# Virtualization as a Teaching Tool for IT-based Courses

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*Abstract:* - Nowadays, the virtualization technologies are more and more often used in many informatics areas. They are applied for better utilization of existing hardware or software resources, servers' consolidation and for security reasons as well. This article shows the possibility of the virtualization technology usage also in the academic environment as a support of laboratory exercises of two academic courses. The case study is based on the idea of virtualization of the physical computer for lower costs and security reasons. The VMware products are used nowadays in our university and the article want to show other, especially free, alternatives to this commercial product like VirtualBox, Microsoft Virtual PC, XEN etc. Described approaches and techniques can be applied to many others similar subjects, not only in these two courses.

*Key-Words:* - Virtualization, VMware, VirtualBox, XEN, Virtual PC, VNC, NoMachine NX server, Paravirtualization, Operating systems

## 1 Introduction

Virtualization has big boom nowadays because of several benefits which are discussed below. But virtualization technique is not a new thing; the beginning of this tool in computer science can be found in 1960s when IBM researches in Cambridge Scientific Center working closely with researches in Lincoln Laboratory introduce operating system CP-40 which was used for virtualization on IBM mainframe computers S/360 [1].

But briefly, what the virtualization is? Virtualization, in general, is an abstraction layer that decouples the physical hardware from the operating system to deliver greater IT resource utilization and flexibility.

Virtualization allows multiple virtual machines (VM), with heterogeneous operating systems to run in isolation, side-by-side on the same physical machine. Each virtual machine has its own set of virtual hardware (e.g., RAM, CPU, NIC, etc.) upon which an operating system and applications are loaded. The operating system sees a consistent, normalized set of hardware regardless of the actual physical hardware components [2].

There are many ways how to provide the virtualized environment. An emulation of the underlying raw hardware can be used (so called Type 1 a 2 hypervisors [3]) as well as some form of paravirtualization [4].

Hypervisor could be understand as a virtualization platform which runs different operating systems in the same time on one host operating system (OS). On the other hand, paravirtualization is special virtualization technique, which recompiles host OS prior to the installation inside the virtual machine [5].

This article doesn't deal with technological background of various virtualization technologies from the hardware point of view, but is aimed to their software implementation and usage area mainly in the teaching environment.

The use of virtualization or similar teaching tools like emulation [6], online tests [7], multimedia tools [8] etc. is not new in the academic field but we can say that it is very popular especially in the e-learning tools [9].

So, let's focus on the advantages which the virtualization brings to the informatics (especially in the academic environment) area. This article describes virtual HW/SW environment used as the support of parallel applications development training [10] and a teaching tool for teaching of a operating systems basics.

## 2 The Fields of Usage

Virtualization has many fields to apply. Starting with simple demonstrative examples, advertisements, etc. through the training

applications for teaching purposes for several not only computer-oriented courses in universities to the complex virtual machines in industry, training kits for NASA etc.

The main advantage of the virtualization in general is that it could rapidly reduce cost and dangerousness of the experiments.

Virtualization could be generally used for simulation of the other OS, totally different from the host OS without deleting host OS, or adding a new OS to another partition or new physical hard drive which is big advantage for people who are worried about installing new OS without competent skills. Most of the software for virtualization runs as a window with virtual OS inside the host OS. There is no need to reboot computer to get another OS.

Another big field of usage is for the companies which host Internet services. They can have one server with numbers of co called dedicated servers for rent. There is no need to have numbers of physical servers which reduces cost rapidly too. Another benefit could be found in the easily portability of the VM to another – just copy the image file of the virtual machine which is usually one big file with a few small configuration files to the new hard disk and VM could run again. Security is another advantage of the solution [11].

Bug, viruses and worms testing uses virtualization as important tool too. Security is very important aspect of development and the risk of computer virus infection can be reduced with the use of VM for testing.

This paper will present the use of virtualization from another point of view – as a teaching tool in two courses in Tomas Bata University in Zlin – Parallel Programming and Operating Systems.

## 2.1 The Use in the Parallel Programming Course

The study course Parallel Programming is mandatory subject for all students in the summer term of the first year in master-degree studies of the Information technologies study branch, study program called Engineering informatics.
Imagine a situation when students are learning various programming techniques dealing with algorithm parallelization and distributed computing.

One of the most important parts of the learning curve is the verification of the obtained knowledge in the real conditions, so it is obvious that students should test their parallel application on the real parallel computation system. Assume that the students are learning the programming techniques suitable for SMP parallel computers with the shared memory architecture (generally all presently

shipped multi-core desktop computers, workstations, servers and notebooks). One of the possible ways how to do this is to provide each student with one multi-core computer. It is obvious that this solution is not ideal – the multi-core computer are still quite expensive, moreover, the utilization of their computing power and other hardware resources (RAM, disk space, etc.) can be poor in this scenario. So, what solution provides efficient learning conditions as well as the most effective hardware and software utilization?

The solution of the situation described above is to usage of one multi-core computer with high number of CPUs/cores and sufficient amount of the RAM and other HW resources. This system can be then partitioned into several virtual parallel machines sharing the underlying hardware running on the host machine. To achieve this, some form of hypervisor monitor must run on the host machine (the currently available hypervisor monitors differs mainly in the way how they manage the virtualized HW and whether they run on the top of the host OS or on the "bare metal").

The first one is shown on the Figure 1. In this scenario, the hypervisor monitor runs directly on the hardware which is partitioned into several independent virtual machines where each of those is configured as two-processor computer with adequate amount of assigned physical system memory.
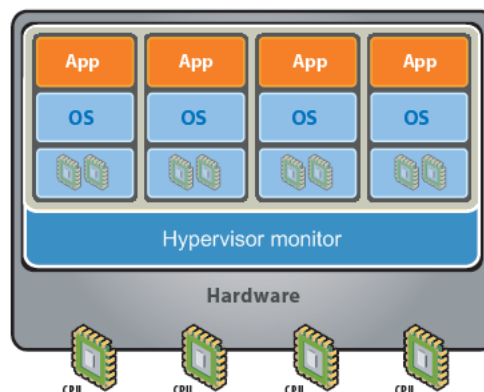


Fig. 1 Virtualized environment without host OS

The second possible configuration shown in the Figure 2 differs from the first one in the sense that the hypervisor monitor doesn't run directly on the virtualized hardware, but on the top of any supported OS. This scenario is suitable for a situation when the underlying hardware is not directly supported by the hypervisor so some other suitable OS must be used for managing it and the

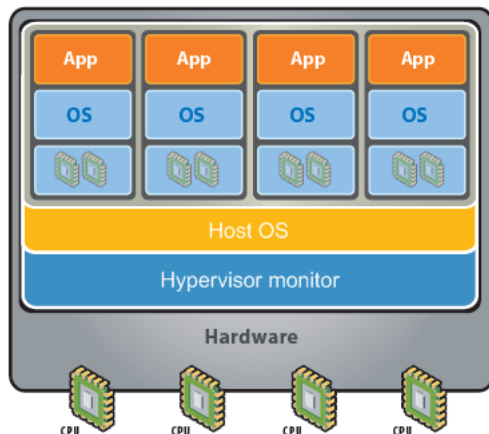hypervisor uses the virtualized HW via the host OS's device drivers.



Fig. 2 Virtualized environment with host OS

## 2.2 The Use in Operating Systems Course

In common offices the number of people accessing one desktop PC, workstation or notebook is limited. In contrast, in academic environment, especially in the case of computer used by the students the amount of the users is simply great. Moreover, often is very difficult (sometimes impossible) to watch all students' activities performed on the workstations. It is obvious that this fact can quite often lead to corruption of PC's operation system integrity and necessity to reinstall whole OS all software equipment. This is much more critical in the Operating Systems course, where we expect students to modify system configuration which could corrupt system and lead to reinstall of the system.

In this situation the virtualization technology can very significantly simplify a software administrator's life.

On reason is that the virtual machine (VM) is completely separated from the host environment (OS). Operational memory and VM's file system are fully virtualized via a file system of the host OS (similarly to classic swap files) so potential virus' attack or crash of the guest OS cannot involve the host OS.

Moreover, it is very simple to backup whole virtual machine (including its configuration, OS and installed software applications) thus any necessary reinstallation can be quickly done by simple rewriting of the damaged VM by the archived image.

The last great advantage of the VM is that it could emulate several types of OS independently on

the host OS – e.g. you can run Linux on Windows Vista host OS without restart etc.

The operating system course is in our university part of the second year bachelor study in winter term for students of study programme Engineering informatics, study branches Automatic control and informatics and Information technologies.

## 2.3 The Use as a Virtual Server

The third possible and currently used field of usage of the virtualization in the academic environment is the use of virtual server for hosting of the student web presentations or generally server-based projects. This could be done for example with the use of VMware server or XEN. Both possibilities will be discussed later.

# 3   Software for VM

There are several suitable software which can be used for Virtualization. The article on Wikipedia which compares Virtual Machines [12] cite the most known 61 of them.

There are several ways how we can divide virtualization software. The first division is from the usage. We can find 5 different types of virtualizations from this point of view [13].

In the first one, so called *emulation*, is hardware fully virtualized by the software. Advantages can be found in absolutely separated virtualized OS from the host OS, it can run applications which does not have supported hardware available and host OS cannot be modified. Disadvantage of this method is that it is very slow and very system-demanding. Typical members of this group are simulators of old computers (ZX Spectrum, Atari etc.), operating systems (DOSBox, DOSEMU etc.) and special tools like Bochs, QEMU etc.

The second group of software is focused on the *virtualization on the operating system level*. This solution has much better performance results with low processor load. Kernel of the host system is shared with the virtualized OS which could be a disadvantage sometimes. This type of virtualization can be found for example in Linux-VServer, Virtuozzo and FreeBSD Jail.

Special type of virtualization is *application virtualization* [14] where virtualization offers only basic components needed for running of hosted OS by encapsulating them from the underlying operating system on which they are executed. This technique offers portability and manageability of applications which are originally used only for one OS.

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| Name | Host OS | Virtualized OS | Method of operation | USB/GUI | 3D acceleration | Licence |
|---|---|---|---|---|---|---|
| Bochs | Win,Lin,Mac | DOS,Win,Lin | emulation | partially/yes | no | GPL |
| DOSBox | Win,Lin,Mac | MS-DOS | emulation | partially/yes | no | GPL |
| QEMU | Win,Lin,Mac | Win,Lin,Mac | emulation | yes/yes | no | GPL |
| Linux-Vserver | Lin | Lin | virt. on OS level | - | - | GPL |
| Virtuozzo | Win,Lin | Win,Lin | virt. on OS level | yes/yes | no | proprietary |
| XEN | FreeBSD,Lin | Lin,Solaris,Win | paravirtualization | no/partially | partially | GPL |
| VirtualPC | Win,Mac | Win,Lin | native virtual. | yes/yes | no | proprietary/GPL |
| VMware | Win,Lin,Mac | Win,Lin,Mac | native virtual. | yes/yes | yes | proprietary/GPL |
| VirtualBox | Win,Lin,Mac | Win,Lin,Mac | native virtual. | yes/yes | partially | GPL |

Table 1 Comparison of different types of virtualized software

Application emulation is well known for Linux users which uses Wine for running Windows applications on their Linux hosts. Another often used tool from this group is Java Virtual Machine.

*Paravirtualization*, as it is mentioned above, is virtualization technique which offers software interface for VM that is similar but not identical to that of the underlying hardware [4]. Big advantage is that this type of virtualization offers high performance. On the other hand, processors without direct support of the virtualization need modification of the kernel. Direct supports of the virtualization have only CPU Pacifica from AMD and Vanderpool from Intel respectively. Virtualization software XEN is based on the paravirtualization.

The last type of the virtualization is called *Native virtualization* [15] where only necessary part of the hardware is virtualized for run of the virtualized OS. This type of virtualization is used in the VMware, VirtualBox of VirtualPC which are discussed lately. Kernel of the system does not need to be modified but the high processor load and the virtualized OS must be dedicated to the same CPU as host OS.

This was the general division of the virtualization software from the type of virtualization point of view. The next difference can be found in tools which they support – USB support, 3D acceleration, Graphical User Interface (GUI) and of course price in the meaning of licence.

This paper is focused mainly on two members of them – VMware and VirtualBox. The reason why we choose these two is that they have all good features (USB support, GUI, installers for Windows and Linux OS etc.). The first one is already used in both courses, the second one is its freeware alternative.

### 3.1 VMware

The virtualization software VMware [2] is product of the American software company VMware, Inc. which is global leader on the virtualization software. This company was founded in 1998 in California. Their virtualization desktop software runs on computers with Microsoft Windows, Linux or Mac OS X. VMware has in their portfolio server solution too – VMware ESX Server.

Desktop products are provided in three main versions. The first *VMware Workstation* provides all features – create and run multiple virtual machines, take snapshots and videos of virtual machines, clone virtual machines, USB 2.0 support etc. It could run on Windows and Linux hosts. Users of MacIntel platform can use all these features in *VMware Fusion*.

The main disadvantage is that these versions are commercial but you can try it for 30 days for free. This disadvantage could be overcome with the third desktop product – *VMware player* which is freeware but the main feature is that you can only run VM which means that images of these VM must be previously created commercial VMware products.

VMware server products has two main leaders – commercial *VMware ESX server* which is included in the main VMware product – VMware Infrastructure 3. ESX server runs on server hardware without any other operating system which has benefit mainly from the costs point of view – you do not need any other licenses for running your own server. On the other hand, the freeware alternative, *VMware server*, runs the host OS. VMware server do not support FireWire, 3D acceleration and more than 3-button mouse [2] which are only small limitation despite the fact that it is freeware. This product has three main parts: Server part runs as a server on host OS and provides run of the VM. Management interface offers basic management through the web browser. The third

part, client console, is strong management tool which communicates with the VM through the TCP/IP protocol. This property offers to install the server part on the powerful server and manage it through the client installed on the notebook. Other advantages can be found in easy creating and managing of the VM and variety of emulated virtualized software. Files exchange only through the TCP/IP protocol.

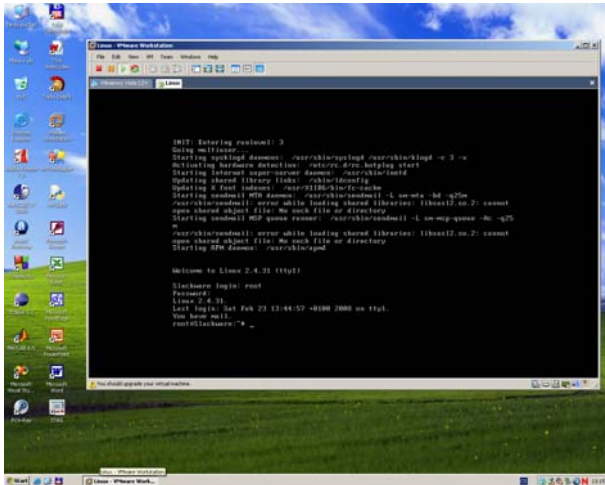Figure 3 shows running VMware workstation with Slackware Linux in hosting Windows XP OS.



Fig. 3 VMware Workstation – Slackware Linux in host OS Windows XP

The reason why the VMware products are mentioned on the first place is that our university has license for VMware Workstation and uses it in the Operating systems courses. Students have images of various discussed OS on their disposal which make the management of the courses easy especially from the system administrator point of view.

### 3.2 VirtualBox
Disadvantage of the solution with VMware workstation is that students can use only created images by the teacher at home on the freeware VMware player. The option of the own image-creating is not included in Player which limits the use at home.

This limitation should be overcome with the use of VMware server, which is free of charge too and offers creation of new VMs.

The second option is the use of VirtualBox [16] which was developed by the German software company Innotek in 2007 and it was acquired by the Sun Microsystems in February 2008. This virtualization software is distributed under licenses

Personal Use and Evaluation License (PUEL) used for free for personal or education use or evaluation of the software and Open Source Edition (OSE) which is released under the free license GNU General Public License. The OSE version is fully functional as the PUEL version but the following features are missing: Remote Desktop Protocol, USB support and iSCSI support for virtual discs. However, our academic environment meets all requirements for GNU/GPL which offers possibility to use full-featured PUEL version.

The display of Win XP running in the VirtualBox inside the Kubuntu Linux as a host OS is displayed in Figure 4.



Fig. 4 VirtualBox – Windows XP in host OS Kubuntu Linux

VirtualBox supports 64-bit VM (only on 64-bit hosts), USB support, remote desktop (RDP) client for Windows VM, seamless mode, shared folders over host and guest VM, Graphical User Interface (GUI) is localized in numbers of languages etc.

Big advantage can be found in fact, that VirtualBox supports VMware virtual machine disc format (VMDF) and Microsoft Virtual Hard Disk (VHD) format which is used in competitive software VMware of VirtualPC. It means that VirtualBox can run virtual disk created in both of these programs.

### 3.3 Microsoft Virtual PC
If we want to find a freeware alternative to the commercial product VMware workstation we cannot omit virtualization software from the giant Microsoft – Virtual PC. This software was originally invented and developed by the Connectix which has sold it to Microsoft in February 2003. Microsoft had released Virtual PC as a freeware in

July 2006 which makes it more accessible for general public users.

Advantage of this product is that it has big support for the Windows-based host OS. This strict policy of only Windows OS support is well known for all Microsoft products and, especially in this case, it could be assess as a big disadvantage.

The last version of the virtualization program Virtual PC 2007 is used for Windows XP, Vista both 32-bit and 64-bit versions and Windows Server 2003 and 2008 and virtualizes to the most common used Windows versions from Windows 98 SE to Windows Vista but you can use older version Virtual PC 2004 for running of MS-DOS 6.22 and Windows 95 as a VM. Virtual PC can run theoretically Linux VM too, but this feature is not officially supported.

Microsoft has released version for the Mac OS X too, but this software is used mainly for the emulation.

### 3.4 XEN

The third VMware alternative here is XEN [17] which belongs to the paravirtualization class of emulation software. The evolution of XEN starts as a project on University of Cambridge Computer Laboratory. The development of the software is managed by the XEN community nowadays under the licence GNU/GPL.

The main difference from to the previously mentioned software is that XEN works as a hypervisor which is boots before the kernel of the OS and the task of the hypervisor is to manage I/O ports and memory control. The OS which boots first in the hypervisor is host OS and it provides management tools for the VMs.

Installation of XEN needs modification of the host OS kernel which makes the installation a bit harder than in previous cases. This modification is not necessary for computers which have processor offering direct virtualization as it is written above – Pacifica from AMD and Vanderpool from Intel [11]. These computers than can run XEN on Windows as a host OS. In other cases the host OS is Linux because Windows does not offer the modification of the kernel.

Advantage of the solution with XEN is that paravirtualization offers better performance results over the normal virtualization.

XEN may also be used on personal computers that run Linux but also have Windows installed. Traditionally such systems are used in a dual boot setup but with XEN it is possible to start Windows "in a window" from within Linux effectively

running applications from both systems at the same time.

Virtualization package XEN is included in some well-known Linux distributions, e.g. Debian, RedHat, SUSE etc. and our "home" Faculty of Applied Informatics uses XEN for virtual hosts servers *http://zamestnanci.fai.utb.cz* and *http://studenti.fai.utb.cz.*

### 3.5 Other VM software

Of course, there exist numbers of other suitable possibilities that can be used as a teaching tool of the virtualization, but in my opinion, software mentioned in the list mentioned above are leaders in the computer virtualization field.

## 4  Performance Tests

The previous chapter discussed various types of virtualization software mainly from the price and usage point of view.

On the other hand, final decision of the optimal choice could be affected by results of the performance tests. However, we do not have chance to compare these products because both Operating systems and Parallel programming courses uses VMware Workstation as a teaching tool but there some results of benchmark test were published previously.

The first tests [13] are focused on the comparison of the different computation tasks on native OS, Microsoft Virtual PC, VMware server on Windows and Linux host OS and finally XEN. Results are shown in Tables 2, 3 and 4 and Figures 5 to 10.

|  | Native OS | VMware on Win | Virtual PC | VMware on Lin |
|---|---|---|---|---|
| The 10001 factorial | 0.177s | 0.194s | 0.196s | 0.177s |
| First 30000 prime numbers | 0.198s | 0.210s | 0.248s | 0.189s |
| The 9x9 matrix determinant | 0.129s | 0.143s | 0.157s | 0.132s |
| The 200x200 inverse matrix | 0.180s | 0.188s | 0.206s | 0.175s |
| The 250x250 matrixes multiplication | 0.222s | 0.242s | 0.307s | 0.231s |
| **Total time** | **0.906s** | **0.977s** | **1.114s** | **0.904s** |

Table 2 Computation time of mathematical operations on different types of virtualization software

This test compares native in the meaning of host OS with four possibilities of VM. As it can be seen from Table 2 and mainly from the Figures 5 and 6, the best computation time is achieved for VMware VM running on Linux environment. On the other hand, the worst results can be found for Virtual PC which is ported only for the Windows hosts which limits the results in this case.
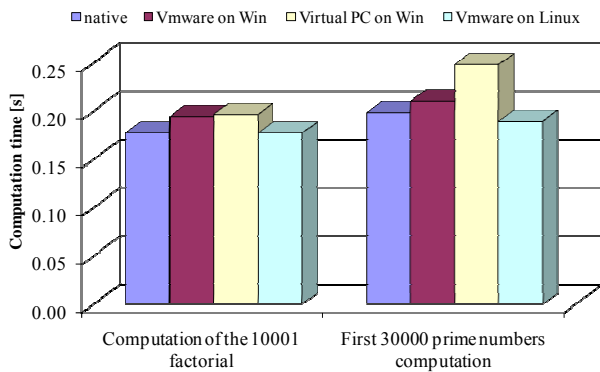


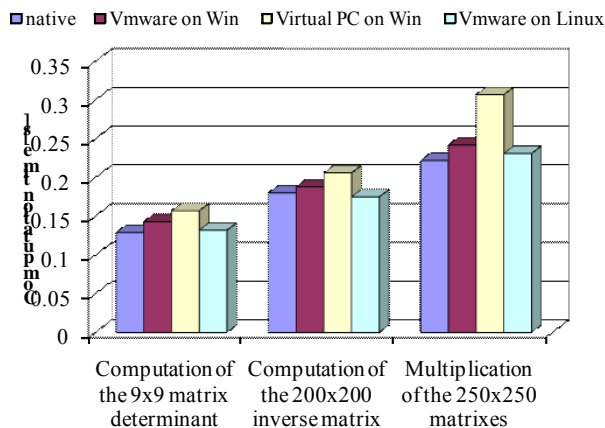Fig. 5 Computation time of the factorial and prime numbers for different virtual machines



Fig. 6 Computation time of matrix operations for different virtual machines

|  | Native OS | Vmware on Win | Virtual PC on Win | Vmware on Linux |
|---|---|---|---|---|
| Dhrystones | 929 | 847 | 804 | 941 |
| Whetstones | 694 | 677 | 626 | 697 |
| MIPS | 797 | 742 | 642 | 808 |
| MFLOPS | 837 | 884 | 725 | 832 |
| **Total points** | **3257** | **3150** | **2797** | **3278** |

Table 3 Results of the benchmark tests on different types of virtualization software

Results of benchmark tests shown in Figure 7 and Table 3 present again VMware as a winner of this test and as a Virtual PC defeated.
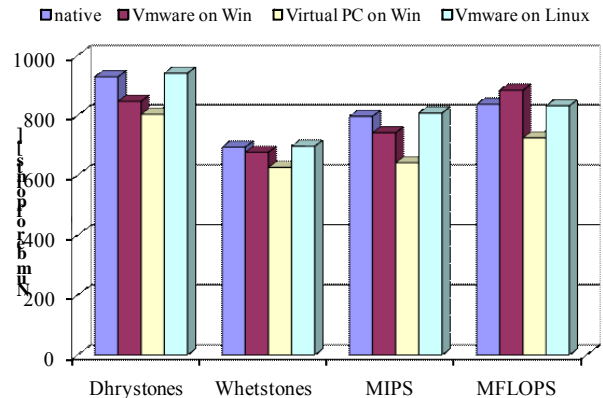


Fig. 7 Results of benchmark tests for different virtual machines

Performance tests presented in the last Table 4 and Figures 8, 9 and 10 are focused mainly on the speed of typical Linux operations like tar and gzip, copping, depiction of the points on the screen and typical mathematical operations. The basic set of VM presented in previous results are now fulfil by the results on the XEN because previous test run only in Windows and XEN is primary determined for Linux as it is mentioned above in previous chapter.

|  | Native OS | Vmware on Win | Virtual PC | Vmware on Lin | XEN |
|---|---|---|---|---|---|
| tar and gzip of the kernel | 00:28 | 01:00 | 01:17 | 00:42 | 00:28 |
| make bzImage | 05:00 | 10:09 | 12:01 | 07:45 | 05:02 |
| Copy of the file (packet=512 b) | 0.5s | 2s | 15s | 1s | 0.5s |
| Copy of the file (packet=10 b) | 3.2s | 6s | 135s | 4.6s | 3.3s |
| Symbol depiction on the screen | 2.5s | 17s | 13s | 13s | 2.6s |
| Mathematical computation | 6.5s | 10s | 15s | 7s | 6.6s |

Table 4 Computation time of Linux operations on different types of virtualization software

Unambiguous winner in this case is XEN, whose results are comparable with the host (native) OS which is very good. The second place could be reserved for VMware running on Linux followed by the same software on Windows and the last is again Virtual PC from Microsoft.

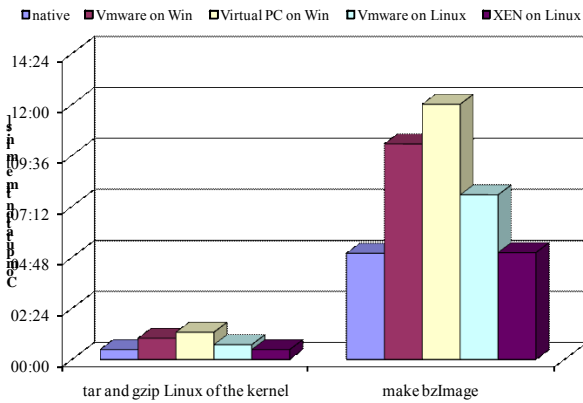Jiri Vojtesek, Michal Bliznak,
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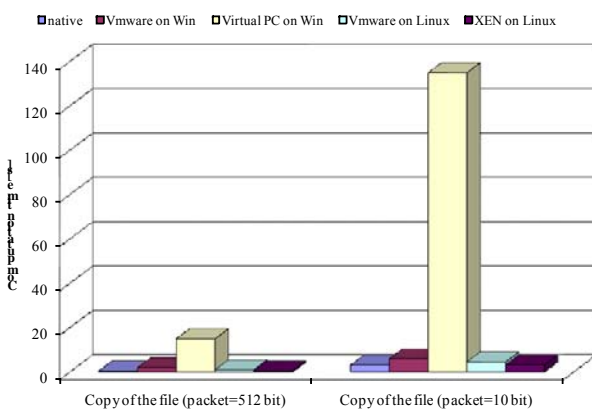Fig. 8 Computation time of Linux operations for different virtual machines



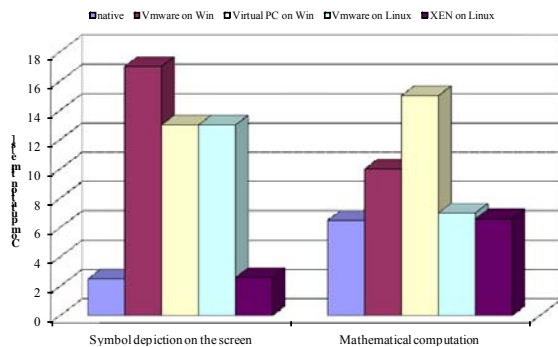Fig. 9 Computation time of copying for different virtual machines



Fig. 10 Computation time of symbol depiction and mathematical operations for different virtual machines

Chapter 3.2 shows Innotek's VirtualBox as a first big competitor of VMware products which are currently used in our university. Following table and figures compares two free VMware player and VirtualBox by the typical benchmark test of CPU, memory, harddisk and network [18]. The host computer runs on AMD Athlon(tm) XP 3000 CPU with 1024 MB of RAM and 160GB IDE hard disk. The guest OS is Windows 2000 and all benchmark tests are performed by the freeware tool FreshDiagnoze from the www.FreshDevices.com.

| | VirtualBox | Vmware player |
|---|---|---|
| **CPU:** | | |
| DhryStone ALU (MDIPS) | 5 716 | 5 711 |
| WhetStone FPU (MWIPS) | 4 189 | 4 401 |
| Multimedia Benchmark | 2 152 | 2 071 |
| **Memory:** | | |
| Integer Assignment | 13 074 | 12 502 |
| Real Assignment | 13 782 | 14 176 |
| Integer Split | 18 027 | 18 885 |
| Real Split | 17 555 | 18 407 |
| **Harddisk:** | | |
| Write Speed (MB/s) | 8.65 | 6.07 |
| Read Speed (MB/s) | 14.65 | 4.68 |
| **Network:** | | |
| Down Speed (MB/s) | 4.9 | 5.3 |
| Up Speed (MB/s) | 5.2 | 4.1 |

Table 5 Results of the benchmark tests for VirtualBox and VMware player
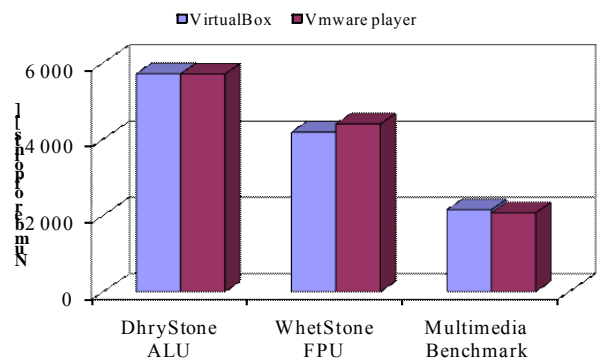


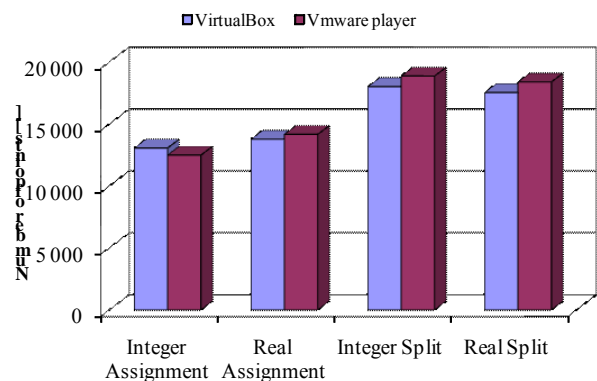Fig. 11 Results of the benchmark tests of CPU for VirtualBox and VMware player



Fig. 12 Results of the benchmark tests of the memory for VirtualBox and VMware player

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Figures have shown very similar results for both virtualization software products. The main difference can be found in the speed of reading and writing to the hard disk drive presented in the last Figure 13 where VirtualBox has significantly better results.
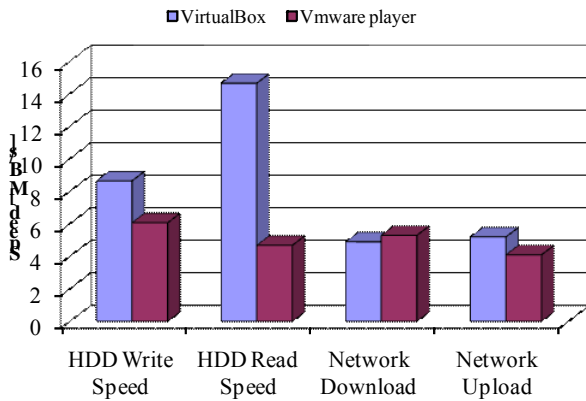


Fig. 13 Results of the speed benchmark tests of harddisk (HDD) and network for VirtualBox and VMware player

## 5 Accessing the virtual machines

A sure thing for running of the VM is remote availability for users. Not every VM can run locally on each computer but some of the training virtualized system can run on the server and students can access them through the internet without installing any special virtualization software.

This feature must be obvious from another point of view too. Imagine satiation when several VMs run on the same hardware and cannot be accessed through standard I/O interface (keyboard mouse LCD ...). In this case some form of terminal approach must be introduced – see Figure 14.

One possible solution is usage of native terminal technologies incorporated in the guest OS running on the VM – for example Remote Desktop (RDP) or Terminal Services in Microsoft Windows. For example RPD is fully supported in the last version of VirtualBox, which means that we can comfortably control virtualized Windows through the RDP even if the host OS is Linux.

The second possible way is usage of 3-rd party software solution providing remote access to the published OS desktop or application sets. In this case both of commercial and free/open source solutions are available. For the first mentioned distribution group the Citrix Metaframe Presentation Server can be good example.
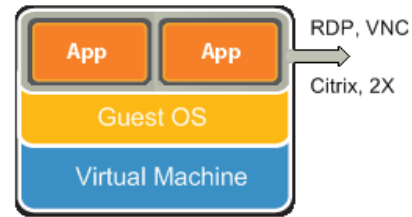


Fig. 14 Access to Virtual Machine

This robust, powerful but very expensive solution can be substituted by other adequate (and cheaper or even completely free) one for example by 2X Application Server [19] allowing publishing of application set as well as the desktop.

More simple solution is the use of VNC server which can publish the desktop only (but the configuration capabilities are more detailed than abilities of Microsoft RDP).

The second solution is the use of NoMachine NX server [20] which has one big advantage in encrypted connection according to simple VNC solution which could be easily hackable. Another advantage could be found in price – the freeware version is fully sufficient for basic remote control of the host OS.
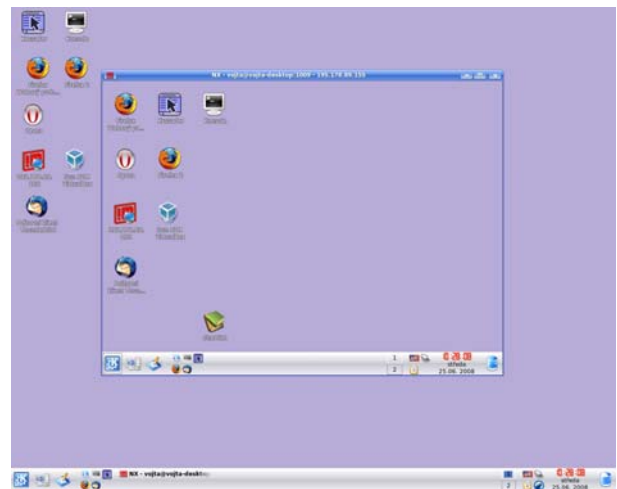


Fig. 6 Remote access with NoMachine NX client

## 5 Conclusion

The article has revealed that the presently spreading virtual technologies can positively involve not only infrastructure of the enterprise information systems but also academic e-Learning environments in two currently running courses in Tomas Bata University in Zlin Czech Republic – The parallel programming and Operating systems. It can be successfully used for better utilization of expensive hardware /

software resources and allows students to share hard achievable technical resources.

Moreover, usage of virtualized environments can decrease (not only) time expenses needed for administration of large amount of intensively and incontrollable used PC desktops and workstations.

One of the goals of this article to give an overview of the possible alternatives to currently used VMware products on our university to this commercial product.

The use of VirtualBox seems to be the best solution from the easy installation point of view. The performance tests presented here have shown similar or better performance results compare to the VMware player.

The best results are achieved for the virtualization software XEN mainly because it works on with the paravirtualization which works on different principal than ordinary native virtualization tools represented by the VMware and VirtualBox.

## Acknowledgements:

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