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DIPLOMA THESIS

Servers' consolidation

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DIPLOMA THESIS ASSIGNMENT

Martin Moravec

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2. Objectives of thesis and methodology
3. Theoretical basis
4. Case study
5. Conclusions
6. Bibliography
7. Supplements

The proposed extent of the thesis: 50 - 60 pages

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Golde, Bernard. VIRTUALIZATION FOR DUMMIES. 2nd edition. Wiley Publishing. 2009. ISBN: 978-0-470-53269-0

Kurek, Dalibor. Konsolidace serverů na platformu mainframe. IT Systems. 2009, roč. 11, č. 7-8, s. 54-55.

Buk, Václav. Servery pro malé firmy. IT Systems. 2010, roč. 12, č. Č, s. 74-75.

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.... Head of the Department

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In Prague: 1st March 2011

Affirmation:

I declare that I worked on the diploma thesis “Servers´ consolidation” on my own. All sources that I used are mention in the references of this diploma thesis.

Prague _________________________ ______________________________

Martin Moravec

Acknowledgement:

I would like to express my deep and sincere gratitude to my supervisor, Ing. Tomáš Rain, Ph. D for his help and support during the processing of the diploma thesis. Further, I would like to gratitude to Petr Krstev, IT administrator of the company Secar Bohemia. His willingness and expression have provided a good basis for my diploma thesis. I would like also express my gratitude to my family for their support during my study.

Servers´ consolidation

Konsolidace serverů

SUMMARY:

Diploma thesis is focused on consolidation of servers as a method to lower overall operating costs of the IT infrastructure. Diploma thesis characterizes terms consolidation and virtualization and shows benefits of these technologies on the case study of the particular company. Further, thesis researches a process of consolidation in the chosen company and benefits of current IT infrastructure in the company in comparison with other solutions. Benefits are analyzed economically and some of the benefits also technologically.

Thesis is divided into two main parts. Theoretical part, which defines and characterizes the key concepts of consolidation and virtualization. Second part, practical, which researches the process of the consolidation and utilization of the virtualization in the company Secar Bohemia and analyzes its current situation. Based on the performed analyzes are energy efficiency and space requirements results compared with other possible solutions. Analyzes showed a certain shortages in the infrastructure and based on these shortages are offered improvements to the current solution.

KEY WORDS:

Consolidation, Virtualization, Server, Storage, Information Technology, Blade, Datacenter, Consumption, Energy, Efficiency.

SOUHRN:

Diplomová práce se zaměřuje na konsolidaci serverů jako nástroje pro snížení provozních nákladů IT infrastruktury. Diplomová práce charakterizuje pojmy konsolidace a virtualizace a poukazuje na výhody těchto technologií na příkladu vybrané společnosti. Dále práce zkoumá postup konsolidace ve vybrané společnosti a výhody, které jí současná IT infrastruktura v porovnání s ostatními možnými řešeními přináší. Tyto výhody jsou analyzovány z ekonomického a některé z výhod také z technologického hlediska.

Diplomová práce je rozdělena do dvou hlavních částí. Teoretická část definuje a charakterizuje klíčové koncepty konsolidace. Druhá část, praktická, zkoumá proces konsolidace a využití virtualizace ve společnosti Secar Bohemia a analyzuje současný stav infrastruktury společnosti. Na základě analýzy IT infrastruktury společnosti jsou porovnány výsledky energetické úspornosti a prostorových nároků výpočetních zdrojů. Z provedené analýzy zároveň vyplynuly některé nedostatky v IT infrastruktuře na základě kterých jsou navrženy možnosti zlepšení současného stavu.

KLÍČOVÁ SLOVA:

Konsolidace, Virtualizace, Server, Storage, Informační Technologie, Blade, Datacentrum, Spotřeba, Energie, Efektivita.

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1 INTRODUCTION

The consolidation means a lowering of space requirements in IT terminology. First step of the consolidation can be utilization of so called blade technology, which lowers space requirements needed for provisioning of the servers. The base of this technology is that blade servers contain just computing components like processors, memory and disks. Servers are put into blade chassis, which is a special box containing operation components like power supply, cooling fans or networking components. This technology enables significant lowering of space requirements needed for servers and offers energy efficiency. Both of these advantages are crucial for today´s business environment, because energy and even datacenter space are very expensive.

Second step of the consolidation is virtualization. Virtualization allows having two or more computers, running two or more completely different environments, on one piece of hardware (Golden & Scheffy, 2008). Although, today´s x86 computer hardware was designed to run a single operating system and a single application, leaving most machines vastly underutilized. Virtualization enables to run multiple virtual machines on a single physical machine, with each virtual machine sharing the resources of that one physical computer across multiple environments (What is virtualization?, 2011).

Virtualization is nothing new in today´s IT world and in many companies is already represented in some form. Virtualization was firstly discovered in the 1960s, because large, mainframe hardware needed a better utilization. x86 computers had the same problems of underutilization till 1990s when VMware has invented virtualization for the x86 platform (VMware, 2011). First wave of virtualization brought higher reliability of the system, flexibility of provisioning of new applications or higher utilization of the servers, because till the virtualization came on, the average utilization of the server was only 10-15%. This wave also brought new questions about rapid growth of the number of virtual servers, higher demands on their management system, and higher demands on IT stuff or a question about the size of memory subsystem, which is crucial to the virtualization.

About the success of the virtualization technologies and its benefits for the companies testifies the growing number of implementations of the virtualization in the IT world. Number of total virtual machines growths annually by 40%, so it looks that companies realize the potential, costs savings and other benefits, which can virtualization bring to the company.

This thesis researches the concrete implementation of the virtualization technology in the company Secar Bohemia from the very beginning and compares its virtualization infrastructure with other possible solutions, which current IT market offers.

2 OBJECTIVES OF THESIS AND METHODOLOGY

2.1 OBJECTIVES OF THESIS

Main objective of the theoretical part of the thesis is to define the term consolidation and term virtualization and its features. Main objective of the practical part is to characterize and evaluate benefits of the virtualization, as a part of IT infrastructure consolidation on the practical study solution of concrete company and economically evaluate the savings, which this popular technology brings. Part of this objective is also the proposal of improvement of the final solution. There are also several partial objectives, which help to achieve the main objective.

Partial objectives are:

- Find out the goals of datacenter modernization and research the fulfillment of these goals in the chosen company
- Analyze energy savings of virtual infrastructure in the chosen company against other possible solutions
- Analyze space requirements of virtual infrastructure in the chosen company against other possible solutions
- Offer the proposal for the datacenter and infrastructure improvement for the chosen company

2.2 METHODOLOGY

Consolidation, virtualization, its´ benefits and disadvantages, function and types of virtualization are defined in the first part of the diploma thesis. Literature overview is processed on the base of studied literature and internet sources mentioned in the literature list at the end of the thesis.

Practical part contains the results of the thesis. Practical part is an analytical part processed on the basis of the research. Practical part deals with the research of the company Secar Bohemia, which had to modernize its datacenter. Practical part researches the fulfillment of the goals stated before the modernization, evaluation of the modernization and researches the economical and technical benefits of the chosen solution for the company. Practical part is complemented by the opinions of IT administrator of Secar Bohemia, technical specialist for x86 platform from IBM and authors opinions. Interpretation is complemented by graphical illustration of energy efficiency for independent solutions and at the end, the final solution of modernization is proposed.

Techniques used for gaining relevant data and drawing up the diploma thesis are study of relevant literature resources, data analyses and semi structured interviews.

STUDY OF LITERATURE RESOURCES

Theoretical part of diploma thesis is the result of literature exploration, other resources followed by their interpretation. Gained knowledge is further processed and synthesized. The list of used resources is mentioned in the chapter Theoretical bases.

DATA ANALYSES

This technique is used in practical part of the thesis. A data analysis involves gaining the numerical values for further counting. Values for energy consumption in the practical part of the thesis were gained from the tool IBM BladeCenter & System x Power Configurator, which enables to configure model configurations and very precisely determine the energy consumption of the configuration. Version of the tool used is 4.5.1.53 from December, 2010.

Method, which utilizes IBM BladeCenter & System x Power Configurator tool, is the decision tree method. Configurator contains data about independent types of components like processors, memories, disk etc. Each type of the component has its own features, defined by the producer. These features (average/maximal consumption etc.) are built in the configurator. User then selects the required configuration of independent servers or whole system configuration and according to chosen components, type of the server and chosen rack is through the decision three (choosing of components) and simple build in calculator calculated the consumption of the particular selection (configuration).

Gained values were processed into tables where they were further processed and used for calculation of the results. Results were then processed into graphs.

SEMI STRUCTURED INTERVIEWS

The use of semi structured interviews in the diploma thesis serve for extension of information needed for practical part. One interview was with the IT administrator of Secar Bohemia, Petr Krstev and second with the IBM System x technical specialist, Jakub Venc. To be able to better interpret the individual opinions, semi structured interviews were chosen rather than questionnaire or structured interview, which does not allow to fully express the basis of the problems, which is necessary for the purposes of this diploma thesis.

The Interview with Petr Krstev served mainly for acquiring information about Secars´ infrastructure, verification of data gained from the analyses and finding out the problems of the infrastructure from the view of operation and technological shortages.

The Interview with Jakub Venc served for obtaining information about current technical possibilities and for deriving the final solution.

Questions from the semi structured interviews are available at the section supplements. Independent answers were recorded and further interpreted in the thesis.

3 THEORETICAL BASIS

3.1 CONSILIDATION

Consolidation is according to definition from a Dictionary of foreign words: “a unification of obligations, debts in one single debt” (Klimeš, 2002). In Information Technology, consolidation means also unification, but from the different point of view. In this case, it is not dealt with obligations or debts, but with lowering the space requirements of the IT infrastructure. Trend of consolidation in the IT was brought by the blade technology. Blade technology saves space requirements by sharing of power supplies, cooling fans and communication cards between several servers which are mounted into the chassis, which we can say replaces classical rack. Servers then contain “only” computing components like processors, memory, disk (if supported) etc.

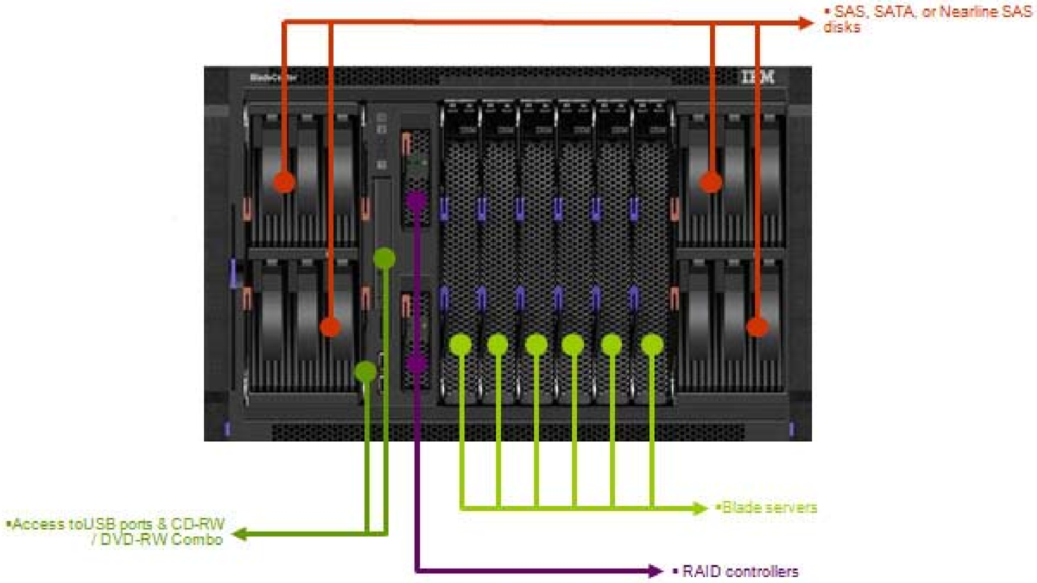
The enclosure (or chassis) performs many of the non-core computing services found in most computers. Non-blade systems typically use bulky, hot and space-inefficient components, and may duplicate these across many computers that may or may not perform at capacity. By locating these services in one place and sharing them between the blade computers, the overall utilization becomes more efficient (HP Blade System Infrastructure, 2011). The specifics of which services are provided and involved in the chassis may vary by vendor.

Advantage is then not only lower space requirements, but this solution includes also other advantages as lower electricity consumption, simplified infrastructure, easy management of all servers, server and storage consolidation and also higher reliability then in the case of classical rack or tower solution. Moreover, simplified infrastructure not only involves fewer cables, less space requirements or simpler management, but also lowers the possibility of human factor failure. For better understanding of the consolidation, this problem can be described by a short “Bus and airport” story:

Blade solution can be compared with the situation that a group of about 40 people needs to go to the airport. It is nonsense to call a cabs, because it would be expensive, not “green” (which is very modern and correct in today’s´ business to be environmentally friendly) and ineffective. Better option is to go by bus, where all the passengers share a one driver, one engine and passengers generally share the bus “resources”. With the blade technology, it is the very same. The chassis with power supplies, cooling fans, network switches or some other common (shared resources) presents bus and passengers are presented by the blade servers in this story.

Because the chassis is the "heart" of the fitted servers, it is necessary that all the components are redundant. Otherwise problem could occur, because all servers can be eliminated by failure of just one component, due to the fact that this component contained in the chassis serves for all servers. Not all vendors are driven by this rule, but logically, it should be done to eliminate this failure opportunity and avoid to a single point of failure. That is why some vendors duplicate internal data (I/O for servers) and power paths. It means that all these paths are redundant and in case of failure of one path are substituted by the second path. It is same with other components like power supplies, network components and also cooling components. If one of the components fails, the redundant component will overtake the job of the first one. This ensures reliability and maximizes the utilization of the platform.

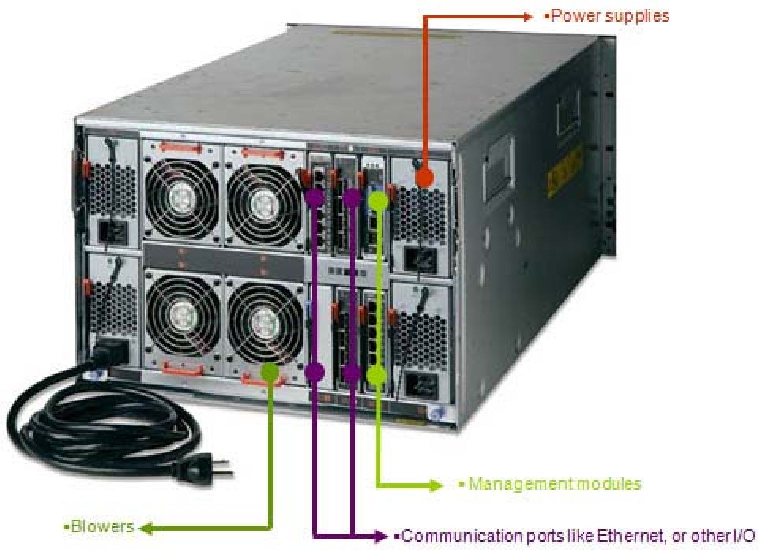
Picture no. 1: *Front view on the blade chassis, IBM*



Source: PPT of IBM Czech Republic, Blade Consolidation, 2010/12/09, slide 17.

From the picture n.1 is visible how the chassis looks from the front view. The picture is just illustrative, different manufactures have different design and the visage also depends on the type of the chassis and its configuration. But both, picture n.1 and also picture n.2 demonstrates the basic though of blade consolidation – box (chassis) with common infrastructure and positions for servers so called blade servers. The pictured solution also have two storage modules, which represents the external disk storage connected to classical rack server – so this solution adds another step to consolidation. All the administration parts are available from the front and also blade servers are available from the front, so in case of failure, server can be removed directly.

Picture no. 2: *Back view on the blade chassis, IBM BladeCenter S chassis*



Source: PPT of IBM Czech Republic, Blade Consolidation, 2010/12/09, slide no.18.

Picture number 2 shows the back view on the chassis. At this type of the chassis, from the back are visible common "life-giving" components like power supplies and cooling fans and also networking switches for external communication of servers in the chassis. Design of the chassis and distribution of the components can vary by the vendor.

Just for the illustration, according to Petr Plodík, configuration in blade chassis with 6 servers, 12 disks, 2 RAID controllers, one management module and dual Ethernet switch is 14U less space demanding than same rack configuration composed by 2U rack servers. Of course it depends on used chassis, because different chassis has different size, but concretely this configuration can be fitted in 7U chassis against 21U in rack version, which means a nice example of consolidation.

3.2 VIRTUALIZATION

Although, today´s x86 computer hardware was designed to run a single operating system and a single application, leaving most machines vastly underutilized. Virtualization enables to run multiple virtual machines on a single physical machine, with each virtual machine sharing the resources of that one physical computer across multiple environments. Different virtual machines can run different operating systems and multiple applications on the same physical computer (What is virtualization?, 2011).

Virtualization is the latest in a long line of technical innovations designed to increase the level of system abstraction and enable IT users to control increasing levels of the computer performance (Golden & Scheffy, 2008).

According to another interpretation of what is virtualization, virtualization is the process of presenting computing resources in ways that users and applications can easily get value out of them, rather than presenting them in a way dictated by their implementation, geographic location, or physical packaging. In other words, virtualization provides a logical rather than physical view of data, computing power, storage capacity, and other resources (Archer, et al., 2010).

At its simplest level, virtualization allows (virtually and cost-effectively) to have two or more computers, running two or more completely different environments, on one piece of hardware. For example, with virtualization, you can have both a Linux machine and a Windows machine on one system. Alternatively, you could host a Windows 95 desktop and a Windows XP desktop on one workstation (Golden & Scheffy, 2008).

In slightly more technical terms, virtualization essentially decouples users and applications from the specific hardware characteristics of the systems they use to perform computational tasks. This technology promises to implement an entirely new wave of hardware and software innovation. For example, and among other benefits, virtualization is designed to simplify system upgrades (and in some cases may eliminate the need for such upgrades), by allowing users to capture the state of a virtual machine, and then transport that state in its entirety from an old to a new host system (Golden & Scheffy, 2008).

Virtualization is also designed to enable a generation of more energy-efficient computing. Processor, memory, and storage resources that today must be delivered in fixed amounts determined by real hardware system configurations will be delivered with finer granularity via dynamically tuned virtual machines (Golden & Scheffy, 2008).

3.2.1 SERVER VIRTUALIZATION

With virtualization of servers it all has begun. Firstly with virtualization of mainframes and then, about 30 years later with virtualization of x86 platform. Because to virtualization of the servers is dedicated main part of this dissertation, about virtualization of the servers very shortly.

Virtualization of the servers is based on sharing of single hardware and distribution of its´ computing components like processor, memory and network components between virtual servers. Virtual machine can be understood as a tightly isolated software container that can run its own operating systems and applications as it would have been run on a physical computer. A virtual machine behaves exactly like a physical computer and contains it own virtual (software-based) CPU, RAM hard disk and network interface card (What is virtual machine, 2011).

3.2.2 DESKTOP VIRTUALIZATION

Virtual Desktop solutions offer access anytime and anywhere. With the use of connection broker, system is able to seamlessly linking end-user devices with centrally hosted applications. The solution acts as a universal connection plug that enables users to access the applications and information they require from virtually anywhere. User just logs on over a secured connection through the Internet and connects to applications that he/she would normally access in his/her environment as present in the office (Archer, et al., 2010).

3.2.3 STORAGE VIRTUALIZATION

In the past, if someone needed more disk space, he/she just purchased a bigger disk drive. But data storage needs grew, so multiple disk drives were developed. Finding and managing these multiple drives became harder and took more time that is why RAID, network-attached storage and storage-area network were developed. But to manage and maintain thousands of disks is even more time demanding. Latest answer to this phenomenon is storage virtualization, which adds a new layer of the software and hardware between storage systems and servers, so that applications no longer need to know on which specific drives, partitions or storage subsystems their data resides. Administrators can identify provision and manage distributed storage as if it were a single, consolidated resource. Because applications are not restricted to specific storage resources and thus insulted from most interruptions, also availability of such solution increases. Storage resources in virtual infrastructure can be updated during the operation without affecting the application performance, so reduce downtime (Kay, 2008).

Companies use centralized storage (virtualized storage) as a way of avoiding data access problems. Furthermore, moving to centralized data storage can help IT organizations reduce costs and improve data management efficiency (Golden & Scheffy, 2008).

3.3 HISTORY OF THE VIRTUALIZATION

Virtualization was firstly discovered in the 1960s. It was due to necessity of partitioning of large, mainframe hardware for better hardware utilization. Till 1990s, computers with x86 platform were faced to same problems of underutilization and rigidity of the hardware. Break through has occurred in 1990s, when VMware has invented virtualization for the x86 platform to address underutilization and other connected issues, which enabled overcome many challenges in the process (VMware, 2011).

Virtualization was firstly implemented about 40 years ago by IBM. It was the time, when computer infrastructure was dominated by large, room mainframe computers. Problem of those mainframes was visible underutilization of the hardware resources of each independent mainframe computer. Solution was to logically partition these mainframe computers into separate virtual machines. These independent partitions allowed mainframes to “multitask”: run multiple, different applications and independent processes at the same time. This improved the efficiency of the mainframe by full utilization of the resources of the mainframe computer. Because mainframes were very expensive resources at that time, they were designed for portioning as a way to fully the inserted investment (VMware, 2011).

According to VMware (2011), virtualization of the large mainframe computers was abandoned during the 1980s and 1990s. It was due to client-server applications and cheap x86 servers and desktops, which started to control the market with servers and market started to deviate from the mainframe computers to x86 platform. Global adoption of Windows and emergence of Linux as a server operating systems in the 1990s established x86 platform as the industry standard for computing. This growth in x86 server platform and desktop platform led to new IT infrastructure and operational challenges, which included following points, which needed to be solved somehow:

- **Low Infrastructure Utilization.** Typical x86 server deployment achieves an average utilization of only 10% to 15% of its total capacity, which is warning value. These numbers are according to market research company International Data Corporation (IDC). Companies have used to run just one application per server to avoid the risk of vulnerabilities in one application affecting the availability of another application on the same server. But experience is little bit complicated – because of cost savings, companies run more than one application on one server, disaster then has much deeper consequences on the operations of the company, because when the server breaks down, more than one application stops its operation and the failure is more extensive.

- **Increasing Physical Infrastructure Costs.** The operational costs to support physical infrastructure are continuously increasing. Most computing infrastructure must remain operational all the time, it results in continuous power consumption, cooling and facilities costs. The main problem is that these costs do not vary with utilization costs – it means that even if the server is underutilized and runs on about 10-15% of its maximum performance, it is still taking the energy and radiates heat as it would be running on 100%. And growing amount of IT infrastructure needs more human resources, which also need to be paid and included in operation costs of the datacenter and will be mentioned as following point.

- **Increasing IT Management Costs.** As computing environments become more complex, the level of specialized education and experience required for infrastructure management personnel and the associated costs of such personnel have increased. At first, high costs are associated with mentioned education, so specialized personnel could develop with the infrastructure. At second, organizations spend much time and resources on manual tasks associated with server maintenance and that is why organization required more personnel to complete these tasks.

- **Insufficient Failover and Disaster Protection.** Organizations are increasingly affected by the downtime of the critical server applications and their inaccessibility of critical and user desktops. The threat of security attacks, natural disaster, health pandemics and terrorism has elevated the importance of business continuity planning for both desktops and servers. Of course, there is software for disaster recovery, but not in 1990s. And security of virtual infrastructure is relatively simple nowadays.

- **High Maintenance end-user desktops.** Managing and securing enterprise desktops present numerous challenges, it is time demanding and hard, demanding ant work. Controlling a distributed desktop environment and enforcing management, access and security policies without delaying and impairing users' ability to work effectively is complex and very expensive. Numerous patches and upgrades must be continually applied to desktops environments to eliminate security vulnerabilities (VMware, 2011).

In 1999, VMware has introduced virtualization on x86 platforms and enabled to address many of these mentioned challenges and transform x86 systems into a general purposes, shared hardware infrastructure that offers full isolation, mobility and operating system choice for application environment. This was a breakthrough on the market with x86 platforms, because all the mentioned challenges could be relatively easily solved. Main advantage and breakthrough was visible on the utilization of the servers, because 15% was really not much. But also other mentioned challenges could be easily improved, e.g. demands on human resources are higher, because virtualization requires perfect abstract imagination, but the total amount of personnel is thanks to virtualization reduced. Advantages of virtualization against mentioned challenges will be mentioned further in the dissertation (VMware, 2011).

Unlike mainframes, x86 platforms were not designed to support full virtualization and VMware during the development of its software had to overcome formidable challenges to create virtual machines out of x86 computers. One problem above the others as an example: The basic function of most CPUs, both in mainframes and also in classical Personal Computers, is to execute a sequence of stored instructions (a processed software program). In x86 processors, there are 17 specific instructions that create problems when virtualized, causing the operating system to display warning, terminate the application, or simply crash altogether. As a result, these 17 instructions were a significant obstacle to the initial implementation of virtualization on x86 computers. To handle the problematic instructions in the x86 architecture, developers of VMware developed adaptive virtualization technique that “traps” these instructions as they are generated and converts them into safe instructions that can be virtualized, while allowing all other instructions to be executed without intervention. The result is a high-performance virtual machine that matches the host hardware and maintains total software compatibility (VMware, 2011).

3.4 VIRTUALIZATION PROS AND CONS

Virtualization of IT infrastructure reduce IT costs and increase efficiency, utilization and flexibility even of current assets. Virtualization eliminates the old model of “one server, one application” and enables to run multiple virtual machines on each physical machine (Virtualization benefits, 2011). It does not mean that the concept of one server – one application is bad or outdated, because it brings better security and minimizes the influence of operations of the company, because if server fails only one application will stop working. But in case of physical infrastructure it is inefficient, because it underlines the underutilization of the physical servers without virtualization. Virtual infrastructure enables the concept of one server – one application too, but modifies it to one virtual server – one application. It is much more efficient, the advantage of security and low influence of operation is same as use of this concept in the physical infrastructure, but the utilization of hardware resources is catapulted to much higher level.

3.4.1 ADVANTAGES OF VIRTUALIZATION

3.4.1.1 HARDWARE UTILIZATION

Many data centers have machines running at only 10 – 15% of total processing capacity. It means that about 85 to 90% of the machine´s power is unused and wasted. Even the lightly loaded machine still takes up the room and draws electricity, so the operating cost of today´s underutilized hardware are very same as if the machine would be running at full performance. This waste of computing resources is unacceptable and degrades the efficiency of the datacenter to poor numbers. With upgrade of the datacenter, next year´s machine (server) will have twice as much spare capacity as current machine (Golden & Scheffy, 2008).

Picture no. 3: *Maximization of hardware resources by virtualization.*

Source: http://www.cryptis.com/img/vmware.gif

As is visible on the picture number 3, virtualization enables a single piece of hardware to run and support multiple systems. By applying virtualization, companies can raise their hardware utilization rates dramatically and use the corporate capital efficiently (Golden & Scheffy, 2008). Hardware resources of a physical machine are distributed between virtual machines which run on the physical machine. This enables to reach the efficiency about 90% in comparison with previous 15%.

3.4.1.2 SPACE REQUIREMENTS

Over the past 20 years, business world has undergone an enormous transformation, not only in a sense of market development, business models, but also and mainly technology. Business process after business process has been captured in software and moved from paper to electronic data. This has been heavily affected by the raise of the Internet. Companies want to communicate with customers and partners in real-time, using the worldwide connectivity of the Internet (Golden & Scheffy, 2008).

However, all this led to huge numbers of servers have been put into use over the past decade and caused the huge problem for companies. Many companies are running out of space in their datacenters and are forced to completely rebuild and oversize their datacenter for the future needs, or go by the way of the consolidation and later on even virtualization. Increasing amount of data, which need to be stored somewhere calls for the new method of data storage – storage virtualization (Golden & Scheffy, 2008).

Because virtualization enables to host multiple guest systems on a single physical server, it allows organizations to utilize unused part of the datacenter (without virtualization, about 85% of the datacenter is unutilized) and avoid the expense of building a new datacenter with more space (Golden & Scheffy, 2008). Just for illustration how large would the expense had been, building of new, modern datacenter costs amounting in tens of millions CZK.

3.4.1.3 ENERGY EFFICIENCY

Energy is more expensive year to year and growing number of electric devices increases its´ consumption. Organization should not underestimate this phenomenon and should consider whether they should look for ways to be less power dependent. More, the impact of green revolution has meant that companies are increasingly looking for the ways to reduce the amount of energy consume – and first place where to look is the datacenter (Golden & Scheffy, 2008).

A study authorized by the AMD and performed by a scientist from the Lawrence Berkeley National Laboratory showed that the amount of energy consumed by data centers in the United States has doubled between 2000 and 2005. Further was expected that that energy consumption will increase by another 40% by the end of the decade. In 2008, the energy consumption of the data centers servers and associated cooling represented 1.2% of the total energy consumption consumed in the United States (Golden & Scheffy, 2008).

Petr Plodík (2011) says that it is very important to realize, that consumption is not only the input power to the servers, but also cooling cost for cooling the heat radiated by the servers and also by the storage. Storage is significant part of the datacenters´ heat radiation – consider the fact, that one disk has radiation about 15-25 Watts and enterprise data storage has large amount of disks. And this heat needs to be cooled by the air-condition – Data Center Environmental Control units (air-condition plus humidity control, because servers, storage etc. are demanding for operating conditions like temperature, humidity, altitude,…), which needs a huge amount of electricity too.

The cost of running computers, coupled with the fact that many of the machines filling up data centers are running at low utilization rate. It means that virtualization´s ability to reduce total number of physical servers can significantly reduce the overall cost of energy for companies and make the company "green" to environment (Golden & Scheffy, 2008).

3.4.1.4 ADMINISTRATION COSTS

Computers do not operate all on their own. Every server and also every other piece of hardware in the datacenter requires care and feeding by system administrators. Tasks of the administrators include monitoring of the hardware status, replacing defective hardware components, installing the operating system and application software, install of the patches, monitoring of the critical server resources like memory and disk use and also backing up of the data to other storage mediums for security and redundancy purposes and also solving of issued problems of the IT infrastructure. All these tasks are labor intensive and person who perform it do not come cheap for the company and need to be co-located with the infrastructure, so they could access the physical resources (Golden & Scheffy, 2008).

As a part of lowering the overall costs, virtualization offers the opportunity to reduce overall system administration costs by reducing the overall number of machines that need to be taken care of. Although many of the tasks associated with system administration (OS and application patching, doing backups…) continue even in a virtualized environment, some of them disappear as physical servers are migrated to virtual servers. Other tasks are drastically simplified, because thanks to virtualization can be executed from a single interface for all virtual servers (Golden & Scheffy, 2008).

3.4.1.5 FLEXIBLE DEVELOPMENT AND TESTING ENVIRONMENT

The ease and flexibility of creating and reconfiguring of guest operating systems (known as virtual machines), means that development and testing environments get significant benefit from virtualization. This enables to simply try and test applications and developed company´s upgrades. Through a few clicks is possible to create, delete or copy the virtual machine, save its´ state and easily ramify the development without dedicating the single physical machine. In fact, this is where the most of these x86 virtualization technologies were used when first available (Archer, et al., 2010).

3.4.1.6 DISASTER RECOVERY

Disaster recovery is another key reason to implement virtualization technologies. Because the whole virtual machine running on any virtualization technology is typically self-contained in a single file, it becomes very easy to manipulate a Windows machine. The file can be easily stored, copied etc. Of course, that backup is needed, but from the backup is the recovery very simple. Administrator just recalls the state before the failure and virtual machine operates again, while the downtime of the machine was minimal (Archer, et al., 2010).

3.4.1.7 APPLICATION DEPLOYMENT

Most of virtualization software of independent vendors store the entire virtual machines in a single large file. As a result, operating system and application provisioning can be achieved by simply copying a standard template virtual machine file to a new file, which becomes the new virtual machine. As a result, you can activate your new VM in a matter of minutes or hours. It significantly simplifies the job of IT administrators and enables them to develop the IT infrastructure more effectively. This point is also connected with the administration costs, because companies do not need as many administrators.

3.4.2 DISADVANTAGES OF THE VIRTUALIZATION

3.4.2.1 HIGH ENTRY COSTS

For installation of the virtualization, it is necessary to create appropriate environment – infrastructure. Not every infrastructure is suitable and in 99% of the cases is necessary to create a new infrastructure. It is caused by the demands of virtualization on hardware resources and the fact of over sizing – infrastructure is better to build with higher standard than to upgrade it later on. Problem is that it is hard to estimate the needed resources. It can be done by qualified person with rich experiences on the field of the virtualization or nowadays exist specialized software, which enable the estimation of resources for individual virtual environments (Krstev, 2010).

Another cost aspect is that for higher functionalities of VMware software are needed shared storage (at least one, but better – more reliable is to have two shared storages or even more). Implementation is also sometimes costly complicated by the fact that in some cases is necessary the upgrade of the licenses – for example is not possible to use OEM Windows's licenses – Original Equipment Manufacturer). This fact also hits the costs and company must dig into pocket. (Krstev, 2010).

3.4.2.2 UNDERESTIMATION OF LIMIT STATES

Host hardware must have required configuration and cannot be underestimated, because it could cause problem and virtual infrastructure would run slowly and also company's operation would not be as efficient as it could be. Hardware performance is necessary especially when starting the whole system. When start of the system is slow, it is inefficient and for infrastructure unacceptable. This is important part and very demanding basically on all components (processor, memory, Input/output components…). Underestimated cannot be also the performance of chipsets in host servers (servers which run virtual machines), otherwise if more I/O intensive virtual machines run on the system, shortage of the chipset performance will occur and be visible (Krstev, 2010).

3.4.2.3 HIGH DEMANDS ON IT ADMINISTRATOR´S ABSTRACTION

In virtual environment is everything virtual – imaginary, abstract. That is why IT administrators are needed to have certain level of abstraction. In physical environment, the situation is easier because the components and everything except software is touchable, so better understanding for human mind. From IT administrators, for handling of casual administration is needed certain level of abstraction. For transfer of physical machines to virtual machines and for different reconfigurations of virtual environment is necessary to have higher level of abstraction and for planning of virtual environment is required even higher level of abstraction(Krstev, 2010).

3.4.2.3 UNSUITABLE ADMINISTRATION TOOLS

Virtual environment brings even in its´ standard version improvement from the view of the administration tools in comparison with not virtualized environment. Especially the measurability of performances is a huge advantage. With the development of IT infrastructure is probable, that in two years from the deployment of virtual infrastructure will be the number of machines three times higher (hosts + virtual machines). This is why is necessary to implement new, appropriate administrative tools and processes, otherwise will be IT department of individual companies overloaded by regular agenda (Krstev, 2010).

3.4.2.4 OTHER NEGATIVE EFFECTS

Between other effects, that can make adoption of virtualization harder (no matter if from the view of costs or technical barriers) are at first the necessity to change the philosophy of back up, so potential if the virtualization could be fully utilized. Other cons is that ease of creation of new virtual machine is addictive and tends to underrating of importance of starting up a new machine and virtual servers are multiplied like a parasites. Number of production servers and run virtual machines is approximately same as the number of not run virtual machines (copies, backups, pattern machines…). This hugely loads storage with data. Sometimes also occur a problem in sense, that first several virtual machines is created very fast (hours) and creation of following other can take about weeks (Krstev, 2010).

3.4.3 CONTRIBUTION OF PROS AND CONS

Among all the benefits and disadvantages of the virtualization, virtualization seems to be very contributive for the whole IT world. It is visible also from the development and implementation boom of the virtualization (further in the part: Current business environment and virtualization). Generally, virtualization can bring to the company several important features, which enable company to operate more effectively and with lower costs. Thanks to virtualization companies are able to gain more from existing resources and pool its resources and radically help to consolidation of servers.

Costs are lowered not only by reduction of physical resources (consolidation) connected with reduced power and cooling requirements, but also by improving the server to admin ratio. Ease of back up of the virtual servers brings improved business continuity and your “hardware” and applications are maximally available even during the planned service interventions and rapidly recovered during the unplanned failures. Virtual infrastructure also enables dynamically respond to market changes and flexibly provision desktops and applications. Among these overall benefits, there should be also included the possibility to run multiple operation systems on just one single computer – Windows, Linux and other on a single hardware.

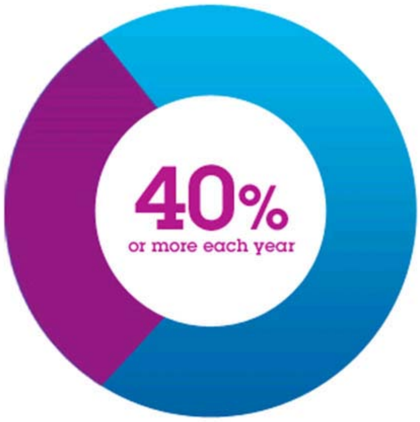
3.5 CURRENT BUSINESS ENVIRONMENT AND VIRTUALIZATION

According to Gartner (world's leading information technology research and advisory company), virtualization has the highest impact on the trend of changing infrastructure and operations of the companies at least to 2012. Virtualization transforms how IT is managed, what is purchased into to the infrastructure, how is it deployed and even how companies plan their strategies. The result is that virtualization is creating a new wave of competition among infrastructure vendors over the past years (Virtualization trends, 2008).

Philip Dawson, vice president at Gartner says: “Virtualization is hardly a new concept, servers, desktops, storage and even networking is virtualized. However, virtualization becomes more omnipresent.” According to Gartner, leading edge of this concept is server virtualization, mainly thanks to significant improvement of underutilized capacity of existing server architectures. The use of PC virtualization is also rapidly increasing. According to Gartner laboratories, by the end of 2011, the overall number of all virtualized PCs is expected to be 660 million.

According IDC, number of virtual machines grows by 40% each year, compounded annual growth rate is expected to be 42,25% and virtual machines should growth from 1.4million in 2010 to 16.6 million by 2012. This value testifies about the boom of virtual infrastructure and that companies realize the potential, benefits and cost saving, which virtual infrastructure can bring to their business.

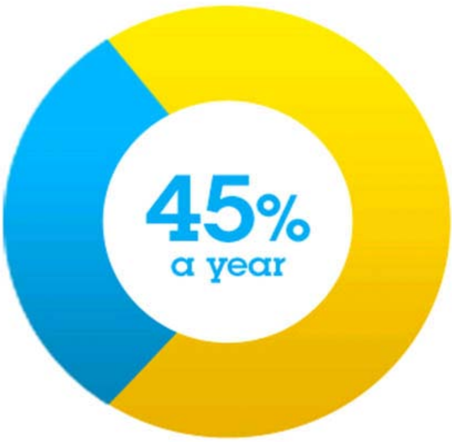
Picture no. 4: *Current market development - number of virtual machines grows by 40% each year.*



Source: IDC (International Data Corporation), Storage Market View, Deck for IBM.

With the boom of virtual servers is connected the expansion of virtual software management, about which IDC made a forecasting research: "IDC expects this market to grow at a 14% CAGR (Compounded Annual Growth Rate) during the 2009–2014 time frame, resulting in total revenue of approximately $1.4 billion by 2014," explains Mary Johnston Turner, research director, Enterprise System Management Software. "As server virtualization moves into production datacenters and is widely used to power private and public cloud computing environments, advanced management functionality will be in high demand." (Server Management Software Forecast, 2010)

Picture no. 5: *Current market development – cloud adoption growing.*



Source: IDC, 31 January 2011, "Cloud System Management Software Gains Momentum with IDC Forecasting Revenues Reaching $2.5 billion in 2015". Press release.

According to IDC, cloud adoption is significantly growing. Compounded annual growth rate between 2010 and 2015 is 45.5%. Petr Plodík (2011) says: “Cloud has become a part of today’s IT world, about which testifies growing number of time dedicated to cloud computing at technical conferences. “ His words are supported by the IDC research, which shows that cloud adoption by different companies grows about 45% a year.

From its invention, virtualization has become appurtenant part of IT world and every organization, which thinks about creation or modernization of the datacenter should consider the opportunity to virtualize. Over higher entry costs, which will be paid back through operating costs, it can bring many financial and business advantages to the company. Except companies, high utilization of servers, lower energy consumption and low space requirements brings benefits even to our environment.

3.6 HOW DOES VIRTUALIZATION WORKS

A number of common uses for virtualization exist, all centered around the concept that virtualization represents an abstraction from physical resources. The two most common types of virtualization applied in the data center are server virtualization and storage virtualization. Within each main type there are different approaches or types each of which has benefits and drawbacks for something else and therefore each one is suitable for slightly different purposes (Golden & Scheffy, 2008).

3.6.1 SERVER VIRTUALIZATION

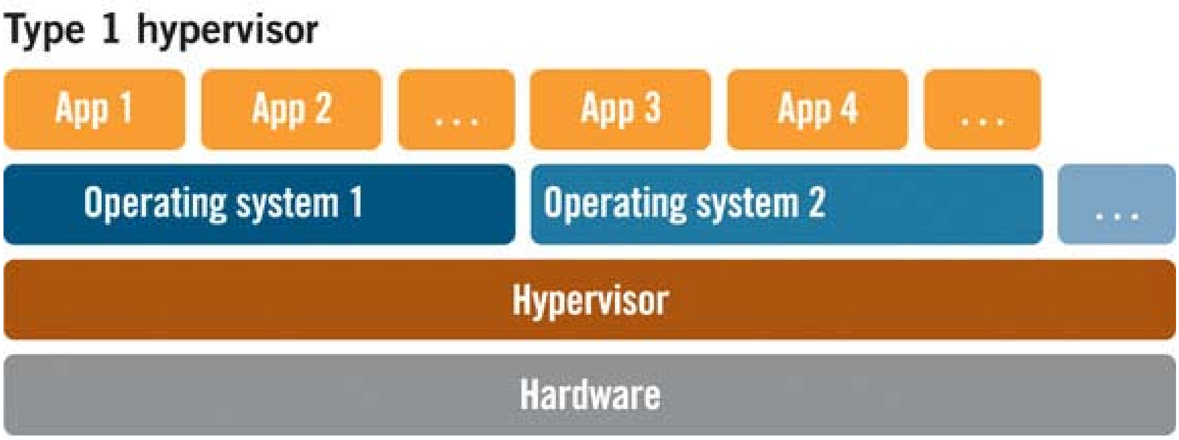
According to book Virtualization For Dummies (Golden & Scheffy, 2008), one of the most common approaches to virtualization is to use hypervisor technology. Today’s hypervisors provide the greatest level of flexibility in how virtual resources are defined and managed and have become the primary choice for server virtualization. Hypervisors use a thin layer of code in software to achieve soft, dynamic resource sharing. There are two types of hypervisors.

Type 1 hypervisors run directly on the system hardware, while type 2 hypervisors run on a host operating system that provides virtualization services such as I/O device support and memory management. Solutions that uses a type 2 hypervisor are also referred to as operating system (OS) virtualization and in some environments are called containers (Golden & Scheffy, 2008).

3.6.1.1 TYPE 1 HYPERVISORS

Type 1 hypervisors are typically the preferred approach for server consolidation because they can achieve higher virtualization efficiency by dealing directly with the hardware. These hypervisors provide higher performance and efficiency and use hardware assisted virtualization technology. These types of hypervisors use a thin layer of code to provide resource sharing within a single hardware platform (Golden & Scheffy, 2008).

Picture no. 6: *Graphical block scheme of the function of type 1 hypervisor.*



Source: http://www.ecnmag.com/Articles/2010/04/Can-hypervisors-Stand-the-Test-of-Real-Time/

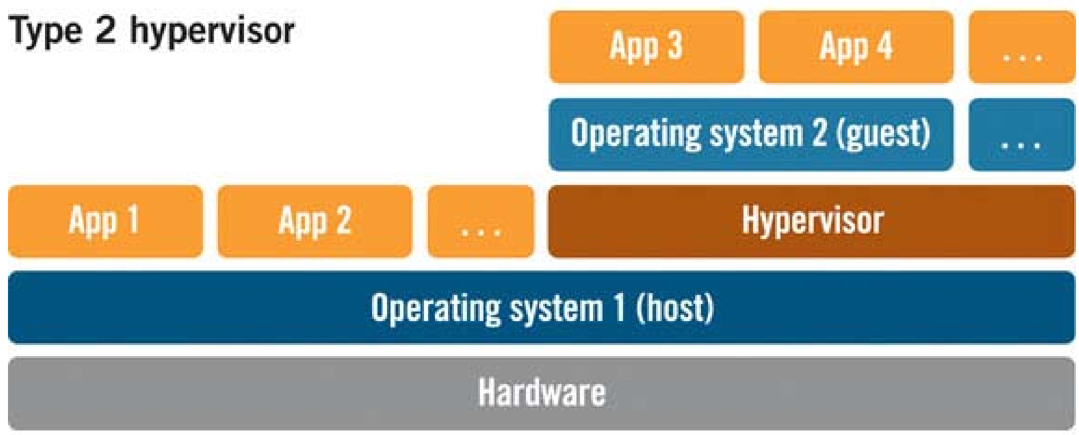
Another way to look at it is that the hypervisor provides a standard emulated hardware environment that the guest OS, sometimes referred to as the virtual machine (VM), resides on and interacts with. The VM encapsulates the guest operating systems and the application into a single entity that provides isolation from the underlying hardware. It is because of this encapsulation that the VM can be migrated from one physical machine to another without any service interruption. This approach support running multiple VMs and also it can support multiple VMs running different types and versions of operating systems (for example, completely different operating systems like Windows and Linux can be run simultaneously on the same physical server) (Golden & Scheffy, 2008).

Type 1 hypervisor solutions are often used for server consolidation to achieve higher levels of resource utilization. Software development or quality assurance environments will also benefit greatly from this type of virtualization due to the ability to allow a number of different operating systems to be run simultaneously. This can facilitate parallel development or testing of software in a number of different operating system environments in a quicker, and potentially more efficient, manner. But this is not the only field where to use them, during past years, this type of hypervisor started to be utilized for almost all purposes (Golden & Scheffy, 2008).

3.6.1.2 TYPE 2 HYPERVISORS (OPERATING SYSTEM VIRTUALIZATION)

Type 2 hypervisors run on a host operating system that provides virtualization services such as I/O device support and memory management. These services give an application the illusion that it is running on a machine dedicated to its use. The key thing to understand is that, from the application's execution perspective, it sees and interacts only with those applications running within its virtual operating system and interacts with its virtual operating system as though it has sole control of the resources of the virtual operating system. Crucially, it can't see the applications or the operating system resources located in another virtual operating system (Golden & Scheffy, 2008).

Picture no. 7: *Graphical block scheme of the function of type 2 hypervisor.*



Source: http://www.ecnmag.com/Articles/2010/04/Can-hypervisors-Stand-the-Test-of-Real-Time/

This approach of virtualization is extremely useful if you want to offer a similar set of operating system functionalities to a number of different user populations while using only a single machine. This is an ideal approach for example for Web hosting companies: They use container virtualization to allow a hosted Web site to “believe” it has complete control of a machine, while in fact each hosted Web site shares the machine with many other Web sites. Similar type of virtualization is used for virtualization of desktops (Golden & Scheffy, 2008).

But, there are some limitations to operating system virtualization. First and foremost, this approach typically limits operating system choice. Containerization usually means that the containers must offer the same operating system as the host operating system and even be consistent in terms of version number and patch level, it is why it is often used for desktop virtualization – all users use same version of operating system. As you may imagine, this can cause problems if you want to run different applications in the containers, because applications are often certified for only a certain operating system version and patch level. Consequently, operating system virtualization is best suited for homogenous configurations — for those arrangements, operating system virtualization is an excellent choice (Golden & Scheffy, 2008).

3.6.2 STORAGE VIRTUALIZATION

The amount of data organizations are creating and storing is exploding. Due to the increasing shift of business processes to Web-based digital applications, companies are being inundated with data (Golden & Scheffy, 2008).

Virtualization operates as an intermediate layer, which is why it becomes the primary interface between servers and storage. Servers see the virtualization layer as a single storage device, while all the individual storage devices see the virtualization layer as their only server. This enables to easily group storage systems – even if the systems are from different vendors. This intermediate layer also protects servers and applications from changes to the storage environment and enables users easily hot-swap a disk or tape drive. Copying of data is also managed at the virtualization layer, it means that data replication, whether for snapshot or disaster recovery, can be handled entirely by the virtualization system (Kay, 2008).

3.6.3 PARTS OF VIRTUAL INFRASTRUCTURE

3.6.3.1 VIRTUAL MACHINE

Virtual machine can be understood as a tightly isolated software container that can run its own operating systems and applications as it would have been run on a physical computer. A virtual machine behaves exactly like a physical computer and contains it own virtual (software-based) CPU, RAM hard disk and network interface card (What is virtual machine, 2011).

Picture no. 8: *Graphical illustration of virtual machine (server, desktop…) from VMware*

Source: 12.12.2010, http://www.vmware.com/virtualization/virtual-machine.html

Operating system does not recognize the difference between a virtual and physical machine. Even the virtual machine thinks that it is a “real” computer. Over all, virtual machine is completely composed entirely of software and contains no hardware components. If we sum all of this, virtual machines offer a number of distinct advantages over physical hardware (What is virtual machine, 2011).

Picture no.8 shows the graphical illustration of the virtual machine according to VMware company. The whole rectangle presents the virtual machine, where at the bottom block are virtual components like CPU, memory, storage and network cards. On that is installed operating system on which run different applications. It is then visible, that virtual machine behaves like a real computer/server.

Concrete advantages of the virtual server (machine) against the physical server are following:

- **Compatibility –** virtual machines are completely compatible with all standard x86 operating systems, applications and device drivers, so it is possible to run all the same software that is run on a physical x86 computer. It is possible, because as a physical computer, virtual machine hosts its own guest operating system and applications and has all the components, which can be found in a physical computer (motherboard, VGA card, network card…).

- **Isolation –** virtual machines can share all the physical resources of a single computer, they remain completely isolated from each other as if they were separated physical machines. It means, that if are four virtual machines run on a single physical computer and one of them fails, the other three virtual machines work normally and remain available. It is the key feature of the virtualization to isolate the virtual machines, otherwise would be the solution useless. Isolation makes virtual infrastructure far more available and secured, than classical physical infrastructure.

- **Encapsulation –** virtual machine is basicaly a software container that is packed on a complete set of virtual hardware resources, operating system and all its applications inside this software package. This make virtual machines really flexible in sense of portability and managability. Virtual machines can be moved and copied from one location to another just like every else software. It is also possible to store in on any of the current data storage media (CD, DVD, USB flash storage...).

- **Hardware independence –** virtual machines are completely independent from the hardware on which they are run. It is possible to configure a virtual machine with completely different virtual components like CPU, network card, SCSI controller, etc. than is in the physical machine. Those virtual machines can even run different kinds of operating system like Windows, Linux, etc. The compatibility is maximally flexible, because virtual machine can be easily moved from one type of x86 computer/server to another without making any changes in operating system, drivers nor applications. Of course it is possible to run multiple operating systems and applications on a single physical computer.
  (What is virtual machine, 2011)

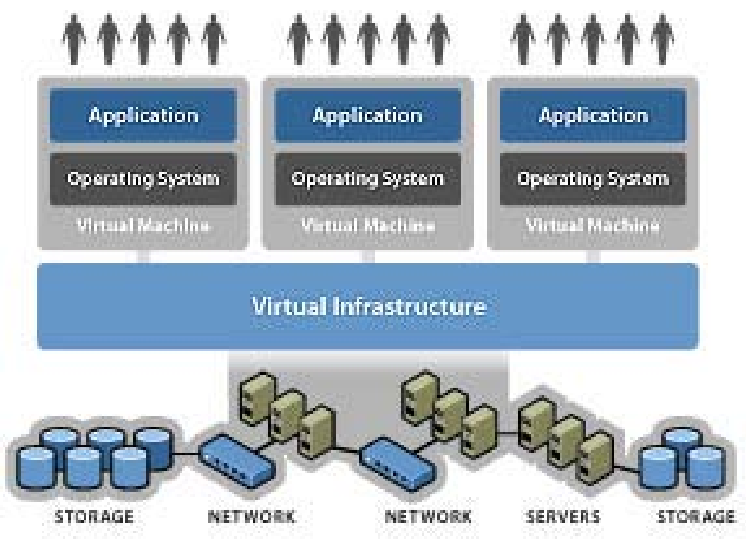
3.6.3.2 VIRTUAL INFRASTRUCTURE

Virtual infrastructure enables to share physical resources of multiple machines across entire infrastructure. Virtual machine enables to share resources of a single physical computer/server across multiple virtual machines and maximal efficiency is reached through this process. Physical resources are shared across multiple virtual machines and applications. The business of each company is then enhanced about dynamic mapping of physical resources in the whole infrastructure to applications. This resource optimization drives greater flexibility in the organization and results in lower capital and operating costs (Virtual infrastructure, 2011).

Virtual infrastructure consists of following components:

- Hypervisor, which enables full virtualization of each x86 server
- Virtual infrastructure services for optimization of available resources between virtual machines
- Automation solution that provides special capabilities to optimize a particular IT processes (provisioning, disaster recovery…)

Picture no. 9: *Graphical illustration of the virtual infrastructure.*



Source: http://www.vmware.com/virtualization/virtual-infrastructure.html

Virtual infrastructure decouples software environment from its underlining hardware infrastructure, so it is possible to aggregate multiple servers, storage infrastructure and networks into shared pools of resources. This kind of innovation enables companies to flexibly build blocks of inexpensive servers and datacenter with high levels of utilization and availability (Virtual infrastructure, 2011).

3.6.4 CRITICAL COMPONENTS FOR VIRTUALIZATION

Computer combines different resources to enable automated processing of data, according to book Virtualization For Dummies (Golden & Scheffy, 2008) are four of them critical for virtualization:

- **Processor –** The central processing unit (CPU) is what turns random information into organized data. Processors manipulate strings of characters, add and subtract numbers, and arrange for information to flow in and out of the system. As mentioned above in the dissertation, virtualization enables a single physical computer to support multiple virtual guest systems. The ability to coordinate processor access by the separate guest systems is one of the main challenges of virtualization, particularly since the x86 processor was never really designed to support multiple guests.

- **Memory –** A computer contains physical memory to store the data that the processor manipulates. Similar to the processor, memory must be carefully managed to enable multiple guests to share a single set of physical memory without allowing separate guest systems to overwrite one another's data. And, as in case of processor, x86 memory was not designed with multiple guest access in mind.

- **Network** – Computers communicate with one another as well as sending and receiving data from the Internet. While data flows back and forth on the physical network card within a virtualized system, it's critical to ensure that each virtual system receives the appropriate network traffic.

- **Storage** – Storage is other critical component affected by virtualization— data residing in a place that it can be retrieved from. Each virtual guest system must have its own data storage and the virtualization software must keep each guest system's storage isolated. (Golden & Scheffy, 2008)

4 CASE STUDY: SECAR BOHEMIA

Practical part contains information and data gained from the semi structured interviews. These data heavily support the practical part of the thesis. Questions from the interviews are available in section 7. Supplements, supplements no. 2 and no. 3.

4.1 BASIC INFORMATIONS ABOUT THE COMPANY

Secar Bohemia is the biggest company in the Czech Republic focused on searching systems. Company, central is placed in Prague, operates nationally and if requested by customer, even internationally. Secar Bohemia provides its services since 1992. Secar Bohemia provides to its customers several product lines for protecting of their cars, utilization of GPS for accounting purposes (log books), protection of buildings and other physical objects and also provides service, which checks intactness of transporting pipelines.

Product portfolio is very rich and includes:

- **SHERLOG Neo** – main and well known product of the company utilizes the principle of radio waves, GPS and GSM for searching and monitoring of cars. Car protection is highly discreet and works 24 hours, 365 days a year. Searching can be also worldwide thanks to EUROWATCH service. This international car monitoring is in the Czech Republic offered only by the company Secar Bohemia. Other companies work only nationally. Quality and popularity of this service is confirmed by 98% success when searching of the stolen cars, increasing number of clients year to year and also trust of insurance companies, which provide large sales on car insurance when product SHERLOG Neo is installed.

- **SHERLOG Safetronic** – improves car security by electronic lock of transmission.

- **SHERLOG Trace** – enables to monitor companies' cars and make log book, which is for companies necessary. Similar service is also offered in cooperation with O2 Czech Republic under the name ***O2 Car Control***. Log book is offered by Secar Bohemia since 1999 and company has become innovator on the market with GPS with log book purposes. System works online through the internet – GPS unit inside the car sends information about movement of the car – in case of signal loss are data about the car positions stored into internal memory of the GPS and send later on.

- **SHERLOG Pipeline** – new and modern system for detection and localization of media leakages from the long distance pipelines (gas, liquids and also its´ intermix). This service is offered on the field of Czech Republic, neighboring countries and also in the eastern countries.

4.2 IMPORTANCY OF SERVERS AND DATACENTER FOR THE COMPANY

Servers and whole infrastructure are necessary for the company Secar Bohemia. Servers run the applications, which receive information from the GPS units – no matter if for searching purposes or for the log book. Information is further processed by presentation server, which also runs the business intelligence and databases. The most demanding layer in the infrastructure is database layer and information layer. All mentioned applications are critical for the company and without centralized IT infrastructure would the whole business be non-functional.

For searching of stolen cars is critical part of infrastructure the speed of chipset. Processor, memory and also storage in this case process the task rapidly enough, but processing of huge amount of small transactions is slowed down by the speed of chipset. If total number of secured units (cars and other objects) would be twice higher, chipset would have been insufficient for computing.

Historical development of the company´s infrastructure set that same map materials for log book and searching of stolen cars run on different servers. This eliminates impacts in case of disaster and also costs defined by the SLA agreement would be minimized in that case.

Virtualization enables easily create for each application dedicated server, which means total opposite against the physical infrastructure, which tends to group applications to one server, because in physical infrastructure are additional server very cost demanding and also the process of purchasing is time demanding. Benefit of virtual infrastructure and dedication of servers is isolation of possible errors (if error occurs on server which is dedicated to one application, it affects only the application on the particular server, not the other). Higher granularity in case of virtualization causes higher density of the system.

4.3 SITUATION BEFORE CONSOLIDATION & REASONS FOR CONCOLIDATION

4.3.1 STATE BEFORE CONSOLIDATION – STATE 0 (2004):

Secar Bohemia had 9 physical servers, 2 branded (one IBM server and one Dell server). Rest of the servers was set up from independent no name parts. Company had two mini server rooms. Each room was equipped by one classical room air-conditioning unit, which was not very reliable. One rack UPS was sufficient, but had no redundancy and no redundancy was on any of the servers, which would be a problem in case of disaster and operation of Secar´s searching steps would be impossible in critical situation. Secar Bohemia had no virtual servers in 2004 – all servers were physical tower or rack servers.

4.3.2 REASONS FOR CONSOLIDATION:

With the decision to move the company address went hand in hand decision to build a brand new datacenter with all modern and technical features. This meant to separate power supply and data distribution system (power supply cables are led under the floor and data distribution system is led by the ceiling) which ensures minimal signal influence.

Reasons for consolidation:

- Ineffective infrastructure
- insufficient performance and too much space occupied
- high consumption of the electricity
- unreliable air-conditioning system in the datacenter (room air-conditioning units)
- datacenter and space of it was insufficient for future development and business strategy
- no redundancy in current datacenter

Situation was not very simple, because so many things had to be planned and solved for building a new datacenter. Planning of new datacenter required increase of bearing capacity of the floor in new server room, because racks and servers are generally very heavy. That is why were steel beams placed in cross on the whole area of the new server room, this also lifted the floor by several centimeters and enabled Secar Bohemia to place power supply cables into the floor. Other task was to choose appropriate air-conditioning system and predict the heat radiated in future in order to avoid buying a new air-condition units.

UPSs (uninterruptible power supply) are also required in modern datacenter. From the very beginning was clear that the sum of UPSs had to be n+1 (n = number of necessary units) in order to ensure redundancy of UPSs, which mean also service of such device without any downtime. Main requirement for UPSs was high effectiveness (portion input power/output power should be higher than 0.9). Efficiency portion of UPSs in Secar´s datacenter is between 0.92 – 0.94, which makes the UPS appliances sufficiently effective.

4.4 GOALS OF THE MODERNIZATION

Before the modernization of the infrastructure several goals, which should be fulfilled in order to improve offered services, were set. Main problems were with insufficient space in the datacenter, undersized air-condition, low efficiency and high requirements on human resources. From this situation were derived following goals of the modernization:

1. Enlargement of the datacenter – original datacenter was compounded from two small server rooms, each with dimensions: $12m^2$,size for about just 4 racks

2. Install modern and adequate air-conditioning units

3. Improve the efficiency of the datacenter in view of the electricity consumption and datacenter reliability

4. Human resource restriction – too many IT administrators was needed

5. Limit the necessity of constant supervision over the infrastructure – with no redundancy, low availability of servers and unstable reliability, Secar´s infrastructure in 2004 needed continuous supervision – if any part of the server or datacenter broke down, the only solution how to fix it as fast as possible was to call IT administrator no matter where he/she was (vacation, home,…)

4.5 INDIVIDUAL STEPS OF THE VIRTUALIZATION

4.5.1 STATE 1 (2005)

Dell server was removed after 3rd fault of the motherboard. It was necessary because unstable server is not acceptable in the business model of Secar Bohemia. Dell, as a supplier of the company's IT infrastructure was forbidden after this incident by the director of the Secar Bohemia.

After meeting and researching the blade technology was decided – Secar Bohemia will use this technology because of general realization of this technology and following advantages: low space requirements, lower TCO (Total Costs of Ownership) and lower power consumption. This technology was/is produced by Hewlett Packard, Dell and also IBM and also some other, smaller players on the market. Dell was forbidden as a supplier after previous experiences with their server and negotiations with HP did not work well. So decision has fallen on IBM.

From reasons mentioned above were deduced following strategic consequences:

- Only products of brand producers will be used instead of no name set upped servers:
    - Servers – IBM
    - Disk storage – IBM (It should be Sun originally, but the costs for Sun storages were too high)
    - Switches – Cisco
    - Infrastructure Fiber Channel – IBM and QLogic

About participated companies:

IBM – International Business Machines Corporation was established in 1888 as the company Computing Tabulating Recording. This company dealt with production of daily needed appliances like weighing machines, automatic meat cutters, clocks etc. In 1911 it has become a joint-stock company and in 1924 it was renamed on International Business Machine Corporation and started with production of punched plates for optimal check of working period. In 60s, IBM has started to produce mainframes (hall computers) and then, in 80s, also personal computers. Today, the IBM is one of the biggest producers of software, hardware and thousands of services on the worldwide level.

Cisco – Cisco Systems Company was founded in 1984 by a few computer scientists from the Stanford University. Cisco engineers were prominent in advancing the development of IP (basic language for communication over the Internet and private networks) from the very beginning. Cisco currently employs about 65 000 employees and is leading player on the field of networking components.

QLogic – Company was founded in 1994, when it has been separated from the Emulex with which is now QLogics´ competitor. Original business of QLogic was disk controllers, which were sold to Marvell in 2005. Today, QLogic is specialized on manufacturing of storage and system networking infrastructure solutions. Product portfolio includes host bus adapters (HBAs), Converged Network Adapters, host channel adapters (HCAs) and of course SAN storage switches or storage routers, etc.

During the state 1, Secar Bohemia was preserving old datacenter, where whole infrastructure has operated. Except above mentioned servers, at this stage Secar run three 1U rack servers, one 2U server and one 3U server, which was rented from company, which operated the information system of the Secar Bohemia. Some of the old servers where substituted by the new rack, mentioned servers.

4.5.2 STATE 2 (2006)

The decision to build up a new datacenter for 11 racks was approved. Datacenter was built according to plan (split power supplies and data paths, build in industry air-conditioning system, rebuilding the insufficient power supply in the whole building and rebuilding of data distribution in the building, etc.). To new datacenter were moved two old room air-conditioning units and one datacenter environmental control (except the temperature controls the humidity in the datacenter, it is a kind of enterprise air-conditioning unit) unit was added. Simultaneously, first IBM BladeCenter chassis and seven blade servers were purchased. Six blade servers were in full operation and one blade server was a spare server. BladeCenter chassis was supplemented by Cisco Ethernet switch and by IBM Brocade FibreChannel switch. Blade technology has been chosen because of low space requirements and high energetic efficiency. UPSs (Uninterruptible Power Supply) were placed outside the server room, so the backup energy sources were separated from the datacenter. Secar Bohemia required more data space, it is why new disk storage IBM DS4800 was bought. Also data recovery and backup is being planned, but because it is very time demanding and costs are high, it was only in planning phase in the state 2. This phase does not presents virtualization but “only” consolidation – BladeCenter and 7 servers placed into chassis takes about 7U instead of 30U in tower servers or 14U in rack servers (if is counted 2U per rack server and 5U per tower server).

Costs in the phase 2 were following:

Datacenter Environmental Control	150 000 CZK
BladeCenter + 7 blade servers	1 400 000 CZK
Data storage	600 000 CZK

BladeCenter was purchased with function Open Fabric Manager, which is software run at management modules and accelerates exchange of blade servers in the BladeCenter. When starting the BladeCenter, Open Fabric Manager persuades all network components, that all blade servers in chassis have preset VNN (FibreChannel) or MAC (Ethernet) address. Advantage is that if administrator must change the blade server, the new blade has automatically the address which had the previous blade in same position. Open Fabric Manager also support the spare function where one blade server can overtake the job of other broken blade server.

4.5.3 STATE 3 (2007)

Meeting and introduction of the virtualization technology of VMware by IT administrators to the management showed distrust of technical director and executive development director for this technology. For testing purposes, IT administrators started to run the Windows OS on VMware virtual server platform and ran also some other unimportant applications on created virtual servers. That led to first familiarization with the virtualization procedures and needs, so administrators at least partly realized the requirements for virtual infrastructure. Map servers, necessary for car monitoring, were transformed to the blade technology and successfully ran via USB hardkey (in old server, map decoder was connected over the parallel port, but blade servers did not have the parallel port, so solution could be done by special switch “octopus” – originally called Server Connectivity Module for IBM chassis, which would be connected to the back of the chassis or by USB key). “Octopus” solution was too complicated, so administrators of Secar decided to use USB keys, which are connected through the USB port on the motherboard of the server. This key serves as a license key for the map materials.

Backup is provided by IBM Tivoli Storage Manager (software for administration of data storage with automatic backup and simple recovery) with separated storage and LTO3 drives (Linear Tape Open – technology of data recording on magnetic tapes which enables from 15 to 30 years of data archiving). At the end of the year 2007 were two virtual servers in full operation and VMware virtual server was transformed to Linux operating system – Secar´s administrators utilized rack servers, which functions were previously moved to blade servers. At the end of the state 3 period had Secar Bohemia in total 15 servers from which were 4 virtual.

This stage brought obvious reduction of the electricity consumption by using the blade server solution. The reduction of consumption would be much more visible, if old servers would not be further used, but their release enabled to move some of the applications from much older and not reliable hardware.

4.5.4 STATE 4 (2008)

At the beginning of the year 2008 has occurred problem with the data storage systems, the performance of the storages was not sufficient. That led to consideration of the option to virtualized also data infrastructure. Additional data storage was bought and data infrastructure was finally virtualized. Secar Bohemia uses the SVC (SAN Volume Control), which is virtualization layer between data storage and server, which enables dynamic assigning of the resources. Whole SVC includes hardware, software and also licenses.

Advantage of the virtualized data storage is saving of the space on the disks. Problem of physical disks is that such disks need more space as a reserve. But virtualized storage does not, because the space can be dynamically assigned. This leads also to cost saving, because company does not need as much storage and also heating is much lower (if we consider that one disk radiates about 10 - 15 Watts).

Another BladeCenter and 13 additional blade servers were purchased. The purpose was that another BladeCenter enabled physical separation of the Ethernet networks in the company.

One BladeCenter runs DMZ (Demilitarized zone, which is semi-layer between company´s network and the internet and runs applications which need to be connected to the internet but needs to be separated from the internal network – for example web server or application server). The other BladeCenter chassis run classical LAN network. This separation improved the company´s security level. Except mentioned security improvement, the purchase also brought capacity increase. Simultaneously with the BladeCenter chassis purchase was bought VMware ESXi for virtualization purposes (vSphere ESXi is a hypervisor, which consolidates applications on a fewer servers, this leads to reduced hardware resources, power, cooling and administration costs). In this stage is also the management of the company convinced about virtualization and its benefits. Base of the new virtual infrastructure were 6 ESXi servers and 1 Virtual Center. Virtual Center is a part of directing part of VMware. Virtual Center is directing pc (server) for virtualized host servers, which is still necessary, because all errors are reported through this server (Virtual Center detects the error and sends the mail, text message or alerts through some other communication channel in case of failure). Some of the original functions of Virtual Centre were implemented into the virtual hosts, but mentioned error detection and some other functions are still part of the Virtual Center, that is why it is still a necessity for virtual infrastructure. In this stage of consolidation, Secar Bohemia ran 22 servers and 13 of them were virtual machines.

For data backup was purchased tape backup library IBM TS3310 with 2 drives and 30 slots where 29 served regularly and one slot stayed for cleaning cartridge purposes. Tape backup library was connected through optical FibreChannel technology, which enabled faster and more reliable data transmission.

In stage 4 were run 11 blade servers – 6 blade servers were physical and 5 were run as virtual host servers. Virtual Centre has run at 3 servers.

Costs of purchased infrastructure components in the stage 4:

Datacenter Environmental Control	150 000 CZK
BladeCenter chassis + 13 blade servers	1 000 000 CZK
SAN Volume Control (HW + SW + Licences)	3 500 000 CZK
DS5300 data storage	100 000 CZK
VMware (Licences)	80 000 CZK

4.5.5 STATE 5 (2009)

With success from the previous virtualization experiences, Secar Bohemia has started to virtualize all physical servers, except the database servers. Database servers were not virtualized, because of fear from the performance of the virtualized database servers. The performance requirements were minimally same as on physical database servers. After virtualization of the application oriented database system due to distrust in physical server which was running mentioned database system, was discovered that this servers (which run web server, database server and business logic) runs in virtual environment much faster than on previous physical server, as from the view of response and also from other IT business parameters. One information system from two was backed up, disks were exchanged for disks with VMware ESXi and on same (old) hardware was run virtualized information system. This system run much faster even though that server could not assign all 16 cores (4 sockets), but only 4 cores (it was not possible in ESXi in 2009, today it is possible already). VMware is able to assign cores and their performance with better efficiency, than Windows itself. It is because Windows was written in the time, when processors with more cores have not existed, that is why Windows is better in assigning processors than cores. Nice surprise was successful virtualization of old NT4 servers. Problem was expected because NT4 servers did not have the direct support for virtualization from the VMware. But from the internet and discuss forums was evident, that it should work.

Level of infrastructure was improved by IP thermometers and IP current meter from the company Papouch. It was necessary to regularly check temperature in the datacenter, because another servers and disks increased the temperature in the datacenter. With the help of the thermometers was discovered that air-conditioning is not sufficient anymore. There were installed eleven thermometers in the datacenter, one at UPS and one at the backup diesel generator. For maximum security of the power was upgraded power supply of the datacenter and strengthen UPS batteries adequately. According to values from thermometers was bought another air-conditioning unit (Datacenter Environment Control). Air-conditioning units were upgraded by other units. Also the software did not stay the same – virtual platform was upgraded to VMware vSphere 4 Enterprise.

Although, data storage systems were upgraded, Secar Bohemia continuously suffered from insufficient performance of data storages. This made IT administrator of the company to reconfigure disk storage systems and improved the cooperation between storages and SVC. Secar

Bohemia also configured second Tivoli Storage Manager server, because of the separation of the networks (LAN and DMZ).

After long waiting and decision making, also map servers were virtualized via USB hardkey connected through IP convertor Papouch. This brought the utilization of map servers in virtualized environment, their better control, separation and also higher reliability.

Because the company realizes how important is to backup all data and be ready for server failures, new plans for the data recovery were planned. Costs for outage are according to SLA agreement (Service Level Agreement). Currently, in 2010, an hour outage would cost about 800 000 CZK. There are also possible some planed outages, which are part of the agreement (about 2 days per year).

Secar Bohemia had in this stage 35 servers in total, from which were 27 virtual machines.

Costs of purchased infrastructure components in the stage 4:

VMware licenses upgrade	250 000 CZK

4.5.6 STATE 6 (2010)

After (above mentioned) performance problems with disk storages was decided that there will be created a performance reserve for the storage part of infrastructure by replacing an older machine (IBM DS4800) with new disk storage system. New data storage IBM DS5300 was purchased and also tape library with software FalconStor VTL 5.20 (Gapp). This software enables smart virtualization of tape backup. Smart means elimination of needs during backup – a lot of data are same during backup and this software enables deduplication.

Simultaneously, vSphere VMware software was upgraded to Enterprise Plus edition. Difference is in added features for hypervisors. This step was made mainly thanks to special offer for previous version of the vSphere software owners. After previous experiences with the virtualization of the database server, IT administrators started to plan virtualization of all database servers in the company. Company feels the need to equip the IT infrastructure with independent monitoring tools for better control of the whole datacenter. So purchase of such tools is also planned.

For easier recovery and administration of the datacenter is also planned the virtual backup of the datacenter. It should bring the space savings and also other electricity consumption spending. Level of the infrastructure was upgraded by the four additional blade servers with independently expandable memory for virtualization purposes. Old, original, air-conditioning units were replaced by two newer 24 kW air-conditioning units (Datacenter Environmental Control). The first Datacenter Environmental Control (state 2) serves as backup for those two air-conditioning units.

In the end of the state 6, Secar Bohemia has 87 servers, from which are 75 virtual.

Costs of purchased infrastructure components in the stage 4:

Tape backup + FalconStor	300 000 CZK
2x Datacenter Environmental Control	300 000 CZK
4 blade servers IBM HX5	1 000 000 CZK

4.6 RESULTS OF MODERNIZATION

According to stated goals before the modernization of the infrastructure are derived results of the modernization. Main problems were with the size of the datacenter, quality of the air-conditioning, insufficient consumption and reliability and high demands on human resources. Results in comparison with stated goals are following:

1. Sufficient size of the datacenter – growth from original 4 racks to 11 racks

2. Sufficient size of the datacenter – Secar originally had 2 small server rooms, each with surface of $12m^2$; new datacenter is centralized in one room and has surface of $60m^2$

3. Regular room air-conditioning units were replaced by three Datacenter Environmental Control units, which checks temperature and humidity in the datacenter

4. Reliability was improved by the new hardware, software and also by enlargement of the computing power, some of the servers are also backed up and in case of failure of the server are automatically recovered

5. Reduction of electricity consumption – overall consumption of the datacenter is higher than at the beginning of the modernization, but as is visible further in comparison of physical and virtual option, savings on the consumption are significant

6. Limitation of human resources – number of person needed for administration of IT infrastructure has grown by two other employees, but in case of complete physical resources would be the increase even higher – as is visible further from comparison of the infrastructure options

7. Limitation of continuous supervision – many things can be monitored through software tools and also administrated through the same tools. Some of the conditions in the datacenter are controlled automatically by the thermometers, Datacenter Environmental Control units etc. This led to limitation of continuous supervision and higher reliability and security of the datacenter.

From the results is evident that goals of the modernization were fully fulfilled and so modernization of the datacenter was successful. Structured interview showed that modernization was successful, because all of the hardware resources fit in the datacenter with large reserves. So that means that points one and two had highest priorities, but also other aspects of the modernization are not negligible.

Modernization brought new business opportunities and was necessary because IT infrastructure is main source of the revenue in the company Secar Bohemia. Services, which Secar Bohemia offers nowadays, would not have been possible if the infrastructure would have stayed on the same level as at the beginning without any modernization. Availability and reliability of the datacenter is secured by the SLA agreement (Service Level Agreement). All business of Secar Bohemia is based on utilization of IT the infrastructure. That is why reliability, performance and security must be kept on the highest level.

In total, costs for modernization are 8 830 000 CZK. In the costs are not included the costs for building a new datacenter, because it would had to be done anyway. Costs are for production hardware and needed storage and virtualization licenses.

4.7 COMPARISON OF PHYSICAL AND VIRTUAL INFRASTRUCTURE

To show how consolidation and virtualization affected costs of the Secar Bohemia, in the following, will be done the comparison of physical and virtual infrastructure from the view of space and energy requirements. For the better imagination and level of comparison, the comparison will be done as of current virtual infrastructure of the Secar Bohemia against corresponding version in rack and blade version.

Current infrastructure of the Secar Bohemia has 87 servers, 75 virtual servers and 12 physical servers. Due to information from semi structured interview and arisen recommendations, for counting of physical versions of the infrastructure are used different numbers of physical servers.

If Secar would have gone by the way of physical infrastructure, the total number of servers would not have been as high as in case of the virtual infrastructure, because financial and time requirements on the physical infrastructure are higher. That is why Secar Bohemia would have used option to run more applications on one server and by this procedure would lower the total amount of servers and would not have purchase as many servers due to the financial demands. Due to this is for counting purposes of consumption and space requirements of the physical infrastructure lowered total number of servers to 2/3 of current state. It means 58 servers instead of 87 servers, in the virtual infrastructure.

As other difference between physical and virtual infrastructure important for counting is the number of the production storage needed. Currently, Secar Bohemia has about 24 TB of the production storage, which is for virtual infrastructure sufficient, but VMware provisioning function enables dynamic allocation of storage to independent servers, so servers get just the space they need and it saves the space and energy consumption requirements needed for storage system significantly. As resulted from the semi structured interview, physical infrastructure would need about 3 times more of storage space. It means that instead of 2 storage systems in virtual environment, Secar Bohemia would have needed 6 storage systems and adequately higher number of disks (3 times higher).

For counting purposes are used following facts:

- ***Virtual infrastructure*** consists of 2 blade chassis, each with 14 positions for blade servers, 12 blade servers are populated (6 in each chassis), average consumption of fully occupied chassis is 3700 Watts, switches are included in the chassis

- ***Blade solution*** consists of 5 blade chassis, each with 14 positions for blade servers, 4 blade chassis are fully occupied, one chassis has only two positions occupied, in total 58 blade servers are populated, consumption of fully occupied chassis is 3700 Watts, switches are included in the chassis

- ***Rack solution*** consists of nine 2U servers with average consumption 300 Watts and forty-nine 1U servers with average consumption 270 Watts, one KVM switch 100W 1U, four Gigabit Ethernet switches - 200W 1U each, four FibreChannel switch – 200W 1U each

- For drawing off the heat radiated by servers is needed air-conditioning unit with the 90% consumption of drawn energy

Table no. 1: *Table of savings*

Server consumption	Virtual infrastructure	Blade version	Rack version
Number of physical servers	12	58	58
Number of virtual servers	75	0	0
Average power consumption per physical server (Watts)	617	271	275
Average power consumption per server (Watts)	85	271	275
Average HVAC consumption per physical server (Watts)	555	244	248
Average consumption of I/O infrastructure (Watts)	0	0	1 700
Total hourly power and HVAC consumption (Watts)	14 064	29 870	33 564
Annual operating hours per server	8 760	8 760	8 760
Annual power and HVAC consumption (kWatt hours)	123 201	261 661	294 021
Storage consumption			
Number of storages	2	6	6
Number of disks	80	240	240
Average power consumption per storage (Watts)	250	250	250
Average HVAC consumption per storage (Watts)	225	225	225
Average HVAC consumption per disk (Watts)	10	10	10
Total hourly power and HVAC consumption (Watts)	1 750	5 250	5 250
Annual operating hours per storage	8 760	8 760	8 760
Annual power and HVAC consumption (kWatt hours)	15 330	45 990	45 990
Administration costs (human resources)			
Number of administrators	4	6	6
Annual average costs per administrator	444 000 CZK	444 000 CZK	444 000 CZK
Total annual costs for administrators	1 776 000 CZK	2 664 000 CZK	2 664 000 CZK
SUM			
Total hourly power and HVAC consumption (Watts)	15 814	35 120	38 814
Annual operating hours per server	8 760	8 760	8 760
Annual power and HVAC consumption (kWatt hours)	138 531	307 651	340 011
Average cost per kWatt hour	2,34 CZK	2,34 CZK	2,34 CZK
Total annual costs for administrators	1 776 000 CZK	2 664 000 CZK	2 664 000 CZK
Total annual power, cooling and administrators costs	2 100 162 CZK	3 383 904 CZK	3 459 625 CZK

Source: Own calculation, own research

Note: HVAC – Heating, Ventilation and Air-Condition

Average power consumption in each solution comes from the data analyses gained from the tool IBM BladeCenter & System x Power Configurator described in the methodology. Average power consumptions are just illustrative and are calculated by simple division of total consumption by the number of servers. HVAC shortage means Heating, Ventilation and Air-Condition and for the calculation is used the general rule, that air-condition consumes 90% of Watts heated to the air. First part of the table deals with consumption of production servers, followed by the part which researches the consumption of the storage needed and other significant part of the calculation is calculation of human resources needed for each infrastructure. In the end, all the individual parts of the calculation are summed and converted to the money in Czech currency. For conversion, is used the constant 2.34 CZK per kWatt hour. It is a value dealt by author with the company Secar Bohemia. This value can be different for different companies, but because it is a constant, the ratios between independent solutions will stay the same even for different price of the kWatt hour.

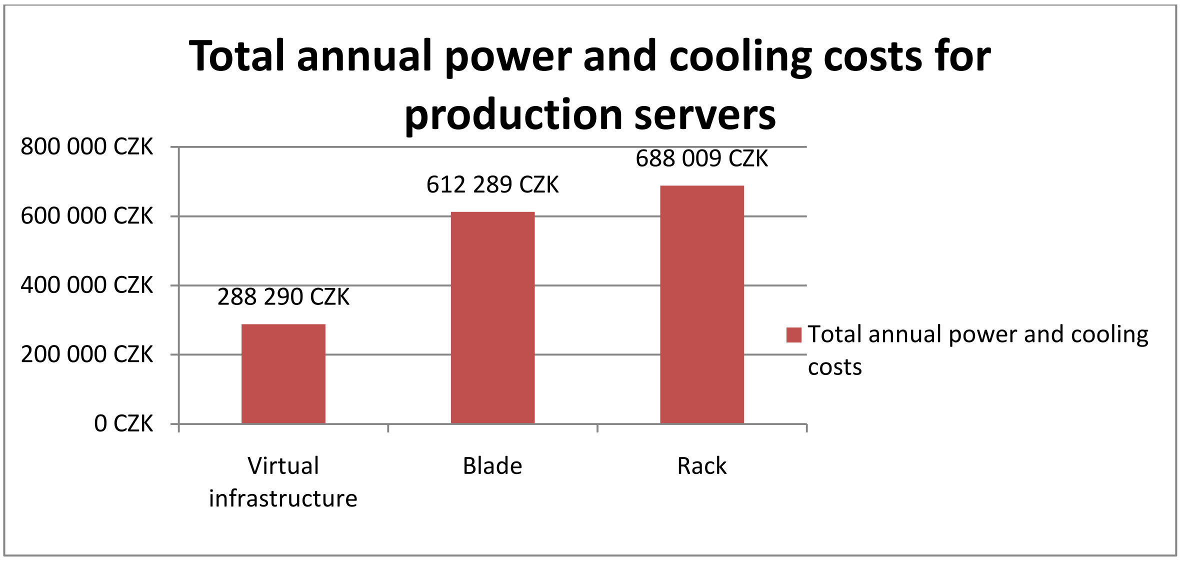
Table no. 1 is a cut from supplement no. 1. In the supplement no. 1 is evident, that solution with virtual infrastructure is clearly the most efficient and cost saving solution from all compared solutions. All measured aspects aim to virtual infrastructure even though that some of the ratios (average consumption per physical servers, average Heating Ventilation and Air Conditioning per server) results point to physical infrastructure. But these results are caused by lower number of physical servers in virtual infrastructure, therefore the average ratio results to rack or blade solution. These two ratios in no wise affect savings in virtual infrastructure – if the ratio would be calculated per total number of servers in the solution, also these ratios would point to the virtual solution.

Difference between virtual infrastructure and other solutions is evident and final amount is evidently lowest from all compared solutions. Difference between blade solution and rack solution is not significant at first sight, but it is 75 721 CZK annually just on energy, but it is not the only benefit. Blade solution enables easy addition of up to twelve servers without any more demanding intervention, because one of five chassis is filled only by two blade servers, so still have twelve free positions for servers. It means that it is possible to add twelve more servers without any significant energy demands changed.

4.7.1 CONSUMPTION OF PRODUCTION SERVERS

Chart no. 1 shows the total power and cooling costs for energy consumed by the production servers and air-conditioning units in the datacenter annually for each version of the computing solution.

Chart no. 1: *Total annual power and cooling costs for production servers*



Source: Own calculation

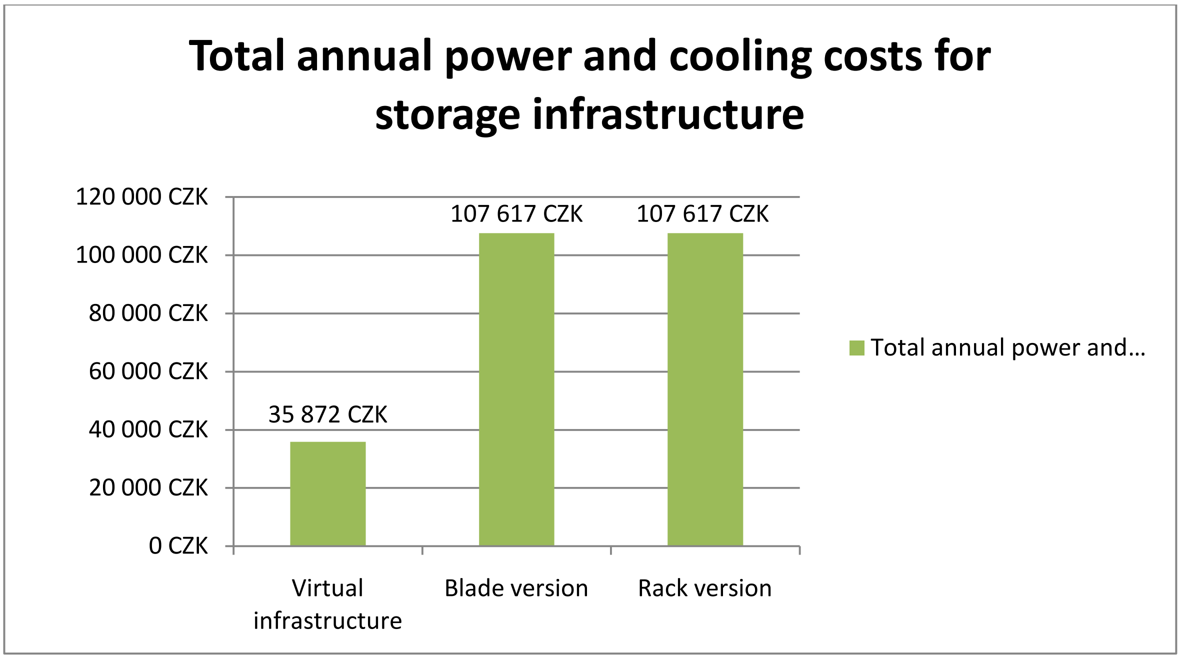
From the chart number 1 is evident, that solution with virtual infrastructure is from the view of power and cooling cost significantly more efficient than any of the other two solutions. In percentage expression, virtual infrastructure is more efficient by 53% in comparison with the blade solution and by 54% in comparison with the rack solution.

Difference between blade and rack solution is only 2,5%. As mentioned above, the advantage of blade solution is also in its potential of its easy expandability in our case and in its permanent energy efficiency even if will be added twelve other servers. Main difference is that blade solution consolidates I/O infrastructure and its consumption is involved in the consumption of chassis, so overall costs on energy are lower and also space requirements are significantly lower, as is visible further.

4.7.2 CONSUMPTION OF STORAGE

Chart no. 2 shows the consumption of the storage system necessary in each solution to be comparable with current situation. In this calculations are involved costs for power supply and also for air-conditioning including the heat radiation of the disks.

Chart no. 2: Total annual power and cooling costs for storage infrastructure



Source: Own calculation

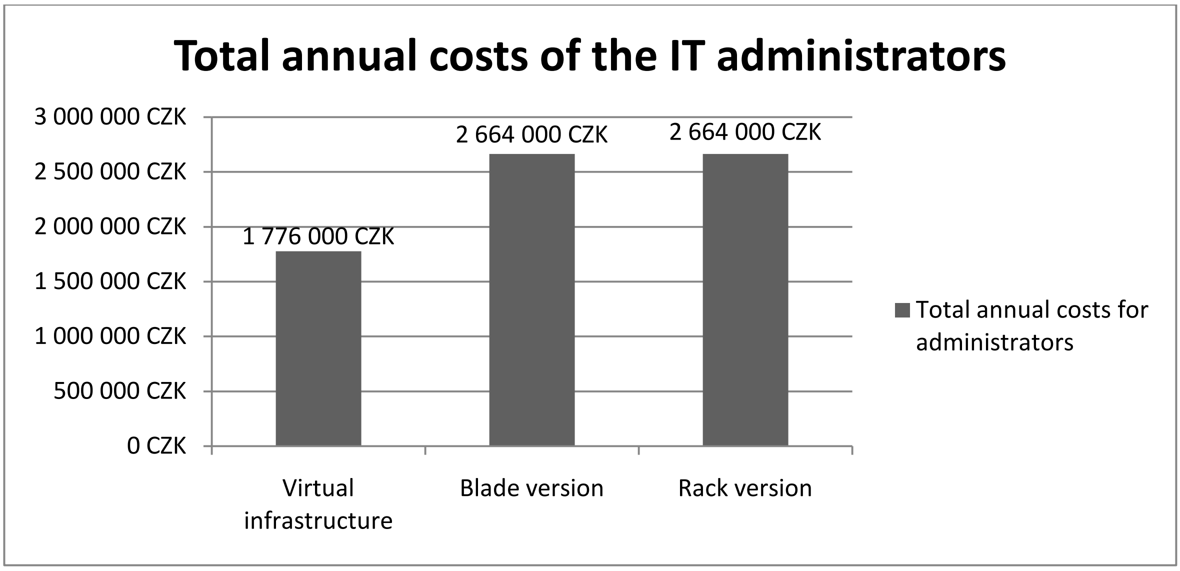
From the chart number 2 is evident, that costs for operation of storage infrastructure in virtual solution are the lowest. Costs are by 67% lower than for other solutions. It is mainly caused by the need of physical infrastructures to add other four disk storage systems, because physical infrastructure does not enable dynamic allocation of storage. It follows that physical infrastructure needs hard allocation of storage, so that higher overall volume of storage is necessary. The fact, that physical solutions need three times higher number of storage systems than is now needed in virtual infrastructure is derived from the interviews.

It is evident, that both physical solutions have same costs for physical infrastructure, because both would need same amount of storage systems with the same amount of disks, so storage system solution is the same for both versions of physical infrastructures – for blade version and also rack version.

4.7.3 ADMINISTRATION COSTS

Chart no. 3 describes the costs for human resources needed in the datacenter. In other words, annual costs of the company for IT administrators whose take care about operation of the datacenter.

Chart no. 3: *Total annual costs of the IT administrators*



Source: Own calculation

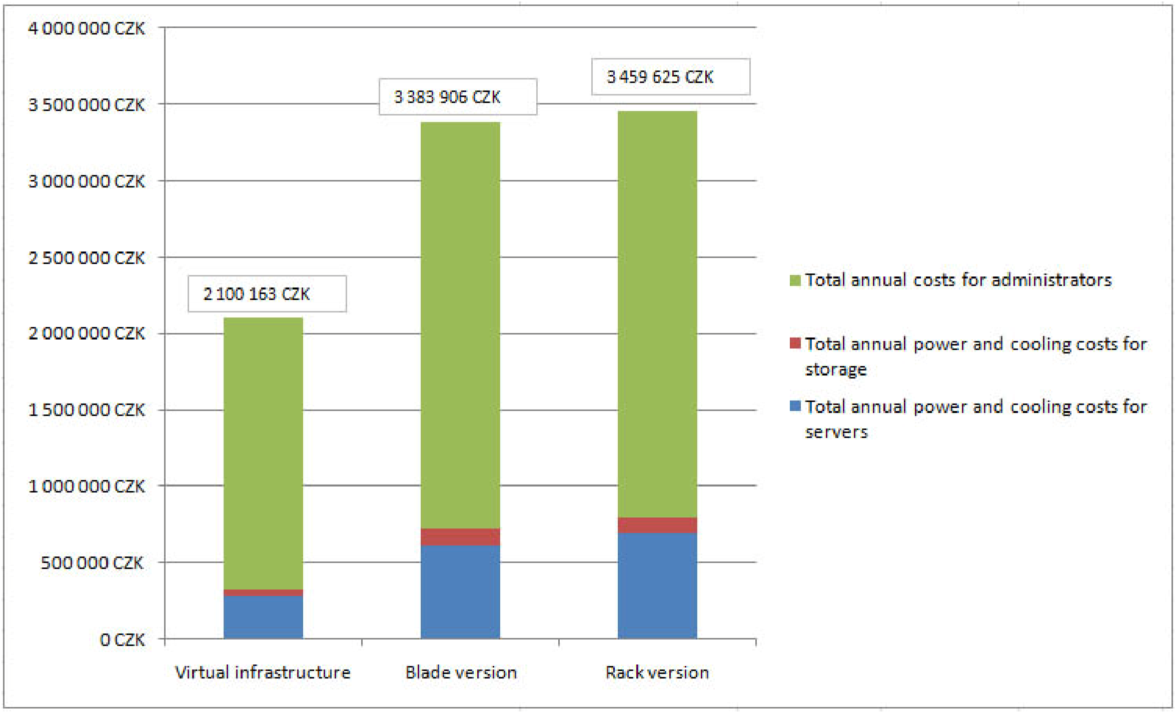
Virtual infrastructure shows significantly lower costs of IT administrators against physical solutions. Main and the only reason is that virtual infrastructure needs by two workers less, than in physical solutions. It is because virtual infrastructure includes less physical resources and for the common tasks are sufficient four workers, while both physical solutions needs 6 IT administrators to manage the necessities. Here is validated simple logical rule – more physical servers need more workers.

In virtual environment are demands for IT administrators higher, because IT administrator must be able to think abstractly and develop his/her own imagination. Advantage of virtual environment is that a majority of casual and also specialized work of the IT administrator is done through the management console and administrator does not have to walk through the datacenter and manually control and manipulate with the physical resources, but must be able to work with the servers and the whole datacenter abstractly (create, edit, manage or delete virtual machines) and realize what effects each operation will have and how it will affect users of the infrastructure or how it will affect run applications.

4.7.4 OVERALL COMPARISON

Chart number 4 shows the overall comparison and cost requirements of individual parts of infrastructure in each solution. Parts are distinguished by colors and shows overall annual costs.

Chart no. 4: *Overall costs comparison*



Source: Own calculation

Chart number 4 shows overall costs on IT infrastructure. Overall costs for virtual infrastructure are 2 100 163 CZK annually, in comparison with about 3 384 000 CZK annually for blade infrastructure and 3 460 000 CZK annually physical rack infrastructures. The difference is significant, in total 38% alternatively 40% which makes it about 1 284 000 CZK annually or 1 360 000 CZK alternatively. These are not small numbers and we can see that virtual infrastructure running on blade technology can save a lot of financial resources, which can be utilized in different way than for just paying of bills.

Difference between blade and rack version is mainly given by the I/O infrastructure included in the blade chassis – so that consolidation. These aspects were already mentioned above. Other advantage, also already mentioned, of the blade solution is the expandability. In our case, one chassis has the potential to work approximately for same cost even if would have been added other 12 blade servers. Other parts of infrastructure, except I/O infrastructure, (costs of IT administrators and storage system costs) could not affect it, because both version of physical infrastructure requires same resources, so also costs are the same, so that cannot affect the overall costs any further, difference is also caused by the lower consumption of the blade infrastructure.

4.8 SPACE REQUIREMENTS ANALYSES

Calculation of space requirements includes all infrastructure components including I/O, KVM (Keyboard, Video and Mouse) switches, Ethernet switches etc. Rack shortage U is a measuring unit used in information technologies to describe the height of the appliance determined to fit into rack. One U is 44.45 mm. As a rack is meant the rack box determined for IT appliances, rack has height of 42U. The side pockets of the rack are fulfilled by PDUs (Power Distribution Unit) for our calculation purposes in all three cases.

Table no. 2: *Comparison of space requirements of individual infrastructure solutions*

Space requirements	**Virtual infrastructure**	**Blade version**	**Rack version**
Number of chassis	2	5	0
Number of servers	12	58	58
Number of 1U servers	0	0	48
Number of 2U servers	0	0	9
Total number of U needed for servers	18	45	67
Number of storage systems	2	6	6
Number of U needed for storage systems	12	36	36
Number of U needed by I/O infrastructure	0	0	9
Total number of U needed	30	81	112
Number of standard racks needed	1	2	3

Source: own calculations, data from semi structured interview

From the table number 3 is evident, that virtual infrastructure is again significantly the most saving solution, even in the space requirements comparison. Virtual infrastructure requires only one industry standard 42U high rack, where occupies 30U. It means that rack is filled only from about ¾ of its capacity.

Blade version requires two industry standard racks, with very small reserve. Rack version requires one additional rack against the blade version of the infrastructure. Advantage of the blade version is that it is constructed in a way which saves space requirements and also all switches are included in the chassis, so this infrastructure does not occupies additional space in rack. We cannot forget the point, that one of the blade chassis is occupied by only two blade servers and has positions for 14 blade servers. It means that this chassis enables other expansion for twelve servers without the necessity to purchase and implement additional rack.

4.9 INVESTMENT SAVINGS AND RETURN OF THE INVESTMENT

Following table shows the investment savings in comparison with the rack and the blade physical solution. Purchasing costs shows the amount needed for purchasing of the current infrastructure. Amount does not include costs for building of the new datacenter, because new datacenter would have to be built anyway. Line Annual operational savings shows annual savings on energy consumption and IT stuff salaries of virtual infrastructure in comparison with the particular solution. These savings data were calculated and are available in the supplement number 1.

Table no. 3: *Return of the investment*

Investment savings	**Virtual infrastructure**	**Blade version**	**Rack version**
Purchasing costs	8 830 000 CZK	-	-
Annual operational savings	-	1 283 742 CZK	1 359 463 CZK
Return of the investment (years)	-	7	6.5

Source: Own calculations

The results in table number 3 shows investment savings and the time in which will be the investment returned thanks to reached savings. Investment return in comparison with the blade solution is 7 years and in comparison with rack solution is 6 ½ years. Because blade solution is a more efficient than rack solution, the time of investment return is in case of blade solution by ½ year longer.

4.10 PROPOSAL OF FINAL SOLUTION

Datacenter went through large modernization, which brought new business opportunities and enlargements of offered portfolio to the company, but if company wants to work even more efficiently than till now and develop itself, modernization of the datacenter cannot be final. According to structured interview, where were mentioned the needs of the company and other structured interview where mentioned technological possibilities of IT technologies were developed following proposals:

***Storage system* –** continuous problems with storage subsystem from the view of its performance leads to possibility of modernization of this part. Modernization in this case means change of the used technology. The modernization does not include increase of the total amount of disks, because capacity is sufficient, but the performance of disk subsystem is not sufficient. Classical rotating disks could be substituted by the new technology of disks with some kind of RAM (Random Access Memory).

Proposed technology is either SSD disks or flash card, which are set directly into I/O slot in the server. Problem of the flash cards is that their amount is restricted by the overall amount of PCI slots in the server and today’s technology does not enable to reach the capacity of classical disks. Increase of the speed of SSD disk against classical disk could not be sufficient, how was showed by the structured interview. Solution could be the new generation of the SSD disks with brand new chipset, which should bring the speed about 30% higher against the speed of today´s SSD disks. This new generation of the SSD disks should enter the market in the second half of the year 2011.

New storage technology should bring faster access to data and because SSD disks do not contain rotation parts, also higher reliability. Energy efficiency is also not negligible part, disks with RAM memory heats only about 1 Watt.

From the comparison of the proposed technology with currently used storage technology (table no. 4) is clear, that new technology can save up to 70% of cost on HVAC (Heating, ventilation and air-conditioning) of storage system. This calculation is general and concrete results would depend on concrete attributes of the each concrete solution.

Disadvantage is higher entry costs, which should on the other hand be returned, according to saves up to 70%, very soon.

Table no. 4: *Comparison of storage solutions*

	Classical rotation disks	RAM disks
Average HVAC consumption per disk (Watts)	10	3
Number of disks	80	80
Annual operating hours per disk	8760	8760
Annual HVAC consumption (k Watt hours)	7008	2102.4
Average costs per k Watt hour	2.34 CZK	2.34 CZK
Total annual HVAC cost	16 399 CZK	4 920 CZK
% difference	**70 %**	

Source: own calculations, data from semi structured interviews

Blade server portfolio enlargement – enlargement of blade severs will bring the possibility to build up more virtual servers, which are necessary for addition of new features to company´s products. New features of products and possibly new products will enable company to expand economically, because the revenue of the company is dependent on the function of the servers and all company´s products are run on the servers. If company wants to offer new product, new servers should be implemented, because certain computing reserve has to be kept and it will not be possible if new servers will not be implemented.

Desktop virtualization – proposed solution is more energy efficient and enables to gain higher performance, because classical desktops are substituted by thin clients and performance is delivered by server.

Thin client as itself has very low power consumption, often as 10 times lower than classical computer. Thin client is a special computer of very small size, which thanks to connection to the application server needs a very low performance and low memory capacity. On the other side, thin client can deliver much greater performance thanks to gaining of the performance from the server.

This solution can bring better utilization of the hardware resources and easier manageability for IT administrators, because they do not have to take care about each "pc" independently, but manage just the application server to which are thin clients connected. Other benefit is up to 90% savings on energy in comparison with classical computers, but this efficiency highly depends on concrete solution. Other benefit is the ease of provisioning of new computers in case of expansion of the company, hardware independency and centralization.

Problem can cause the entry cost, which can look higher at the first look, but this solution has the investment return ability potential.

Improvement of management tools for infrastructure – as a management tool is currently used VirtualCenter from the VMware. VirtualCenter delivers centralized management, operational automation, resource optimization and high availability to IT environments. It is not useless, but it serves only for managing of the virtual infrastructure and some other tools like for example monitoring of the performance, backup functions and others are not included. These funtions are included in proposed solutions Vizioncore vEssentials or Akkori Balance Point.

Vizioncore vEssentials – is composed of three other tools with independent names. All together enable to secure, monitor and backup running virtual machines and also monitor the performance values.

Akkori Balance Point – tool monitors all critical components and from gained data creates report, which evaluates data and shows the source of potential performance problems. This management tool also offers the GuidePoint application, which makes recommendations based on the monitored data and modeling of the workload across the various components of a virtual infrastructure.

5 CONCLUSION

Appropriately chosen IT infrastructure is important for every company, which uses computer resources. The choice of appropriate hardware and software resources is the main requirement for good function of each company. This applies twice as much when hardware and software resources generate majority of the company’s revenue. It depends on IT department to choose appropriate hardware and software resources for company´s operation. IT administrators in the company Secar Bohemia has chosen the way of virtualization, which brought flexibility, efficiency and significant cost savings to the company.

As the first pages of this diploma thesis may tell, for x86 platform, the virtualization is technology, which has been used for the past 20 years for consolidation of IT resources and maximal utilization of these resources. In comparison with other technologies, virtualization brings many benefits, no matter from which view, technological or economical.

Diploma thesis researches the implementation of the virtualization in the company Secar Bohemia from the very beginning. Although the virtualization was not supported by the management at the beginning, the IT administrators of the company have pushed the technology through and started the era of the efficiency. Despite the higher entry costs, according to calculated savings on energy, the return on investment is 6 ½ year against the rack solution and 7 years against the blade solution.

Calculations showed that virtual infrastructure saves 1 283 742 CZK annually against the blade infrastructure and 1 359 463 CZK annually against the rack infrastructure. About 70% of these amounts are saved on IT stuff, because less hardware resources need less IT administrators. 6 % of the savings is saved by the simplified storage resources and so connected lower consumption of storage systems, because virtual infrastructure enables to dynamically assign the free space of the storage systems, which is not possible in the physical infrastructure and more storage systems is needed. The rest of the savings is saved on the consumption and cooling of production servers. Here are also the biggest differences between independent solutions. It is mainly caused by the consolidation of I/O resources in blade technology, which lowers the overall consumption and by lower overall consumption of blade servers.

In total, virtual infrastructure brings 40% annual savings of the costs needed for the operation of the production resources. The calculation includes costs for energy consumption of production servers and storage systems, the costs further include ventilation of the heat radiated by servers, storages and disks and costs for IT administrators.

Important and notable advantage of the virtual infrastructure is also space requirements of this solution. In comparison with other solutions, it is significantly less demanding on space needed in the datacenter. Virtual infrastructure requires only one rack and enables further extension, because the chassis is filled only about to its half capacity, so enables further extension by 16 blade servers. Blade infrastructure without virtualization would need two racks, which would be fully filled. One blade chassis would only hold two blade servers and so would enable the extension by 12 blade servers without any need for additional rack, switches and other I/O. The possibility of psychological advantage to extend the infrastructure without the need to add new rack is uncountable. Finally, the rack infrastructure would require three racks, because except the fact, that rack servers are bulky, they need separated I/O options, which conveniently blade infrastructure involves in the chassis.

The semi structured interview with the IT administrator of the Secar Bohemia, Petr Krstev, showed some shortages of the infrastructure in the company. These shortages are the main subject for the proposed final solution. Other semi structured interview with technical specialist for x86 platform, Jakub Venc and own research showed the possibilities how to solve these shortages.

Company Secar Bohemia is not satisfied with the performance of current disk subsystem. As a solution new SSD disks could be implemented, which would next to higher speed bring also about 70% annual savings on energy and cooling against currently used rotation disks. For extension of company´s product portfolio and functions of independent product, company will need additional computing capacity, which is why author recommends the purchase of new servers appropriate for virtualization. In order to reach additional savings on energy consumption, virtualization of desktops is recommended. Except energy efficiency, this solution can supply more performance to the end users and save time of IT administrators. Once this solution is implemented, IT administrators will be able to manage the whole company´s infrastructure through just one environment available from almost everywhere. And the last proposal for improvement is tightly connected with manageability. Current management tool (Virtual Centre) enables to operate with wide spectrum of functions, but author suggests adopting of advanced management tool for better measurability and higher control over the infrastructure and backup processes, than is offered by the Virtual Centre.

These improvement solutions should bring new business opportunities to the company and so improve its revenue, save costs for the IT infrastructure and improve the efficiency of the stuff in the company. All mentioned effects are main demands of every company in today´s business environment and adoption of these proposals and technological innovations could help to Secar Bohemia to gain valuable competitive advantage.

6 BIBLIOGRAPHY

Archer, B., Ausilio, M., Bauman, W., Kuhlmann, C., Ferri, F., Madduri, M., et al. (2010). *System x Virtualization Strategies.* ibm.com/redbooks: International Business Machines Corporation (IBM).

Erben, L. (2010, September). CIO case study 2010. *CIO Business World* , pp. 44-45.

Golden, B., & Scheffy, C. (2008). *Virtualization for Dummies.* Indianapolis: Wiley Publishing.

HP Blade System Infrastructure. (2011). Retrieved March 24, 2011, from Hewlett-Packard: http://h18004.www1.hp.com/products/quickspecs/12330_div/12330_div.html

Kay, R. (2008, October 6). *Storage virtualization*. Retrieved Febuary 14, 2011, from Computerworld: http://www.computerworld.com/s/article/325633/Storage_Virtualization

Klimeš, L. (2002). *Slovník cizích slov.* Praha: SPN - Pedagogické Nakladatelství.

Server Management Software Forecast. (2010, August). Retrieved Febuary 27, 2011, from IDC, International Data Corporation: http://www.idc.com/getdoc.jsp?containerId=224493

Virtual infrastructure. (2011). Retrieved March 1, 2011, from VMware: http://www.vmware.com/virtualization/virtual-infrastructure.html

Virtualization benefits. (2011). Retrieved Febuary 19, 2011, from VMware: http://www.vmware.com/virtualization/why-virtualize.html

Virtualization trends. (2008, April 2). Retrieved December 20, 2010, from Gartner: http://www.gartner.com/it/page.jsp?id=638207

VMware. (2011). *History of the virtualization*. Retrieved March 22, 2011, from VMware: http://www.vmware.com/virtualization/history.html

What is virtual machine. (2011). Retrieved Febuary 12, 2011, from VMware: http://www.vmware.com/virtualization/virtual-machine.html

What is virtualization? (2011). Retrieved december 12, 2010, from VMware: http://www.vmware.com/virtualization/what-is-virtualization.html

7 SUPPLEMENTS

List of supplements:

Supplement no. 1 – Comparative table

Supplement no. 2 – Questions for semi structured interview with IT administrator of Secar Bohemia, Petr Krstev

Supplement no. 3 – Questions for semi structured interview with IBM x86 technical specialists, Jakub Venc

Supplement no. 1: Table for calculation of the savings and comparison of the savings

	A	B	C	B-A	C-A	C-B
Server consumption	**Virtual infrastructure**	**Blade version**	**Rack version**	**Total annual savings**		
Number of physical servers	12	58	58	46	46	0
Number of virtual servers	75	0	0	-	-	-
Average power consumption per physical server (Watts)	617	271	275	-346	-342	4
Average power consumption per server (Watts)	85	271	275	186	190	4
Average HVAC consumption per physical server (Watts)	555	244	248	-311	-307	4
Average consumption of I/O infrastructure (Watts)	0	0	1 700	0	1 700	1 700
Total hourly power and HVAC consumption (Watts)	14 064	29 870	33 564	15 806	19 500	3 694
Annual operating hours per server	8 760	8 760	8 760	-	-	-
Annual power and HVAC consumption (kWatt hours)	123 201	261 661	294 021	138 461	170 820	32 359
Storage consumption						
Number of storages	2	6	6	4	4	0
Number of disks	80	240	240	160	160	0
Average power consumption per storage (Watts)	250	250	250	-	-	-
Average HVAC consumption per storage (Watts)	225	225	225	-	-	-
Average HVAC consumption per disk (Watts)	10	10	10	-	-	-
Total hourly power and HVAC consumption (Watts)	1 750	5 250	5 250	3 500	3 500	0
Annual operating hours per storage	8 760	8 760	8 760	-	-	-
Annual power and HVAC consumption (kWatt hours)	15 330	45 990	45 990	30 660	30 660	0
Administration costs (human resources)						
Number of administrators	4	6	6	2	2	0
Annual average costs per administrator	444 000 CZK	444 000 CZK	444 000 CZK	-	-	-
Total annual costs for administrators	1 776 000 CZK	2 664 000 CZK	2 664 000 CZK	888 000 CZK	888 000 CZK	0 CZK
SUM						
Total hourly power and HVAC consumption (Watts)	15 814	35 120	38 814	19 306	23 000	3 694
Annual operating hours per server	8 760	8 760	8 760	-	-	-
Annual power and HVAC consumption (kWatt hours)	138 531	307 651	340 011	169 121	201 480	32 359
Average cost per kWatt hour	2,34 CZK	2,34 CZK	2,34 CZK	-	-	-
Total annual costs for administrators	1 776 000 CZK	2 664 000 CZK	2 664 000 CZK	888 000 CZK	888 000 CZK	0 CZK
Total annual power, cooling and administrators costs	2 100 162 CZK	3 383 904 CZK	3 459 625 CZK	1 283 742 CZK	1 359 463 CZK	75 721 CZK

Supplement no. 2: Questions for the semi structured interview with Petr Krstev, IT administrator of the company Secar Bohemia

1. What was the state before the modernization?
2. What let the company to the modernization of the datacenter?
3. What have you expected from the modernization?
4. When did you firstly meet with the technology of consolidation? How?
5. What about virtualization?
6. How did look the way to the current state of the infrastructure?
7. Are you satisfied with the infrastructure?
8. Where in the infrastructure do you feel weak spots? Why?
9. What do you think, that virtualization brought to the company?
10. Do you feel that virtualization has brought some kind of improvement? Which one?

Supplement no. 3: Questions for the semi structured interview with Jakub Venc, IBM x86 technical specialist.

1. What are the benefits of the virtualization?
2. Why would you recommend implementing the virtualization?
3. What are crucial parts of the infrastructure?
4. In what extent can virtualization saves the company´s resources?
5. What are the differences between virtual and physical infrastructure from the view of the demands on physical resources?
6. Why would you recommend using blade solution in comparison with rack solution?
7. What are the advantages and limits of the desktop virtualization?
8. Where do you think that are weak spots in managing of the virtual infrastructure?