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Performance Evaluation of Private Clouds: OpenStack vs Eucalyptus

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Abstract: With the rapid growth of cloud infrastructure in the organizations, more applications are dependent on the quality of services like network, disk, memory, processor. Due to this, many organizations drift towards choosing right cloud for deploying the application which caters to user's needs. Currently, opensource cloud platforms (OpenStack, Eucalyptus, Cloudstack, Opennebula etc) are gaining a lot of popularity that establishes private cloud with low cost. But it is difficult for organizations to choose a platform suitable for hosting web application or running virtual machines for high availability. This paper focuses on choosing right cloud platform for network, disk, processor, and memory in running application specific to user's need. The efficacy of our method is validated through a series of experiments which consists of benchmarking the performance of OpenStack and Eucalyptus opensource private clouds. The experimental result shows that Eucalyptus cloud performs better for Network, Memory and Processing operations while OpenStack cloud performs better for Disk I/O operations.

Keywords: Benchmarks, Cloud, Eucalyptus, OpenStack.

I. Introduction

With the emergence of cloud, many software organizations focus on the quality of products which provides good response time and run for a longer period of time. These organization partitions their workload into the cloud such that users get high-performance services[1]. Users are more interested in high-performance services which run in a cost-effective and flexible way. Many organizations are not yet interested to adopt public cloud as they don't provide complete control access for applications related to security [2]. As a result, opensource cloud platforms like OpenStack, Eucalyptus, opennebula, cloudstack etc. are more popular these days as it establishes private cloud in a rapid and cost-effective manner. As compared to the commercial cloud, these opensource clouds help the organization to simulate their business needs before venturing commercial cloud [2]. For production use, MAAS (Metal as a service), an OpenStack tool along with Juju manages the OpenStack services. These services can be assigned and deployed on the cloud resource pool for efficient allocation of services [3]. With the availability of many opensource cloud platforms, it is difficult for users to choose or decide upon a suitable cloud platform based on their application needs [4, 19]. The onset of several opensource cloud platforms guarantees the performance and uptime though it is not easy for naive users to choose from the different available cloud platforms without perceiving the traits and benefits of each one of the existing platform [5]. It is essential to choose the right cloud to run the application for a longer period of time. The quality of service the application caters is reliant on the performance metrics like network delay, memory space, processor speed etc. The performance of the run-time cloud application is not managed fully by managing the server requirements. It also depends on the qualitative features of cloud and quantitative parameters like benchmark operations. Users are allowed to create and manage their own infrastructure using qualitative feature comparison [6]. On the contrary, the quantitative comparison provides more insights of the cloud using standard benchmarks. There is a difference in authentication of OpenStack and Eucalyptus cloud. The users are monitored by providing a unique username and password to login virtual machine. Once the virtual machines are launched on OpenStack cloud or eucalyptus cloud, users are completely unaware of which VM is most preferred to achieve maximum performance gain from the cloud [7]. This result in the application underachieves with more costs. For better performance gain, a high-performance computing infrastructure is adopted in which a large number of resources are required to conduct actual calculations and analysis [6]. A lot of work has been done on evaluation of traditional HPC and opensource HPC, although there is an increase in performance but it requires an increased cost in server setup and its maintenance.

The contribution of this paper includes the work on a wiser selection of opensource private cloud on limited computing resources both qualitatively and quantitatively. For the qualitative feature comparison of two clouds with respect to user's console, authentication is taken into consideration. In order to achieve a quantitative comparison of cloud, benchmarking the performance is a crucial step to evaluate the performance of cloud [6]. In addition, we take into account that benchmarking can also be done on limited computing resources. The rest of the paper is organized as follows- Section II discusses an overview of related work. Section III provides a comparison of different open source clouds, Section IV gives a cloud configuration and methodology for deployment and organization of cloud VMs. Section V discusses the results. Section VI gives a conclusion.

II. Related Work

With the availability of various opensource cloud tools, benchmarking the cloud performance is an important aspect to determine the advantages and disadvantages of cloud platforms. A lot of work has been done related to performance evaluation using different benchmarks. Mumtaz M. Ali et.al. [2] benchmark the performance of Cloudstack and Eucalyptus cloud in which cloud stack outperforms all except Disk I/O. Adib Habbal et.al [8] use the Technology Acceptance Model (TAM) in the evaluation process. It specifies the relationship between perceived ease of use and security in private clouds. Ahmed Zerouali et.al. [9] analyzed two popular cloud platforms: cloud stack and eucalyptus related to the identification of bug in cloud systems. This analysis was done in Java and there was a performance improvement in testing approach. Adib Habbal et.al [10] assess and evaluate the private cloud using web of system performance (WOSP) model. Subhasish Mohapatra [11] provide a comparative study between CPU Performance of public cloud and private cloud (e.g my cloud). Travis Brummet et.al [12] evaluated the performance of three open source clouds: OpenNebula, Eucalyptus, OpenStack using CPU, Network, and Disk I/O benchmarks in which openNebula outperforms from all except Network. Dylan Steinmetz et.al [13] evaluate OpenStack and eucalyptus cloud using BYTE UNIX benchmark in which large copy size test, serial excel, and serial shell tests were executed. The result states that OpenStack outperforms Eucalyptus in large copy test while Eucalyptus outperforms OpenStack outperforms OpenStack in serial excel and serial shell tests. Mardhani riasetwan et.al[14] analyzed the simulation of a virtual machine and benchmark the resource isolation performance on Proxmox, and Eucalyptus cloud. Navdeep Kaur et.al [15] benchmark the performance of Cloudstack using Linpack to analyze the effect of virtual machines dedicated to a particular host. Vo Nhan Van [16] analyzed the performance of OpenStack and VMware to determine to create/deleting instances, memory usage of instances created. Mohammad A Khamis et.al [17] examine the performance of HPC Eucalyptus and Amazon EC2 cloud using SPEC MPI 2007 benchmark in which Amazon EC2 cloud is found to be more scalable and flexible while Eucalyptus cloud falls short in fault tolerance. The work also insisted on more usage of different benchmarks to provide more insights about both clouds. Y Tamura et.al [18] worked on the performance evaluation and software dependability of dynamic cloud environment where actual datasets of OpenStack cloud compute the jump of users in login time.

Our work is inspired by [12] as we run Network, Disk I/O, benchmarks on OpenStack (devstack) and Eucalyptus fast start. But the difference is that we run memory and processing benchmarks also to provide a better comparison of OpenStack and Eucalyptus and for disk I/O, we use an alternate tool for computing read and write inputs and outputs. Although, these benchmarks do not provide complete information due to different usage scenarios and different resource allocation of memory in the operating system[15] but at the end, it provides an overall performance in context to VM launch and release.

III. Comparison of Opensource Clouds

There are a lot of open source technologies and their tools available for the deployment of private cloud, so there arises confusion in selecting the suitable technology choice. In this section, we compare different opensource clouds: OpenStack, Open-Nebula, and Eucalyptus on the basis of architecture and hypervisors [7].

A. Architecture

OpenStack provides broadly scalable and feature-rich resources to the cloud [7]. The architecture includes services such as [20]-

- Nova (computer), which supports lifecycle of instances in the cloud.
- Swift, the storage infrastructure in OpenStack, is a scalable object storage system.
- Horizon provides a customized user interface to manage the resources.
- Keystone provides a common authorization and authentication layer.

Open-Nebula architecture includes three layers [21]-

- Drivers layer communicates directly with the underlying operating system and encapsulates the underlying infrastructure as an abstract service.
- A core layer is a centralized layer that manages the virtual machines full life cycle.
- Tools layer provides an interface such as command line interface, browser, and libvrt API.

Eucalyptus architecture includes five components [22]-

- Cloud controller provides AWS EC2 functionality means it allows virtual server resources.
- Walrus provides object storage functionality used for backup or for storage of media files.
- Cluster Controller provides management service for a cluster in the cloud.
- Storage Controller provides block storage functionality.
- Node Controller controls virtual machine instances

B. Hypervisor

OpenStack supports all hypervisors such as Xen, KVM, Hyper-V, QEMU, UML, XenServer, LXC. Open-Nebula supports hypervisor such as VMware, KVM, Virtual Box, Xen and libvirt Eucalyptus supports hypervisor such as VMware, KVM, Xen and ESX, Virtio[5] There are some other parameters also for comparison of opensource cloud[5] as shown in table 1

TABLE I: PARAMETERS FOR COMPARISON

Tool/Properties	OpenStack	OpenNebula	Eucalyptus
Cloud Type	Public, Private and Hybrid	Public, Private and Hybrid	Private
Storage Compatibility	EC2,OpenStack API	Open Multiplatform	Elastic CC S3
Scalability	Massively Scalable	Dynamic Scalable	Scalable
OS supported	Linux	Linux	Host Linux and Windows VM

IV. CLOUD CONFIGURATION AND METHODOLOGY

We deployed OpenStack cloud (devstack) and Eucalyptus fast start on intel-core i3-2130 CPU: 3.40 GHz consisting 4GB RAM, 500GB Hard-disk, single gigabit NIC. For external access to VM, machines should be in a private network.

A. Organization of OpenStack Cloud

Launching of VM includes five organizing steps: create key-pair, manage security, groups/firewalls, cloud image-type, flavor-type, post-creation

- *Create Key-Pair*: In order to access a virtual machine without a password, SSH key pair is necessary. From the access and security tab in OpenStack dashboard, click on either create key-pair or import key pair
- *Manage Security Groups/Firewalls:* By default, all incoming connections to VM are blocked. To open additional ports, we need to add rules. For example: to allow incoming traffic, port 22 is open for TCP and CIDR 0.0.0.0/0 should be provided to allow data from all IP

Fig. 1: VM Types in OpenStack Cloud for 512MB and 2GB RAM

- *Cloud Image-Type:* In order to run benchmarks, a cloud-image template is created. It is deployed on the virtual machines to reduce both launch time and run-time. For example VDI(virtual disk image), qcow2 formats are used to make virtual machine fast at runtime and is not network intensive such that it puts a low load on the network
- *Flavor Type:* Flavor type defines virtual machine specifications in terms of core, RAM, disk. It displays the offering VM type such as m1.tiny, m1.small, m1.medium, m1.large etc. We can also create new flavors based on our own requirements. Here, due to limited resources, we only have two types: m1.tiny and m1.small, specifications of both types are shown in table 2.

TABLE II: OFFERING VM TYPES

S.no	Flavor-type	RAM	VCPU	Disk
1	m1.tiny	512MB	1	1
2	m1.small	2GB	1	20

- *Post-Creation:* By default, cloud image is passwordless. To log in a virtual machine, we need to generate a password using the script as input:

  # cloud-config

  password: ubuntu

  chpasswd:{ expire:false}

  ssh_pwauth: True

This script can also be used to manage passwords for multiple users. When admin launches VM for the user, it sets the unique passwords for each user so that user is not granted access to VM dedicated to another user. The script for multiple users is rewritten as:

#cloud-config

chpasswd:

list: |

user1:password1

user2:password2

expire: false

For OpenStack cloud, currently, 3 virtual machines are running in parallel as shown in figure 1.

Fig. 2: VM Types in Eucalyptus Cloud for 512MB and 2GB RAM

B. Organization of Eucalyptus Cloud

Launching of VM includes five steps: enable virtualization in BIOS, cloud-image type, flavor-type, create key-pair, create security groups

- *Enable Virtualization in BIOS:* This is necessary otherwise VM will be pended and ultimately terminate. For this go to BIOS settings and enable the virtualization. Without enabling, the eucalyptus virtual machine instances cannot be launched.
- *Cloud-Image Type:* Choose the Eucalyptus machine image of VDI (Virtual Disk Image) type from console
- *Flavor-type:* Choose the same offering VM type (512 MB and 2GB RAM) for the fair comparison.
- *Create Key-Pair:* Generates a key-pair same as OpenStack cloud, public key (saved in Eucalyptus) and private key (given to user).

Create Security Groups: Here also we provide CIDR 0.0.0.0/0 to allow traffic from all IP addresses.

Here we don't require a postscript to login VM. Instead, we log in as "ec2-user". This is a drawback in terms of security as login to VM via ssh without keying password can be infeasible.

*ssh –ikey.pem ec2-user@10.0.27.*100

```
[admin@cloud ~]$ cd /home/admin/Desktop
[admin@cloud Desktop]$ chmod 400 key1.pem
[admin@cloud Desktop]$ ssh -i key1.pem root@10.0.27.100
The authenticity of host '10.0.27.100 (10.0.27.100)' can't be established.
RSA key fingerprint is bb:a2:23:cc:cf:08:ab:cb:99:98:4e:7a:91:77:6f:3d.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '10.0.27.100' (RSA) to the list of known hosts.
Please login as the user "ec2-user" rather than the user "root".

Connection to 10.0.27.100 closed.
[admin@cloud Desktop]$ ssh -i key1.pem ec2-user@10.0.27.100
[ec2-user@ip-172-31-254-217 ~]$
```

As shown in figure 3, ssh login terminal is an only way to log in. ssh key is created and the ssh connection is established between ec2-user and cloud. 10.0.27.100 is a public IP address and after ssh connection, the user is assigned a VM.

VM of private address 172.31.254.217 on benchmarks run to evaluate the performance of Eucalyptus cloud.

For eucalyptus fast start cloud, currently, three virtual machines are running in parallel as shown in Figure 2.

The difference between OpenStack cloud and Eucalyptus cloud w.r.t user's console is that OpenStack cloud is accessible in the same subnet, creates strong authentication for multiple users to login VM while eucalyptus cloud is not accessible in the same subnet as authentication for ec2-user creates problem after the first login. This means the public address is assigned to the first instance. In case of the second login with ec2-user,

public address creates redundancy in launching the same virtual machine. There is no redundancy of public address in the OpenStack cloud. So, Eucalyptus fast start falls short of good authentication as compared to OpenStack cloud.

To evaluate the performance of both OpenStack and Eucalyptus cloud, benchmarks are used. Some popular benchmarks are shown in table III

TABLE III: BENCHMARKS FOR COMPARISON

S. No	Benchmarks	Testing resource
1	IPerf	Network
2	Bonnie++	Disk I/O
3	Stream	Memory
4	Linpack	Processor

- Iperf measures network performance to obtain bandwidth using both TCP and UDP streams. IPerf works in a client-server model in order to measure throughput in bps [23]
- Bonnie++ measures disk i/o performance using a series of tests which includes data read and write speed, the maximum number of seeks per second, the maximum number of file creations [24].
- Stream measures the memory bandwidth in MB/s. It is specifically designed to work with datasets much larger than the available cache on any given system so that the results are more performance driven [25]
- Linpack measures the processor performance in terms of floating point rate of execution. It can be done by solving dense n by n system of linear equations in double precision [26,27]

V. RESULTS AND DISCUSSION

In this section, we evaluate the performance of OpenStack cloud and Eucalyptus cloud using benchmarks. On the basis of numerical values from benchmarks, we plot these values into graphical and tabular form for better visualization and then recommend a better cloud choice.

Case Study 1: Network performance of OpenStack cloud versus eucalyptus cloud using IPerf benchmark

We ran the IPerf benchmark for 10-15 seconds on both OpenStack and eucalyptus cloud VM and then record the results as shown in Figure 4. Here, we measure UDP Throughput as a network metric. The y-axis values denote the bandwidth in Mbits per sec.

[root@ip] *#iperf –u 10.0.0.16 –i 5 –t 30 –b 10G*

[root@ip] *#iperf –u 172.31.254.217 –i 5 –t 30 –b 10G*

Avg.UDP Throughput (openstack cloud)= 105 Mbps

Avg.UDP Throughput (eucalyptus cloud)= 806 Mbps

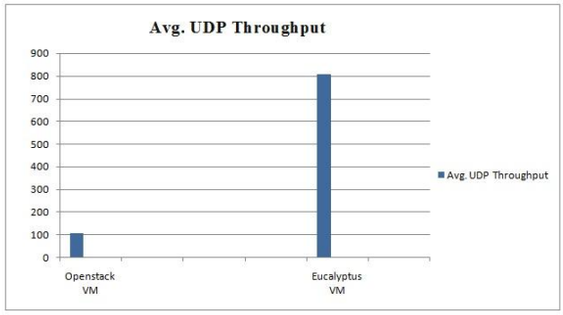

Fig. 4: Avg UDP Throughput for OpenStack vs Eucalyptus VM

Observation 1: The network performance result concludes that eucalyptus is a better option for networking (i.e supporting higher bandwidth) as compared to OpenStack since Avg UDP Throughput of eucalyptus cloud VM is more than that of OpenStack cloud VM.

Case Study 2: Disk I/O performance of *OpenStack cloud* versus *eucalyptus cloud* using Bonnie++

We ran the bonnie++ benchmark on the OpenStack and eucalyptus cloud VM. And record the results as shown in Figure 5. This test takes two steps: writing intelligently and reading intelligently. It tests concurrency and latency for sequential input, sequential output, random create and sequential create. The y-axis values denote the Kbits per sec

[root@ip] # bonnie++ -d /tmp –r 512 -u

[root@ip] # bonnie++ -d /tmp –r 2048 -u

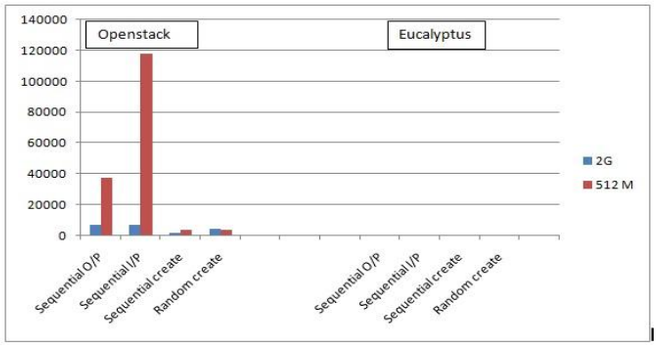

Fig. 5: Disk I/O for OpenStack vs Eucalyptus Cloud VM

Observation 2: The sum of image size plus swap (512MB) is larger than the selected instance type. So, the eucalyptus VM instance terminate and the solution of this to allocate more disk space by switching to higher flavor types that is 4GB, 8GB etc. But, OpenStack VM have enough disk space for both 512MB and 2GB RAM. Based on these points, the disk I/O performance is better for OpenStack as compared to eucalyptus cloud.

Case Study 3: Memory performance of *OpenStack cloud* versus *eucalyptus cloud* using stream

We ran the stream benchmark on the OpenStack and eucalyptus cloud VM of both 512 MB and 2GB RAM to evaluate the memory bandwidth (in Mbps) as shown in Figure 6.

This offers functions like copy, scale, add and triad [26].

Copy: a(i)=b(i)

Scale: a(i)=s*b(i)

Add: a(i)=b(i)+s*c(i)

[root@ip] # gcc –o stream.c –o stream

[root@ip] # ./stream

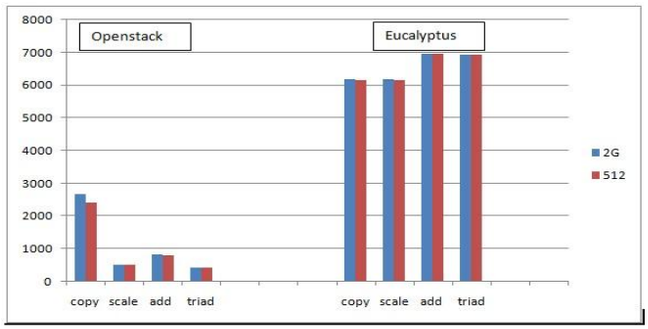

Fig. 6: Memory Bandwidth of OpenStack vs. Eucalyptus Cloud VM

Table IV: Stream Results of Openstack Vs. Eucalyptus VM

VM	Copy	Scale	Add	Triad
OpenStack (2GB)	2678.2482	520.4779	830.8397	441.7944
OpenStack (512MB)	2422.3	524.0	816.0	428.5
Eucalyptus (2GB)	6182.1	6195.1	6953.3	6940.2
Eucalyptus (512MB)	6147.2	6143.9	6950.9	6935.2

Observation 3: From Table 4; copy, scale, add, triad values of OpenStack VM's are greater as compared to eucalyptus VM's. So, the above memory performance results conclude that eucalyptus performs better than OpenStack cloud for memory operations. The percentage increase of eucalyptus VM (2GB) is 130.8 % in comparison to OpenStack VM (2GB). The percentage increase of eucalyptus VM (512MB) is 153.77 % in comparison to OpenStack VM (512MB).

Case Study 4: Processor performance of OpenStack cloud versus eucalyptus cloud using LINPACK.

We ran the LINPACK benchmark on OpenStack cloud VM of both 512 MB and 2GB RAM to evaluate processing performance in terms of MFLOPS (millions of floating point operations per second) which is the rate of CPU execution as shown in Figure 7. The benchmark used is to solve a dense system of linear equations [27]. The results may vary from the Linpack Benchmark Report for the same machines and even on the same processor due to load on the system, clock accuracy, size of cache, bandwidth, amount of memory. All these factors vary from machines to machines but results are same [21]. The y-axis values denote the rate of execution.

[root@ip] # gcc –o linpack_bench.c –o linpack_bench
[root@ip] # ./linpack_bench

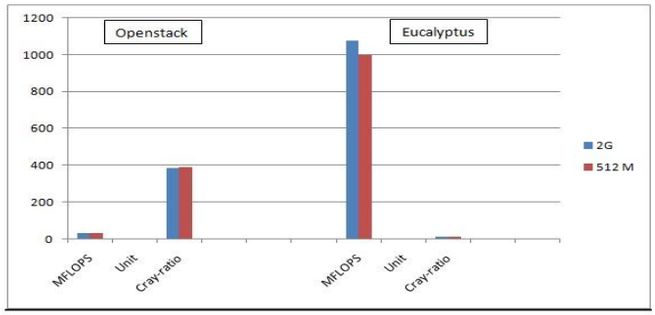

Fig. 7: Processing Speed of OpenStack vs Eucalyptus Cloud VM

Table V: Linpack Results Of Openstack Vs Eucalyptus VM

VM	MFLOPS	UNIT	CRAY-RATIO
OpenStack (2GB)	31.264280	0.063971	381.92071
OpenStack (512MB)	30.722679	0.065098	388.65342
Eucalyptus (2GB)	1078.494624	0.001854	11.071429
Eucalyptus (512MB)	998.0099	0.002004	11.964286

Observation 4: From Table 5, MFLOPS values of eucalyptus cloud VM are very large as compared to OpenStack cloud VM. Here, MFLOPS is considered as a metric as it decides the CPU execution rate. So the above processing performance results conclude that eucalyptus cloud performs better than OpenStack cloud for power supported applications.

VI. Conclusion and Future Work

In this paper, we presented a work on how to choose a right cloud platform which caters to both the user and the running application requirements. First, we have discussed how to organize the virtual machines(VM) of OpenStack and eucalyptus cloud for VM launch. This can be done by creating ssh key-pair which helps VM to login without a password, creating flavor type for offering virtual machine such as m1.tiny, m1.medium. Also, there is a management of security groups by allowing traffic through open blocked ports and finally add the post-script to isolate the multi-users for the OpenStack cloud.

In case of Eucalyptus cloud, the connection of ec2-user with the cloud is done with the help of ssh-key creation. Furthermore, we have performed a qualitative feature comparison of both clouds. Results show that OpenStack cloud is more secure than Eucalyptus cloud as it includes post-script which isolates multi-users from VM access. Second, we evaluated the performance of both clouds by running benchmarks on two cloud virtual machines: 512MB and 2GB. The benchmark results may vary from system to system having same specifications due to system load, clock accuracy, amount of memory etc. The benchmark results show that both OpenStack and Eucalyptus clouds have advantages and disadvantages in terms of performance. For Network, Memory and Processing operations, Eucalyptus cloud is a better choice as compared to OpenStack cloud. For disk I/O operations, OpenStack cloud is a better choice as compared to eucalyptus cloud.

In future work, we aim to extend our work in testing more benchmarks for OpenStack, eucalyptus and also for other such as opennebula, cloudstack etc.

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