

# Performance Analysis of VMM Using LINPACK and CLOUDSIM

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**Abstract**—Virtualization is a core part of cloud computing which divides the resources of a computer into multiple execution environments. Virtualization offers a lot of benefits including flexibility, security, ease to configuration and management and reduction of cost but at the same time it also brings a certain degree of performance overhead. Furthermore, Virtual Machine Monitor (VMM) is the core component of virtual machine (VM) system and its effectiveness greatly impacts the performance of whole system. In this paper, different software & tools i.e VMware, VirtualBox, LINPACK Benchmark and CloudSim are used and conducted experiments to measure the performance of virtualized XP are described. The quantitative and qualitative comparison of both virtual machine monitors can be done by measuring the processing speed and response time of virtualized XP.

**Keywords:** LINPACK, CloudSim, Virtual Machine Monitor (VMM), VMware and VirtualBox

## I. INTRODUCTION

With the rapid development of internet, Cloud computing has recently emerged as a new paradigm for hosting and delivering services over the Internet [1,2]. Cloud computing is best for business owners to grow from lower resources to large due to increasing demand of service. This technological trend has enabled the realization of a new computing model called cloud computing, in which user can access services from anywhere, at anywhere over the Internet in an on-demand fashion [2].

The deployment of clouds have many attractive benefits such as scalability and reliability, reduced cost, elasticity, quality of service (QoS); however, development of clouds to provide more economical solutions as consumers only need to pay for what resources they required while providers can capitalize poorly utilized resources. From a provider's point of view, the maximization of the profit is major concern.

Many years ago, a problem invoked that how to run multiple operating systems on the same machine simultaneously? The solution to this problem was virtual machines created by VMM [1,8]. Virtual machines monitor the core part of virtual machines sits between one or more operating systems and the hardware and gives the illusion to each running OS that it controls the machine. Virtual Machine technology starts to focus on virtualization [9,10] which enables to run multiple OS environments simultaneously on the

same physical hardware in strong isolation. Virtualization can be used to perform isolation, consolidation and migration of resources in cloud computing. VMs share the conventional hardware in a secure manner with help of VMM which control guest OS on host, while each VM is hosting its own operating system and applications.

Virtual Machine technology [8, 9] begins to emerge as a focus of research and deployment. Virtual Machine technology such as Xen, VMWare, Microsoft Virtual Servers, and new Microsoft Hyper-V technology etc, enables multiple OS environments to coexist on the same physical computer in strong isolation. VMs share the conventional hardware in a secure manner with excellent resource management capacity, while each VM is hosting its own operating system and applications. Hence, VM platform can facilitate server-consolidation [11] and co-located hosting facilities.

Behind the scenes, the monitor actually is in control of the hardware, and must multiplex running OSES across the physical resources of the machine. Indeed, the VMM serves as an operating system for operating systems but at a much lower level; the OS must still think it is interacting with the physical hardware. Thus, transparency is a major goal of VMMs [5].

At the end of the 1960s, the virtual machine monitor (VMM) came into being as a software abstraction layer that partitions a hardware platform into one or more virtual machines. Each of these virtual machines was sufficiently similar to the underlying physical machine to run existing software unmodified. There was time; general-purpose computing was the domain of large, expensive mainframe hardware and users found that VMMs provided a compelling way to multiplex such a scarce resource among multiple applications. Thus it brought modern multitasking operating systems and a simultaneous drop in hardware cost, which eroded the value of VMMs. As mainframes gave way to minicomputers and PCs, VMMs disappeared because computer architectures no longer provided the necessary hardware to implement them efficiently.

By the late 1980s, neither academics nor industry practitioners viewed VMMs as much more than a historical curiosity. Fast forwarding to 2005, VMMs becomes hot topic In academia and industry. Virtual-machine-based technologies such as Intel, AMD, Sun

Microsystems, and IBM are developing virtualization strategies that target markets with revenues in the billions and growing. In research labs and universities, researchers are developing approaches based on virtual machines to solve mobility, security, manageability and virtualization problems.

In the 1990s, Stanford University researchers began to look at the potential of virtual machines to overcome difficulties that hardware and operating system limitations imposed: This time the problems stemmed from massively parallel processing (MPP) machines that were difficult to program and could not run existing operating systems. With virtual machines, researchers found they could make these unwieldy architectures look sufficiently similar to existing platforms to leverage the current operating systems. Today virtual machine has become popular due to various reasons. Server consolidation is one such reason. In many settings, people run services on different machines which run different operating systems and yet each machine is lightly utilized. In this case, virtualization enables an administrator to consolidate multiple Operating systems onto fewer hardware platforms and thus lower costs and ease of administration. Virtualization has also become popular on desktops, as many users wish to run one operating system but still have access to native applications on a different platform. This type of improvement in functionality is also a good reason. Another reason is testing and debugging. While developers write code on one main platform, they often want to debug and test it on the many different platforms that they deploy the software to in the field. Thus, virtualization makes it easy to do by enabling a developer to run many different operating system types and versions on just one machine [18,19].

## II. VIRTUAL MACHINE MONITORS (VMM)

### A. VMware

VMware [10] is a virtualization and cloud computing software provider for x86 compatible computer architecture. VMware Inc. is a subsidiary of EMC Corporation, well known in the field of system virtualization and cloud computing. VMware's software allows users to create multiple virtual environments, or virtual computer systems, on a single computer or server. Essentially, one computer or server could be used to host, or manage, many virtual computer systems, sometimes as many as one hundred or more. The software virtualizes hardware components such as the video card, network adapters, CPU, memory and hard drive called hardware virtualization which is very useful for enterprisers by setting up multiple server systems on single server or physical hardware without having to purchase separate hardware for each of them.

User can create virtual servers using VMware's software, leads to saving a lot of time and money [11].

Virtual machine (VM) is heart of virtualization, tightly isolated software container with an operating system and application inside. Because each virtual machine is completely separate and independent, many of them can run simultaneously on a single computer. thin layer of software called a hypervisor decouples the virtual machines from the host and dynamically allocates computing resources to each virtual machine as needed.

The x86 architecture offers four levels of privilege known as Ring 0, 1, 2 and 3 to operating systems and applications to manage access to the computer hardware. While user level applications typically run in Ring 3, the operating system needs to have direct access to the memory and hardware and must execute its privileged instructions in Ring 0. Virtualizing of x86 architecture require placing a virtualization layer under the operating system to create and manage the virtual machines that deliver shared resources. Some sensitive instructions cannot effectively be virtualized as they have different semantics when they are not executed in Ring 0. The difficulty in trapping and translating these sensitive and privileged instruction requests at runtime was the challenge that originally made x86 architecture virtualization look impossible so VMware resolved this problem by developing binary translation techniques that allow the VMM to run in Ring 0 for isolation and performance, while moving the operating system to a user level ring with greater privilege than applications in Ring 3 but less privilege than the virtual machine monitor in Ring 0. It does not support Hyper Threading3 and requires a host operating system, which means an extra layer and additional overhead.

### B. VirtualBox

VirtualBox is a cross-platform virtualization application, installs on the existing Intel or AMD-based computers, whether they are running Windows, Mac, Linux or Solaris operating systems. Secondly, it extends the capabilities of a user's existing computer so that it can run multiple operating systems inside multiple virtual machines at the same time. A user can run Windows and Linux on Mac, run Windows Server 2008 on Linux server, run Linux on Windows PC. User can install and run many virtual machines, but the only practical limits are disk space and memory.

VirtualBox is simple and easy to use, *yet also* very powerful to manage VM. It can run everywhere from small embedded systems or desktop class machines. Oracle VirtualBox is an x86 cross platform open source virtualization software package developed by Oracle Corporation as part of its family of virtualization products. Virtual Box is also called hosted hypervisor, host OS is required on which VMM is installed. To a very large degree, VirtualBox is functionally identical

on all of the host platforms and same file, image formats are used. It provides the option to enable hardware virtualization on a per virtual machine basis when running on AMD-V and Intel-VT capable CPUs. On more recent CPU designs, VirtualBox is also able to make use of nesting paging tables to improve virtual machine performance.

### III. BENCHMARK

#### A. LINPACK

The LINPACK [3,4] package was based on another package, called the Level 1 Basic Linear Algebra Subroutines (BLAS) [5]. Most of the floating-point work within the LINPACK algorithms is carried out by BLAS, which makes it possible to take advantage of special computer hardware without having to modify the underlying algorithm [4, 5]. In the LINPACK Benchmark, a matrix of size 100 was originally used because of memory limitations with the computers. Such a matrix has 10 000 floating-point elements and could have been accommodated in most environments of that time. At the time it represented a large enough problem.

LINPACK (LINear system PACKage) contains a number of FORTRAN subroutines based on BLAS (Basic Linear Algebra Subprograms) library to work out different linear equations and linear least-squares problems written by Jack Dongarra, Jim Bunch, Cleve Moler and Pete Stewart. LINPACK [7] was designed for applying to supercomputers in the 1970s and early 1980s and now acts as one of the most authoritative benchmarks in high performance computers. The TOP 500 computers in the world are sorted by the LINPACK's result. To follow the development of computer architectures, LINPACK evolves into EISPACK and LAPACK. EISPACK mainly dedicates to numerical computation of the Eigen values and eigenvectors of matrices. LINPACK measures the actual peak value of float-point computing power indicated in giga of float-point operations per second (GFLOP) [3-5].

The original LINPACK Benchmark is an accident and was originally designed to assist users of the LINPACK package by providing information on the execution times required to solve a system of linear equations. The first 'LINPACK Benchmark' report appeared as an appendix which comprises data for one commonly used path in the LINPACK software package. Results were provided for a matrix problem of size 100, on a collection of widely used computers. This was done so users could estimate the time required solving their matrix problem by extrapolation. The LINPACK package is a collection of FORTRAN subroutines for solving various systems of linear equations. The software in LINPACK is based on a de-compositional approach to numerical linear algebra. The package has the capability of handling many different matrix and data types and provides a range of options.

#### B. CloudSim

CloudSim is a new generalized and extensible simulation toolkit and application which enables seamless modelling, simulation, and experimentation of emerging cloud computing system, infrastructures and application environments for single and internetworked clouds. The existing distributed system simulators were not applicable to the cloud computing environment due to evaluating the performance of cloud provisioning policies, services, application workload, models and resources under varying system, user configurations and requirements. To overcome this challenge, CloudSim can be used. In simple words, CloudSim is a development toolkit for simulation of Cloud scenarios. CloudSim is not a framework as it does not provide a ready to use environment for execution of a complete scenario with a specific input. Instead, users of CloudSim have to develop the Cloud scenario it wishes to evaluate, define the required output, and provide the input parameters. CloudSim is invented as CloudBus Project at the University Of Melbourne, Australia and supports system and behaviour modelling of cloud system components such as data centers, virtual machines (VMs) and resource provisioning policies. It implements generic application provisioning techniques that can be extended with ease and limited efforts. CloudSim helps the researchers to focus on specific system design issues without getting concerned about the low level details related to cloud-based infrastructures and services. CloudSim is an open source web application that launches preconfigured machines designed to run common open source robotic tools, robotics simulator Gazebo. SimJava is a toolkit for building working models of complex systems. It is based around a discrete event simulation kernel at the lowest level of CloudSim. It includes facilities for representing simulation objects as animated icons on screen.

### IV. PROBLEM FORMULATION

Cloud computing is emerging as a significant shift as today's organizations which are facing extreme data overload and high energy costs. Many Years ago, a problem aroused. How to run multiple operating systems on the same machine at the same time? The solution to this problem was virtual machines. Virtual machines monitor, the core part of virtual machines sits between one or more operating systems and the hardware, it also gives the illusion to each running OS that controls the machine. Behind the scenes, the monitor actually is in control of the hardware, and must multiplex running Oses across the physical resources of the machine. Indeed, the VMM serves as an operating system for operating systems, but at a much lower level; the OS must still think it is interacting with the physical hardware. Thus, transparency is a major goal of VMMs.

## V. EXPERIMENT SETUP

Today, the benchmark is used by scientists and engineers worldwide to evaluate computer performance, particularly for innovative advanced-architecture machines. An accurate performance evaluation is a complex issue so to accommodate its evaluation; the LINPACK Benchmark suite provides separate benchmarks that can be used to evaluate computer performance on a dense system of linear equations for a  $100 \times 100$  matrix and is dependent on the algorithm chosen by the manufacturer and the amount of memory available on the computer being benchmarked. In the case of LINPACK 100, the problem size was relatively small and no changes were allowed to the LINPACK software.

Thus, as described before, many high performance machines may not have reached their asymptotic execution rates. However, the benchmark is still important because it approximates the performance rates of numerically intensive codes written by the user and optimized by an optimizing compiler quite well. The comparison of VMware and VirtualBox is done by benchmarking virtual machines using LINPACK and CloudSim. The virtual machines were created on VMware and VirtualBox One on VMware and another on VirtualBox each with the fixed configuration. Both contains Windows XP SP3 edition as guest OS. In the first experiment, LINPACK is used to compare the floating point operations of virtualized XP in VMware and virtualized XP. The input to the LINPACK tool was the problem size. The configurations were as follows:

TABLE 1 EXPERIMENTAL CONFIGURATION

Processor	Intel i3
RAM	1 GB
CPU Frequency	2.294 GHz
No. of CPU's	1
No. of Cache	2
No. of thread	4
No. of virtual machine	2

The output is the number of GFlop operations per second. 5 tests were performed with problem sizes 1000, 2000, 3000, 4000, 5000 their corresponding leading dimensions being 2000, 4000, 6000, 8000 and 10000 respectively. The number of trials will be 8 with data alignment value of 8 KB.

In the second experiment, CloudSim is used which is a cloud network simulator tool to compare the response of each virtual machine. The client sends the data to the server and CloudSim checks the speed and the quality of the networking. Here, we have the same system as the client and server. Server receives the packets from a port which is different from the port from where the client sent the data.

The simplest one consists of modelling the case where a single, centralized Cloud data center is used to

host the social network application. In this model, all requests from all users around the world are processed by this single data center. Data center has 5 virtual machines allocated to different 5 applications. The second scenario consists of the use of two data centers, each one with 5 virtual machines dedicated to the application. The third scenario consists of three data centers, each one with 5 virtual machines. In the next scenario, the MIPS used by Cloudlet and VM are same or different. Each of these scenarios was evaluated with execution of the workload previously described. Results are discussed next.

## VI. RESULTS

The set of performance results reveals the asymptotic behaviour of VMM on a cluster of Intel i3.294 GHZ processors. Performance tests were also performed on a larger system. The LINPACK Benchmark results for this system are presented in Table 2: which shows LINPACK results on VMware and Table 3: shows LINPACK results on VirtualBox. However Fig 1 shows there is slightly more GFlops in case of VMware than VirtualBox with very small variation. So from this experiment it can conclude that VMware performs slightly better than VirtualBox.

TABLE 2 LINPACK'S RESULTS ON VMWARE

Problem Size	Array Size	Trail	Time(ms)	GFlop
1000	2000	8	0.08	8.18
2000	4000	8	0.43	12.20
3000	6000	8	1.60	11.01
4000	8000	8	3.56	11.97
5000	10000	8	6.90	12.11

TABLE 3 LINPACK'S RESULTS ON VIRTUALBOX

Problem Size	Array Size	Trail	Time(ms)	GFlop
1000	2000	8	0.10	7.43
2000	4000	8	0.46	11.90
3000	6000	8	1.58	10.50
4000	8000	8	3.73	11.67
5000	10000	8	7.20	11.51

With respect to cloud simulation, the Table. 4 and 5 depicts variation of average response time. Results show that bringing the service closer to users improves the quality of service such as response time. It is an expected effect, because users experiment less effects from high latency and low bandwidth when they are geographically close to the application server. Results also show that service quality can be further improved with the application of load balancing in the application across data centers, which are supposed to be managed by different service brokerage policies and at virtual machine level. But the levels of improvement achieved depend largely on the load balancing algorithms employed. So, application of good load balancing

strategies is paramount for large-scale distributed applications. It is not a matter of great concern in Cloud data centers, which apply economy of scale to make their business profitable and so they can offer more resources during peak traffic.

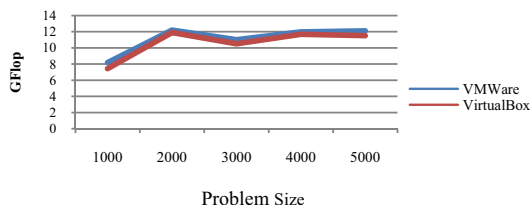


Fig. 1 Linpack Comparison Chart

TABLE 4 CLOUDSIM RESULTS ON VMWARE

Datacenter	VM	Host	Cloudlet	CL & VM	Response Time	Processing Time (ms)
1	1	1	1	Yes	0.2	1000
1	1	1	1	No	0.2	500
1	5	5	5	Yes	0.2	2000
1	5	5	5	No	0.2	500-2000
2	1	1	1	Yes	0.2	1000
2	1	1	1	No	0.2	2000
2	5	1	5	Yes	0.2	2000
2	5	1	5	No	0.2	500-1000
3	5	1	5	Yes	0.3	2000
3	5	1	5	No	0.3	500-1000

TABLE 5 CLOUDSIM RESULT ON VIRTUAL BOX

Datacenter	VM	Host	Cloudlet	CL & VM	Response Time	Processing Time (ms)
1	1	1	1	Yes	0.2	1000
1	1	1	1	No	0.2	500
1	5	5	5	Yes	0.2	2000
1	5	5	5	No	0.2	1500
2	1	1	1	Yes	0.2	1000
2	1	1	1	No	0.3	2000
2	5	1	5	Yes	0.3	2000
2	5	1	5	No	0.3	1000
3	5	1	5	Yes	0.3	2000
3	5	1	5	No	0.4	2000

Once again, elastic cloud providers solve this problem by charging consumers proportionally to the amount of resources used. At the same time provider offer tools to automatically increase and decrease resources available to applications in order to meet established service level agreements (SLA).

## VII. CONCLUSION AND FUTURE SCOPE

The basic knowledge about VMware, VirtualBox, benchmark LINPACK, CloudSim and conducted experiments to measure the performance of virtualized

XP on VMware and VirtualBox are described. The processing speed in the basis of number of floating point operations per second and the response time are measured. Significant results were produced with which the comparison can be done. The recent trends in high-performance computing will shape the near future of the LINPACK and CloudSim Benchmark suite.

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