Virtualization of Hardware Resources as a Method of Power Savings in Data Center

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Abstract – An excessive power consumption characterizes all industries, even IT. Today, different methods of energy savings are in use, due to the pollution of the environment and the greenhouse effect. One of the newest methods in the IT is green IT that is directly connected with the virtualization of hardware resources. This study illustrates the procedure of hardware virtualization using real-world example and the analyses of the results in power consumption before and after the virtualization.

I. INTRODUCTION

Virtualization has been, for a long period of time, in the spotlight of the contemporary information technology. Although it rapidly developed in the last few years, it was present for quite a long time in everyday use. In the 1960's IBM started using virtualization. However, the mass utilization started with different innovation like terminal services or software solutions like Java Virtual Machine.

Today, we speak of virtualization in terms of hardware virtualization, that is, in terms of using one single computer to concurrently run multiple operating systems and applications [1, 2, 3, 7]. Application of the virtualization technologies vary for use in simulations and testing of new applications as well as in testing its coexistence. But the most prominent characteristics and its advantage is in downsizing of the number of physical servers (consolidation) and power conservation, so called Green IT which is directly related with the downsized number of physical servers.

II. VIRTUALIZATION OF HARDWARE RESOURCES

In order to use all of the advantages of the virtualization the special software is needed which could provide simultaneous usage of physical computer's resources [4, 6]. This software is called hypervisor and different vendors implement it in different commercial or free solutions.

Hypervisors, by theirs functionalities, can be divided into two groups:

- Type one hypervisor, or native which is run directly on the server hardware and is called bare – metal hypervisor.
- Type two hypervisor, or hosted, which is in fact an application run in operating system installation.

To accomplish the best efficiency hypervisors of type one are used the most because the operating system is not needed. Type two hypervisors are applicable to simulation and testing environments because it can be run both on client and server versions of the operating systems and in the environments with insufficient hardware resources.

III. MICROSOFT HYPER-V

Microsoft Hyper-V is a virtualization solution product of Microsoft Corporation [5, 8]. Hyper-V is a server role in Windows Server 2008 and Windows Server 2008 R2, except Web editions of the mentioned products. There is also separate product Hyper-V server which is free to use. Server Core is the most appropriate version of Windows operating system for Hyper-V implementations because it has small memory footprint and better security, but it also does not have GUI which is more difficult to administer.

In the architectural sense, Hyper-V is type one hypervisor, i.e. it is sufficient for implementations of virtualization solutions. As all type one hypervisors, Hyper-V is run under kernel of the operating system in ring-1. This provides creating of the partitions, one parent and one or more child partitions. Parent partitions are used for management and configuration of virtual machines as well as child partitions. Child partitions execute guest operating systems. Kernels of the operating systems execute in their native mode, i.e. ring 0, no matter if they execute in parent or child partition. All applications are executed in ring 3, as expected.

Microsoft Hyper-V architectural model is shown in Fig. 1.

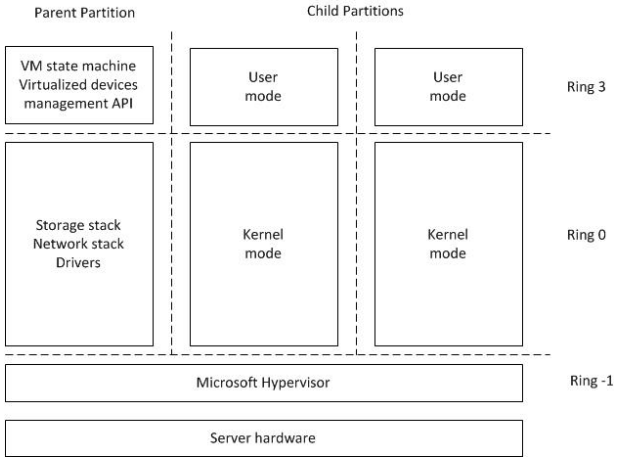

Fig. 1. Microsoft Hyper-V architectural model

Hypervisor itself represents very small piece of code and it is microkernel based, which means that device drivers are installed in the operating systems running in parent and child partitions. This simplifies management and creation of the partitions and makes system more reliable [4]. Hypervisor on the other hand controls only the minimum of hardware devices such as CPU, memory and interrupt controllers.

In a logical sense, hypervisor is divided into two layers – lower layer with microkernel which manages memory, threads, signaling and hardware abstraction mechanisms and upper layer which represents virtualization services interface by hypercall API's. Virtualization services provide partition and virtual CPU creation and address translation [1].

Partitions are environments in which an operating system is run with its applications. The purpose of the partition is to separate the guest operating systems and their simultaneous execution in such way that any of them could not affect the others. Separation is done by the hypervisor. As we mentioned before, there are two types of the partitions – parent and child partition. The parent partition is specific by the fact that although it is virtual environment it owns all hardware resources not owned by the hypervisor itself. Parent partition runs all device drivers and it manages all virtual environments.

In contrast to parent partitions, child partitions, which we could have of any number, are software emulated hardware and they cannot access server hardware directly. Some of these devices have its counterparts in real hardware like CPU, memory and these are called emulated devices, while others which do not have its counterparts are called synthetic devices. Synthetic devices pack requests generated by virtual devices into messages and send them through VM Bus (which is inter-memory structure i.e. pipeline) to physical device and provides high speed communications. Emulated devices use additional software installed on the host computer to fulfill requests and they are used in specific cases when the guest operating system is not aware of its execution in virtual environment [5].

To improve energy efficiency Microsoft Windows Server 2008 R2 uses technology called Core parking. It makes possible for the operating system to use only CPU cores needed to run specific task. That means that inactive CPU cores are using small amount of power. Besides, Windows Server 2008 R2 can also control so called P-states of the CPU to regulate power consumption. But, states of CPU cores inactivity are short (a few nanoseconds) and they depend of the CPU load and server load in general. There is also question of efficiency of these states. When we take into consideration that Windows Server 2008 R2 supports up to 256 CPUs (either logical or physical) and that some systems are running 24x7 the savings become satisfactory.

IV. IMPLEMENTATION OF THE HARDWARE VIRTUALIZATION IN THE EXPERIMENT

Sarajevogas d.o.o. is a public gas distribution company with the network of 200 computers. As the method of choice for energy saving company decided to deploy virtualization solution. It is based on Microsoft Hyper-V using computer blades and where five servers were consolidated into virtual environment. The solution is implemented on the cluster which provides high availability in case that one of the server need to shut down or in case of the failure. Blade solution also provides expandability because the system can be expanded by additional blades without cluster shutdown and which also does not interrupt business processes.

V. DATA ANALYSIS AND RESULTS

For the analysis we used an example in which we replaced a part of the existing infrastructure with the virtual one. We found that the average power used in one server 450 watts. Based on the actual price of the power the monthly cost of energy was derived for each server. Analysis was based on the nine servers, but for virtualization experiment we used five. Server configuration used in the experiment is shown in Table I.

TABLE I
SERVER CONFIGURATION USED IN THE EXPERIMENT

Windows Server 2003					
Physical servers	**Operating System**	**Server Role**	**Average watts**	**Number of clients**	**Location of clients**
one enter-prise-class server	WS2003 R2	Application sever	**450,00**	40	Network

Monthly energy costs for the server configuration are shown in Table II.

TABLE II
MONTHLY ENERGY COSTS FOR FIVE PHYSICAL SERVER CONFIGURATIONS

	Monthly power consumption cost (€)	**Number of servers**	**Total (€)**
September	81,55	5	407,75
October	105,99	5	529,96
November	105,99	5	529,96

In order to compare server costs with company's costs we gathered data on company's total energy costs. These costs are shown in Table III.

TABLE III
COMPANY'S TOTAL COSTS FOR POWER

	Total power consumption cost (€)
September	2321,48
October	2591,47
November	3442,03

Fig. 2. shows servers' costs compared to company's costs. It is concluded that servers' costs have great impact on company's costs.

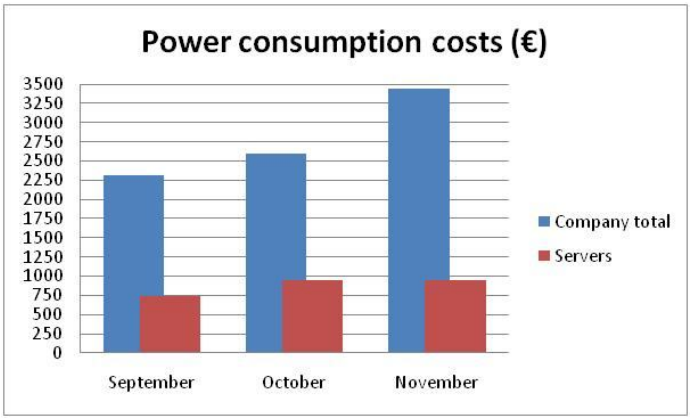

Fig. 2. Comparison of the power consumption costs of the company and servers

In order to analyze impact of the virtualization we took power costs of the Microsoft Hyper-V installed on one server which ran five virtual machines. Physical server configuration used in this experiment is shown in Table IV.

TABLE IV
SERVER CONFIGURATION USED IN VIRTUALIZATION EXPERIMENT

Hyper-V with 5 Virtual Machines

Physical servers	Operating System	Server Role	Virtual Machines	VM role	Average watts (PS1+PS2)
one enterprise-class blade chassis	WS2008 R2	Hyper-V	4	Application server	**1200,00**

Virtual Machines	Role	Location of VM	Number of clients	Location of clients
VM0	Application server	Internal HDD	40	Network
VM1	Application server	Internal HDD	40	Network
VM2	Application server	Internal HDD	40	Network
VM3	Application server	Internal HDD	40	Network
VM4	Application server	Internal HDD	20	Network

Power consumption costs of this system were less than with no virtualization, as it was expected. The exact data are given in Table V.

TABLE V
MONTHLY POWER CONSUMPTION COSTS IN THE VIRTUALIZATION EXPERIMENT

	Monthly power consumption cost (€)
September	217,48
October	282,65
November	282,65

The comparison of the servers' power consumption costs before and after virtualization is illustrated in Fig. 3.

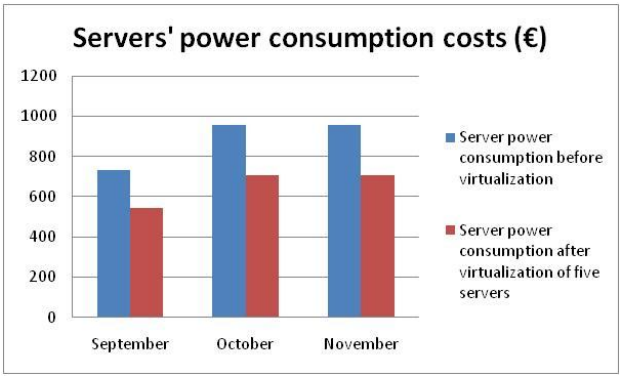

Fig. 3. Comparison of the servers' power consumption costs before and after virtualization

Finally, we can conclude that virtualization brings reduction in power consumption, which is shown in Fig. 4.

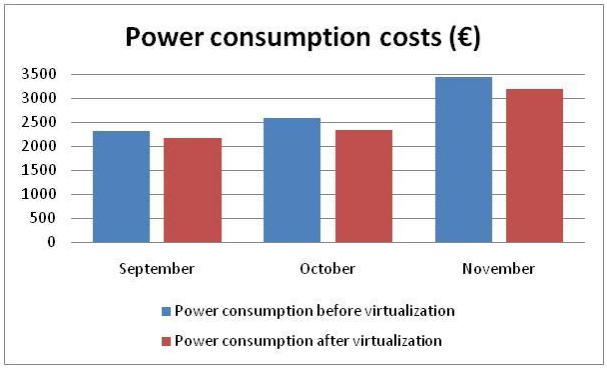

Fig. 4. Comparison of the power consumption costs before and after virtualization

VI. CONCLUSION

Pollution and limited energy sources are in focus of the world today, because all industries even IT generate demand for power. During the period of past 10 years, some industries adopted new technologies for power saving. Quick development of the IT industries did not take into consideration demand for power saving, but in the last few years a lot of has been spoken about the Green IT. Green IT deals with issues regarding power saving. One of the proposed methods which are used mostly today is virtualization technology. It comes in different varieties but when we speak about the Green IT, the method of hardware virtualization is that what is used for power saving. Hardware virtualization brings income to IT companies which deliver solution based on virtualization products but it also brings money savings and less power consumption to the compa-

nies which invest in virtualization solutions. Virtualization also improves device utilization because it can run multiple, even different operating systems on one physical server, instead running different under-utilized roles on separate physical servers. Our tests were conducted in the company which used virtualization solution from Microsoft, i.e. Hyper-V role installed on top of the Microsoft Windows Server 2008 R2 Enterprise Edition.

It also showed that virtualization environments were simplifying daily operations in the data center especially backup and restores procedures which were easily implemented. Virtualization with clustering technologies provided uninterruptable operation of the operating systems software installed into virtual machine.

We also showed that a company which used virtualization solution from Microsoft could save funds and later use it for its own development and investments. The power consumption is less than when company used physical servers, which brings us to the conclusion that any company with more than five physical servers should invest in virtualization technology.

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