ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome IX [2016] , Fascicule 2 [April – June]
ISSN: 2067 – 3809

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PERFORMANCE ANALYSIS OF SERVER SYSTEM VIRTUALIZATION IMPLEMENTED USING HYPER-V HYPERVISOR

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Abstract: This paper considers and describes possibilities for server system virtualization, methods of virtualization and performance of virtualized server systems. A special accent is given to the use of Microsoft Hyper-V hypervisor as a server virtualization technology, its architecture and practical implementation of server system virtualization using that technology. Performance of implemented virtualized server system is analyzed in details and compared with non-virtualized server system solution. Advantages of this type of virtualization are shown and listed in details. Disadvantages, with emphasis on usual performance decrease of virtualized server systems, are also pointed out. Results of detailed analysis and comparison of performance of virtualized and standard server systems are shown in the paper.
Keywords: Server Virtualization; Virtualization tools; Hyper-V hypervisor; Server performance

INTRODUCTION

The term server virtualization refers to the abstraction or masking of physical server resources that would logically look different than they are physically. It gives the ability to system administrators to relocate and adjust load of the machines. Briefly, the term abstraction of machines implies a set of technologies that perform abstraction of the entire physical system or server, and ensures that all its resources are integrated and shared. Such abstraction of machine performs a logical abstraction and isolation of the operating system and applications from the hardware [1].

There are several studies dedicated to the performance of virtualized systems. Most of those researches have been conducted in order to determine impact on I/O workload and networking performance [2-4], as well as general research of the impact of virtual machines and host configuration on performance [5-7]. In this paper, performance is analysed for CPU, RAM memory and HDD, for the operation of multiple virtual machines running on a single host server using a Microsoft operating system and hipervisor Hyper-V.

SERVER VIRTUALIZATION TECNOLOGIES

There are many software manufacturers who offer products for server virtualization. Tendency of increasing usage and the level of development of virtualization as a platform are constantly increasing. The products with the highest percentage of presence are of several virtualization software manufacturers, while the influence of others can almost be neglected. TechTarget's "2013 Data Center and Reader's Choice" survey may be cited to support that fact [8]. For years, as was confirmed by the study, the largest percentage of companies that are introduced into the server virtualization rely on VMware technologies. In addition to VMware Microsoft Windows Server 2012 R2 and Hyper-V have a significant percentage of practical participation. They are followed by Citrix Zen [8, 9].

However, in recent years with the new versions of Hyper-V technology, Microsoft has made significant progress and therefore it has become more present in companies that are introducing server virtualization. This can be confirmed by comparing the above research with data TechTarget's research from 2010 of „intent for purchase and introduction of virtualization software". According to that survey, at the time, VMware had 76% usage share and Microsoft had only 13% [10]. In addition to the fact that companies opted exactly for this technology, it is important to keep in mind specifications that are required to support hypervisor [10].

When it comes to the choice of technology which is being used for virtualization of server systems it is of highest importance to consider the hypervisor characteristics and simplicity of use. Hypervisor that takes up less space reduces the surface on which external attacks can happen, also being easier to maintain because it requires less software "patches", and therefore the security and stability of work of the data centers is increased [10]. Installation on the host hardware, configuration, management and upgrades are also less complicated. Any error or vulnerability of parent operating system directly affects the hypervisor, even if it is in a component that is not directly related to virtualization. Therefore, it is important that the security settings are installed directly on the hypervisor, which directly protects virtual machines and entire virtualization technology. It is important to choose the technology that provides the largest selection in terms of hardware and applicative components, technology that is not only vertically organized and which offers a choice and expansion, high availability, support for hardware and applications, and also provides a high level of utilization of hardware.

MICROSOFT HYPER-V HYPERVISOR

Hyper-V hypervisor is available in two versions: standalone free version called Microsoft Hyper-V Server which includes full Hyper-V functionality, and an optional feature installed with Windows Server. Hyper-V is free, but Windows Server must be paid for. System Center Virtual Machine Manager (SCVMM) can be purchased as an add-on. It supports the creation of large virtual data centers with multiple physical servers and a large number of virtual machines [10, 11].

The hypervisor for server virtualization Microsoft Hyper-V Server allows to consolidate loads helping organizations improve server utilization and reduce costs. Hyper-V is a dedicated, standalone product that contains hypervisor, Windows Server driver model and virtualization capabilities. Hyper-V Server leaves a small footprint, and requires minimal costs. Organizations that do not want a new license for Windows Server operating system or who only perform server consolidation using an alternative operating system also introduced Hyper-V server. In contrast, Windows Server is recommended for organizations whose required virtualization rights are flexible and cost-effective. Virtualization Rights for Windows Server are enabled by purchasing the required versions of the software. Windows Server Datacenter version provides unlimited virtual instances [12].

Figure 1 shows architecture of Hyper-V. The installation of Windows Server and other necessary drivers is required to enable Hyper-V. It is therefore thought that Hyper-V has to work on the operating system. When you enable the Hyper-V option, it is installed "under" operating system to run directly on the hardware, on the ring of the processor. At this point, Windows Server installation is known as the Management OS [13].

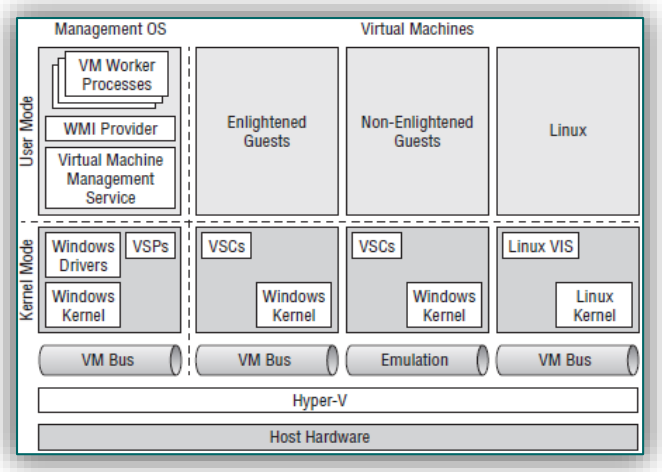

Figure 1. Hyper-V hypervisor architecture [13]

The current version of Hyper-V is included in Windows Server 2012R2, however Windows Server 2016 should be released by the end of the year 2016. Currently, Windows server 2016 is in a technical preview stage, but main capabilities of Hyper-V for Windows server 2016 are already available in Hyper-V for Windows 10 operating system. These features include many improvements of Virtual machines and Hyper-V manager, as well as the posibility of using a Hyper-V cluster with mixed Hyper-V version, nested virtualization and many other features [14].

SERVER VIRTUALIZATION ADVANTAGES AND DISADVANTAGES

Key benefits of this virtualized infrastructure can be divided as follows [1]: server consolidation (reducing the number of physical servers, reducing the power and cooling expenses for data center, reducing the complexity of entire IT infrastructure), business continuity and disaster recovery, development and test systems, dynamic data center. In addition to the above, the introduction of virtualization server system provides reliable and cost effective system for disaster recovery and provides a high resistance to failure of physical infrastructure, and thus the reliability of the entire IT infrastructure. With this approach, total cost can be reduced and the deployment speed (flexibility) can be increased significantly compared to non-virtualized systems.

There are also some disadvantages and potential problems in working with virtualized servers. Some of the disadvantages are [9]: single point of system failure; need for better hardware performance; system performance may decrease; additional

training for personnel to work with new tools. Potential problem with single point of system failure is connected with the possibility of system failure and it can be eliminated by using two servers functioning redundantly in a cluster. The need for better hardware performance as the second potential problem comes from running multiple virtual machines on a single server which needs hardware that has significantly better performance than individual servers. However, the fact that a single server attaches several machines, leads to reduction in the required number of physical machines. System performance may decrease since virtualizing hardware can cause severe performance degradation. Additional training for personnel is needed since virtualization adds a number of tools for system manipulation and it is necessary to train administrators to use these tools.

PERFORMANCE ANALYSIS AND COMPARISON OF VIRTUALIZED AND NON-VIRTUALIZED SERVER

Hyper-V is a technology which is rapidly evolving, and it comes as a part of the Windows operating system, both on the server and desktop versions. In this way, the cost of virtualization are reduced for small and medium companies whose business relies on information systems. In this paper, for practical implementation and for performance analysis of virtualization server systems were used Hyper-V virtualization tools. Guest operating system was Microsoft Windows 10.

Performance analysis of the host non-virtualized server and virtualized server machine virtualized using Microsoft Hyper-V Server was performed by performance monitor tool - PassMark Performance Test version 8.0. Server with the configuration shown in Table 1 was used for the practical implementation and performance testing.

In a real environment, several virtual machines operate on one host server. Any of them are not aware whether the other virtual machines are present or are they in a working state. In this case, four virtual machines were running. All of them are dedicated to the different purposes: application, database, backup, reporting. This means that they are executing specific jobs and they are not multipurpose machines. Virtual machine on which the performance is tested is a database virtual machine with Microsoft SQL server 2012 installed. The goal was that the configuration at the host has the approximate performance as the configuration of virtual machine. Virtual machine is on the host on which the performance is analyzed. The host has four CPU cores, and virtual machine has four virtual processors. Maximum RAM memory size that this virtual machine can take up is 8 GB. Disk space on same SSD disk is set to 60 GB.

Table 1. Host computer configuration

Component	Host	Database Virtual machine
CPU	CPU Intel Core i7-4790 @ 3.6 GHz, 8 MB Cache, 4 Cores	4 Virtual CPU
RAM memory	16GB SDRAM 1600MHz PC3-12800 DDR3 HyperX	4 GB Virtual memory, max memory 8 GB
Hard Drive	Samsung SSD 850 EVO 250GB	60 GB Virtual disc

Performance analysis results of the most important components of the system are shown in Figure 2. The blue color shows results for performance of host server and the red represents benchmark performance of virtual machine. The results are expressed in points and are given as average scores based on integration of all results by the test software. More points indicate better performance. Figure 2 presents results of a comparative test of the processor, RAM and hard disk drive performance on the host computer and the virtualized machine running on that host.

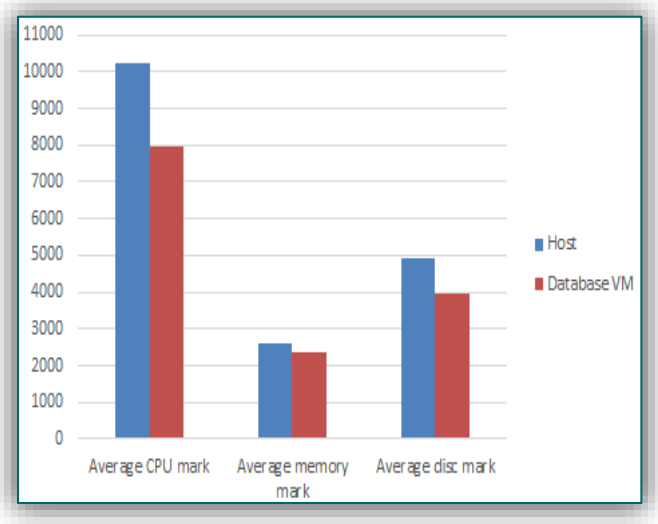

Figure 2. PassMark Performance Test overall results

Figure 3 shows compared processor performance achieved on host and virtual machine. During this testing performance measurement software ran various procedures performed by the CPU and measured execution speed of host and virtual machine. These procedures are related to speed of execution of individual processor instructions. This is primarily related to speed of mathematical instructions for prime, integer and decimal numbers, complex mathematical and physical formulas and instructions, data compression, encryption and sorting. In Figure 3 it is visible that there was a

reduction in CPU performance of virtual machine compared to non-virtualized server.

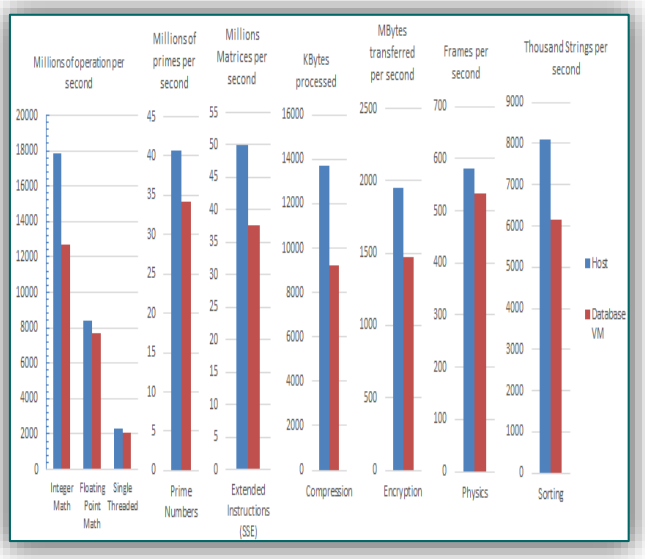

Figure 3. Results of comparative analysis of processor performance

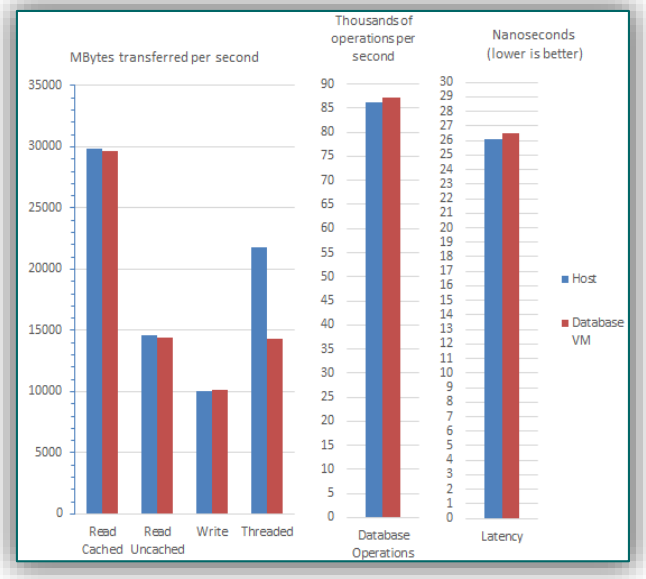

Figure 4. Results of comparative performance analysis for RAM memory

Figure 4 gives performance analysis of RAM memory operation on host computer and virtual machine.

All tests use a combination of 32-bit and 64-bit data when reading or writing from or to RAM. The test measures speed of large data arrays manipulation during manipulation of data from the database. Reading speed test was performed on smaller blocks of memory completely stored in the cache and speed of reading of large blocks of memory not stored in the cache is measured as well. After these tests, the test of speed of reading data from RAM memory was performed. These tests are performed on a single process and on the two at the same time, in order to get information how fast RAM memory manipulates multiple processes simultaneously. Special analysis refers to the latency of RAM memory and the time that it takes to transfer a byte from memory to the CPU for processing. The latency test was measured in nanoseconds, and in this case lower values are better. The Figure 3 shows that performance decrease on virtualized machines exists, but it is small. Testing the performance of memory in maintaining large structures of data showed that the performance of virtual machines when working with databases is even better than on the physical server.

The reason is that virtual RAM is a distributed software which has better usability with a large number of database operations. This means that RAM memory is better distributed with virtual machines.

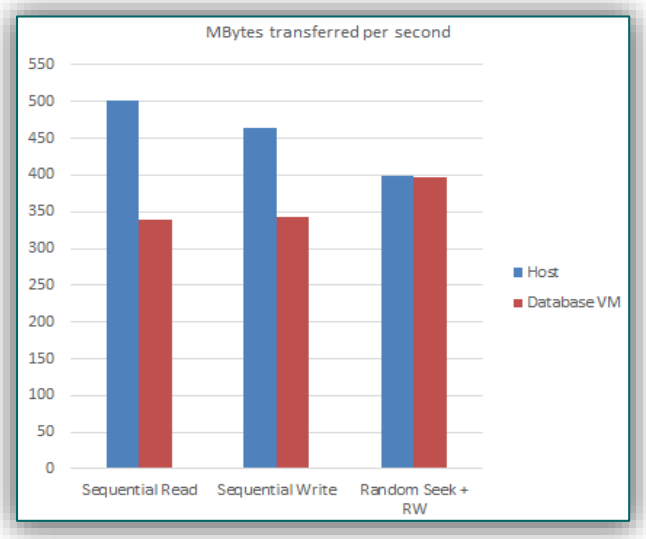

Figure 5. Results of comparative analysis of disk performance

It is also important to test disk performance of the entire system. The disk performance was tested on a disk with installed operating system in the host computer and in the virtual machine. In this system there is no separate virtual machine for shared storage by default. It uses memory of virtual machine on which operating system is located. Standard reading and writing to the disk test, created a temporary file in the root directory of the logged in user on the disk partition on which the operating system was installed. The size of this file is usually around 200 MB. Reading data from disk is tested first. Data was already generated in file fragments each measuring 20% in size and on those files sequential read from beginning to end of the file was performed. The same process was repeated to test sequential write to the disk. After that, parallel write and read was performed with randomly selected positions on the disk.

Comparative analysis of the disk performance of the host computer and the virtual machine is shown in Figure 5.

Considering all shown comparative analysis, it is evident that there has been some decrease of virtualized system performance in almost all observed segments. This decrease was approximately 22% for CPU performance, 9% for memory performance and 20% for disk performance.

In earlier versions of Hyper-V, after the installation of hypervisor, feature was hidden from virtual machines to prevent guest virtual machines from running Hyper-V server role among other hypervisors. [15]. When released, Windows Server 2016 will enable nested virtualization for Hyper-V, in contrast to Windows 10 in which it can be enabled now. Considering that nested virtualization is one of the newest features in Microsoft virtualization tools, performance testing on nested Hyper-V as a virtualized host was performed also. Nested virtualization is not enabled by default, and in this stage of development the only way to use this feature is to install the same version of Windows 10 operating system on host and virtual machine on which nested virtualization should be enabled. Both operating systems must have the latest updates installed for Pro or Enterprise editions. After that, nested virtualization needs to be enabled through Windows PowerShell tool, for every virtual machine separately. Hyper-V is then exposed to Windows guest operating system and it can be installed on a virtual machine. That virtual machine can act as a virtual host with virtual hardware virtualization on which is possible to install a virtual machine. Nested virtualization was enabled on the virtual machine used to conduct initial performance testing. Nested virtualization using Hyper-V on Windows 10 is shown in Figure 6.

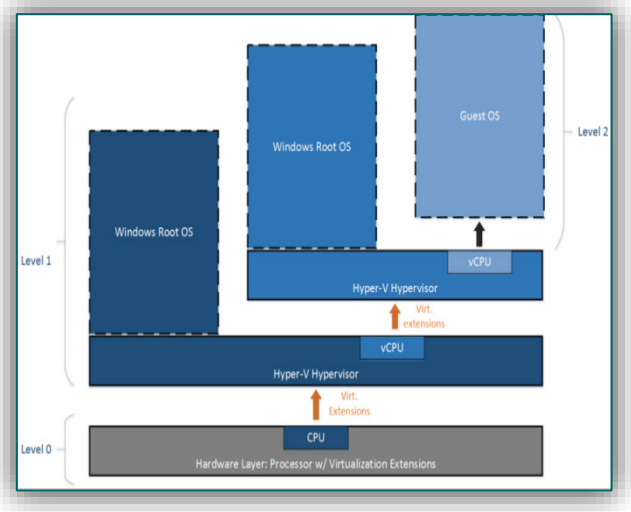

Figure 6. Nested virtualization [15]

The installed operating system on nested virtual machine was also Windows 10. Virtual hardware allocated to nested virtual machine was the same as virtual hardware of virtual machine on native Hyper-V. Performance testing was conducted using the same PassMark performance test tool of version 8.0, and in the same conditions as in previous tests.

Tests were performed for CPU, RAM memory and disk separately. Overall results considering all tests, as well as the performance of nested virtual machine compared to native Hyper-V and to physical host performance are shown in Figure 7. Blue color depicts performance of host, red color depicts native Hyper-V virtual machine, and green color depicts overall performance of nested virtual machine. It can be observed that the performance of nested virtualization were reduced by approximately 30% in CPU segment, 12% on memory and 2% on disk performance compared to native Hyper-V. This is no surprise considering that the nested Hyper-V was on virtualized host and it is not installed directly on the physical hardware. Although there is a significant drop in performance, especially in the CPU segment, this type of server virtualization may have significant usage in the server consolidation, administration and management of student laboratories, classrooms, etc.

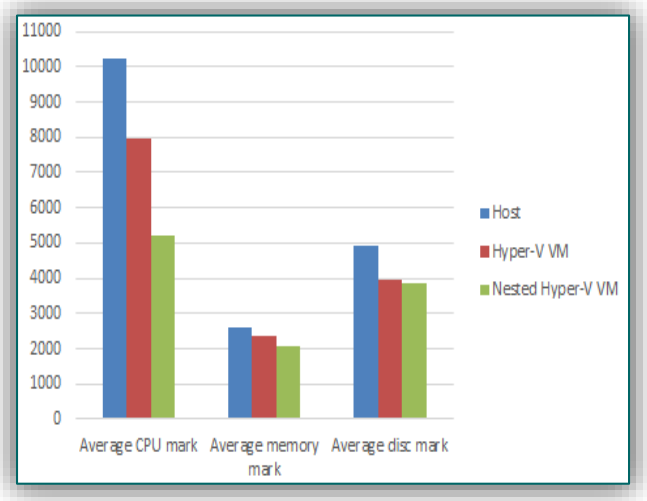

Figure 7. PassMark performance test compared overall results

However, when using virtualization, the attention should be paid to making a proper calculation of hardware resources needs and then perform the allocation of resources, taking into consideration needs of the individual virtual machine and available physical resources. That is a prerequisite in order to keep performance degradation at a minimal level. Also, it will not affect the working process in relation with system efficiency increase with virtualization. In the case that distribution of resources is not done correctly or has reached

maximum of hardware capabilities of the system, potential decrease in performance is possible, but these problems are the same for non-virtualized system.

CONCLUSION

Expansion and improvement of the hardware specifications in their production and use are permanent and all the leading companies engaged in the production of software have various virtualization tools. Although the virtualization can slightly decrease the performance of server systems, correct calculation of needs and correct selection of hardware, as well as correct assignment of resources to individual virtual machines can even increase performance in relation to non-virtualized system, with very significant lower overall cost. Hardware components are adapting for use in the virtual environment. Also, increasing number of IT service providers, as well as IT companies, and other growing companies have some form of server virtualization. Keeping all this in mind, as well as interest in virtualization technologies of all types of users, virtualization of server resources has a foreseeable future in the field of information technology. The continued expansion and improvement of virtualization tools for all IT platforms can be expected.

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ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING
ISSN:2067-3809