# Comparative Analysis of Various Open Source Cloud Computing Tools

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***Abstract***—Cloud computing is a service oriented architecture which provides the end-user with greater flexibility. Due to which several commercial and open source infrastructures as a service frameworks have emerged. To deploy public or private cloud there are many open source software available such as Eucalyptus, Nimbus, OpenStack, OpenNebula and CloudStack. The main objective of this paper is to compare and evaluate competitive open source cloud solutions on the basis of their performance. The comparison presented in this paper will benefit the developers in selecting the best open source Software for enterprises and the service providers.

***Keywords***—*Cloud Computing, Eucalyptus, Nimbus, OpenStack, CloudStack, OpenNebula*

## I. INTRODUCTION

In recent years cloud computing has become the most popular in the world of Information Technology. It is a new term but it has advantages of many other technologies which already exist in the IT world which makes cloud computing successful. The key attributes of cloud computing are dynamic, abstraction, resource sharing and virtually infinite scalability [1]. Cloud Computing allows users to access the resources on local, remote or other internet connected devices. It delivers all IT related capabilities as services.

### A. *Cloud Computing services*

- *Software as a Service (SaaS)*: It delivers 'software' as a service over the Internet, eliminating the need to install and run the application on their own computers and simplifying maintenance and support.
- *Platform as a Service (PaaS)*: It delivers to user a computing platform and/or solution stack as a service. It facilitates deployment of applications without the cost and complexity of buying and managing the underlying hardware and software layers.
- *Infrastructure as a Service (IaaS)*: It delivers computer infrastructure, typically a platform virtualization environment, as a service to the user. Clients can buy those resources as a fully outsourced service instead of purchasing [2].

### B. *Cloud Deployment*

- *Private Cloud*: The cloud infrastructure has been deployed, and is maintained and operated for a specific organization.
- *Public Cloud*: The cloud infrastructure is available to the public on a commercial basis by a cloud service provider.
- *Hybrid Cloud*: The cloud infrastructure consists of a number of clouds of any type, but the clouds have the ability through their interfaces to allow data and/or applications to be moved from one cloud to another [3].

Cloud computing management platforms generally refer to software and technologies used by enterprises and public administrations to construct and manage their own cloud architectures. Cloud management tools ensure cloud computing-based resources are working optimally and properly interacting with users and other services. Building their own cloud for these enterprises or organizations requires a robust and elastic open source management platform tool, which has spurred a great deal of interest in this area A cloud management platform consists of cloud consumers that consumer provides remote and secure interfaces to different consumers of cloud platforms and cloud management helps to set up and support different cloud deployment models and various basic components.

This paper provides a general overview of architecture, components, supports, and application of some of the most commonly used open source cloud platforms.

## II. LITERATURE REVIEW

Extensive research has been done in the area of cloud computing, open source software and open source cloud computing solutions. This section highlights the work of eminent researchers and explores the challenges, which still needs to be addressed.

Cordeiro et al. [4] presented a comparative description about three most popular cloud computing solutions – XCP, Eucalyptus and OpenNebula. The work also discussed differences about each one and described illustrative examples of use. It is hoped that by understanding some of the main differences between them, one may decide where and when each solution can be used appropriately. Martinez et al. 10)

[5] reported on an evaluation of open source development tools for Cloud Computing. It was made in the context of building a national application for managing weather data using open source and Cloud Computing tools. The main tools examined were Eucalyptus, Apache Hadoop and Django-Python. These tools were used at different layers in the construction of our notional application. All the three technologies have been evaluated based on a capability matrix used to characterize several important features. Wind [6] has analyzed the four open source platforms for the detailed comparison with regard to their structuring cloud solutions and recommendations for their implementation. This has shown that commercial enterprises are already able to construct cloud solutions on the basis of open source platforms. This article focuses on the different functional methods, platform commonalities and their differences. Voras et al. [7] analyzed the set of criteria to be very applicable to capture the most important features offered by open source products, their easy adaption and direct use for evaluation of closed/commercial products. Having a common evaluation framework for a wide range of products creates a necessary comparison baseline and allows IT professionals and management to make educated decisions. Wen et al. [8] show the clear differences of OpenStack and OpenNebula from provenance, architecture, hypervisors, security and other angles, etc. This paper provides some deployment recommendations according to different user demands and platform characteristics. The evaluation presented in this will help people understand their functions, goals and diversities and the recommendations will result in a better use of OpenStack and OpenNebula. Ristov and Gusev [9] studied the security aspects of four most common open source cloud solutions that provide IaaS cloud service layer, i.e. OpenStack, Eucalyptus, OpenNebula and CloudStack. After installation the security evaluation was realized by evaluating the compliance of cloud solutions with relevant control objectives defined by standards that depend on cloud solution. General conclusion of the evaluation is that all open source clouds take care about certain level of security. The results of the evaluation show that CloudStack is integrated the maximum security level in its architecture. Eucalyptus and OpenNebula has also reached good score in security. Li et al. [10] compared performance of HPCC Benchmark in different KVM-based Open Source Cloud platforms. OpenStack shows the best performance for HPC. This paper focuses on the most effective Cloud platform for HPC environment and its performance analysis. Real applications have been used to understand the virtualization consumption. Jain et al. [11] presented comparative analysis for open source cloud computing platform in his paper. The paper explained characteristics of cloud computing, service model, deployment models, architecture and compares the five most popular and commonly used open source software such as CloudStack, Eucalyptus, Nimbus, OpenStack, and OpenNebula. The analysis and summarization 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 cloud platform according to their compatibility, scalability, implementation, interfaces, deployment requirement, and development support. This helps in implementation and support for developers in selecting best open source software for enterprises and service providers. Ismaeel et al. [12] gives a general description of most commonly used open source IaaS service platforms. It includes descriptions and comparisons of OpenNebula, Eucalyptus, Nimbus, OpenStack and CloudStack platforms, and it should be accessible to a wide audience. This paper covered the principles of the most commonly used IaaS open source management platforms. Labiri et al. [13] provide a qualitative comparison of current open-source IaaS frameworks. This research paper provides the overview of the five main open source cloud IaaS frameworks – OpenStack, CloudStack, OpenNebula, Eucalyptus and Nimbus. This review provides researchers and potential users with an up to date and comprehensive overview of the features of each solution and allows for an easy comparison between the open source solutions. Serrano et al. [14] examined the enterprise cloud market and technologies. This paper provides the hands-on guidance for making the right decisions and selection of different technologies from different prospective. Labiri et al. [15] studied and analyzed clod computing solutions to present comparative description about the three most important cloud computing solutions - OpenNubela, Eucalyptus, OpenStack from architecture, hypervisors, security and other aspects for selection. OpenStack shows the best overall choice to be used in the open source cloud environment for enterprise. Vogel et al. [16] researched and analyzed IaaS cloud solutions for deploying private clouds. Such study contributes for new insights concerning flexibility and resiliency. This paper demonstrated their distinct capabilities through a enhanced methodology that can be used for future studies as well as update the information of the surveyed tools.

## III. EXISTING MODEL

Open source IaaS frameworks take advantage of open source code which can be modified by users to create a single functional package that can be applied to a network of servers and storage to produce IaaS. These are used to develop private clouds they are also suitable for hybrid and public cloud development models. Five major projects, OpenStack, Apache CloudStack, OpenNebula, Eucalyptus, and Nimbus dominate the market for Open Source IaaS. These are found to be the most popular overall Open Source Cloud Computing solutions [13].

### *A. OpenStack*

OpenStack software allows data centers to pool the compute, storage, and networking resources and manage them through a dashboard or via the OpenStack API. A free, open-source platform, OpenStack was created with the ambitious target of giving infrastructure-as-a-service to consumers in a rapid, self-serve manner. It is now one of the most popular open-source cloud projects with the likes of eBay and Walmart relying on its framework[17].

The seven core components of OpenStack are Identity (Keystone) service that provides authentication and authorization services throughout the entire cloud by providing identity. Compute (Nova) provides a framework that allows a user to create, manage, and deploy VMs using a

programmable API. Image (Glance) provides a catalogue of services for storing and querying virtual disk image management services. Networking (Neutron) for providing various networking services to cloud users. Object Storage (swift) for storing and retrieving arbitrary data in the cloud that is best used for static data such as media files (MP3s, images, videos), virtual machine images, and backup files. Block Storage (cinder) provides persistent block storage for compute instances. Orchestration (Heat) engine to launch multiple composite cloud applications based on templates in the form of text files [18].

OpenStack will help your business in accelerating the time-to-market, integrating with a variety of key businesses, and delivering the most value from the cloud. So, enterprises need to consider building their cloud platform with OpenStack [19].

### *B. CloudStack*

Apache CloudStack is designed to deploy and manage large networks of virtual machines. This Apache Project offers a turnkey Infrastructure as a Service cloud computing platform. It's used both by public cloud computing vendors and by organizations running their own private clouds [20].

The main components of CloudStack are Compute Nodes (CNs) servers where VM instances are instantiated. Cluster is consists of several CNs that share the same hypervisor along with the same Primary Storage System. Pod is hardware including switches and clusters. The Availability Zone includes one or more Pods, with a Secondary Storage equivalent to a single data centre. The Management Server provides web-user interfaces and APIs, manages the assignment of VM instances to particular hosts, public and private IP addresses to particular accounts, and the allocation of storage [21].

CloudStack Glance has a client-server architecture that provides a REST API to the user through which requests to the server can be performed [22].A Glance Domain Controller manages the internal server operations that are divided into layers. Specific tasks are implemented by each layer. All the file (Image data) operations are performed using glance store library, which is responsible for interaction with external storage back ends and (or) local file system(s) [23].

### *C. Eucalyptus*

Eucalyptus allows organizations to easily migrate apps and data to build private or hybrid cloud environments that are compatible with Amazon Web Services. It gives an Infrastructure as a Service solution [24]. Eucalyptus is an open source Linux based software architecture which provides an EC2-compatible cloud computing platform and S3-compatible cloud storage platform [25]. It implements scalable, efficient-enhancing and private and hybrid clouds within and organization's IT infrastructure .Users can use commodity hardware [26].

The main components of Eucalyptus are the Cluster Controller (CC) that manages one or more node controllers and is responsible for deploying and managing instances on them.The Cloud Controller (CLC) is the front end and interacts with the rest of the components of the Eucalyptus infrastructure on the other side. The Node Controller (NC) is the basic component that maintains the life cycle of the instances running on each node by interacting with the OS. In the end the Walrus Storage Controller (WS3) is file storage system that stores machine images and snapshots. The Storage controller (SC) allows the creation of snapshots of volumes and provides persistent block storage to the instances[12][28][29].

### *D. OpenNebula*

OpenNebula was established for the research purpose. It was designed to help companies build simple, cost-effective, reliable, open enterprise clouds on existing IT infrastructure. It provides flexible tools for storage, network to enable the dynamic services. Its components consists of the following three layers The Driver layer is responsible for the creation, start-up and shutdown of virtual machines (VMs), allocating storage for VMs. The Core layer manages the VMs' full life cycle, including setting up the virtual network dynamically. The Tool layer provides the Command Line Interface (CLI) to communicate with users and manage VM. A scheduler manages the functionality provided by the core layer. The tool layer provides the interface to the External users for functionalities [30].

It can be primarily used as a virtualization tool to manage virtualized infrastructure in the data centre or cluster, which is usually referred to as private cloud. It supports hybrid cloud to combine local infrastructure with public cloud-based infrastructure, enabling highly scalable hosting environments. It also support Public cloud by providing cloud interfaces to expose its functionality for virtual machine, storage and network management [31].

Its virtual infrastructure helps user and administrator functionality for virtualization, networking, image and physical resource configuration, management etc. These cloud infrastructures provide users with an elastic platform for the fast delivery and scalability of services to meet dynamic demands of the service end-users. All the services are hosted in Virtual Machines (VM) and then monitored and controlled in the cloud by using the virtual interfaces such as Command Line interface [32].

### *E. Nimbus*

Nimbus is an open source software cloud computing components written in Java and Python specifically for the needs of the scientific community, but also supporting other business users [32]. The main component is the Workspace service which represents a standalone site VM manager with different remote protocol frontends that support Nimbus WSRF frontend and partially Amazon EC2. While Workspace service represents a compute cloud, there is also a quota-based storage cloud solution Cumulus, designed to address scalability and multiple storage cloud configurations [33].

There are two types of clients: cloud clients for quick instance launch from various sites, and reference clients acting

as full command-line WSRF frontend clients. Context Broker service allows clients to coordinate large virtual clusters launches using Context Agent, a lightweight agent on each VM. Context Broker manages a common cloud configuration in secure context across resources provisioned from potentially multiple clouds, with a possibility to scale hybrid clouds across multiple distributed providers [34]

## IV. COMPARISON

The purpose of this paper is to provide a qualitative review of the top five open source IaaS frameworks presented in the section above. This section provides a comparative analysis to aid in framework selection decisions. The frameworks included in this paper have been chosen based on literature reviews and perceived industry acceptance. The open source frameworks detailed in this paper are OpenStack, CloudStack, OpenNebula, Eucalyptus and Nimbus.

TABLE 1: COMPARISON OF VARIOUS OPEN SOURCE CLOUD COMPUTING TOOLS

| **Features** | **Eucalyptus** | **OpenNebula** | **Nimbus** | **OpenStack** | **CloudStack** |
|---|---|---|---|---|---|
| Architecture [8][11] | Hierarchy grouped from Cloud Cluster via the Cluster Controller , Storage Controller to the Node Controller | Three modules contain all components | Three modules contain all components | Integration of three core software project - OpenStack compute, storage and image infrastructure | Hierarchical structure to manage servers |
| Application areas [6][7][11] | Large data centres, Research Institutions | Large Commercial companies and Public Institutions | Scientific Community, Research Institutions | Enterprises, Service providers and Researchers | Enterprises, Service providers and Researchers |
| Cloud Types [12] | Private Hybrid | Private Hybrid | Private Public | Public Private Hybrid | Public Private Hybrid |
| Programming Language [11] | C and JAVA | JAVA, RUBY and C++ | JAVA and PYTHON | PYTHON | JAVA |
| Operating System [17] | Linux | Ubuntu | Linux | Linux | Linux and Ubuntu |
| User Interface [35][36] | Euca2ools( CLI) | Web interface and Command Line Interface | Web Services, Nimbus Web | Web Interface (Dashboard) and Command Line Interface to mange VM | Web interface and Command Line Interface |
| Storage [37][38][39] | Walrus, storage controller | Database, Shared file systems storage | Cumulus service, File system backend storage system | Object, block and file storage | Secondary storage uses Network File System |
| Security Issue [40][41] | Public/Private Key code pair generated by Cloud Controller is used for authentication | Authentication by passwords using RSA key | Authorization Policies | Administrators mange the user accounts | Security groups keep checks |
| Reliability [41] | Separate clusters reduces errors | Permanent Databases provide backend | Periodic verification for regular backups | Replication | Replication |
| Load Balancing [12][42] | Simple load balancing by Cloud Controller | Nginx server use Round Robin or weighted selection mechanism | Launches self configuring virtual clusters i.e, the Context Broker | Cloud Controller | TCP Load Balancer |

## V. CONCLUSION AND FUTURE WORK

Open source cloud computing deployment is a difficult choice in all of the companies, especially in the leading technical companies of the world. This paper has presented an up to date qualitative review of the main open source infrastructure as service frameworks. With the help of the comparison these platforms can be utilized to build cloud in a better way and make a deeper research so as to improve the performance of the cloud service provider. Some features and functions are added into or updated with the development for further research. The main aspect is to carry on research so as to ensure quality of service and that the services are provided to the users without any kind of failure.

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