UDK 004.946:378
DOI 10.7251/ZRSNG1708053A
COBISS.RS-ID 7297816

Security analysis and economic feasibility for virtualization usage in University datacenters

Sigurnosne analize i ekonomska izvodljivost za upotrebu virtualizacije u univerzitetskim datacentarima

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***Abstract*—In this paper, authors have analyzed economic and security aspects of server virtualization. The experimental analysis includes: the business value of virtualization and impact of virtual environments on computing and security parameters, with applying modern cryptographic systems for data protection. The experiment was designed simultaneously on the traditional server and virtual environment. The obtained results show the significant advantages of virtual environment in the form of optimal allocation and utilization of physical computing resources. Also, the results indicate a significant improvement of parameters in the information security, introducing of the virtual network adapter which presents virtualized communication channels concept between the application server and database server.**

***Keywords* — Datacenters, Energy efficiency, Virtualization, Security.**

I. Introduction

The traditional organization of datacenters requires significant financial resources. Server virtualization is a solution that is implementing simplest way to efficiently manage the available resources within a data center. Until 2003, about 70% of all software for virtualization were related to the development and testing of software. This includes technology development and testing in the laboratories of large companies [1,2]. It is believed that it was up to this year virtualization technology has become a stable product (solution). The period up to 2005 has been a shift in consumption of electrical and thermal energy [3]. Stability and test software environments have led to the development of applications within the part of the production IT infrastructure. Focus was on the encapsulation of multiple applications to maximize utilization and reduce power and cooling costs.

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Efficient use of server hardware and software is reflected in the implementation and the role that servers perform. Depending on the degree of utilization of computing resources, datacenter can achieve savings of 20-70% in energy consumption [4,5]. With the use of virtualization technology, cloud computing and the consolidation of servers, datacenters are able to reduce number of physical servers with the same efficiency considering clients workload. This reduces power consumption as the direct result of a reduction of operating costs and emissions [6,7]. The paper presents the concept of virtual servers compared to physical servers. Experimental measurements led to the results of the consumption and energy savings based on the improvement of IT services to educational institutions.

After determining the economic and environmental feasibility of using virtualization server solutions, authors have analyzed the performance and security of these solutions in the real environment of the university datacenter. The goal of any organization is to preserve the confidentiality of sensitive data in databases containing customer data and personal business documents. Service of integrity and confidentiality can only be achieved using cryptographic mechanisms, which use a significant percentage of computer resources. As a further guarantee for the possibility of a realistic assessment of security solutions applied is the use of reliable supporting software components whose source code is open and available.

One of the basic conditions for the successful implementation of a solution, is its ease of use and software ergonomics. Ideal in concrete solutions is end users that do not feel the presence of cryptographic solutions, i.e. that their work is not complicated and it does not change the time resources in the execution of tasks. Realization of the solutions to protect the database provides an excellent method for protecting sensitive data, but on the other hand leads to reduced performance and complicated application.

Implementation of cryptographic mechanisms is possible in the database server or application server, or in combination on both servers simultaneously. Over cryptographic algorithms data is physically protected on the server. These cryptographic mechanisms for the University datacenter are implemented using popular standard algorithms AES, DES or 3DES.

Authors have analyzed the performance during the encryption and decryption of the database server and the application server, within the traditional server infrastructure and modern virtualized infrastructure. At the end of the paper authors discussed parallels between traditional datacenter and virtualized datacenter with all its advantages and disadvantages.

II. University Datacenter

University institutions mainly own datacenters consisting of many server stations and services, and for that reason University's pay great attention to the IT professionals who manage them. Datacenters are often small in size, but that does not diminish the problem of cooling and providing a continuous source of electricity. For the smooth process of activities at the university it often needed up to 30 servers for different purposes and configurations [12].

A. *The physical datacenter*

Figure 1. shows diagram of an operational university data center that has 12 servers, while Figure 2. shows a diagram of consolidated and virtualized datacenter. The main roles performed by servers are domain controller, backup domains, DNS, firewall, FTP, database server, application server, a system for electronic testing of students, the system for distance learning, web server, and university information system.

To meet all customer requirements such data center requires great investment in the purchase of hardware, software and infrastructure, and also a major burden on the budget are the operating costs of cooling, maintenance and administration.

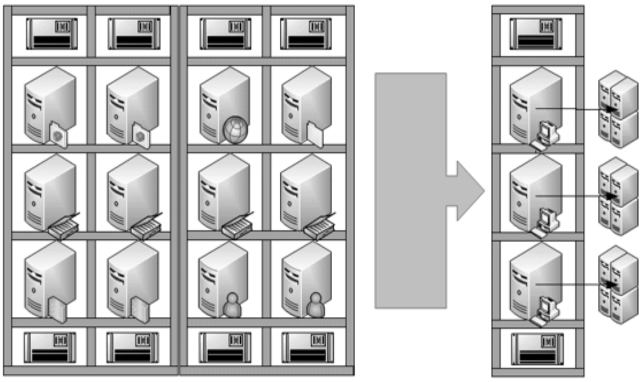

Fig. 1. Illustration of university datacentre
Fig. 2. Consolidated datacentre

B. *Virtual Datacenter*

As already mentioned, the energy efficiency is a major challenge for today's datacenters. The solution to this challenge is presented in the form of a virtual computer that is based on an energy efficient architecture. Virtualization technologies can consolidate server resources, reduce maintenance complexity and accelerate the pace of adjustment to new requirements as shown in Figure 2, virtual datacenter can reduce the number of physical servers from the current 12 to 3 physical servers containing 12 virtual servers.

III. Analysis Of Experimental Results

This section will show the results of measurements, analyze consumption and energy costs, and carbon emissions, which directly affects the cost of cooling the server room. As the authors have already dealt within the previous works [22] with the performance of virtual and physical computers, the focus of this analysis will be the consumption of electricity and the production of greenhouse gases. Resources that were used in the experimental measurements are:

Two physical (non-branded) server following the configuration:

- Configuration 1 - Intel® S5000VSA Server Board [13], 2x Intel® Xeon® [14] 5063 2C/4T 3.2GHz 4MB, 8x 1GB FBDIMM DDR2 667MHz, 320GB HDD SATAII,
- Configuration 2 - Intel® S5000VSA Server Board, 2x Intel® Xeon® 5110 2C/2T 1.6GHz 4MB, 4x 1GB FBDIMM DDR2 667MHz, 320GB HDD SATAII,

One physical (branded) server the following configuration:

- IBM® System x3400 M2 [15], Intel® Xeon® E5620 4C/8T 2.4GHz 12MB , 3x 4GB ECC DIMM DDR3 1333MHz, 3x 500GB SAS HDD SATAIII,

The unit for measuring electricity consumption and greenhouse gas emissions APC® Back-UPS Pro 900 [16],

Operating Systems: Linux Slackware 13 [17], Microsoft® Windows® 7 Professional x64 SP1 [18.], Microsoft® Windows® Server 2008 R2 Enterprise SP1 [19]

Software for benchmark: FinalWire AIDA64 Engineer Edition [20].

A. *Measuring power consumption*

On the following diagram - Figure 3 presents the measurement of electricity consumption, which were conducted in three modes: server does not require client (idle), the burden of 40-70% (optimal) and when the server is fully loaded (full benchmark the processor, RAM memory and hard disk using software AIDA64).

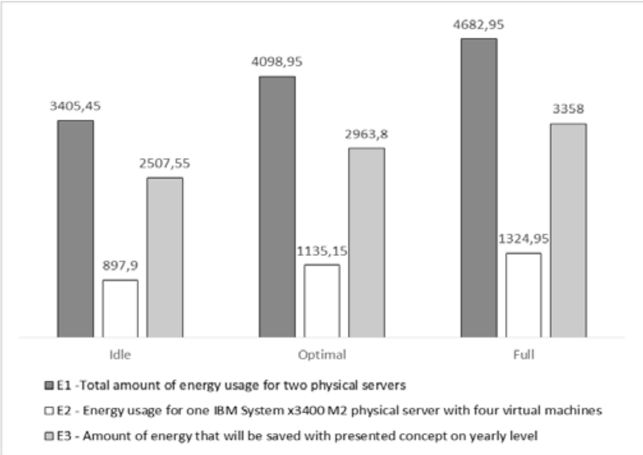

Fig. 3. Measurements of power consumption in three server load modes in kW

• E1 represents the measurements of energy spending for two physical servers that perform the role of e-testing system for students (Configuration 1) on Linux Slackware 13 and the database server (Configuration 2) operating system Microsoft® Windows® 7 Professional x64 SP1.

• E2 is representation of energy consumption for IBM® System x3400 M2 running Microsoft® Windows® Server 2008 R2 Enterprise with SP1 [21] running four virtual machines:

o System for electronic testing of students (4VT, 4GB of VRAM, 10GB vHDD) on Linux Slackware 13,

o Database server (1W, 2GB VRAM, 80GB vHDD) on Microsoft® Windows® Server 2008 R2 Enterprise SP1,

o Primary Domain Controller (2vT, 2GB VRAM, 50GB vHDD) on the Microsoft® Windows® Server 2008 R2 Enterprise SP1,

o Firewall server for the VPN tunnel (1W, 1GB VRAM, 30GB vHDD) on the Microsoft® Windows® Server 2008 R2 Enterprise SP1.

• E3 shows the savings in electricity consumption on an annual basis.

As the diagram showed, the consolidation of servers and use of virtualization technology, in this case, Microsoft ® Hyper-V ™ [21] it is possible to reduce the power consumption almost three times. Also, as you can see, in this case a branded server replaces up to four physical servers and the power consumption can be reduced even further. If we take into account that the host server itself can perform a role, then we can conclude that he could replace the five physical servers.

To equip the datacenter with branded servers that are scalable in terms of adding two or four physical processors and to increase working RAM memory and up to 2TB of data, storage up to 8 drives (500GB in size, 1, 2 or 4TB) initially datacenters need to invest more financial resources. Energy savings using these servers and virtualization software is evident, so that for a longer period of their purchases and use more cost-effective. The following diagram - Figure 4 presents predicted savings in financial resources annually with a reduction in power consumption. Based on the analysis of the results, the cost would be reduced two-and-a-half times for the example of two physical servers, while the shutdown of multiple physical servers increase the number of multiple reduce costs.

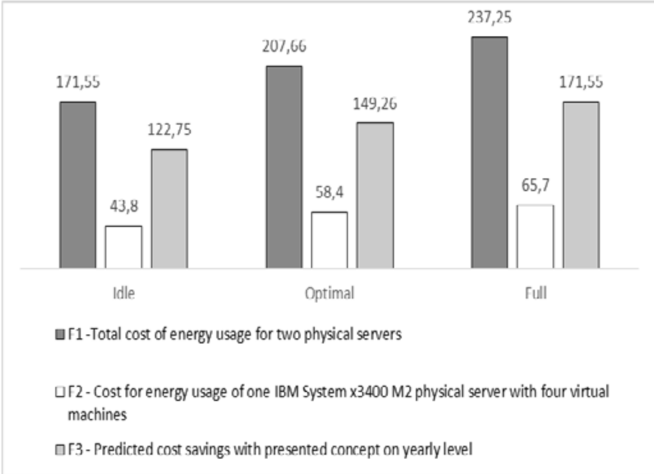

Fig. 4. Predicted savings in financial resources annually

IV. BUSINESS VALUE OF VIRTUALIZATION

The paper also analyzes available from of virtualization for different levels of acceptance. The presented data and tables compare the usefulness non-virtualized business environment in relation to the virtualized environment. It also discusses basic and advanced virtualization.

Figure 5 shows that the virtualization results in a larger (three times larger) number of users per server, and the server administrator personal in relation to the physical environment. This indicates the direct benefit of using virtualization. The relocation of non-virtualized infrastructure in basic infrastructure virtualization increases the number of users per server from 143 to 423, the number of potential users per system administrator is growing from 240 to 1100, all based on an increase in the number of servers by a system administrator [4,15,16].

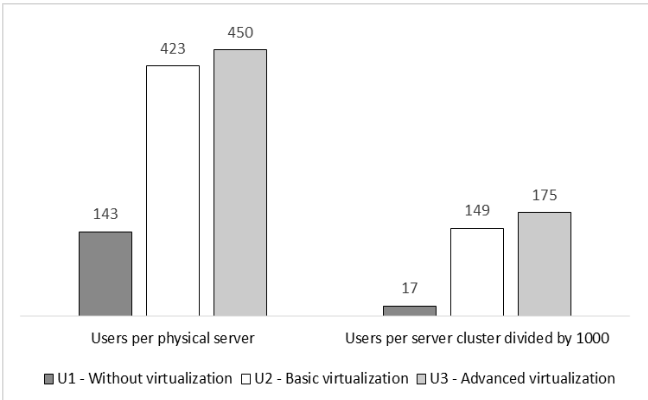

Fig. 5. The ratio of the number of users associated with the use of virtualization, and the type of virtualization

Figure 6 shows the new features of the transition to a virtualized infrastructure. As it might be expected, the number of physical servers per administrator almost doubled, from 17 in non-virtualized infrastructure, on 30 in advanced infrastructure virtualization. These data are directly related to the data presented in Figure 5 [7,8].

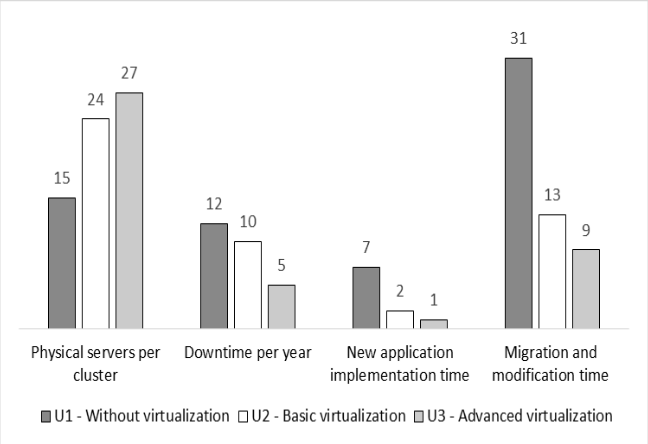

Fig. 6. Analysis of the business value obtained by introducing virtualization

Figure 6 includes the first business value of virtualization elements that exceed the total cost of ownership (TCO). TCO elements are analyzed and presented, less downtime virtualized servers, significantly reducing the time required to run the application. The time required for the upgrade and migration was also significantly reduced.

Figure 7 elements presents detail measurable indicators of cost savings.

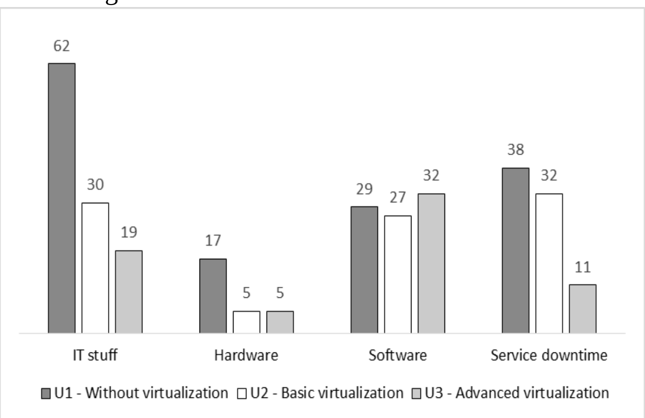

Fig. 7. Measurable indicators of the impact of virtualization on costs

The cost of software remain consistent, or even a slightly increased. Cost of hardware dramatically fall. One of the most important items of costs are labor costs. However, it is possible to significantly reduce labor costs by switching from the basic level to the level of virtualization with advanced virtualization.

Experience shows that the use of standardized operating system and installations directly on hypervisor leads to a more stable environment. This is a key factor in reducing costs incurred in connection with the maintenance of the server and the basic functioning of the services on those servers. Loss of user productivity, the cost of downtime, decreases in moving from basic virtualization to advanced virtualization.

Figure 8 compares the cost reduction option for basic and advanced virtualization. Reducing the cost of hardware for each of the options differ only slightly because of the cost savings typically come from one-time reduced costs do not significantly affect the core virtualization infrastructure versus advanced virtualization as it is shown in Figure 8. Move from base to advanced virtualization has a decisive influence to the reduction of costs in relation to reducing downtime and productivity.

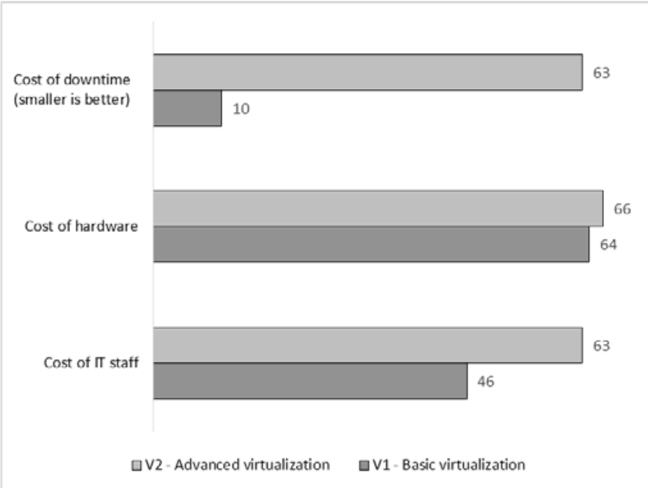

Fig. 8. Comparison of obtained using the basics and advanced virtualization, expressed as a percentage

V. BENEFITS DATABASES IN THE VIRTUAL ENVIRONMENT

For the purposes of the experiment we are installed traditionally physical environment which contain two servers. On a single server is the application server with installed cryptographic module based on the AES encryption. Data is encrypted at the application server, then to the local network infrastructure, in encrypted form, forwarded to the database server.

The second part of the experiment has been done on the physical environment, installed a virtual environment with single physical server on which are both virtual servers - database server and application server. On the application server is a cryptographic module, which is identical to the module from the traditional physical environment. The data encrypted at the application server are sent in encrypted form to the database server via a virtual network infrastructure in within of a physical server. In this way, we eliminates the physical network infrastructure, which is encapsulated within a virtualized environment, a case is shown in Figure 9.

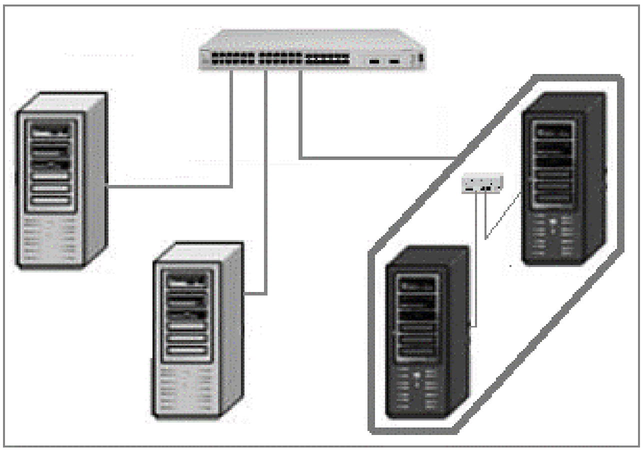

Fig. 9. Comparison between virtual and physical environment

This implementation of virtualized client-server architecture with aspects of performance and system security, showed significantly better results, it is confirmed through experimental results shown in Figure 10.

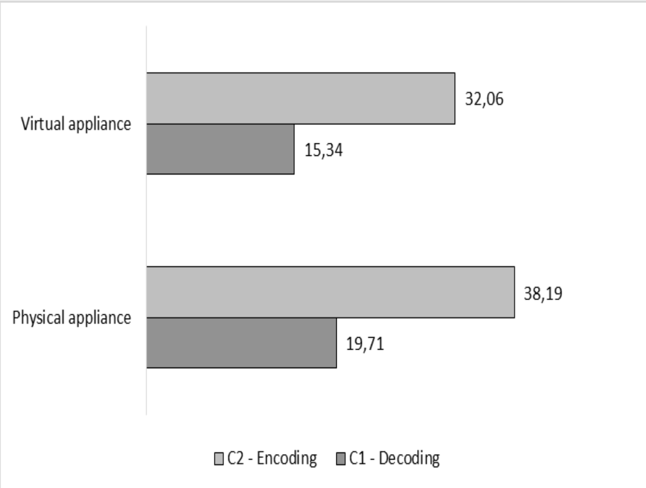

Fig. 10. Comparison between physical and virtual appliance

A comparative analysis of the results revealed that the time performance of the virtual infrastructure significantly better than performance on traditional infrastructure.

In the next phase experimental work, we analyzed the requirements for CPU performance resources for the successful implementation of cryptographic modules to traditional server infrastructures compared with a virtual server infrastructure. The test was performed string 300 characters length, and each iteration of measurement has had 1000 repetition.

In all measurements, we used the maximum key length of 256 bits, with CBC encryption mode. The results are shown in the table below. Based on the data, we conclude that the speed of the encryption considerably greater than the speed of decryption. It is not a paradox, the encryption function is completely inverse function to decrypt (expectedly some time). Reasons for the decrease speed of encryption is unequal rate between read/write operations on the hard disk, which indicates the existence of a bottleneck on the hard disk drive.

TABLE I. RESULTS

Types of experimental measurements	Time (s)	Traditional infrastructure CPU (%)	Virtual infrastructure CPU (%)
Read/write non-encrypted data in the database			
Write	22.30	6	2
Read	1.23	96	26
Encryption/ Decryption data with AES integrated in the database			
Encryption	0.18	89	21
Decryption	0.18	90	22
Encryption/ Decryption data with AES integrated in the application server			
Encryption	5.35	96	26
Decryption	5.30	99	23
Encryption/ Decryption data with AES integrated in the database and Read/Write data in database			
Write and Encryption	22.66	7	1
Read and Decryption	0.21	92	22
Encryption/ Decryption data with AES integrated in the application server and Read/Write data in database			
Write and Encryption	27.34	54	13
Read and Decryption	5.50	95	23

The table above shows the CPU load rate for traditional server infrastructure. Load rate is near the maximum, which in moments of exploitation can cause the problems in the exploitation (system or service delays). On the other hand, cryptographic mathematical complexity on the virtual infrastructure, provides a low level of CPU load rate, which will not cause problems in exploitation.

VI. CONCLUSIONS

The global economic crisis and the crisis in energy, inspired the authors of the research presented in the paper. Dissemination of knowledge in the field of energy efficiency opportunities to improve IT services and saving financial resources are just some of the reasons for the continuation of further research. To ensure that virtualization is successful, it is vital that IT organizations take a pragmatic approach to the relevant risks and implement controls to reduce those risks. While virtualization has real benefits, it can also cause certain problems, especially for organizations that do not apply the appropriate management tools needed to manage the new environment.

The experiment was performed in two different environments, but with the same feature, which means, among other things, and a cryptographic module. Complete experimental analysis showed that there are great advantages of virtualized solutions. Complete implementation of the virtualized environment is set within a single physical server.

Because of the virtual network adapter obtained better performance than the communication server to the physical environment. From the aspects of security, achieved greater network isolation system from the environment. The paradigm of virtualization allows you to create backups and creates hardware independence as well as optimal utilization of the hardware. Considering all these advantages, we can say that the concept of virtualization is a mature product in IT industry.

The results of this work indicate that the CPU performance of today's computers are not sufficient for full utilization of cryptographic mechanisms to encrypt data on the traditional server infrastructure, but as a solution inevitably imposes a virtual server infrastructure.

On the other hand, the need to study and development of new cryptographic algorithms is inevitable, because the amount of data on a daily basis exponentially increases. The need for more powerful computing resources is greater than ever before, which means that for a given cryptographic system we can rigorously prove nominated security in relation to an attacker who has a specific time and computer resources. The importance of this area has several dimensions such as political, military, economic, social, ethical, etc.

ACKNOWLEDGMENT

This work was supported by the Ministry of Science and Technological Development of Serbia through the projects TR32054, III 44006 and ON 174008.

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