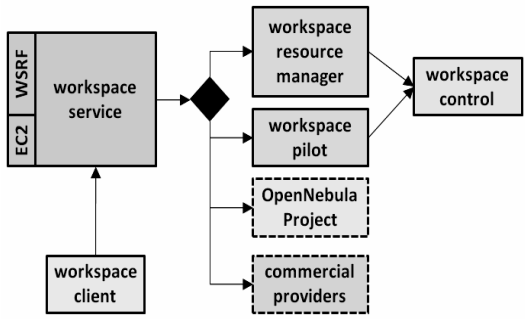

Fig.4 Architecture of Nimbus

Nimbus Architecture includes many different components, like client, agent, resource manager and so on. Generally, all these functional components can be classified as three kinds, client-supported modules, service-supported modules and background resource management modules.

- *Workspace service:* is based on web services and provides security with the GSI **(**Grid Security Infrastructure) authentication and authorization. Currently, Nimbus supports two frontends: Amazon EC2 and WSRF.
- *Workspace control:* is responsible for controlling VM instances, managing and reconstructing images, integrating a VM to the network and assigning IP and MAC addresses. The workspace control tools operate with the Xen hypervisor and can also operate with KVM5.
- *Workspace resource management:* is an open source solution to manage different VMs, but can be replaced by other technology such as OpenNebula.
- *Workspace pilot:* is responsible for providing virtualization with a few changes in cluster operation. This component handles signals and has administration tools.

E. Openstack

OpenStack [15][17] launched in July 2010 is an initiative of Rackspace Hosting and NASA. OpenStack is designed to create freely available code, standards, and common ground for the benefit of both cloud providers and cloud customers. The goal of OpenStack is to allow organization to create and offer cloud computing capabilities using open source software tool running on standard hardware. It is written in Python and currently implemented in two control APIs, the EC2 API and Rackspace. It uses different drivers to interface with a maximum number of hyper visors (Xen, KVM, HyperV, Qemu). OpenStack is dedicated to provide the computer industry with the opportunity to build a hosting architecture and massive scalability and is completely open source [18]. Figure.5 depicts the Architecture of OpenStack [19]. OpenStack architecture is built using seven core components of OpenStack: Compute, Object Storage, Identity, Dashboard, Block Storage, Network and Image Service.

- *OpenStack Object Store:* allows users to store or retrieve files. Object Storage is used to create a storage space redundant and scalable for storing multiple petabytes of data. It's not really a file system but is especially designed for long term storage of large volumes. It uses a distributed architecture with multiple access points to avoid SPOF (Single Point of Failure).
- *OpenStack Imaging Service*: provides storage services, recording and distributing the images to virtual machine disks images. These disk images are most commonly used in OpenStack Compute. A multi-format image registry, OpenStack Image Service allows uploads of private and public images in a variety of formats, including VHD, VDI, Qemul. Service providing companies that use private cloud and institutions with physical hardware can use OpenStack for large-scale cloud deployments.
- *OpenStack Compute:* is open source software designed to provision and manage large networks of virtual machines, creating a redundant and scalable cloud computing platform. It has the software, control panels, and APIs required orchestrating a cloud, including running instances, managing networks, and access control. Compute requires no prerequisite hardware and is completely independent of the hypervisor.
- *Dashboard:* provides a modular web-based user interface for all the OpenStack services. With this web GUI, user can perform most operations on cloud like launching an instance, assigning IP addresses and setting access controls.

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- *Identity:* provides authentication and authorization for all the OpenStack services. It also provides a service catalog of services within a particular OpenStack cloud.

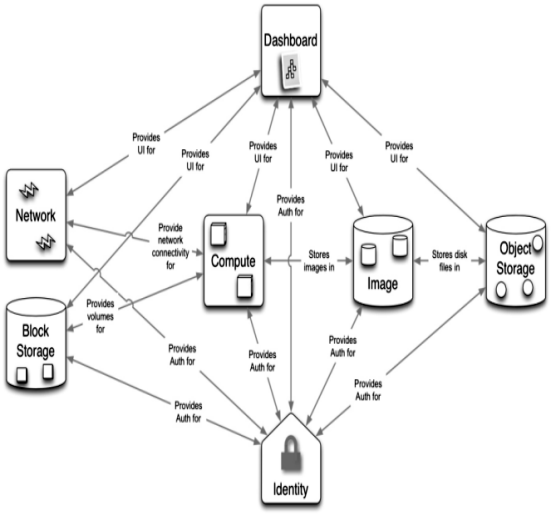

Fig.5 Open Stack Architecture

- *Network:* provides "network connectivity as a service" between interface devices managed by other OpenStack services. The service works by allowing users to create their own networks and then attach interfaces to them.
- *Block Storage:* provides persistent block storage to guest VMs. Block storage does not share like file systems NFS or CIFS share.

Among the seven core components in the architecture, *Compute, Image, and Object storage* are main components. All of the code for OpenStack is freely available under the Apache 2.0 license. OpenStack is aiming at virtualization portability where user will be able to move from virtualization technologies including those hosted in the cloud and will be able to migrate seamlessly, that includes VMs running in VMware, Xen, HyperV and KVM.

F. TPlatform

TPlatform [20] is a cloud solution that provides a development platform for web mining applications, which is inspired by Google cloud technologies, and acts as a Platform as a Service (PaaS) solution. Its infrastructure is supported by three technologies: a scalable file system called Tianwang File System (TFS) which is similar to the Google File System (GFS), the Big Table data storage mechanism, and the Map Reduce programming model. The TPlatform framework [20] is composed by three layers as shown in the Figure.6.

- *PC Cluster:* this layer provides the hardware infrastructure for data processing.
- *Infrastructure:* this layer consists of file system (TFS), distributed data storage mechanism (BigTable), and programming model (MapReduce).
- *Data Processing Applications:* this layer provides the services for users to develop their application (e.g. web data analysis and language processing).

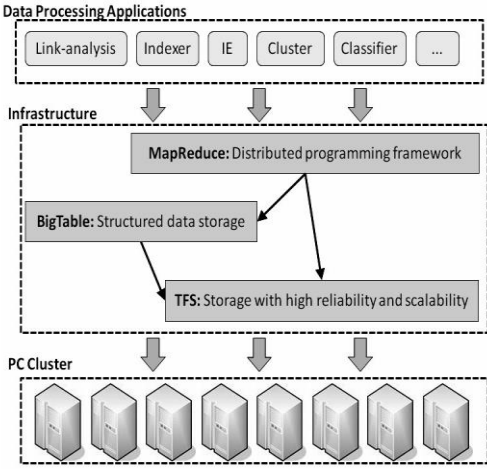

Fig.6 TPlatform Framework

G. Apache Virtual Computing Lab (VCL)

Apache VCL [21] is an open-source solution for the remote access over the internet to dynamically provision and reserve computational resources for diverse applications, acting as Software as a Service (SaaS) solution. VCL has a simple architecture formed by three tiers:

- *Web server:* represents the VCL portal and uses Linux/Apache/PHP solution. This portal provides a user interface that enables the requesting and management of VCL resources.
- *Database server:* stores information about VCL reservations, access controls, machine and environment inventory. It uses Linux/SQL solution.
- *Management nodes:* is the processing engine. A management node controls a subset of VCL resources, which may be physical blade servers, traditional rack, or virtual machines. It uses Linux/VCLD (Perl)/Image library solution. VCLD is a middleware responsible to process reservations or jobs assigned by the VCL web portal. According to type of environment requested, VCLD should assure that service (computational environment) will be available to user.

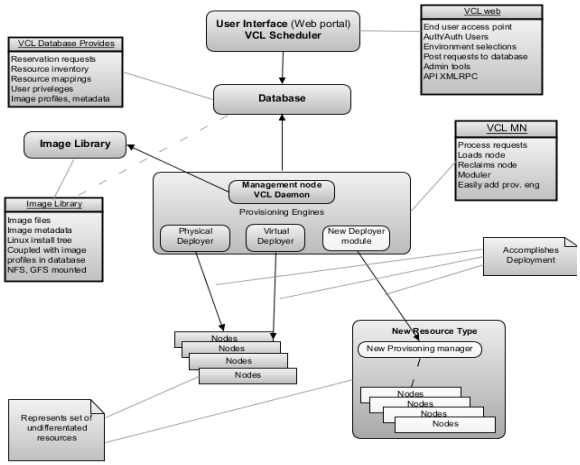

Fig.7 Apache VCL Architecture

Figure.7 shows the Architecture of the Apache VCL [21], where the user must connect firstly to the VCL Scheduling Application in order to access its resources through a web

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interface. Users may request a reservation to use the environment immediately or schedule to use it in the future.

H. VMware vCloud

VMware vCloud [22] provides guidance to architect an Infrastructure-as-a-Service (IaaS) cloud based on VMware vCloud Director (VCD). VMware vCloud simplifying the delivery of resources to end users requires the coordination of various infrastructure platforms. VMware vCloud is a common set of cloud computing services for enterprises and service ability for running applications in public and private vCloud instances. vCloud Director implements the vCloud API, which provides compatibility and interoperability with other vCloud instances. VMware recommends decoupling resources allocated for management functions from resources dedicated to user-requested workloads. This can be partitioned into:

- A *management cluster:* It contains core components and services needed to run the vCloud. This includes core vCloud components such as VMware vCenter Server, vCloud Director, and vCenter Chargeback Server.
- *Resource groups:* It represents dedicated resources for end-user consumption. Each resource group consists of VMware ESXi hosts managed by a vCenter Server, and is under the control of vCloud Director. vCloud Director can manage the resources of multiple resource groups.

Figure.8 shows the Logical Architecture [22] of VMware vCloud, architecture mainly is divided into Management cluster and Resource Group. Apart from the above component mentioned, the management cluster also includes virtual machines or has access to servers that provide infrastructure services such as directory (LDAP), timekeeping (NTP), networking (DNS, DHCP), logging (syslog), and security.

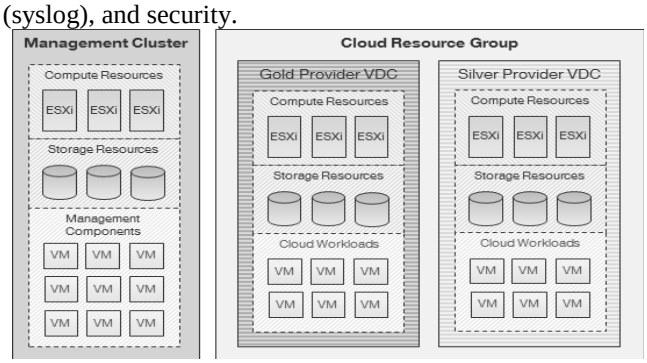

Fig.8 VMware vCloud Logical Architecture

Both the management cluster and resource groups reside in the same physical site to provide a consistent level of service. This minimizes latency issues, which could arise in a multi-site environment if workloads move between sites over a slower or less reliable network.

IV. COMPARISON AND FINDINGS

Several popular Cloud Service Tools are studied in detail and compared with each other in terms of various factors like, provider, types, services, etc. The compared details are given in the Table 1(see APPENDIX I). Eight tools are considered for comparative studies. This study reveals that most of the tools except Amazon EC2 are open source. These tools are used in all the cloud types. There are tools available for Infrastructure as a Service (IaaS) than the other services. All the tools are designed in such a way that all the operating systems are compatible with them. These tools are supportive with the open source languages like, Java, Python, and PHP etc. The popular Virtual Machines support these tools. All these tools are highly scalable in cloud environment. Compatibility among the specific tools is possible.

V. CONCLUSION

Cloud Computing emerged from utility computing, parallel computing, and grid computing. Now there are number of Cloud Service Tools (CST) used in different cloud services like SaaS, PaaS and IaaS. It is important for a cloud user to understand the usage of these tools. For the studies, eight popular tools are taken which are used in cloud services. From the study, it is realized that there are differences in the architecture, characteristics of different CST. A detailed comparison of different cloud service tools is presented. From the comparative study, it is evident that more tools are available for Infrastructure as a Service (IaaS) than the other services. Almost all the tools are applicable for public cloud environment and they have OS compatibility. All the tools except Amazon EC2 are open sources. From this comparison and findings, users can better understand the characteristics and choose the CST according to the cloud type, interfaces, compatibility, implementation, deployment requirement, and development support, etc.

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APPENDIX I

Table 1. COMPARISON OF CLOUD SERVICE TOOLS

	Amazon EC2	**Eucalyptus**	**OpenNebula**	**Nimbus**	**OpenStack**	**Tplatform**	**Apache VCL**	**VMware vCloud**
Provider	Amazon	Eucalyptus	OpenNebula	Melia Technologies	RackSpace	Tplatform	Apache	VMware Inc
Cloud Type	Public & Private	Private& Hybrid	Private, Public & Hybrid	Public	Public & Hybrid	Public	Private & Public	Private & Public
Cloud service	IaaS	IaaS	IaaS	IaaS	IaaS	PaaS	SaaS	IaaS
Source Type	Closed	Open	Open	Open	Open	Open	Open	open
OS Support	Linux, Windows	Cent OS	Linux, Open Solaris, Open SUSE	MS Windows XP/Vista	Linux, Ubuntu	Linux	Linux, Cent OS	GNU/Linux
Language Support	Java, PHP,python, ruby,windev	Java	Java, PHP, Perl	Java, Python, HTML	Python	Java	PHP	PHP, Java
VM Support	VMware	VMware, Xen, KVM	Xen, VMware,KVM	Xen, KVM	Xen, KVM	Vmware,Xen	VMware	VMware
Web Interface	API, command line	Web service, command line	Web based Application/ Control panel	Web Service Based	Web service based	Web Interface	VCL portal	vSphere Web
Scalability	High Scalable	Scalable	Dynamic, Scalable	Scalable	Scalable	Scalable	Scalable	Scalable
Compatibility	Support Multiple	EC2,S3	Open, Multi Platform	EC2	Supports Multiple	-	-	Eucalyptus, Amazon EC2