Analysis of Virtualization Tools for Education Purposes

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***Abstract*—The aim of this article is to compare virtualization platforms. Emphasis is focused on the performance parameters of different hosting and hosted operating systems. Firstly, the key benefits of virtualization are described. Then, selected virtualization platforms and major features of these platforms are introduced. Next, a methodology of testing and an overview of the selected tools for testing are introduced with the emphasis on the set of CPU test, RAM test, HDD test, etc. Finally, the results and comparison of the selected virtualization platforms based on the performed tests are described.**

***Index Terms*—Virtualization; Education; Tools; Comparison; Speed.**

I. INTRODUCTION

Nowadays, virtualization is an integral part of server operation [1] as it brings several benefits, such as consolidation of servers, simplification of server's administration, ease of server migration and lower operation cost of a server [2, 17]. Virtualization, a concept originated in the late sixties of the twentieth century, is a method that allows several physical entities to merge into a single virtual unit or to treat a single physical entity as multiple logical entities [3]. Virtualization can be made at different layers, including hardware virtualization, virtualization of architecture, operating system's kernel virtualization or application virtualization [4, 5]. Virtualization is defined as a technology that creates a virtual environment. This environment behaves as a completely independent physical computer [6, 7]. It allows a greater number of applications to run on a single physical machine, in which these applications are not mutually affected [8]. The reasons for using virtualization are such as the more effective use of available system resources, security, backup, testing and development [9, 10].

II. VIRTUALIZATION

The dispatcher called Virtual Machine Monitor (VMM), which has direct access to a computer's (hardware) physical resources, is the base element for enabling virtualization. VMM allocates individual resources to virtual machines. VMM is also called a hypervisor. There are two types of hypervisors. There arises the concept called a hosting operating system that runs directly on real hardware and it creates an environment for running the hosted operating system. A hosted operating system uses the resources of a hosting operating system for its operation. [11]

A. Benefits of virtualization

Consolidation: One of the biggest benefits of virtualization is a server´s consolidation. The idea is to convert existing physical systems into a virtual environment and run them all on a single physical machine. The average CPU load of a common server is around 15 percent; thus, the remaining 85 percent of power is wasted.

Backup: From the viewpoint of backup, files, which represent virtual machines can be easily duplicated and copied to another server. This helps avoid problems, when a physical server fails due to a malfunction or natural disaster and many others. A virtual machine can be easily backed up and restored. [12]

Isolation: The benefit of this isolation is that a failure of a single service or an entire virtual machine is not a risk for other virtual machines and their services. A service or an entire machine can be restarted or renewed after a failure, without affecting other virtual machines.

Testing: Virtualization is ideal for testing, thanks to isolation and easy duplication of virtual machines. It provides an option for installing, modifying or removing software or other modification of the system itself or a part of it. Administrators can easily create snapshots of virtual machines, which can be easily restored at any time.

Development: The testing is closely related to development. New software typically requires a functionality testing on different operating systems with different hardware and virtualization allows all of these features. We can easily create a database of various different systems, which serves as a test environment. Without virtualization, it would be necessary to purchase many different computers and software, thereby testing software physically on each of them needs to be done. In case of violation of the operating system, a difficult recovery needs to be done. If the virtualization is used, we can easily restore the previous snapshot. [12]

III. VIRTUALIZATION PRODUCTS

Oracle VM VirtualBox: VirtualBox is a multiplatform virtualization product from Oracle. It requires an operating system, which is installed on a physical hardware. Hypervisor is implemented as a core service for an operating system. Among the great advantages of this virtualization solution is the support of various systems, which can be installed, and support various operating systems that can be virtualized [4].

Hyper-V: Hyper-V is a virtualization solution from Microsoft. A license is required for operating systems that are virtualized. Hyper-V has a hybrid hypervisor, which is installed from Windows. However, it modifies the architecture of the operating system during installation and it becomes a separate layer on the physical hardware. Then, it behaves as a first type of hypervisor. Its installation is possible on 64-bits processors from x86-64 version of

Windows only. A hosted operating system can be 64-bit and 32-bit [13].

KVM: KVM (Kernel-based Virtual Machine) is a virtualization solution for Linux x86 and x86-64 architecture. The source codes of KVM are open-source, which greatly contributes to their safety because they are under permanent supervision of a large community of developers. Based on this, any security flaws are quickly identified and corrected. KVM meets all criteria of the first type of hypervisor [16].

Open-VZ: Open-VZ is a free and open-source virtualization solution for Linux systems. Individual instances of isolated operating systems are called containers, or even VPSs (Virtual Private Servers), or VEs (Virtual environments). OpenVZ uses a modified Linux kernel, which is shared by individual containers. Thus, it is a method of shared kernel virtualization, where the hypervisor is not used. An individual hosted system must have a support of kernel, in which a hosting operating system runs. For this reason, only operating systems like Linux can be hosted because they support the kernel. The biggest advantage is a minimum loss of performance [1].

LXC: LXC is very similar to OpenVZ. It is a container virtualization like OpenVZ. An individual container shares the kernel of the hosting system. LXC is distributed for free. LXC uses *cgroup* core functions that enable the restriction and prioritization of system resources. There is no need for pausing or restarting a container. LXC is a relatively new solution. The first stable release was released 20th of February, 2014. The following stable release was released on the 6th of April, 2014 [15].

VMware Workstation Player: VMware Workstation Player is a virtualization solution that uses a second type of hypervisor. Each virtual machine is fully isolated and, it is also protected and it encapsulates an operating system and installed applications, which includes a virtualization layer, and maps hardware resources to individual virtual machines [14].

IV. Methodology of Testing

A performance testing of various systems resources, such as CPU, RAM, HDD, NIC and GPU of selected virtualization solutions, was selected as a methodology of testing. We choose the multiplatform tests, which should ensure the relevance of the results. We selected the hosted operating systems as a group of operating systems, represented by both MS Windows and GNU/Linux.

To achieve a higher accuracy and a relevance of the tests results, each of the tests were executed twenty times for every single virtualization solution. The hosted operating system was restarted, between each set of tests. The restart was followed by at least a sixty-second pause to ensure a stabilization of the entire system. We selected the 64-bit version of desktop system Microsoft Windows 10 Pro and Ubuntu 16.04.1. Both of the systems were fully updated before performing the tests. Firstly, the tests were performed on systems that run directly on the hardware of hosting machine and then the tests were performed on all the variants of individual virtualization solutions.

A. Hardware of hosting machine

Hardware specification of the hosting machine is as follows:

- Processor: Intel Core i5-6500, 3,20GHz, turbo 3,60GHz, 32KB L1, 256KB L2 a 6MB L3 cache, IVT-x support, 4 cores, 4 threads
- Graphic card: Intel HD 530, 350MHz/1,05GHz
- RAM: Hynix/Hyundai 8GB, 2133MHZ, DDR4
- HDD: Seagate SATA, 500GB, 7200 RPM, 8MB cache
- NIC: Realtek 8111, Gigabit LAN

B. Virtual machine configuration

Four cores of the processor, 4GB RAM and 50 GB of disk space were allocated for all virtual machines. NTFS file system was used for Windows operating system and the default file system Ext4 was used for Ubuntu. All available updates and drivers were installed for each virtualization solution to improve the performance of the systems. Hardware assisted virtualization and para-virtualization drivers were used, if the virtualization solution allowed this option.

V. Performed Tests

The multiplatform testing tools were chosen for testing the virtualization solutions. These tools can be executed on both the Windows 10 Pro and the Linux distribution Ubuntu, so it was possible to obtain relevant results.

CPU test – Pi calculation: For the calculation of Pi, a tool called y-cruncher version 0.7.1 was used. This software used the Chudnovsky formula (or Chudnovsky algortithm), which was introduced in 1989. Y-cruncher allows us to select the number of processor cores to be used for calculation. The number Pi has been calculated to 100 million digits and the result is the time, in which Pi was calculated.

CPU test – GeekBench: The GeekBench (version 3.4.1) was the second testing tool for CPU performance analysis. It is a multiplatform tool from Primate Labs. It contains a group of tests that aim to simulate the normal load of the processor. GeekBench has its own performance evaluation system. The result is the score (points) for one core and for all cores. A higher score indicates a better performance.

HDD test – y-cruncher: To optimize a calculation, which a y-cruncher is able to perform, it also contains a tool, which tests the speed of sequential reading and writing to the disk. Y-cruncher allocates 90 percent of free RAM for this tool, in order to prevent distortion of results by writing to RAM instead of HDD. After that, it reads and writes a file to the HDD with a total size of about 20 GB. The test result is the speed of reading and writing to HDD in MB/s.

RAM test – RAMSpeed: RAMSpeed tool version 3.5.0 for Linux and version 1.1.1 for Windows was selected to test a RAM. Although the numbers of versions are different, it is the same tool, which has been released at the same time. It contains 18 different tests to test the memory speed. Two of them were chosen: operation with integers and operation with decimals. The conducted operations was copying, addition and multiplication. The result is the average speed of memory.

NIC test – iPerf: The iPerf tool, version 3.1.3 was used in order to test a network interface throughput. The iPerf server was started on a test virtual machine and a second virtual machine sent a request to measure the throughput. The size of data was set to 2GB. The result represents a transfer rate in

MB/s.

GPU test – Unigine: Graphic performance testing was conducted by using a free multiplatform benchmark from Unigine. Benchmark Valley version 1.0 was selected for testing. It is a benchmark, which includes 18 nature oriented graphical environment with automatically moving camera. The number of frames per second is measured, and according to them, the benchmark gives the score (points) at the end of the test. We design the same benchmark setting for testing individual virtual machines, namely the resolution 640x480, low level of texture quality, turned off antialiasing, disabled 3D and OpenGl rendering.

VI. TEST RESULTS

The obtained results of individual tests are summarized in the following section. For better clarity, the results are shown in the form of a boxplot chart that provides a suitable way on how to depict statistical data. The legend, which is displayed in the left side of the figures, is in the shape of a hosting operating system, virtualization solution and hosted operating system.

A. CPU test – Pi calculation

The first results are the results of Pi calculation. Figure 1 depicts those results. The first place is shared by LXC container virtualization and native Ubuntu system. The KVM and Hyper-V solution with hosted OS Windows were faster than the native Windows. The differences between these solutions are very small. The bigger differences were recorded for the VMware virtualization solution, especially if the hosted system was Ubuntu. The big drop was seen in the VirtualBox solution, which needed about twice as long to calculate the Pi number and the processor utilization reached 100 percent of capacity. Smaller capacity utilization was recorded only in VirtualBox and VMware, where the hosting and hosted system was Ubuntu. Hyper-V with the Ubuntu hosted system had similar results. Processor utilization for these three solutions was about 80 percent.

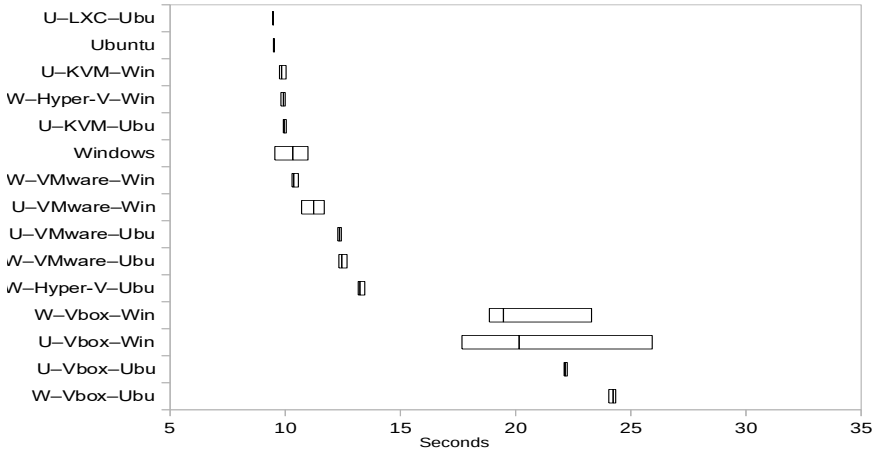

Figure 1: Pi calculation

B. CPU test – GeekBench

Other interesting results are in the CPU test with GeekBench tool. Figure 2 depicts that in the first place, there is again a VirtualBox solution with hosted and hosting system Ubuntu. Hosted Ubuntu in VMware on Windows, native Ubuntu, LCX container virtualization and hosted Ubuntu in VirtualBox on Windows are all very close to the first place with small differences. The results of hosted Ubuntu system were better than the hosted Windows system. Only Ubuntu that was hosted by Hyper-V, was ranked in the last place with 11 percent performance difference compared to the first solution. Processor utilization of all the solutions was ranked between 30% and 70%. It is caused by the way the GeekBench works. The testing consists of several small jobs.

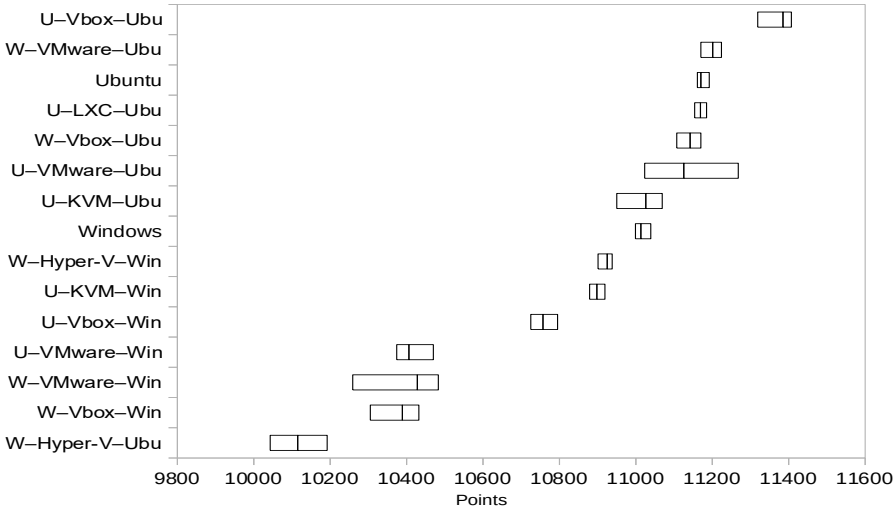

Figure 2: CPU test

C. HDD tests

Y–cruncher writing is the test results of writing the data to the disk. The best result was achieved by the native Windows, which is followed by the hosted Ubuntu with KVM, but with relatively huge difference. Figure 3 depicts these results. A small difference was seen between the VMware with hosted and hosting system Ubuntu and container virtualization LXC. The next solution is the KVM with hosted Windows, VMware on Windows with hosted Ubuntu and Hyper-V with hosted Ubuntu and Windows. The worst result was achieved in all variants using the VirtualBox The difference in performance between the first and the last place is about 35 percent. Processor utilization in most virtualization solutions ranged up to 5 percent. The higher loads was recorded up to 20 percent for the hosting, which hosted operating system Ubuntu in the VirtualBox only.

Y–cruncher reading involves the test results of reading the data from the disk with y-cruncher tool. The best result was achieved by native Windows, while the next was KVM on Ubuntu and then, surprisingly, the VirtualBox with hosting and hosted Ubuntu. The fourth to seven place was occupied by Windows on KVM, VirtualBox on Ubuntu with hosted Windows and LCX. The bigger difference was in VMware on Windows with the hosted Linux and in Hyper-V. The worst result was achieved by the VMware on Ubuntu with the hosted Windows. Virtualized Windows was able to read the data from the disk only a tenth of the rate, compared to native Windows. Figure 4 depicts those results, in which the highest CPU load reached up to 20 percent by the VirtualBox. Other solutions show up to 3 percent of processor utilization.

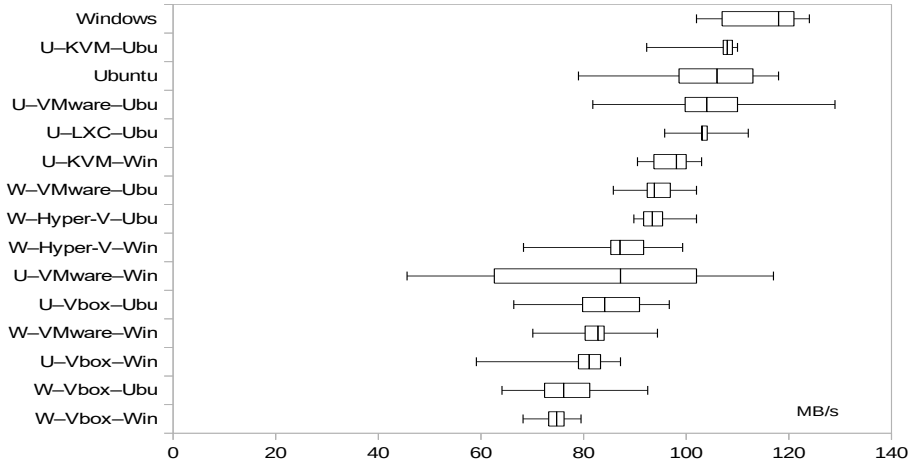

Figure 3: HDD writing test

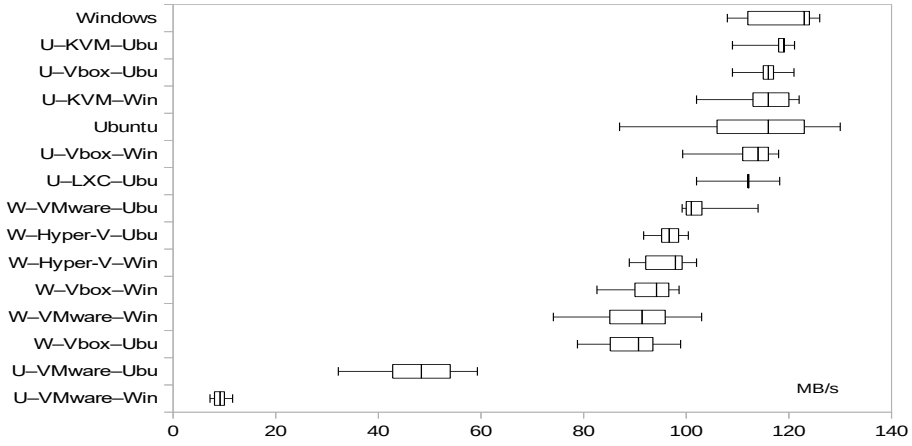

Figure 4: HDD reading test

D. RAM test – RAM speed

Figure 5 depicts the obtained result of the RAM test, which is very interesting. VirtualBox with the hosted and hosting system Ubuntu has the best results. The WMware with hosted Ubuntu was in the second place, followed by the native Windows, KVM with hosted Windows, VirtualBox on Windows with hosted Ubuntu, container LXC and native Ubuntu. The worst results with huge differences were shown by KVM with hosted Ubuntu and Hyper-V with hosted Ubuntu. The difference between the first and last place is less than 18 percent. The native Windows that utilized the CPU load showed up to 25 percent. On the other hand, the native Ubuntu utilized the CPU achieved up to 50 percent. The hosted Windows utilized the CPU load achieved up to 30 percent and hosted Ubuntu achieved up to 65 percent. The VMware and VirtualBox were the solutions that utilized most of the CPU load.

E. NIC test – iPerf

In the test of network throughput, the first six virtualization solutions reached very similar results with minor deviations only. They are LXC, native Ubuntu, native Windows, VMware on Windows with hosted Ubuntu, VirtualBox with hosting Windows and hosted Ubuntu, and VMware with

hosting and hosted Windows. The difference in performance of these solutions is less than 1 percent, followed closely is VirtualBox with Ubuntu running on the same system and both variants of Hyper-V and KVM. The worst, which is with large variance is achieved by VMware running on Ubuntu and VirtualBox, where the hosting system is different from the hosted system. Figure 6 depicts those results.

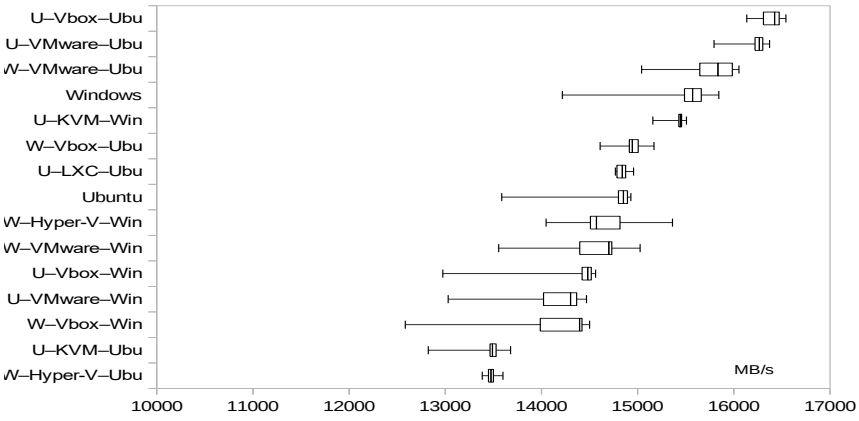

Figure 5: RAM speed test

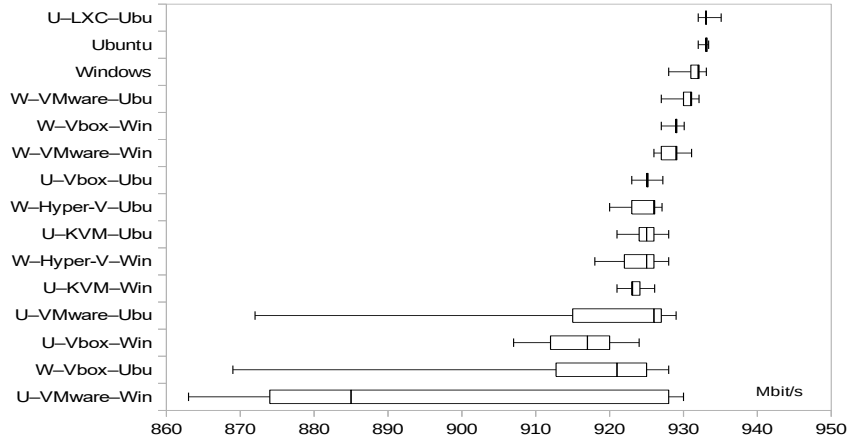

Figure 6: NIC throughput test

F. GPU test – Unigine

The last obtained results are the graphic card performance tests. Figure 7 depicts those results. The best results were achieved by the native Windows, which reached around 2600 rating points and the processor utilization was only around 17 percent. In the second place, there was the native Ubuntu, which reached around 1300 rating points and the processor utilization up to 30%. In comparison with the others, the WMware on Windows with hosted Windows had a good score of 205 points on average. It is less than a tenth of the performance compared to the native Windows. CPU utilization was about 40%. Other virtualization solution is reached nearly the same rating. Based on this, we can say that all the calculations were performed by CPU but not by graphic card.

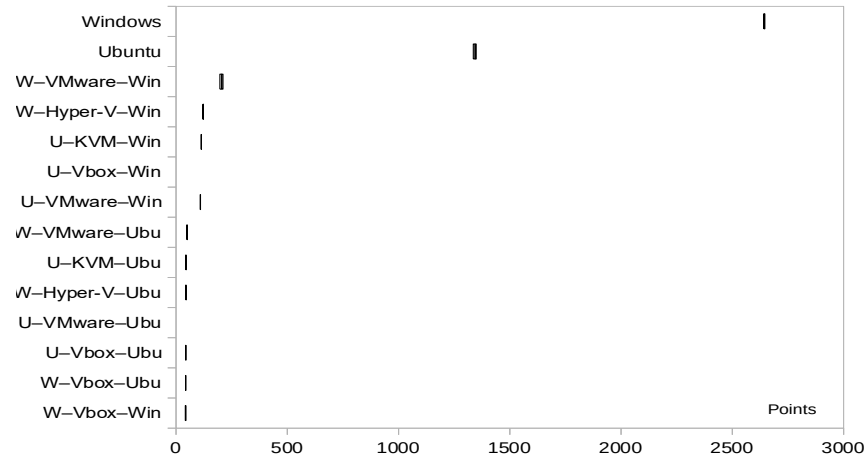

Figure 7: GPU test

VII. CONCLUSION

The aim of this paper was to analyze the tools for virtualization. For this purpose, the virtualization solutions from many different providers were compared. Several multiplatform tests were used for comparison. They were focused on speed tests of CPU, HDD, RAM, NIC and GPU. Based on the obtained results, we can say, that if the operating system Windows is used as a hosting system and hosted systems are Windows and Linux, it is recommended to use a Hyper-V virtualization solution from Microsoft. It reached stable results with both hosted operating systems. Hyper-V CPU loaded for disk and network tests was less, with comparison with VirtualBox and VMware. Hyper-V is available only in Windows 10 Pro version. If this version is not available, then the other suitable solution is VMware. However, the significant difference is not with the use of VirtualBox. All of these three solutions have easy management of virtual machines. The container solution LXC is the best solution for hosting and hosted Linux systems. Its performance in conducted tests was the same or even better than the native Ubuntu. But its administration is more complex and its utilization is recommended for server systems rather than desktop systems. KVM shows as the best virtualization solution for education purposes. Its results were good and stable in all conducted tests. Its management and creation of virtual machines is very simple. It also allows us to virtualize both Linux systems and systems from Microsoft.

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