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Performance Benchmarking of Hypervisors - A Case Study

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Abstract

Objectives: Benchmark the performance of the different hypervisors using standard benchmarking tools considering the different parameters like CPU, RAM, DISK Read-Write, Network Read-Write. We use different types of hypervisors and compare the performance of hypervisors how they behave differently for above mentioned parameters. **Methods/ Statistical Analysis:** Experiment setup consists of three hypervisors namely Virtual Box 6.0, VMware workstation as a hosted hypervisors and Xen as a Native or bare metal hypervisor. Open source hypervisor considered for the experiment. VMware Workstation 9.0, Virtual Box 5.0 as a hosted hypervisor and Citrix Xen as the native hypervisor were considered. Stress is used as the standard benchmarking tool and Glances tool helps to collect and monitor the traces. **Findings**: The virtualization is carried out by the software layer called as the Hypervisor or Virtual Machine Monitor (VMM). Hypervisor is widely used in cloud datacenters. Bench-mark is the measurement of best practice performance. Bench-marking is very essential term for the discovery of the best performance given by the particular system. Benchmarking can provides you the external references and the best practices on which to base your evaluations and to design your system pro-cesses which can be very useful in finding the gaps in the system to achieve the desired performance. The Bare metal Hypervisors have the direct access to the hardware resource rather than accessing resource via operating system as in hosted hypervisors. Performance analysis of desired work shows the keen differences in performance related to CPU, RAM, DISK Read-Write, and Network Read-Write performance. Results concludes that hosted hypervsors have good performance in N/W, Disk read and write because the architecturally bounded to operating system where interact with base OS while Xen as native hypervisor has a good CPU Performance because Virtual machine has direct access to hardware layer through Virtual machine manager. **Improvements**: We used single benchmark tool to test all parameters, it has potential to use different benchmarking tools specific to parameters like for Network Read-Write, AIO stress can be used. Further concentrates bench mark comparison of hypervisors and containers, where container adoption has increased in cloud data centers.

Keywords: Benchmarking, Cloud, Glances, Hypervisors, VMware, Xen

1. Introduction

Virtualization constitutes of large number of technologies and concepts that are meant to provide an abstract environment for applications to run. Virtualized then it leads to the increase in the resource availability and flexibility of their management[1]. It allows the creation of secure, customizable and isolated environment to run the applications either if they are un-trusted, without affecting

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the user's applications. For Example, Windows operating system on top of virtual machine, which is running on Linux operating system. Virtualization provides a great opportunity to build and develop elastically scalable system, which are capable of provisioning high computing capability with minimum cost. Virtualization market has grown up tremendously based on number of reasons[2] as like, increased performance and computing capacity: Now days growth of semiconductor technology provided desktop machines, personal computers are more powerful enough to fulfil almost all requirements of user and most of the computing capacity is underutilized. Lack of space is also one the reason i.e., companies like Google, Microsoft expand their infrastructure by building data centres as large as foot ball fields that host thousands of nodes. There are many benefits of virtualization like consolidation, migration, security, portability and emulation of servers which helps to save the cost, energy consumption and maintenance time.

Benchmark is the measurement of best practice performance. Benchmarking is very essential term for the discovery of the best performance given by the particular system[3]. Bench-marking can provides you the external references and the best practices on which to base your evaluations and to design your system processes which can be very useful in finding the gaps in the system to achieve the desired performance. The various hypervisors with similar hardware configuration, operating system are used to measure w.r.t various performances aspect such as CPU speed, RAM usage, Memory speed.

We focused on study of Virtualization, Hypervisor and Benchmarking. We have carried out experiment to benchmark different hypervisor performance with respect to CPU use, RAM use, Disk Speed and Network speed. From the experiment carried out we may conclude that Best CPU performance is given by Xenserver 6.5. While Best RAM performance is given by VMware. DISK and N/W Performance of Virtual Box is much better than other two. The Performance of hypervisor may vary for different perspectives. The performance of different hypervisors may get influenced by the environment and the resources.

Virtual machines are used widely in cloud service providing organization. State of art of an Infrastructure as service is largely synonymous with virtual machines[3]. The cloud service providing platform provides virtual machines to customer and their applications are made run inside the virtual machines. The cloud services like Platform as a Service and Software as a Service are built with all their workload running inside the virtual machines. Since all workload at cloud is made run within the scope of virtual machines the performance of virtual machine is the crucial point of overall performance of cloud[4]. Hypervisor that is responsible for running virtual machines and the control of resource. So this paper is focusing on the performance given by the different Hypervisors.

Overall structure of the paper is as follows Section II briefly describes about prior work. Section 2 describes the fundamentals of virtualization which motivated to conduct the experiment. Section 3 indicates the proposed methodology adopted to bench mark the hypervisors. Section 4 describes about experimental results and discussion. Lastly the Section 5 concludes the overall research work.

2. Prior Work

The detail research exploration of bench marking techniques for hypervisor had been undergone. Most of the re-search in this area is from industry and few research articles are form academia.

In[5] had used the three different hypervisors to run several map reduce bench mark codes like Word Count, TestDSFIO[6], and TeraSort[7] and further validated and observed hypothesis using micro benchmarks. They concluded that CPU benchmark results negligible and keener difference found in I/O bound benchmarks.

In[8] conducted different performance tests on three hypervisors XenServer, ESXi and KVM. All three hyper-

visors are bare metal hypervisors and results are collected using SIGAR API[9] (System Information Gatherer and Reporter) and Passmark[10] benchmark suite. Performance test was carried out in Cloud environment on Cloud Stack 4.0 and calculated the performance using SIGAR, netperf and Passmark. Their results show there is significant performance in various factors.

A study by VMware[11] provides a quantitative and qualitative comparison of two virtualization hypervisors for the x86 architecture namely VMware ESX Server 3.0.1 and open source Xen 3.0.3[12] respectively to validate their readiness for enterprise datacenters. They used different bench mark tools and concluded that VMware ESX Server is superior, production ready performance and scalability required for efficient and responsive datacenter.

The study[13] performed an extensive performance comparison under hardware-assisted virtualization settings considering four popular virtualization platforms, Hyper-V, KVM, vSphere and Xen, and they identified that the over-heads delivered by the each hypervisor incurred by each hypervisor can vary significantly based on the type of application and the resources used.

The performance benchmarking of 32bit Debian 6.0 Virtual Machines running on Xen and VMware ESX. The benchmark is carried out to test the performance of hypervisor based on parameters like try to measure the performance of virtual machines with Network activity, File system I/O, CPU and Memory performance. Results shows that the performance is varied based on type of application[14]. Choose on how the different hypervisor behave on heterogeneous workloads where it helps to choose high performance hypervisor for variable workloads[15].

The study[16] had done Quantitative comparative study of two hypervisors and to understand how the different architectural decisions taken by different hypervisor developers affect the resulting hypervisors, to help hypervisor developers realize areas of improvement for their hypervisors.

All the literature[17,18] survey carried out as above mentioned only tells about bench marking of native as well as hosted hypervisors but research work carried out by us differentiates and compares results of both type of hypervisors basedtheir performance factors like CPU usage, RAM Usage and so on.

3. Virtualization

3.1 Taxonomy of Virtualization Techniques

Considering the taxonomy of virtualization techniques, Virtualization[2], mainly classified in to many types based upon execution environment, storage, network etc. Among the most techniques execution virtualization has grown up tremendously and be-come most popular where it's used and applied in the most computing domain. It's classified in to process level and system. level. We are more keen interested in investing system level virtualization. Hardware-level virtualization that provides an abstract execution environment for computer hardware on top of which a guest OS can be run. Guest is the operating system on top of hypervisor; the host is represented by physical computer hardware. Here hypervisor emulates the underlying hardware by which helps in create virtual machines. The hypervisor is generally a program or a combination of software and hardware that allows the abstraction of the underlying physical hardware[2]. Architecture of Virtual box and VMware is shown in Figure 1 and Figure 2 respectively.

The fundamental component of hardware level virtualization is hypervisor which emulates or recreates the hardware environment to run the guest operating system. The guest operating system thinks that it also has its own physical hardware. Based upon the working principle, hypervisors are classified in two categories:

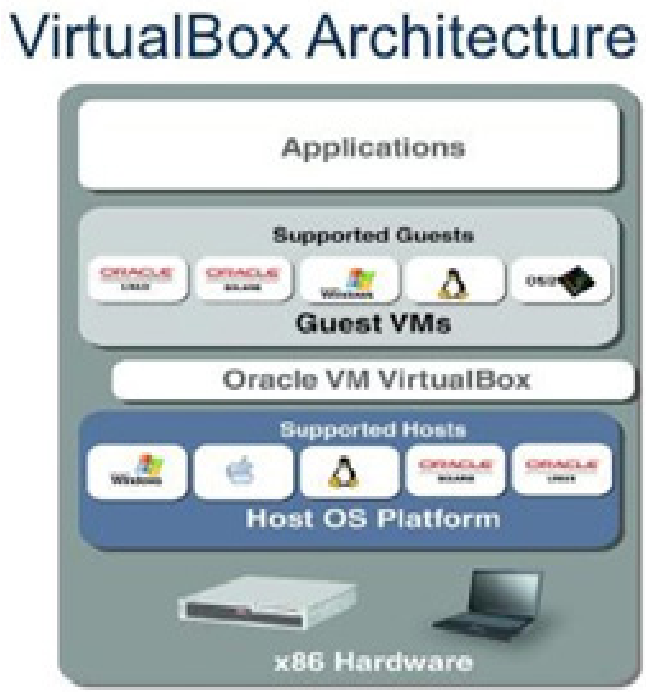

Figure 1. Virtual box architecture.

- Type I or Native Hypervisor: Run directly on the top of hardware.

- Type- II or Hosted Hypervisor: Require the support of an operating system.

Native hypervisor are most popular in enterprise data centres, cloud data centres and large infrastructures. Our investigation mainly concentrates on the benchmarking of native hypervisors because most of the mission critical, enterprise applications are running where performance is a major concern. Hosted hypervisors are used mainly in the personal computers and desktop infrastructure. Hardware-assisted virtualization,Full and Para-virtualization. Hardware-assisted virtualization in this scenario the hardware provides architectural support for building VMM (Virtual Machine Manager) which can able to run the Guest operating system in total isolation[2,3].

Full virtualization is the ability of running programs most likely as an operating system directly on the top of VM prior to any modification just like it is running on the raw hardware to make this possible entire underlying hardware must be emulated to VMM. Para-Virtualization partial emulation of underlying hard-ware is provided to the VMM thus the guest operating system is not executed in complete isolation. Para-virtualization can run many applications transparently but not all that features are provided applications are running where performance is a major concern.

Hosted hypervisors are used mainly in the personal computers and desktop infrastructure. Hardware-assisted virtualization, Full and Para virtualization. Hardware-

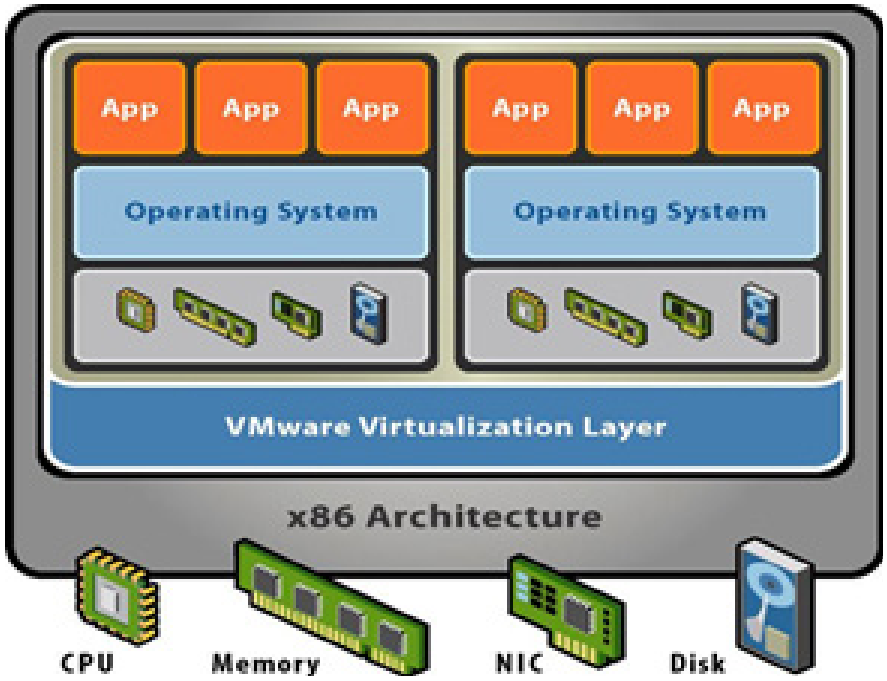

Figure 2. VMware architecture.

assisted virtualization in this scenario the hardware provides architectural mainly concentrates on the benchmarking of native hypervisors because most of the mission critical, enterprise Native hypervisor are most popular in enterprise data centres, cloud data centres and large infrastructures. Our investigation those are provided in full virtualization[2,3].

4. Proposed Methodology

This section detail describes about the methodology followed, different types hypervisors and bench marking tools used in the experiment.

4.1 Hypervisors

Virtualization is carried out by the software layer called as the Hypervisor or Virtual Machine Monitor (VMM). There exists various type of hypervisors like open source Hyper-visors and commercial Hypervisors. In the area like Distributed Database, Parallel computing and Cloud computing Hypervisor is widely used[2]. Below are the three different hypervisors taken for experiment?

4.1.1 VMware[19]

Here we used the VMware workstation 9.0 as the hosted hypervisor. VMware Workstation, in the Windows

and Linux operating systems running a hosted hypervisor (an earlier version of the x86 version available) 64-bit version; it enables the user to build a single physical machine Virtual Machine (VM), and use them at the same time along with the actual machine. Each virtual machine can run its own operating system, including Microsoft Windows, Linux, BSD and MSDOS version. VMware Workstation developed and sold by a division of VMware Inc., EMC Corporation. An operating system license is required to use proprietary, such as windows. Ready Linux VM settings for different purposes are available; reference architecture is as shown in Figure 2.

4.1.2 Virtual Box[20]

Virtual Box virtualization is a cross-platform application. It hosted hypervisor type. It installs on your

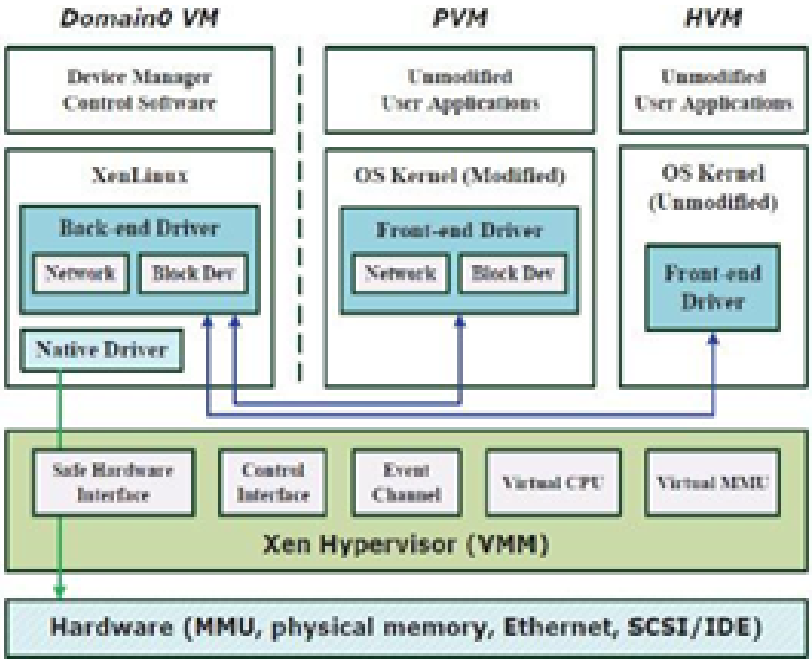

Figure 3. Xen hypervisor architecture.

existing Intel or AMD-based computers, whether they run on Windows, Mac, Linux or Solaris operating system. Secondly, it extends the existing capabilities of the computer, so that it can run multiple operating systems at the same time (multi-virtual machine). Thus, for example, you can run on Mac Windows and Linux, 2008, on a PC running Linux running on your Linux server Windows Server Windows, etc., are to retain the existing applications. You can install, and you like running multiple virtual machines - the only limit is the actual hard disk space and memory. Virtual Box is deceptively simple but very powerful. It is available from small embedded systems or desktop class machines all the way to the data centre deployments, and even cloud computing environments running everywhere. The reference architecture is shown in Figure 3.

4.1.3 Xen hypervisor[21]

Xen Hypervisor solution is originally developed at the University of Cambridge. It is the only bare metal hypervisor which is available as open source. Xen Hypervisor is lightweight because it can delegate management of guest domain (DomU) to privileged domain (Dom0) Xen hypervisors are useful for CPU scheduling and Memory partitioning of various virtual machines running on hardware device. Dom0 is a unique virtual machine running on Xen Hypervisors that has special right to access physical I/O as well as interact with other virtual machines, While DomU have no direct access to physical hardware. Figure 3 indicates the architecture of Xen Server.

4.2 Benchmarking

Benchmark is the measurement of best practice performance. Benchmarking is very essential term for the discovery of the best performance given by the particular system. Bench-marking can provides you the external references and the best practices on which to base your evaluations and to design your system processes which can be very useful in finding the gaps in the system to achieve

the desired performance. Motivation is the virtualization is widely used technology and the virtualization is carried out by the means of the hypervisors. Benchmarking of the hypervisors can give the guideline for selecting the appropriate hypervisor among the number of hypervisors present in the market. So providing guideline for selecting the hypervisor is the motivation.

4.2.1 Benchmarking Tools

There are different tools avail-able to benchmark and as well to generate the stress to operating systems and then measure the performance of the hypervisor. In the conducted experiment following tools are used.

4.2.2 Stress[22]

Stress is Open source software in Linux which is used to create the stress on OS and this will help in analysing the performance. Stress is a deliberately simple workload generator for POSIX systems. It imposes a configurable amount of CPU, memory, I/O, and disk stress on the system. It is written in C, and is free software licensed under the GPLv2.

4.2.3 Glances[23]

The Glances is free software to monitor Linux operating system from a text interface. Glances use the library ***libstatgrab*** to retrieve information from the operating system and it is developed in Python.

4.3 Factors Considered for Benchmark

The performance measure is use of CPU, use of RAM, DISK Read and Write speed, NETWORK Read and Write speed.

CPU:CPU performance measurement is very important for large scale infrastructure like cloud data canters. In Large scale systems CPU Computing power is allocated/shared in between to run multi tenant environments. It includes the percentage of CPU used for carried out the task given by the stress. The CPU is stressed using four processes.Figure 4 shows CPU utilization for the hypervisors.

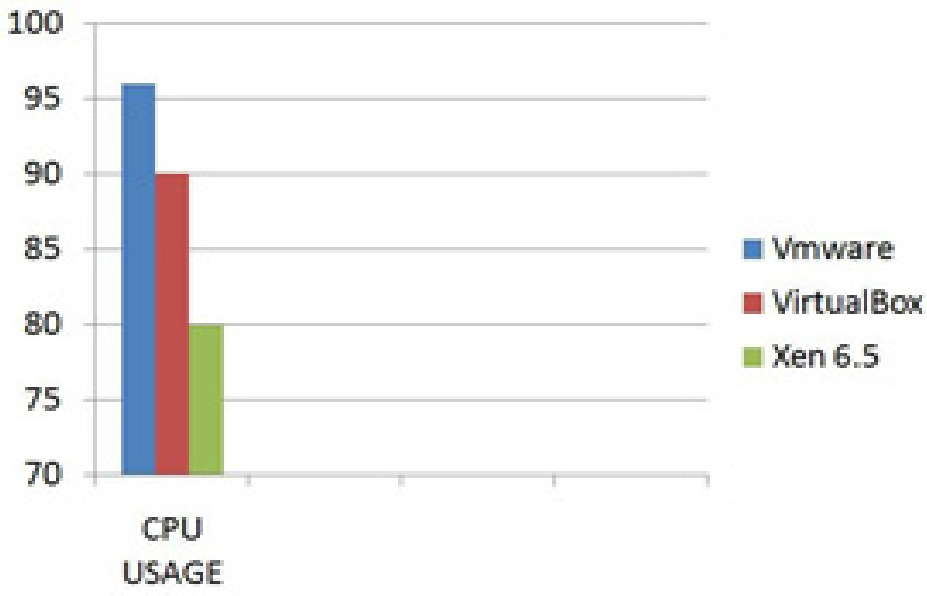

Figure 4. CPU utilization measured in percentage (Lesser is better).

RAM: It includes the percentage of RAM used. RAM will be stressed using 2 processes (each sizing around 256MB).

DISK Read and Write speed: It gives the write and read speed of the disk, the DISK will be stressed with a process that is about 1GB in size.

N/W Read and Write speed: Network transmission and receiving speed is checked. Network latency is more important for data intensive applications in the cloud computing data centers.

4.4 Experiment Set Up

Experiment setup consists of three hypervisors. Open source hypervisor considered for the experiment.VMware Workstation 9.0, Virtual Box 5.0 as a hosted hypervisor and Citrix Xen as the native hypervisor were considered.

The description of the hypervisor was mentioned in the above section IV. Hardware and software requirements for the experiment of hosted hypervisor consists of personal computer with configuration Processor i5-4590 @3.30 GHz, 4GB DDR2 RAM, 500GB of hard drive with Windows 7 operating system. The hardware and software requirements of native hypervisor consists of a bare metal computer with configuration Processor i5-4590 @3.30 GHz, 4GB DDR2 RAM, 500GB and Virtual Machines were created with help of Xen Center, each VM has configuration of Processor i5-4590 @3.30 GHz with one processor, 2 GB DDR2 RAM and 40GB hard drive. The maximum Disk Write and Read speed is given by Virtual Box while minimum Disk Write and Read speed is given by Xen hypervisor.

The hypervisors selected are installed with the same configuration given to them and after installing the hypervisors Ubuntu 14.04 LTS Linux operating system as a guest operating system installed on the top of the hypervisors. And the Stress software is used to give the stress on the hypervisor and Glances framework is used to analyse the performance. The stress is used to provide the stress to the OS with factors mentioned above. If we want to stress

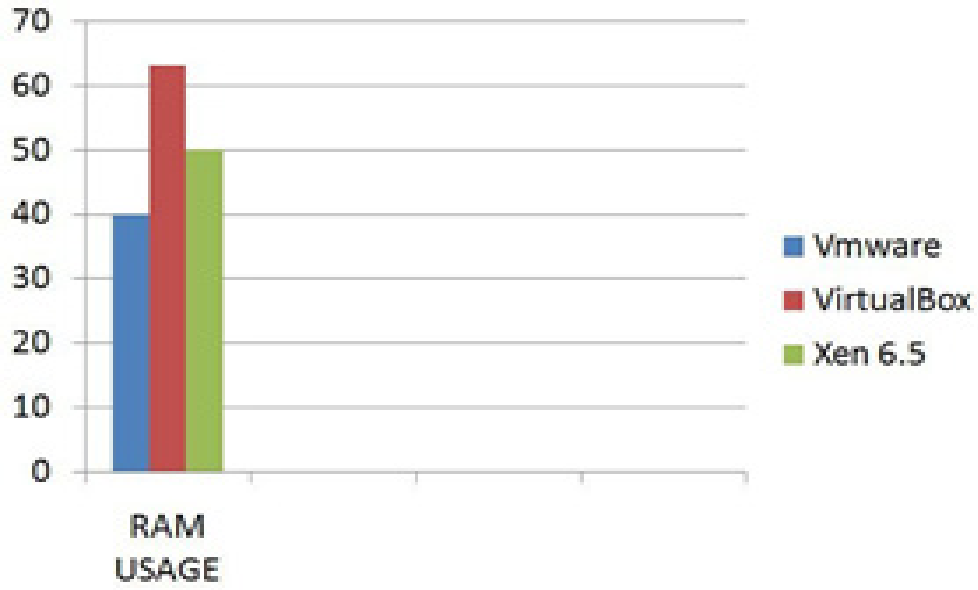

Figure 5. RAM utilization measured in percentage (Lesser is better).

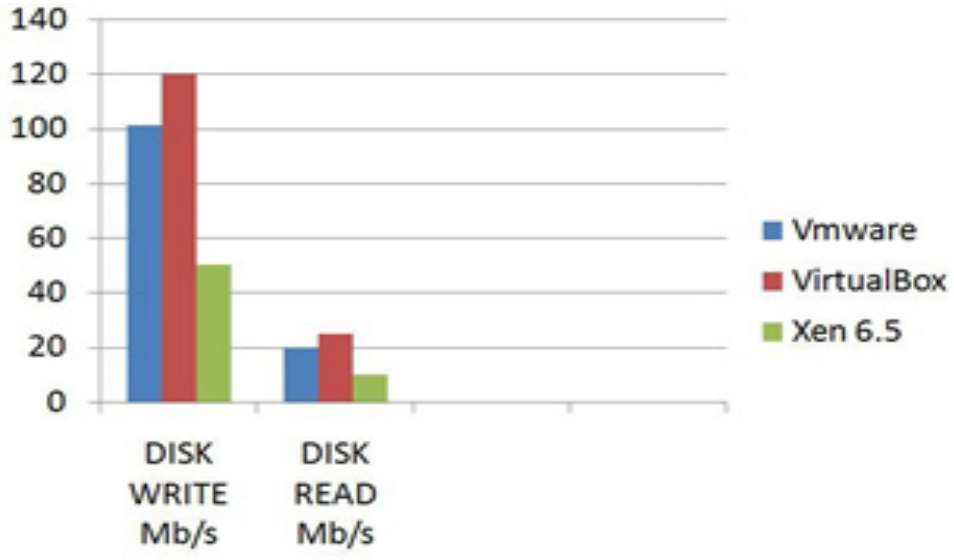

Figure 6. Disk speed (Write and Read) measured in Mb/s (Maximum is better).

the CPU, RAM and the HDD at the same time, the format of command is given below.

4.4.1 Stress c 4 m 2 d 1 t 40s

Time limit considered for the stress is 40 seconds and it is common for all hypervisor. The command Stress will stress the CPU using four processes, RAM will be stressed using 2 processes (each sizing around 256MiB) and the DISK will be stressed with a process that is about 1GB in size.

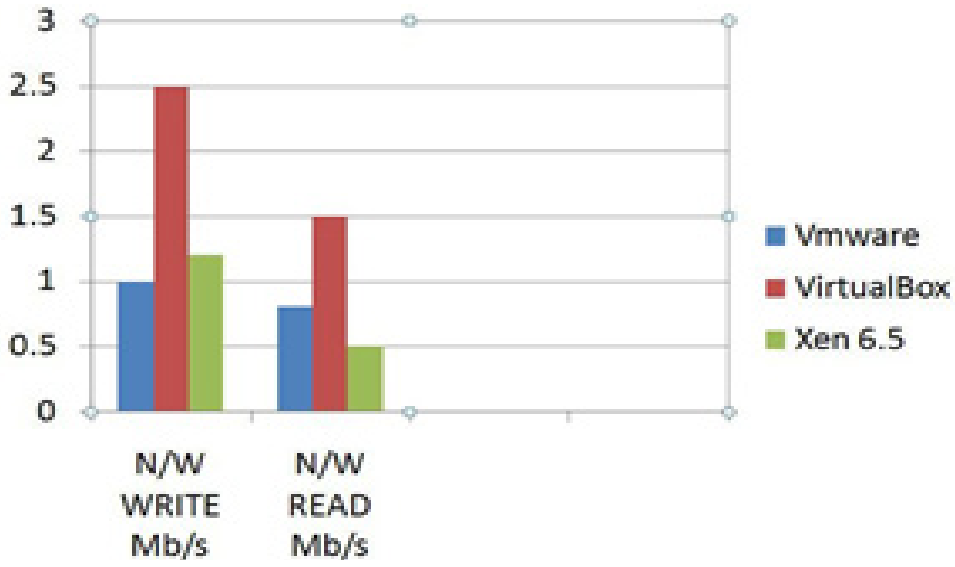

Figure 7. Network speed measured in Mb/s and maximum is better.

5. Results and Discussion

Once the stress command is executed the performance of the system is monitored till 40 second as time line.

The above result is obtained by carrying out the experiment for 25 times on each hypervisor. The reading for each second is noted down and the best performance given by the hypervisor is mentioned in result graphs. While consideringthe CPU use and RAM use less percentage use is the better as it requires the less amount of resource for carrying out the task. As we executed the same stress for each hypervisor it is very convenient to compare them as we have given them similar hardware configuration as well as the similar stress is given.

Each hypervisor have the same Linux operating system on the top of it i.e., Ubuntu 14.04. The stress software is installed on Linux and the stress is given to check the performance of CPU Use as shown in Figure 4 [This indicate how much CPU used by each VM. The maximum amount of CPU used by VMware while the Xen 6.5 server uses the minimum amount CPU].

The maximum RAM used by the VirtualBox whiles the minimum amount of RAM used by VMware as shown in Figure 5. Figure 6 indicates that DISK read, write performance of Virtual Box is powerful than other hypervisors. The better Network Write and Read speed is given by Virtual Box as shown in Figure 7. While the Xen hypervisor give relatively lower performance than other two hypervisors.

This research might contribute to guideline for the choosing appropriate virtualization technology. VMware, Oracle Virtual Box and Xen are most the popular and the most commonly used virtualization tool by individual as well by organizations. So this benchmarking will guide to users to choose proper virtualization technology considering the cost and availability of the resources. Our Research show cases that if the application is compute intensive than the use can choose Xen Hypervisor as the virtual infrastructure and id the application in more memory intensive the VMware Virtualization will result in better performance From the above case studies we can conclude that Performance of hypervisors under different condition may vary.

6. Conclusion

We focused on study of Virtualization, Hypervisor and Benchmarking. We have carried out experiment to benchmark different hypervisor performance with respect to CPU use, RAM use, Disk Speed and Network speed. From the experiment carried out we may conclude that Best CPU performance is given by Xenserver 6.5. While Best RAM performance is given by VMware. DISK and N/W Performance of VirtualBox is much better than other two. The Performance of hypervisor may vary for different perspectives. The performance of different hypervisors may get influenced by the environment and the resources.

The considered case studies in the report are with the different research papers regarding the benchmarking the performance of the hypervisors in different environment. The performance of different hypervisors may get influenced by the environment and the resources. Further study can be carried out in discovering the new benchmarking techniques for benchmarking the hypervisors.

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