UDC 374.2

VIRTUALIZATION AND WINDOWS SERVER 2012

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Purpose. Comparison solutions for creating virtual machines aimed to run operating system Windows Server 2012 R2, their main features and performance. **Methodology.** We have applied experiments comparing several most popular virtualization tools through which virtual machines run operating system Windows Server 2012 R2. We measured performance of created virtual machines, such as CPU test, disk performance test, memory and 2D graphics test, which allowed us to range performance of tested virtual tools. **Results.** We have created virtual machines using following virtualization tools: Microsoft Hyper-V, VMWare Workstation, Oracle VritualBox. Also, we tested performance of physical machine running tested operation system. We provided performance measurements using NovaBench and PassMark software bundles. We provided two-phases experiment: firstly we measured the overall system performance using NovaBench software to get the basic insight on performance. Secondly, using PassMark Performance Test software we measured CPU performance, Memory performance, Disk performance and 2D Graphics performance. As expected, the physical machine was the most powerful among the all machines. Among the virtual machines, the best overall score received Hyper-V which appears to be the most effective virtualization tools for virtualizing the Windows Server 2012 R2. **Originality.** For the first time, we have carried out the integrated research on operation of different virtualization tools for running operating system on the example of Windows Server 2012 R2 operating system. **Practical value.** Research results could be used during construction virtual system aiming to achieve their best performance. References 19, tables 20, figures 5.

Key words: virtualization, Windows Server 2012, Benchmark, VMWare , Oracle, Microsoft.

СТВОРЕННЯ ВІРТУАЛЬНОГО СЕРЕДОВИЩА ТА WINDOWS SERVER 2012

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Роботу присвячено питанню порівняння ефективності роботи засобів створення віртуального середовища на прикладі роботи операційної системи Windows Server 2012. Проаналізовано робочі параметри низки розповсюджених засобів побудови віртуального середовища, призначених для створення віртуальних машин, на прикладі створення віртуальних машин для роботи обраної операційної системи. При проведенні експерименту, за допомогою спеціалізованих програмних засобів проведення еталонних тестів, вимірювались параметри продуктивності віртуальних машин, такі як швидкодія роботи центрального процесора, швидкодія роботи оперативної пам'яті, швидкодія виконання дискових операцій, продуктивність роботи двовимірної графічної системи, та оцінювався найбільш ефективний засіб створення віртуального середовища серед аналізованих у експерименті.

Ключові слова: віртуальне середовище, Windows Server 2012, еталонний тест, VMWare , Oracle, Microsoft.

PROBLEM STATEMENT. Since 1970s, the virtualization has been a subject of intensive research and attention. With a constant growth of its popularity, the virtualization has been already deployed almost in all areas of IT industry. Undeniable advantages and significant benefits make the virtualization even more attractive beside its initial purpose. The main benefits such as consolidation and cost saving make virtualization being preferred before other solutions. Virtualization is now widely used in the IT industry for multiple specific purposes. Therefore, there exist several types and forms of virtualization itself. One of the most popular types is a server virtualization, which is a part of the main focus of this article.

A term virtualization itself is very general and abstract term. However, in principle, virtualization means to recreate virtual version of something. In practice, virtualization is used for creating virtual resources or devices, such as operating system, server, desktop client, storage or even applications or networks. Definition according to [1]: "Virtualization as a framework or methodology of dividing the resources of a computer into multiple execution environments, by applying one or more concepts or technologies such as hardware and software partitioning, time-sharing , partial or complete machine simulation, emulation, quality of service, and many others".

EXPERIMENTAL PART AND RESULTS OBTAINED. *Terminology in virtualization*. In order to understand relationships within virtualization, it is necessary to denote the most used, fundamental terms. Definitions according to [2].

Host Machine: "A host machine is the physical machine running the virtualization software. It contains the physical resources, such as memory, hard disk space, and CPU, and other resources, such as network access, that the virtual machines utilize".

Host OS: "A host OS (operating system) is the first OS installed on a machine to enable a machine to support multiple virtual operating systems. The host OS accesses the physical machine's resources, such as its physical memory and processor speed, and allocates those resources to virtual OS's as needed".

Virtualization Software / Tools: "Virtualization

software is a generic term denoting software that allows a user to run virtual machines on a host machine".

Virtual Machine: "The virtual machine is the virtualized representation of a physical machine that is run and maintained by the virtualization software. Each virtual machine, implemented as a single file or a small collection of files in a single folder on the host system, behaves as if it is running on an individual, physical, non-virtualized PC".

Guest OS: "A guest OS is an operating system that runs in a virtual environment. A guest OS may be a client desktop, physical server or any other operating system that runs independently of dedicated hardware resources. Instead, the guest OS uses hardware resources allocated dynamically through a hypervisor or similar intermediary software".

Hypervisor or Virtual Machine Manager: "A hypervisor also called a virtual machine manager (VMM), which is a program that allows multiple operating systems to share a single hardware host. Each operating system appears to have the host's processor, memory, and other resources all to itself. The task of this hypervisor is to handle resource and memory allocation for the virtual machines, ensuring they cannot disrupt each other, in addition to providing interfaces for higher level administration and monitoring tools".

Advantages of virtualization. There are several reasons for implementing virtualization in the enterprise environment listed below:

Sandboxing: Virtual machines run within isolated – sandbox – environment. This way the potentially dangerous application cannot jeopardize the host OS by any harmful actions.

Running cross-platform applications: Virtualization allows running an OS with different kernel than the kernel of the host OS. This means, for example, that it is possible to run Linux-based OS within virtual machine while the host OS is Windows-based. Therefore, the applications that would not be possible to be executed within Windows-based OS can run flawlessly on VM running Linux.

Virtual hardware: Virtualization tools allow to set up a virtual machine specific hardware configuration, according to the actual need.

Easy backup and restore: Virtual machines store their data in virtual hard drives. Virtual hard drives are made of a single or sometimes multiple files. Therefore, it is easy to back up the hard drive image and restore it when necessary.

Cost Saving: This is major and most considered benefit. Consolidation of hardware, i.e. using less physical machines for multiple purposes reflects in lower total cost. This is due to reducing cost for hardware, lesser power consumption and costs for maintenance.

Consolidation: The main idea of consolidation is unifying workloads into fewer or single physical machine running several virtual environments. This leads to better utilization of resources and hardware and lesser power consumption. Reducing the amount of physical platforms also decreases time and needs for maintenance as well as space.

Hypervisors. Hypervisor, or sometimes also called virtual machine monitor, is the core of the virtualization. It forms a layer between host operating system and computer hardware. There are three types of hypervisors.

Type I: Bare-Metal Hypervisor

This type of hypervisor is loaded directly on physical hardware. It means that there is no host operating system running below it and the hypervisor behaves like an operating system itself. Main advantage of the type I is direct control of a hardware.

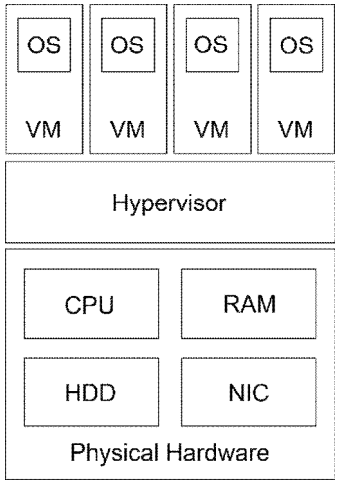

Figure 1 – Architecture of Type I Hypervisor interface

Type II: Hosted Hypervisor

Hypervisor of the type II is loaded in an OS running on the physical hardware. It is installed and run as any other normal application. An operating system running within type II hypervisor is called guest operating system. They are powerful and do not require replacing current OS running on the physical machine.

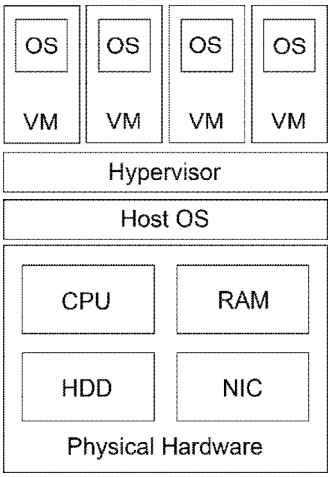

Figure 2 – Architecture of Type II Hypervisor

Monolithic Hypervisor

This type of hypervisor hosts and manages hypervisor-aware drivers for all hardware it accesses. All guest operating systems interact with the underlying physical hardware directly via hypervisor-aware device drives. This means that monolithic hypervisor does not need a parent operating system.

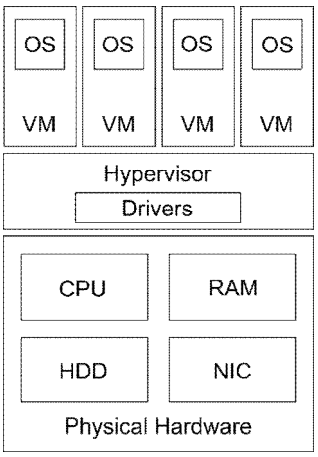

Figure 3 – Architecture of Monolithic Hypervisor

Benchmark-performans measurements. The main goal of the experiment is to measure the overall performance of virtualization tools used for virtualization and to determine which of them is the most efficient to use. The measurements are done via running a benchmark test on each virtual machine running Windows Server 2012 R2. The benchmark results of virtual machines are compared with the benchmark results of the physical machine running the same operating system.

The experiment is performed on a physical machine, a PC configured to run Microsoft Windows Server 2012 R2 as a primary system. The hardware specification of the physical computer is:

Motherboard: Gigabyte Z97-HD3
CPU: Intel Core i5 4460 @ 3.20 GHz, Quad Core
RAM: 8GB Dual-Channel DDR3 @ 666 MHz / 4GB DDR3 during benchmark test
GPU: nVidia GeForce 260GTX 896MB
HDD: Seagate Barracuda 320GB 7200rpm
Optical Drive: LG DVDRAM GH22NS40

Virtual machines configuration reflect the configuration of the physical computer in terms of CPU and RAM. Each machine is configured with 1 CPU / 4 Cores and 4GB RAM. Virtual GPU is specific per each hypervisor. HDD is configured with 20 GB of storage space. Each virtual machine can access the optical drive.

All virtualization tools used for the experiment contain Type II hypervisor. Type I hypervisor was not possible to test due to incompatibility with the physical computer hardware. Virtualization tools which run the tested virtual machines are Microsoft Hyper-V, VMWare Workstation Pro and Oracle VirtualBox.

Performance measurements are done via benchmarking software. The experiment uses NovaBench and PassMark software bundles. The experiment has two phases. The first phase measures the overall system performance to get the basic insight on performance. This phase is done via NovaBench software. NovaBench measures the performance of the physical machine and three virtual machines created in Hyper-V, Workstation and VirtualBox. Test has been run 10 times per each machine.

The second phase measurements are more complex. They have been performed via PassMark Performance Test software. PassMark Performance Test contains several test categories - CPU Mark, Memory Mark, Disk Mark, 2D Graphics Test and 3D Graphics Test. The last one however was not performed since this test is irrelevant in this case. Each testing category contains several tests. This makes this benchmarking more relevant and accurate. PassMark tests have been performed 5 times and the average score has been calculated from the obtained results.

Benchmark results. Machines was the physical one, as expected. Among the virtual machines, the Hyper-V won over the Workstation and VirtualBox respectively. Hyper-V showed its dominance in memory, disk and 2D graphics tests. The CPU test was however not successful for Hyper-V. VirtualBox and Workstation managed to get a better results.

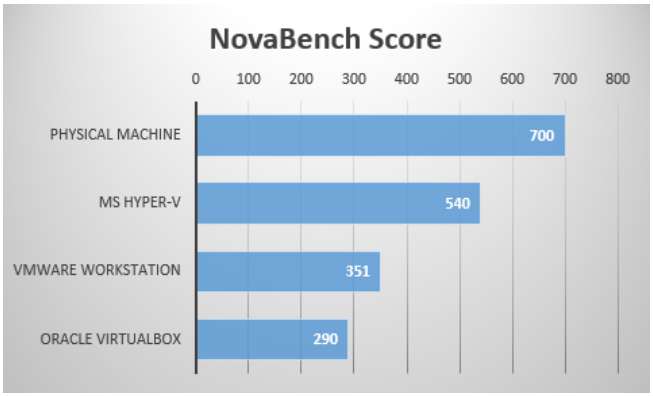

Figure 4 – NovaBench Results

In NovaBench, the physical machine scored 700 points. The second most powerful ended VM in Microsoft Hyper-V with 540 points. Virtual machine running in VMWare Workstation finished with score 351 and VM running in Oracle VirtualBox got 290 points.

Fig. 5 shows the overall results of all machines per each testing category. In CPU Mark, the physical machine (blue) scored 6421.4 points. Hyper-V (orange) scored 4737.3 points. Workstation (grey) reached 5887.8 points and VirtualBox (yellow) obtained 6128.5 points. In Disk Mark test, the physical machine scored 855.4 points, Hyper-V scored 641.3 points, Workstation scored 447.8 points and VirtualBox scored 317.3 points. In Memory Mark, the physical machine

scored 2160.0 points, Hyper-V scored 1778.1 points, Workstation scored 1357.7 points and VirtualBox scored 1496.1 points. The last test measured the performance of the 2D graphics. The results are following. Physical machine scored 709.3 points, Hyper-V scored 382.9 points, Workstation scored 237.7 point and the virtual machine run within the VirtualBox scored 79.2 points.

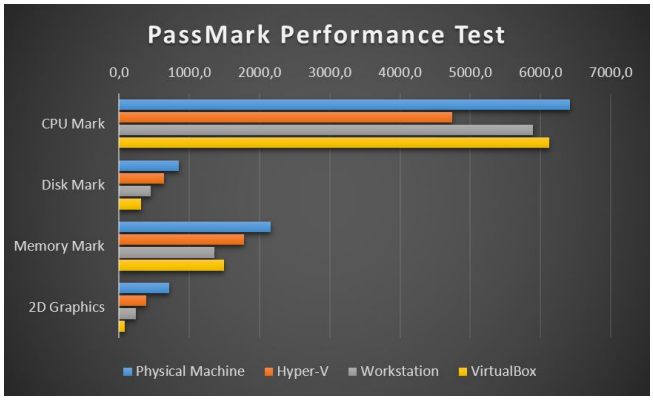

Figure 5 – PassMark Results

Benchmark results – Tables. In previous chapter average values are presented. Every Nova Benchmark test was performed at least 10 times. Results of specific tests are presented in following tables:

Table 1 – NovaBench – Physical Machine

Attempt	*Score*
1	701
2	697
3	702
4	700
5	695
6	699
7	700
8	699
9	700
10	705
Average	*700*

Table 2 – NovaBench – Hyper-V

Attempt	*Score*
1	505
2	329
3	345
4	335
5	335
6	319
7	324
8	337
9	342
10	339
Average	*351*

Table 3 – NovaBench – Workstation

Attempt	*Score*
1	505
2	329
3	345
4	335
5	335
6	319
7	324
8	337
9	342
10	339
Average	*351*

Table 4 – NovaBench – VirtualBox

Attempt	*Score*
1	313
2	296
3	313
4	258
5	287
6	254
7	299
8	305
9	289
10	284
Average	*290*

PassMark tests result group various tests in specific categories - marks: CPU Mark, Disk Mark, Memory Mark and 2D Graphics. Result for specific category is calculated from partial results. Results of partial tests of every category are presented in following tables:

Physical Machine:

Table 5 – PassMark – CPU Mark results – Physical Machine

CPU Mark	*Average Score*
Integer Math	7652.2
Floating Point	6845.3
Prime Numbers	30.2
Extended Instructions	22.0
Compression	7446.1
Encryption	1224.7
Physics	421.7
Sorting	5085.4
Single Thread	1777.9
Overall	6421.4

Table 6 – PassMark – Disk Mark results – Physical Machine

Disk Mark	*Average Score*
Sequential Read	115.8
Sequential Write	113.4
Random Seek + RW	7.4
Overall	855.4

Table 7 – PassMark – Memory Mark results – Physical Machine

Memory Mark	*Average Score*
Database Operation	77.8
Read Cached	23049.9
Read Uncached	13413.4
Write	8363.6
Available RAM	3294.3
Latency	28.1
Threaded	18847.4
Overall	2160

Table 8 – PassMark – 2D Graphics test results – Physical Machine

2D Graphics Test	*Average Score*
Simple Vectors	16.3
Complex Vectors	148.3
Fonts and Text	227.4
Windows Interface	159.7
Image Filters	834.7
Image Rendering	825.6
Direct 2D	24.5
Overall	709.3

Hyper-V:

Table 9 – PassMark – CPU Mark results – Hyper-V

CPU Mark	*Average Score*
Integer Math	5397.9
Floating Point	4735.1
Prime Numbers	23.5
Extended Instructions	15.5
Compression	5228.1
Encryption	871.5
Physics	323.3
Sorting	3903.0
Single Thread	1529.4
Overall	4737.3

Table 10 – PassMark – Disk Mark – Hyper-V

Disk Mark	*Average Score*
Sequential Read	82.3
Sequential Write	88.3
Random Seek + RW	6.8
Overall	641.3

Table 11 – PassMark – Memory Mark – Hyper-V

Memory Mark	*Average Score*
Database Operation	49.9
Read Cached	23683.4
Read Uncached	13194.7
Write	8471.9
Available RAM	3291.9
Latency	30.5
Threaded	18666.5
Overall	1778.1

Table 12 – PassMark – 2D Graphics test – Hyper-V

2D Graphics Test	*Average Score*
Simple Vectors	17.1
Complex Vectors	73.1
Fonts and Text	97.5
Windows Interface	69.8
Image Filters	777.3
Image Rendering	597.5
Direct 2D	7.6
Overall	382.9

Workstation:

Table 13 – PassMark – CPU Mark results – Workstation

CPU Mark	*Average Score*
Integer Math	7634.0
Floating Point	6789.5
Prime Numbers	28.7
Extended Instructions	21.9
Compression	7416.9
Encryption	1219.6
Physics	404.5
Sorting	5053.2
Single Thread	1071.1
Overall	5887.8

Table 14 – PassMark – Disk Mark results – Workstation

Disk Mark	*Average Score*
Sequential Read	68.4
Sequential Write	48.4
Random Seek + RW	7.2
Overall	447.8

Table 15 – PassMark – Memory Mark – Workstation

Memory Mark	*Average Score*
Database Operation	33.9
Read Cached	15046.0
Read Uncached	8479.5
Write	6447.6
Available RAM	3294.3
Latency	35.8
Threaded	18421.1
Overall	1357.7

Table 16 – PassMark – 2D Graphics test results – Workstation

2D Graphics Test	*Average Score*
Simple Vectors	12.5
Complex Vectors	41.5
Fonts and Text	52.3
Windows Interface	32.5
Image Filters	341.2
Image Rendering	239.8
Direct 2D	7.8
Overall	237.7

VirtualBox:

Table 17 – PassMark – CPU Mark results – VirtualBox

CPU Mark	*Average Score*
Integer Math	7552.7
Floating Point	6732.9
Prime Numbers	27.9
Extended Instructions	21.6
Compression	7350.5
Encryption	1203.3
Physics	400.5
Sorting	5011.0
Single Thread	1464.4
Overall	6128.5

Table 18 – PassMark – Disk Mark results – VirtualBox

Disk Mark	*Average Score*
Sequential Read	58.2
Sequential Write	22.6
Random Seek + RW	6.9
Overall	317.3

Table 19 – PassMark – Memory Mark results – VirtualBox

Memory Mark	*Average Score*
Database Operation	39.1
Read Cached	16530.1
Read Uncached	9523.5
Write	7711.7
Available RAM	3391.1
Latency	31.6
Threaded	18222.4
Overall	1496.1

Table 20 – PassMark – 2D Graphics test results – VirtualBox

2D Graphics Test	*Average Score*
Simple Vectors	8.2
Complex Vectors	19.8
Fonts and Text	10.9
Windows Interface	7.2
Image Filters	234.3
Image Rendering	98.6
Direct 2D	3.0
Overall	79.2

CONCLUSIONS. The experiment was based on measuring the performance of several virtualization tools through which the virtual machines running the operating system Windows Server 2012 R2 were created. According to the expectations, the physical machine was the most powerful among the all machines. Among the virtual machines, the best overall score received Hyper-V which appears to be the most effective virtualization tools for virtualizing the Windows Server 2012 R2. Second best score among virtual machines belongs to the VMWare Workstation. It showed an excellent processing power and solid performance in other tests. The VirtualBox finished last one mainly due to poor 2D performance. However, it is still worth to be used for virtualization. In certain CPU tests, the VirtualBox excelled with surprising score. To make a final conclusion, all virtualization tools are more than satisfactory. For virtualization specific system such as Windows Server 2012 R2 is the Hyper-V the most reasonable choice. With the other systems, such as Linux-based systems, the other virtualization may be even more effective. This, however, is a subject for a different topic.

ACKNOWLEDGEMENT.

We support research activities in Slovakia / Project is co-financed from EU funds. This paper was developed within the Project "Centre of Excellence of the Integrated Research & Exploitation the Advanced Materials and Technologies in the Automotive Electronics ", ITMS 26220120055

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СОЗДАНИЕ ВИРТУАЛЬНОЙ СРЕДЫ И WINDOWS SERVER 2012

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Рассматривается вопрос сравнения эффективности работы средств создания виртуальной среды на примере работы операционной системы Windows Server 2012. Выполнен анализ рабочих параметров ряда распространённых средств построения виртуальной среды, предназначенных для создания виртуальных машин, на примере создания виртуальных машин для работы выбранной операционной системы. При проведении эксперимента, при помощи специализированных программных средств проведения эталонных тестов, измерялись параметры продуктивности виртуальных машин, такие как быстродействие работы центрального процессора, быстродействие работы оперативной памяти, быстродействие выполнения дисковых операций, продуктивность работы двумерной графической системы, и оценивалось наиболее эффективное средство создания виртуальной среды среди проанализированных в эксперименте.

Ключевые слова: виртуальная среда, Windows Server 2012, эталонный тест, VMWare, Oracle, Microsoft.

Стаття надійшла 28.02.2017.