Business Benefits from the Virtualization of an ICT Infrastructure

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Ivan Pogarcic[1], David Krnjak[2] and Davor Ozanic[3]

1 Polytechnic of Rijeka, Rijeka, Croatia (Information Science/Information Technology)
2 INA d.o.o., Rijeka, Croatia (Information Science/Information Technology)
3 Faculty of Economics, Rijeka, Croatia (Economics/Information science)
* Corresponding author e-mail: pogarcic@veleri.hr

Abstract Virtualization is a technique that may be encountered in all parts of an ICT infrastructure. The benefits of virtualization for an infrastructure are recognized by a growing number of companies. In this way, virtualization creates prerequisites for the further improvement of the entire information system. Another reason is the growing awareness of environmental issues at the global level, which has become a large external sponsor of this technology. While virtualization technology has been known about for several decades, its hay day is yet to come. In the following years many jobs will be create because of it, from the user desktop and notebook computers, to the server in all businesses. This article examines the impact of virtualization in business enterprises, with emphasis on infrastructure costs and improved business functions. It points to the large savings that can occur even in medium-sized enterprises. Claims are verifiable quantitative indicators, particularly in the procurement of equipment. It also demonstrates the benefits of virtualization while performing everyday tasks that take place within the IT department. We discuss the correlation of increased flexibility and convenience, and agile response to market demands, while reducing capital and operating costs, and increasing the competitiveness of companies in the market.

1. Introduction

ICT which increases usability of resources dates back to the early 1960s, but it was not until the 1980s that the first commercial products emerged defined as target-computers, or later on, generations of grid computers. They all intend to maximally use disposable resources respectively to minimize those that are unused. Realization of the final goal is possible through merging several separate computers into one more efficient computer with much stronger performance. To be more precise, realization is enabled through a separate level of software, so-called middleware, which is supposed to divide tasks into several parts and to locate them on several computers. It usually concerns a large number of computers which are in different organizations connected into the virtual organizations. In that way each administrative unit, which is part of a complex, has its resources consigned and shared among the community. The advantage of such organization is recognized in improving efficiency by truly small alterations.

As an alternative to grid systems, cloud technology has appeared which provides resources to users in the mode of services. The basic problem with cloud computing is represented by the need for a huge quantity of resources emerging only temporarily. The thing that cloud technology provides is availability of infrastructure to users, depending upon their needs, when and as required, small initial investments, more efficient usage of resources, tasks are performed quicker and realistic indication of costs.

The basic problem is adequacy of the described technologies within certain environments. In small and medium systems, these technologies will frequently not meet demand. These environments usually have a need for a greater number of service servers which perform many small and simple tasks. While the grid system in such environments is inefficient, cloud technology is applicable but still in its primary phase. Safety, the method for evaluating different risks and legal regulation of relationships still represent a problem. Therefore, virtualization as a principal means of organizing tasks in one physical computer for a service server is an acceptable solution. Simply put, virtualization is technology which enables a virtual initiation of two or more computer environments into one computer, e.g., it is possible to parallel start Windows and Linux operative systems on the same computer. Technically considered, virtualization represents the appreciation of computer resources which divide resources or requirements for services from a lower hardware that performs a defined task.

In general, present data centres spend very little disposable data base resources. With the power increase in modern processors, percentage (use of database) has decreased even further. The reason for this could be that important services are usually kept in completely separate environments. This increases the time taken to provide services connected to already describe environments. At the same time, the operative costs of weaker service servers are almost equal to those with a greater percentage of utilization. An increase in the level of computer utilization can decrease total operative costs. The same effect will be achieved when decreasing the number of physical service servers and preserving the autonomy of administering with system.

This paper's objective is to examine the influence of virtualization solutions with emphasis put on the virtualization of service servers and the effect they can have over enterprises' business when considering economic effects, functionality and availability. The authors will try to prove that virtualization contributes to process. They will also offer an insight into the hypotheses required for further examination of virtualization technologies.

2. Virtualization

Virtualization by definition represents abstraction of computer resources. It introduces a new level between the applications performed and the resources themselves. The very idea of virtualization in not entirely new, though it has been extended only recently and has become one of the most common concepts in ICT. The reason for this is   the fact that only with backup for x86 platforms could this have been applied on most existing systems without bigger investments made in new applicative solutions and systems. Therefore, there has been no need for alterations of program equipment, operative systems and others, and on the other hand, the door was opened to the complete process of virtualization.

In 2003, Intel announced its then named "Vanderpool" technology, which was supposed to enable a backup for virtualization at a low hardware level. Though solutions then existed which performed this task on IBM platforms, later on even within existing operative system, they all had restraining factors for massive usage. Up until then the x86 platform, from the hardware point of view, did not support the requirements of virtualization defined by Gerald J. Popek and Robert P. Goldberg [1]. Not long after the announcements of the first x86 processors with backup for virtualization technology, by the end of 2005 and beginning of 2006 AMD [2] and Intel [3] announced their processors. AMD by then named its technology AMD-V while Intel took the name "Intel VTx", so those technologies keeping these names to this day.

Today it is almost impossible to read text concerning virtualization which does not mention concepts such as consolidation, business continuance, resources' optimization, green IT, etc. All this influences conventional methods which tried to solve the same problems.

2.1 Development of modern virtualization software

Despite problems connected to the x86 architecture, which back then prevented virtualization within a contemporary architecture, Californian firm VMWare Inc in 1999[4] announced its virtualization software called VMware workstation. That tool was initiated within the main "host" operative system, while simultaneously supporting Windows and Linux environments. It enabled the running of guest operative systems within the software. Guest OS could be the same as the OS host or a different. Though, until then virtualization on x86 architecture was frequently considered impossible, VMware turned a new page and is often considered the originator of modern virtualization.

The company VMware was established in 1998 in Paolo Alto, California. It was established by Diane Greene,

Mendel Rosenblum, Scott Devine, Edward Wang and Edouard Bugnion. In 1999, VMware entered the desktop computers market, and not long after in 2001 it also entered the service servers market due to its VMware GSX Server and VMware ESX Server tools. The main difference between ESX and GSX was that one ran within the operative system, while the other ran directly on the computer's hardware. In 2004, the company was taken over by hardware and software giant EMC which is the majority owner even today.

The thing that makes VMware most popular is its solution for the virtualization of x86 computers. VMware has actually made a combination of direct execution of instructions with a binary translation of the same. In that way it enabled the running of the OS in the first ring in comparison to a previously mandatory zero level of privilege (ring 0). It is already known that user applications actually run in the third ring. That same fact VMware used when finding the way to move the OS into the first ring, while its virtualization software was moved in the zero level (ring). After the rising of processors which supported virtualization technology, a greater number of producers started to enter this market segment. So today one can differentiate several categories of virtualization, among which the most popular are complete virtualization that uses binary translation (type 1 and 2), hypervisor-virtualization, hardware supported virtualization, virtualization at the OS level.
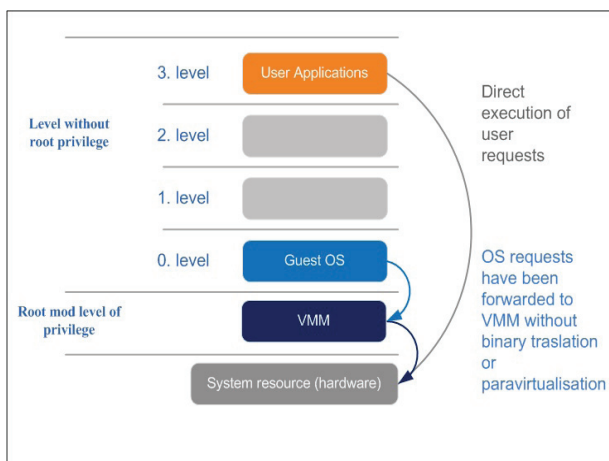

Figure 1. Hardware supported virtualization on x86 architecture (XenSource, Inc. uses a form of virtualisation process named paravirtualisation)

2.2. Contemporary virtualization products

The main producers of virtual solutions basically have not changed much. Citrix, with its range of products is pretty strong in the field of application virtualization. Its XenApp boasts that it is the only one which supports local application delivery, while also hosting application delivery. Microsoft has reached this goal through its two

tools for application virtualization, APP-V and MED-V. APP-V solution is the one performed in the standard principle of virtual applications, while MED-V actually sends the virtual (OS) environment together with the application so that it enables running of applications independently from the system they have been designed for. VMware does not lapse in this matter and it offers its Thinap as a solution for application virtualization.

In the field of OS virtualization or system virtualization, things have changed a little with the entry of Microsoft and Paralles. VMware is no longer the only big producer that offers these solutions on the market. Paralles' price is several times smaller, while in a new version it also brings migrations on the living systems. XenServer Citrix is a virtualization server whose original code became publicly available in 2009[5] and presently is offered completely free of charge to both private and commercial users. Microsoft has also offered a system of living migration that is, to date, the main advantage of the VMware tool.

3. Practical investigation

This research has been based upon medium and large companies, and different solutions have been tested that are to be used for the construction of future system architecture. Though there may exist a solution with a more competitive price, such as Citrix Xenserver, it was determined that the most suitable solution would be one based on the Windows Server architecture. Namely, Windows Server 2008 R2 without additional benefits offers the possibility of adding virtualization roles to the server. Since all contemporary servers in our company have been based upon Windows server architecture, this solution provides huge savings in hypervisor licences, while it also eliminates the need for heterogeneous solutions. In addition, due to current agreements of maintenance and specific agreements of licences that the company has signed with Microsoft, this solution appeared to be the logical choice.

The company has in total 10 service servers of which two are Windows DC servers and one is the Windows Exchange server. Due to company's internal policy the DC and Exchange servers have to be separated from the other services. This paper will therefore base its research upon seven other servers.

3.1 Windows Server 2008 R2 Hyper-V

Windows Server 2008 R2 (version 2) is the successor to Windows 2008 products. Microsoft Windows Server 2008 R2 Hyper-V is a virtualization platform, e.g., a hypervisor available as (so called the server's role) standard versions, enterprise version and data-centre version as well as

specific versions connected to hardware manufacturers. All listed versions include Hyper-V in their basic price. It is an interesting fact related to virtual machines that the enterprise version includes four free of charge Windows Server licences that can be used within virtual environment, standard includes one while the data-centre includes an unlimited number of Windows Server virtual licences [6]. Besides Windows Server 2008 R2, Hyper-V one can also find a completely free hypervisor with slightly smaller hardware possibilities without graphic interface.

In comparison to VMware, vSphere products (which themselves require a licence and operative system that they run) also require a licence. Since Hyper-V role of Windows Server 2008 R2 refers to the operative system, clearly it does not need an additional licence for the OS. Hence, besides being a virtualization platform, that same server as for any other Windows server (printing, applications, data bases, file sharing). Also, as opposed to the VMware approach (monolithic architecture), Microsoft applies architecture with micro cores. The main differences lie in the mode of providing support for physical hardware (Picture 10). The microkernelized approach installs drivers within a basic partition within the hypervisor itself. The monolithic approach integrates drivers as an integral part of the hypervisor so they cannot be changed by the users.
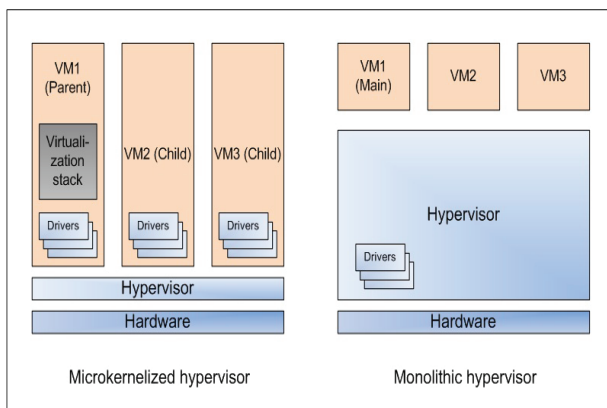

Figure 2. Monolithic hypervisor and Microkernelized hypervisor

3.2 Economic effects of applying software in virtualization

Research puts emphasis on the total costs of ownership (hereinafter TCO) due to the specific situation that requires investment in hardware, while licences, in particular investments in virtualization tools, are unnecessary since hypervisor of the monitored system is completely free. TCO costs represent the cumulative of all connected costs that emerge by mere owning of certain resources. It is used for the indication of costs otherwise unlikely to be presented within other economic methods. These costs include electric power, cooling, maintenance, etc. In order to successfully conduct research, it is necessary to define monitored costs before or without

virtualization and later, in the future virtualization environment. This paper will observe the major cost categories so as to indicate the most realistic insight into the true effects. The monitored categories are:

- Hardware costs – these represent the total value of hardware planned to be purchased and depreciated during the stipulated usage period of four years. The calculation uses the following formula: number of physical servers * decreased annual cost of server. Decreased annual cost of server is calculated as follows: unit purchase price of a server * depreciation rate.
- Costs of electric power used for operating and cooling – these represent the costs of electric power consumption for the operative work of the computer infrastructure and its cooling with air conditioners.
- Costs of procuring and preparing servers – these represent the cost of the working hours needed for modifying the server so it could work. The calculation uses the following formula: total number of purchased servers per year * number of working hours for modification of servers * average price of working hour per system administrator.
- Costs of administering servers – these represent all the costs connected with managing servers. The formula for their calculation is: engagement coefficient for position of administering servers (physical or virtual) * average annual payment of a system administrator.
- Costs of software required for virtualization or its managing – these represent the costs of an annual licence for using software and backup. During the stipulated period of usage that lasts for four years, the cost is four times higher.
- Excluded costs – these represent some categories of infrastructural costs that are not addressed in this paper. The reason for their exclusion is an assumption that they have minimal or no influence over achieving the economic effects, or they are not significantly moderated with the introduction of virtualization because they remain relatively proportional. Examples of such categories are costs of data servers and networking and physical space. Another assumption is that the company has a system administrator who could independently learn how to use software for virtualization so excluding the costs of training, support and maintaining hardware.

3.2.1 Costs analysis

Before the costs analysis itself, Table 1 indicates information about contemporary and future infrastructure, and data relevant for future growth and infrastructural depreciation.

Description	Value	Source
Present number of physical servers	7	Interview
Number of physical servers – post virtualization	2	Own source
Life time of server	4 years	Industrial best practice
Chosen model of server	Dell PowerEdge 2970	Own source
Number of virtual machines per physical server	4	Industrial best practice
Annual growth of servers	0.25 servers per year	Interview

Table 1. Important infrastructural information

3.2.1.1 Costs analysis before and after virtualization

Before the application of virtualization, the purchase of seven new servers was planned. Since the company has a global contract with Dell, server Dell PowerEdge 2970 has been chosen. This server is one of the most popular Dell servers and also the most expanded within the observed company. It supports up to 64GB working storage, is of a standard 2U size and supports 6 SAS discs of 1 TB size. Its price in Croatia is approximately 12, 000 Kunas.

As mentioned before, after the process of virtualization, seven servers will be assorted into two physical servers. The reason for this lies in transferring working load to other servers if only one is planned for maintenance. In addition, the dislocated unit requires minimally one server on location so it was decided to place one physically at location A, while the other should be placed at location B. The physical server chosen for virtualization is the same as that used by the Dell 2U server. A difference exists only in disc space and RAM. The price of such a strengthened server that has enough resources to accept all 7 (8) virtualized servers is approximately 24,000 Kunas. The price includes 32GB of RAM and 2TB space in RAID 1 configuration.

3.2.1.1.1 Hardware costs before and after virtualization

For one to calculate hardware costs, one should calculate the value of depreciation per single server keeping in mind that each four years on average a new server should be procured. A depreciation rate of 25% has been used in the calculation according to the company's internal policy.

3.2.1.1.2 Electric power costs before and after virtualization

When calculating complete consumption of electric power per server and electric power required for their cooling, the parameters indicated in Table 2 should be considered. The calculation of the complete consumption of electric power has not considered indirect costs or savings of depreciation and maintenance of cooling devices, neither the equipment for distribution of electric power. A detailed calculation should include these parameters, but this paper will not get that detailed so to keep matters as simple as possible.

The costs of operating electric power and electric power consumed for cooling after virtualization have been based upon two servers over the whole four years, while costs before virtualization have been based upon seven servers in the first three years and eight servers in the fourth year.

Entrance	Description	Value	Source
Declared power of a server (a)	Declared power of a server	750W	Producer's specification[7]
Price of electric power per hour (b)	Price of 1kWh of electric power	0,64 Kunas	HEP[8]
Conversion of electric input into a real input(c)	Coefficient for conversion of electric input into a real input	0,67	According to APC[9], in average electric inputs are 33% higher than real
Cooling load (d)	Evaluated value needed to disperse 1W of heat	0.8	Forrester Research[10]
Redundancy of air flow (e)	Redundancy required to cool data centre	125%	SearchDataCenter [11]
Deceleration of air power (f)	Percentage of air required for cooling	80%	SearchDataCenter [11]
Operative hrs per server (g)	Total number of operative hours per year	8760h	Own source

Table 2. Parameters for calculation of electric power

Based upon these parameters, the following formulas have been derived. The total operative electric power per server annually will be calculated according to the following formula:

$$Pp = a * b * c * g$$

Total electric power per server needed for cooling devices:

$$Ph = Pp * d * e / f$$

Total consumption of electric power for all servers equals sum of Pp and Ph, and is the product of the total number of servers.

3.2.1.1.3 Costs related to procurement and preparation before and after virtualization

Calculation assumes an average payment for a Croatian system administrator [12] of 11.500 Kunas gross value (gross 1), that sums to app 13.500 Kunas with all allowances (gross 2) [13]. The average hourly wage per month, that includes 180 working hours, also amounts to 75 Kunas/h. The average times for preparing the server, as indicated during the interviews, amounts to 20 hours.

After virtualization, the time required for preparation of servers and operative systems that it will run, relevant to the costs of procurement and preparation, has been increased to 35 hours. The hourly wage remains the same.

3.2.1.1.4 Costs of administering before and after virtualization

According to IDC and Alinean evaluations carried out for VMware, one IT administrator fully engaged can provide support for 40 physical servers. This leads to a conclusion that engagement of seven servers equals 17.5%, respectively eight servers 20% of effective working hours.

The costs of administering servers after virtualization considered the engagement coefficient of 9.33% for seven virtual and 10.66% for eight virtual machines. It is assumed that the administrator can, during his full working hours, manage 75 virtual servers helped by virtualization.

3.2.1.1.5 Costs of software used for virtualization

Since Microsoft Hyper-V has been chosen as the virtualization platform, the licence itself is free of charge. Still, Hyper-V does not include a module for managing the data centre as a virtualized environment. One of such tools is available within the Microsoft System Centre family. The tool is named the System Center Virtual Machine Manager (abbreviated SCVMM) and it enables advanced supervision and managing of virtual machines and servers. It has been evaluated that a supervised company could have a need for such a tool so this is basically the only cost of virtualization licences. The tool is available through several licences, but in the observed case the optimal solution would be the Virtual Machine Manager 2008 R2 Workgroup Edition that enables the tracking of five physical servers and does not require additional licences for the servers. Its price in Croatia amounts to approximately 3,000 Kunas.

3.2.2 Economic effects

Upon the analysed costs for each individual category, the complete costs for the usage period of the stipulated four years have been calculated. Firstly they have been calculated without virtualization and then after virtualization. By comparing the calculated values, the economic effects of each cost category and total economic effects have been calculated (Table 4). The calculation proved that the application of virtualization software can lead to significant positive economic effects. In the observed example, a saving of almost 57.63% has been achieved. The biggest saving has been achieved in electric power costs - 72.41%.

The total saving in the examined case study goes slightly beyond 230, 000 Kunas. It should be mentioned that the prices used in this paper are subject to changes, so the indicated results are based upon prices valid at the time of writing this paper.

CATEGORIES OF COSTS	TOTAL COSTS		ECONOMIC EFFECTS	
	WITHOUT VIRTUALIZATION	WITH VIRTUALIZATION		
HARDWARE	87,000.00 Kunas	48,000.00 Kunas	39,000.00 Kunas	44,83 %
CONSUMPTION OF ELECTRIC POWER	183,823.59 Kunas	50,710.00 Kunas	133,113.59 Kunas	72,41 %
PROCUREMENT AND PREPARATION OF SERVERS	12,000.00 Kunas	5,250.00 Kunas	6,750.00 Kunas	56,25 %
ADMINISTERING SERVERS	117,450.00 Kunas	62,639.96 Kunas	54,810.04 Kunas	46,67 %
VIRTUALIZATION SOFTWARE	0.00 Kunas	3,000.00 Kunas	-3,000.00 Kunas	
TOTAL	400,273,59 Kunas	169,599,96 Kunas	230,673.63 Kunas	57,63 %

Table 3. Comparison of the analysed costs

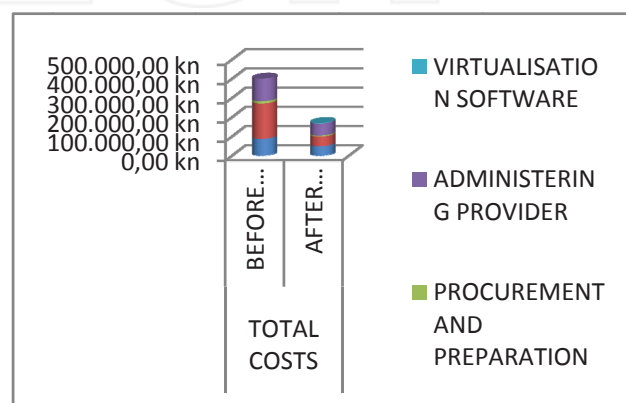**Figure 3.** Comparison of total costs before and after virtualization

Picture 3 shows comparison of total costs before and after virtualization.

4. Additional savings

This paper dealt with just one segment of savings enabled by virtualization - infrastructural costs. As mentioned before, some aspects have been excluded during the research due to the volume of the paper itself. Despite the above, with regard to the research and possible savings which have emerged throughout the implementation of virtualization solutions, the following should be noted:

- The savings realized through virtualization of desktop computers are achieved in electric power, maintenance, preparation of computers, etc. It could be mentioned that all categories included in the paper could be applied to virtual desktop computers as well, with a remark that desktop computers in most companies are ten times more frequently used than servers;
- The advantages accomplished through higher availability of services greatly decrease incidents which cause possible fines from third parties if a company has signed contracts which regulate this question;
- Savings on network and cooling machines are required for a large number of servers. After virtualization, if the company has several servers and their number was decreased ten times during the virtualization, savings over the relatively expensive equipment and its maintenance become an important factor. This cost category was also noted in the paper, but due to a small number of servers it would have a negligible influence;
- Savings in operative space which occur by eliminating redundant equipment and by reallocation of that space. The price of real estates and rent of business locations represent an extremely important factor in each company's business. If the price of each free square is known, it is easy to calculate the true saving. These savings are usually made by removing closets for servers and their additional equipment, possible only with a greater number of servers;
- Increasing the reputation by presenting the company as an ecologically aware organization with environment and possible competitive advantages deriving from that fact.

5. Conclusion

From its start, virtualization has spread to all parts of the IT infrastructure. The advantages of infrastructural virtualization are being recognized by larger numbers of companies so their implementation actually does create preconditions for further development. Greater awareness among the population when it comes to ecological matters has also become one of the biggest external sponsors of this specific technology. Though it could be said that virtualization technology has been common for already 40 years, the author believes that the virtualization era is yet to come. Within several years, many people will become a part of it, from users of desktop computers and laptops, to servers in all companies.

This paper's goal was to examine the influence of virtualization on a company's business with special attention given to infrastructural costs and improvement of business functions. The paper has proved the great savings which emerge even in medium to large companies, provable in quantity when purchasing new equipment. The paper has also proved the advantages of virtualization during performance of everyday tasks within an IT department. Greater flexibility of the system enables an easier and more agile reaction to market demands, while a decrease of capital and operative costs increases a company's competitiveness in the market. All these facts question the cost effectiveness of further usage of physical resources in comparison to switching to virtualization resources wherever possible considering the architecture of technology and outlined business goals.

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