Performance Study of Virtualization Platforms for Virtual Networking Laboratory

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Abstract – **Virtualization is a modern software technology that quickly spreads in various areas of the IT sector. However, its use in higher education is still insufficient widespread. Virtualization platforms provide flexible and efficient utilization of existing infrastructure. They offer the capability to integrate advanced topics into courses in a way that gives students control so that they can perform hands-on activities that would be infeasible on physical computers. Due to, the teaching will become more adequate to the rapidly changing world of IT industry. This article presents a comparative analysis of performance of virtual platforms for building a virtual networking laboratory.**

Keywords – **Virtualization, Virtual Platforms, Virtual Laboratory, Higher Education.**

I. INTRODUCTION

Virtualization is a modern software technology that quickly finds spreads in various areas of the IT sector. However, its use in higher education is still insufficient widespread. The traditional method of teaching requires students to attend the laboratory in individual laboratory rooms. University laboratories typically involve a fixed number of computers and network equipment. Each computer has installed a separate operating system and software according to the material. The existence of different courses in different semester, requires the installation and maintenance of various software packages. The software packages have specific requirements to the capabilities of the hardware, which limits their use only in certain computer labs. However, these computers and software require specific engineering support, and need to invest in new hardware.

Using virtualization platforms (VPs) can resolve a number of existing problems. This can be realized in several ways. Firstly, these platforms provide cost-efficient environments for training and research in the form of virtual laboratories. Second, the use and sharing of hardware with a different purpose can reduce the need for investment in new equipment. At the same time VPs will reduce the cost of equipment maintenance in terms of reinstalling operating systems and software packages.

Virtualization allows providing a single computer to every student. The implementation of remote access to virtual infrastructure will reflect in the quality of teaching, as students will be able to access virtual laboratories at any time. This will compensate for the insufficient number of computer labs and workstations.

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The paper presents a comparative performance analysis of virtualization platforms, suitable to build virtual network university laboratories.

II. VIRTUALIZATION TECHNOLOGIES

The virtualization is defined as an „abstracting a computer's physical resources into virtual ones with the help of specialized software" [1].

The virtualization platform virtualizes or transforms the hardware resources of very popular x86-based computers, including CPU, RAM, hard disks and network controllers. It creates a fully functional virtual machine (VM) that can run its own operating system and applications just like a real computer [2]. Each virtual machine contains a complete system, eliminating potential conflicts. Virtualization works by inserting a thin layer of software directly on computer hardware or the host operating system. This software is a virtual machine - monitor or hypervisor which allocates hardware resources dynamically and transparently. Multiple operating systems can run simultaneously on one physical computer and share hardware resources with each other. By encapsulating the entire machine, including CPU, memory, operating system and network devices, virtual machine is fully compatible with the all standard x86 operating systems, applications and drivers. We can run multiple operating systems and applications at the same time on one computer, and each user can have access to the resources he needs and when he needs.

A. Virtualization Environments

There are two main types of virtualization: hosted virtualization and bare-metal environments (Fig.1).

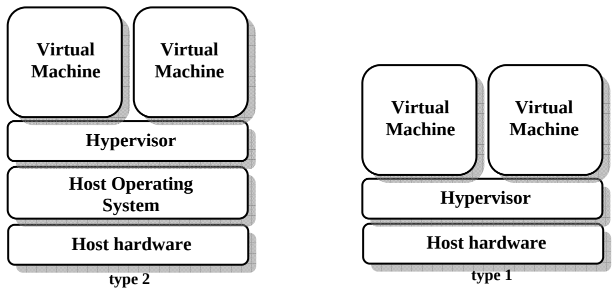

Fig.1 Virtualization environments

In hosted environment the hypervisors (type 2) are software applications running within a conventional operating system environment of the host. The hypervisor controls the resources that are allocated from the operating system on the lower level. This type of hypervisors are generally used in systems where there is a need for different input/output devices that can be maintained by the host operating system and client systems with low efficiency. Examples of such hypervisors are: Parallels Workstation, Microsoft Virtual Server, VMware Server and VMware Workstation.

In bare-metal environments the hypervisors (type 1) are software systems that run directly on the host hardware. They use a hardware control for monitoring the guest operating system. These types of hypervisors are the preferred approach to virtualization because they are running directly on hardware, thus achieving higher efficiency and performance. Examples of such hypervisors are: Citrix XenServer, VMware ESX and Microsoft Hyper-V.

B. Types of virtualization

Depending on the image of the software, virtualization software can be divided into two categories: server virtualization and desktop virtualization.

The server virtualization (Fig.2a) allows consolidation of multiple servers on a single high-performance server machine. Thus can reduce the number of physical servers and hence the cost of maintaining the equipment and the power. The hypervisor isolates the individual VMs, thus protecting against improper interference and changing configurations, processes and other resources. Examples of server virtualization are: VMware ESXi, Microsoft Virtual Server and Xen Server Enterprise.

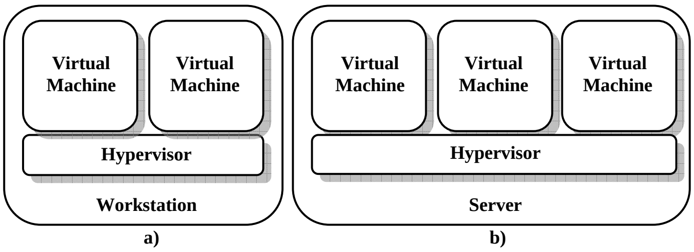

Fig.2 Desktop (a) and server (b) virtualization

Desktop virtualization (Fig.2b) allows virtualization on a desktop OS. One or more VMs can run on desktop machine. The virtual machine accesses resources via hypervisor. Desktop virtualization allows use of existing computers without the need to buy more powerful and expensive servers. Examples of such type of platforms are: Microsoft Virtual PC, Oracle Virtual Box, VMWare Workstation, Xen Server (Free Ed).

III. REQUIREMENTS FOR VIRTUAL LABORATORY

A virtual laboratory is a tool to which students have a remote access via the Internet and they use to conduct specific laboratory tasks [3, 4]. The choice of virtualization platform is determined by the nature of training. In Table 1 are shown the training courses related to network technologies teaching in Department of Computer Science at Technical University of Varna.

The table shows the need of different OS and different software packages. The choice of virtualization platform must consider the following factors:

- The performance of the equipment;
- The cost of the virtualization platform;
- The maintenance of devices and software.

TABLE I
NETWORKING COURSES

Course name	Operating system
Computer networks	Linux
Network infrastructures	Windows Server 2008
Network administration	Linux
Distributed programming	Linux
System Administration	Windows Server 2008

A. The performance factor

The power of the used computer equipment is essential for the effectiveness of training. Modern software packages bring ever greater requirements on computing resources. Unfortunately, the subsidies for university laboratories are insufficient to purchase the necessary equipment. From this perspective, the best solution is to use existing desktop PC computers in laboratories instead of buying powerful servers. The creating of virtual network infrastructure requires efficient management of network resources with access to devices on a computer.

B. The virtualization environment cost

Using a cost-effective platform for teaching and learning process is a direct consequence of the problem with the universities subsidizing. The market offers a wide variety of virtualization platforms with different status of use.

A much better solution is offered by the VMWare is an ESXi server with numerous features. Unfortunately its price model is not acceptable for the realization of our intentions. Several tools are provided with cost from $5000 to $12,000. Some certain features are shareware. Despite the rich features of this platform, the cost limits its use for our purpose.

The limited resources of desktop computers (in comparison with those of the server machine) are a prerequisite for choosing a platform for desktop virtualization. The VMWare offers VMWare Workstation [5] with enough features, but its use is shareware. This will need reinstallation after the trial period, which is not desirable to break the learning process.

Offered by Microsoft Virtual PC [6] is freeware, but requires installation under Windows, with is very big limitation.

Another representative of desktop virtualization environments is Oracle VM Virtual Box [7]. It is also freeware and can be installed under different OS, supporting multiple guest OS.

A possible solution is the use of Xen platform [8]. Apart from being distributed under the GPL, an important advantage is that it allows starting and managing virtual machines from two popular types of virtualization: paravirtualization and full virtualization. Xen also supports multiple guest OS.

C. Maintenance

Maintaining a virtual laboratory infrastructure is vital to the effectiveness of the learning process. There are different courses in different semesters and they require different software packages. However, students work with administrative privileges, thus often leads to problems and crashes of the OS as a result of deleting configuration files or applications. From this perspective, the recovery system must be fast. These requirements are covered by the technique of snapshoot. With this technique it is possible to save a snapshot of the guest OS with fast recovery if necessary.

D. Comparison

Table 2 shows the base features of the presented platforms for virtualization. The presented platforms have similar features, so crucial for the selection test will be performance tests.

TABLE II
VIRTUALIZATION PLATFORMS FEATURES

Feature	VMWare Workstation	Virtual PC	Oracle VirtualBox	Xen
Product use	shareware	free	free	free
Host OS	Windows, Linux	Windows based only	Windows, Linux	Bare-metal
Snapshot	Yes	no	yes	yes
USB 2.0	Yes	yes	yes	yes
Virtual net	Yes	limited	yes	yes
Seamless	Yes	yes	yes	yes

On the basis of the features presented most closest to the criteria for virtual network laboratory platforms are VirtualBox and Xen. These two platforms were selected for testing experiments on real desktops computers in a real laboratory.

IV. EXPERIMENTAL STUDY AND RESULTS

The analysis of the performance of virtual machines is based on the benchmark tests performed respectively on Linux, and Windows Server 2008 in a computer laboratory. Performance tests were made on both platforms, respectively the Oracle VirtualBox and the Xen hypervisor. Software used for testing is: Unix Bench for Linux virtual machines and Performance Test 7 Passmark for Windows virtual machines. Tests were performed in parallel on the computer configuration model HP Desktop 500B with parameters: CPU Intel Core Duo E5800 3,2GHz, 2G DDR3 RAM, G1 Express chipset, Intel GMA graphics.

A. Performance test for Linux VM

The purpose of the benchmark UnixBench is to provide a basic indicator of the performance of Unix-based systems [9]. The set of tests were used to test various aspects of system performance. Their results are compared with values of the BASELINE System, i.e. baseline assessments which are used to calculate the index. Then these indices are combined to generate an overall index of the system. The UnixBench consists of several individual tests that are aimed at different aspects of performance. In Table III are shown the results for VirtualBox, and in Table IV - for Xen hypervisor.

TABLE III
UNIXBENCH FOR VIRTUALBOX

System Benchmarks Index Values	Baseline	Result	Index
Dhrystone 2 using register variables	116700	12871170	1102.9
Double-Precision Whetstone	55	2351.4	427.5
Execl Throughput	43	490	114
File Copy 1024 bufsize 2000 maxblocks	3960	37510.5	94.7
File Copy 256 bufsize 500 max blocks	1655	9552.4	57.7
File Copy 4096 bufsize 8000 max blocks	5800	140643.4	242.5
Pipe Throughput	12440	40775.2	32.8
Pipe-based Context Switching	4000	7452.1	18.6
Process Creation	126	1177.4	93.4
System Call Overhead	15000	986973.3	658
System Benchmarks Index Score	137.8		

TABLE IV
UNIXBENCH FOR XEN

System Benchmarks Index Values	Baseline	Result	Index
Dhrystone 2 using register variables	116700	26366570	2259.3
Double-Precision Whetstone	55	3294.7	599
Execl Throughput	43	1328.6	309
File Copy 1024 bufsize 2000 maxblocks	3960	304156.8	768.1
File Copy 256 bufsize 500 maxblocks	1655	82718.2	499.8
File Copy 4096 bufsize 8000 maxblocks	5800	678869.9	1170.5
Pipe Throughput	12440	483750.5	388.9
Pipe-based Context Switching	4000	61750.9	154.4
Process Creation	126	2799.9	222.2
System Call Overhead	15000	502553	335
System Benchmarks Index Score	516		

E. Performance test for Windows Server 2008 on VirtualBox

The determining of the performance of a virtual machine with Windows Server 2008 is implemented by PassMark PerformanceTest 7.0 [10]. Different tests are done: performance of the CPU (Fig.3), a test of memory read / write (Fig.4) and input-output operations of the virtual HDD (Fig.5).

Fig.3 CPU performance test on VirtualBox

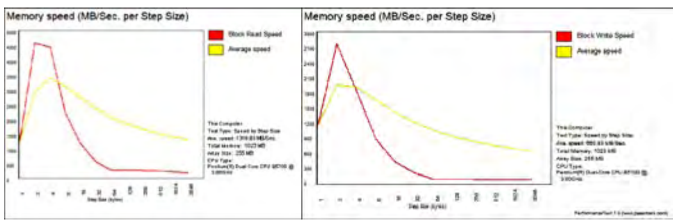

Fig.4 Memory read/write test on VirtualBox

The test includes integer math operations, floating point operations, multimedia instruction, compression, encryption, sorting strings, SSE, 3DNow instructions. Based on the results of each test an overall assessment of the CPU is formed.

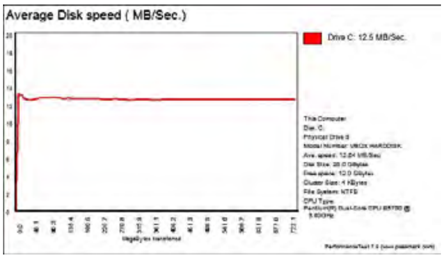

Fig.5 Virtual HDD test on VirtualBox

E. Performance test for Windows Server 2008 on Xen

Similar test are made on Xen hypervisor platform (Fig.6-8).

Fig.6 CPU performance test on Xen

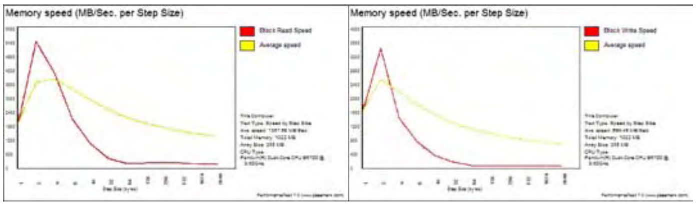

Fig.7 Memory read/write test on Xen

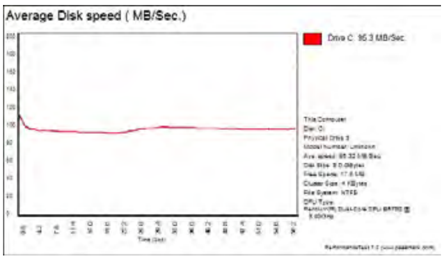

Fig.8 Virtual HDD test on Xen

F. Summary results

In Tables V and VI are shown the summarized results from the tests. The curves have similar shapes indicating that both platforms have similar mechanisms of resource management.

The analysis of the performance of virtual machines on both platforms showed that Xen platform has better indicators than VirtualBox. On this basis it can be concluded that virtualization platform Xen hypervisor is a more suitable choice for the building of virtual networking laboratory on the existing infrastructure in University.

TABLE V
SUMMARY RESULTS FOR LINUX VM

System Benchmarks Index Values	Xen	Virtual Box
Dhrystone 2 using register variables	2259.3	1102.9
Double-Precision Whetstone	599	427.5
Execl Throughput	309	114
File Copy 1024 bufsize 2000 maxblocks	768.1	94.7
File Copy 256 bufsize 500 maxblocks	499.8	57.7
File Copy 4096 bufsize 8000 maxblocks	1170.5	242.5
Pipe Throughput	388.9	32.8
Pipe-based Context Switching	154.4	18.6
Process Creation	222.2	93.4
System Call Overhead	335	658
System Benchmarks Index Score	**516**	**137.8**

TABLE VI
SUMMARY RESULTS FOR WINDOWS SERVER 2008 VM

Tests	Xen	Virtual Box
CPU	1021.8	984.6
Read	1367.68 MB/s	1318.83 MB/s
Write	699.45 MB/s	660.83 MB/s
HDD transfer	95.32 MB/s	12.54 MB/s

V. CONCLUSION

This paper provides an introduction to virtualization technologies and discusses the use of such platforms to build a virtual networking laboratory. Using desktop virtualization enables efficient use of available computers in the labs, thus reducing the cost of infrastructure but saving the performance. The experiments show that the choice of Xen hypervisor satisfies the requirements for virtual infrastructure. Goal of future work is actually building a virtual network laboratory and examine the implementation of virtualization to improve the quality of education at the university. The work will improve the university teaching methodology, will bring new learning techniques and will enrich the experience of both students and lecturers.

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