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Abstract: In this paper we present results from the deployment of F/OSS virtualization platform. This platform was used both for providing existing NDC's services, in a production environment, and for developing additional new services using agile development methods. In greater detail, F/OSS virtualization was selected as the best solution in order to meet a number of different NDC's requirements, these are in fact quite common in a wide area of IT environments and projects. NDC's virtualization benefits are quantified while F/OSS specific benefits are especially highlighted. These include, apart from reduced energy consumption and hardware requirements, reduced licensing costs and most importantly significantly increased flexibility due to combining virtualization and F/OSS. This combination leads to project and organization wide benefits. These make F/OSS virtualization a particular well fit for organization using agile development methods and facing a number of strict technical, economic, administrative or regulatory constraints. Similar situations can be found variety of situations, from SMEs to government organizations. Finally, focusing on licensing and maintenance costs, we compare in a general way the benefits for using F/OSS virtualization when compared to closed source virtualization or non virtualized platforms.

Keywords: F/OSS deployment, F/OSS virtualization, Xen hypervisor, virtualization benefits, agile development, staging environments

1. Introduction

Free/Open Source Software (F/OSS) has changed significantly the landscape, both in software development practices and to IT system's deployment, maintenance and management. Open source provides a new development practice and enables significant IT infrastructures to operate efficiently, utilizing its unique characteristics. F/OSS is nowadays widely accepted and its reported benefits range from the economic acquisition and TCO savings to the freedom it provides to its end users and to vendor locking avoidance.

Open Source software has the potential to offer capabilities that would be impossible through tradition software development. Besides the fact that cost effectiveness by itself is enough for the success of open source software is arguable, there is no doubt that open source software continues to gain market share. Key factors for this to happen are flexibility, performance, customization options and security (Lin, 2007), (F. Henker, 1999), (Lerner, Tirole, 2003).

On the other hand virtualization has provided another paradigm shift to IT systems management and dimensioning. The concept of virtualization has been introduced so early as the late 60's as a solution for the optimization of costly mainframe systems. The idea is that virtual machines are a fully protected and isolated copy of the underlying physical machine's hardware (Creasy, 1981). Two decades later the significant drop of hardware costs as well as the development of multitasking operating systems made virtualization benefits to seem obsolete. However in 2000's virtualization draw the attention of researchers, universities and major vendors again. This boost came as solution to researchers for mobility, security, and manageability problems, including energy and environmental reasons (Rosenblum and Garfinkel, 2005). At the moment various virtualization solutions are available both open and closed source, as well as commercial. The leader of the market is VMware with a wide range of products and ESX Server as its hypervisor flagship. Citrix recently acquired XenSource and continuously gains market share along with Microsoft which announced its own virtualization solution Microsoft Virtual Server. Another major player is RedHat which includes Xen Hypervisor to its RHEL 5. Last but not least, Sun Microsystems already announced early access to Sun XVM Hypervisor for Solaris platforms. The above mentioned solutions are commercial solutions but XenSource, Sun Xvm as well as Xen Hypervisor are F/OSS products. Furthermore there are various other open source projects supported by open source communities. The most important of them are Bochs, Qemu and KVM (Ribière, 2008).

In this paper we will show and attempt to quantify the combined benefits derived from the development and deployment of a fully F/OSS virtualization platform, used both for providing existing and for developing new, services to the Greek Research and Science Community. We will show that apart from the inherited virtualization benefits, F/OSS virtualization provides a significant combined effect, making it the most appropriate solution in a wide range of situations and environments, especially when multiple constraints exist and agile development methods are used. F/OSS virtualization benefits came from the inherent flexibility of open source and virtualization and allows to develop and provide systems were strict deadlines are in place, resources are not abundant or flexibility in procurement procedures is limited. The National Documentation Center (NDC) case study experience, quantitative results, and relevant conclusions are presented. Finally, the economic benefits, focusing in the licensing costs, of a fully F/OSS virtualized platform are compared to alternative virtualizated and non virtualized environments, in a generalized manner.

This paper is structured as follows: in section 2 the case study for the deployment of the F/OSS virtualization platform for NDC is presented and the high level business requirements are examined. In the next section the migration from a non virtualized three - tier platform to a virtualized infrastructure is presented while in section 4 the benefits of this approach are evaluated using metrics such as power consumption and software licensing and TCO related costs, while an estimation of the added value that F/OSS virtualization gave, in terms of flexibility, is performed. In section 5 these benefits are generalized, and the benefits of using an end to end F/OSS virtualization approach compared to a number of different deployment scenarios which use, exclusively or partially closed source software is examined. Finally, in section 6 overall conclusions are drawn.

2. Business needs and constraints

In this section we highlight the needs and requirements that led to the deployment of an end to end F/OSS virtualization platform at NDC. Its purpose is not only to report practical experiences but also to be used as an introduction to a class of business needs and requirements that are quite wide spread in the IT industry. The National Documentation Centre (EKT/NDC) is the backbone organization of the Greek national infrastructure for scientific documentation, online information and support services on research, science and technology. Among others it hosts the national dissertation thesis archive, the union journal catalog of the Greek Academic Libraries, develops and supports the ABEKT Library Automation System, collects, digitizes, annotates and provides scientific and cultural content and science related databases, using a mix of third party, in house developed and open source software. In order to provide the aforementioned services NDC operates an enterprise level IT infrastructure which exhibits, the following characteristics:

- A wide range of diverse applications and services built using different technologies.
- Different categories and classes of end users.
- Heavy F/OSS applications usage and customization.
- Significant number of legacy applications developed over different time periods.
- 3rd party applications hosting.
- Need for frequent and rapid development of new applications and services.

The required fragmentation in applications and services raises the complexity of the requirement infrastructure, and in-house software development. However, this fragmentation can be avoided entirely since experience has shown that one size does not fit all, especially when using F/OSS applications. For each class of applications requirements the best available options are used.

The aforementioned characteristics are frequently overlooked as major IT issues however they are common in a variety environments which are mainly characterized by a large number of diverse applications, a large and varied number of heterogeneous user groups, constant service updates featuring significant new and non-trivial requirements and purpose built applications for vertical sectors.

Furthermore, NDC has set as target to, develop applications and infrastructures providing open access services (Kaufman-Wills, 2005),(Friend, 2005),(Berlin Declaration Signatories, 2003) to the Greek scientific community (NDC,2008). These include institutional and subject based scientific repositories, open access scientific journals and additional relevant applications and services, such as informational and awareness raising activities. In order to provide the aforementioned services a number of F/OSS applications should be evaluated, customized, new modules developed, provided in a pilot manner and deployed while scientific content was collected, evaluated for copyright license status, digitized if necessary and annotated in a collaborative manner. The aforementioned high level objectives were to be pursued as part of a large scale project, characterized by its relevant features and constraints. The relevant, for the IT part of the project constraints, were the following, both at the administrative and technical level:

- Timing constraints. With regard to the project's objectives the available time although sufficient was especially tight.
- Administrative and regulatory constraints. The aforementioned timing constraints were further enhanced due to procurement procedures. These implied that required equipment for development, pilot and production phases could only be purchased after significant project time would have pass and on a single purchase. Thus a trade off existed among the time needed for the design of a large scale open access infrastructure and the immediate need for developing the system and providing pilot implementations. The delay in purchasing necessary equipment could jeopardize the capability to develop, test and initially deploy the necessary software components.
- Economic constraints: the capability for large scale procurements outside the projects scope was limited and should be kept at reasonable low level.
- Requirements posed on the in house software development process, such as the short development time, the amount of actions that should be performed in parallel, changing user requirements, non trivial software modules etc. Due to the aforementioned requirements and the overall nature of the project an agile software development methodology was selected, as the best available option. That created an environment where flexibility and speed of response was crucial for the project's success.

It should be emphasized that the aforementioned constraints are not unique to the NDC's case. They are frequently being meet by a number of non-trivial IT projects, that share the following general characteristics:

- Changing service requirements which demand the use of agile software methodologies are essential.
- Needs can rapidly arise and specialized execution environments and custom made applications are needed.
- Proactive planning of the required IT infrastructure is challenging, due to the shifting requirements.
- Administrative flexibility is restricted with regard to equipment and software purchase, either due to budget, cash flow or regulatory constraints.
- In house development of a large number of applications in a separated test environment while the production environment should keep providing high quality and availability services.
- Need for extremely short time to market or for early working prototypes

It is apparent that the aforementioned characteristics and needs are not a unique for NDC, they represent a widespread set of industry requirements, including SMEs, government organizations, and research and educational institutes.

3. The deployment of the F/OSS virtualization platform

3.1. Selecting a F/OSS virtualization platform

In order to accommodate the aforementioned requirements NDC has at its disposal at the project's initiation a classic three tier platform, where resources while were sufficiently over provisioned the overall configuration could not support the needed flexibility. In greater detail there were already several applications to support the required services using a variety of technologies. Most of these applications where based on J2EE running on Apache Tomcat, however, also PHP, Ruby on rails and legacy Oracle and JES applications were used. Furthermore, those applications needed a database backend which varied between Oracle, PostgreSQL and MySQL. A specific development environment has been envisaged for some of the key technology choices. However it was apparent that the number of the existing development environment nodes was underestimated in the light of the forthcoming services and applications. At the same time a significant amount of legacy servers were running applications that should be ported to newer available equipment. A classic three tier architecture while satisfactory for a static, slowly changing (static) homogeneous environment greatly limited flexibility at:

- Allocating resources
- Porting applications to different hardware platforms
- Dynamically dimensioning services
- Incorporating new functional requirements and demands

while at the same time it prohibited the synchronous development of the required number of new services and applications. Thus, the following options, or a combination of them, were available at the time of the project initiation:

- Reduce the production environment redundancy, availability and performance level in order to free resources for the development and the gradual (pilot) roll out of the new services.
- Fully begin the development and the initial roll out of services when the proper equipment is purchased.
- Expedite the procurement procedures with the risk of not thoroughly planning using the earliest possible estimation of the final requirements.

None of the above options was satisfactory, thus virtualization technology was evaluated in order to accommodate these different requirements. It was decided that the best option was to exploit the virtualization technology in order to consolidate resources from the existing production infrastructure, both current up to date production servers, and legacy ones, without losing significant redundancy or performance characteristics; in any case resources could be easily reallocated. Moreover, using virtualization pilot applications could be rapidly rolled out, while the development environment could accommodate all the rapidly changing requirements in a structured manner. Lastly, the purchase of the required equipment could be done with a pace that guaranteed that the purchased equipment was what the project required for the full production phase, which could be safely estimated only after specifications and requirements from the development phase were mostly frozen. Having decided on creating a virtualized platform, available option at the middle of 2007 were limited, and were essentially the F/OSS XEN hypervisor, and supporting Linux distributions, and the Vmware Server, featuring however significantly less than native performance, and the ESX Server. However, due to the aforementioned set of, timing, administrative, budget and regulatory constraints, the aforementioned platform would be only possible to implement if only F/OSS was used exclusively, at the guest OS level, the application and the virtualization platform level. A mix of Redhat Enterprise Server 5 Advanced and of the Community Enterprise Operating System 5 (CentOS) was selected.

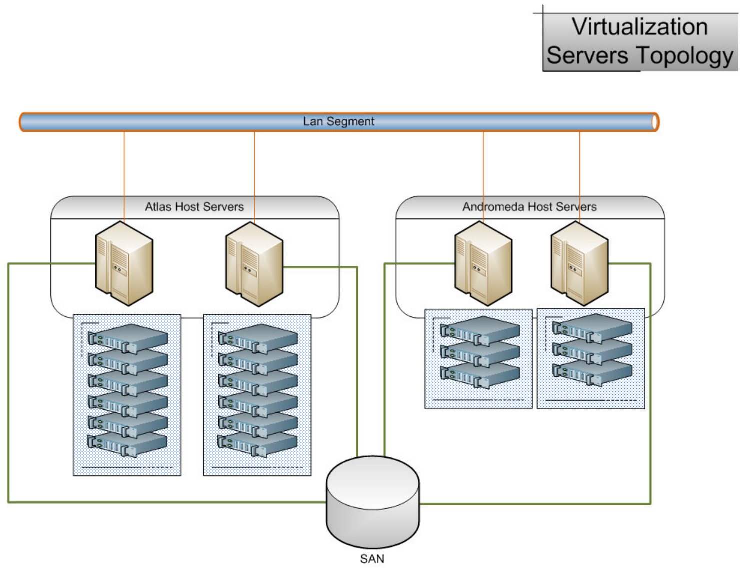
3.2. Deploying and migrating to the platform

The virtualization platform comprises four high capabilities servers, featuring two distinct configuration of two and four dual core 64 bit x86 processors with 4GB and 16GB of RAM memory respectively. All servers were connected through double 2GB Fiber Optic links to a shared SAN space of 4TB. Moreover each server connects to the same LAN segment through multipath enabled Gigabit links for high availability purposes and traffic shaping.

In this four-server platform 18 virtual machines were hosted for production, development and migration of legacy applications purposes using the XEN open source virtualization tools. The host operating system is CentOS EL5, due its binary compatibility with RHEL 5, with Xen enabled kernel. In order to be able to streamline OS installations we prepared the initial installation environment on one of the four servers. The installation environment required the installation of an HTTP Server to provided OS images. Virtual machines configuration is done through simple text files describing the characteristics of each system. To minimize administration fuss template configuration files were stored on each server to cover all aspects of configuration combinations.

During the first production stage of the virtualization platform we installed several development servers. Up to that time development servers where physical machines with commodity hardware. Those servers suffered from zero administration, lack of backups and most of the times where out of the control of the NDC NOS imposing various potential risks to the organization's infrastructure. The configuration of the development virtual machines was identical. Each virtual machine had 2 virtual cpus, 1 GB of RAM and 20GB of disk space as a separate volume on the SAN space. For every development server CentOS EL5 was installed and the appropriate development tools. After some initial testing of correct functionality we migrated the required data from the existing physical servers. Results and feedback from users allowed the migration of the first production server. This server supported internal development providing Subversion and Bug tracking services. The existing physical server run on CentOS EL5 so it could be migrated to the new virtualization platform simply by changing the OS kernel to support Xen hooks.

The second production phase began three months after the beginning of the first production phase. During that phase several production server have been installed on the new virtualization platform. This phase began by migrating the organization's internal mail server, which provides services for almost 100 users and 30 mailing lists and newsletters. As we had the expected results regarding compatibility and performance we decided the migration of all Linux Apache web servers and all Linux Tomcat application servers to the new platform. This phase lasted 2 months as we chose to move the servers one by one and have enough time to ensure stability and performance for each one. At the end of this phase we had 15 servers in total running on our virtual platform. At this time the platform was mature enough to complete the 3-tier architecture migration of our infrastructure to the virtual platform. The final steps was to migrate both legacy database servers, such as Oracle 9i, as well as open source databases to support various applications, such as MySQL and PostgreSQL. This phase included database testing and optimization for the new platform.



Picture 1 – Final Virtualization Platform Architecture

Virtual machines have been distributed across servers in order to have as little interference between virtual machines as possible. By achieving this we could get realistic performance metrics regarding CPU utilization and memory needs on the host servers. Based on the metrics, with 18 virtual machines running both development and production environments the results were impressive. An average of less than 10% CPU usage, in 5 minute interval counters on the host servers. Also we virtual machines had close to zero memory swapping and no obvious delays regarding network traffic and I/O operations.

4. Quantifying the benefits for the NDC case study

Virtualization benefits are widely reported and range from the reduction in power consumption and the smaller environmental footprint of an IT infrastructure, to hardware costs reduction, shorted project development times and increased deployment flexibility. These benefits are usually reported in a qualitative manner and without taking into account whether the virtualization infrastructure is implemented using F/OSS or closed source software. In this section we will quantify the benefits from implementing the NDC virtualization platform. Furthermore, we will focus on the F/OSS solution selected by two means. Initially we will compare the software licensing costs when compared with other commercial alternatives and then we will evaluate the project-level benefits derived from the combined flexibility of virtualization and F/OSS.

4.1 Power and Environmental benefits

Power consumption is increasingly a major cost of the total cost of a large scale IT infrastructure. It has been reported that at 2005 servers and auxiliary server cooling equipment consumed the 1,2% power of the total at the U.S (Koomey,2007). Power consumption in a datacenter is determined by the number and efficiency of server and IT equipment in general, the cooling requirements for these equipment, and the power lost at the power distribution level. One apparent benefit of virtualization consolidation is the reduction of the total number of servers required. This reduces both the overall power consumption, the requiring cooling power, the environmental footprint of an IT infrastructure and the required datacenter floor space.

In order to evaluate the actual benefits by deploying the NDC's virtualization platform the total power consumed will be compared to:

A. The initial system before virtualization consolidation took place. This includes both non virtualized production servers and legacy ones.

B. A fully functionally equivalent alternative scenario, where physical servers were used instead of virtualized ones and legacy servers have been removed.

C. Realistic alternative scenario were a large scale consolidation of applications and services to single physical servers is performed. While this is not fully equivalent to virtualized platform functionality, it represents the realistic alternative that would have being pursued if virtualization was not an option, including the removal of legacy servers.

In order not to overestimate benefits for scenarios B and C we have assumed that the lower end servers available at the time at NDC would be used to built the non virtualized equivalent platform. Two metrics will be used. The total server **nominal power consumption**, including cooling requirements, as defined by the server specifications and the total **actual power consumption** based on PDU (Power Distribution Units) measurements. The cooling power requirements, are derived from the relevant server power consumption assuming a conservative Power Usage Effectiveness (PUE) (Greenberg 2006, Greed Grid, 2007) ratio of 2,0. PUE is the ratio of the IT equipment to the total datacenter power demand. Usual PUE for datacenters is around 3, but an optimally designed datacenter can achieve a PUEs of 2,0. In order not to overestimate power savings we calculate cooling power consumption with one of the best realistically achievable scenario for a datacenter. Based on the aforementioned platform configuration, on vendor datasheets and on a series of PDU measurements the power consumption results, for the full and only the virtualized platforms, are the following:

Table 1. Total NDC's platform Nominal Power Consumption

	Initial	Virtualized	Fully equivalent	Realistic Alternative
Total Power Consumption	35,8KW	21,26KW	34,22KW	27,22KW[1]
Reduction comparing to initial	-	40%	4,4%	23%

Table 2. Virtualization Platform Power Consumption

	Virtualization platform	Fully equivalent	Realistic Alternative
Nominal	5,040KW	18KW	11KW[1]
Actual	2,208KW	6,624KW	4,048KW[2]
Reduction comparing to Realistic Alternative - Nominal	45%	63%(increase to realistic alternative)	-
Reduction comparing to Realistic Alternative - Actual	45%	63%(increase to realistic alternative)	-

While the nominal power consumption may seem like an overestimation of required power actually it is a key indicator in planning the capacity of a datacenter. Power distribution equipment and switching, UPS, cooling equipment, etc. should be designed in accordance to the nominal energy consumption. Thus the nominal consumption provides information about the infrastructure set up cost while the measured (actual) consumption provides information about the long term energy costs of the infrastructure. The overall conclusion is that due to the F/OSS virtualization employed NDC reduced significantly the total power consumption of the NDC datacenter while achieving to postpone the need for a possible costly power distribution infrastructure upgrade. Economic gains can be expected from this reduction, however since the focus of the paper is on F/OSS virtualization specifically we do not expand on this.

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[1] Assuming 40% of virtual servers are consolidated to physical servers

2 Calculated using measured server consumption and the best scenario where PUE=2

4.2 Comparing licensing costs

In this section the licensing costs for implementing the NDC virtualization infrastructure using exclusively F/OSS will be presented. Furthermore, they will be compared to the cost of building a similar platform using closed source software alternatives will be analyzed. In this stage this comparison will be performed based on data from the specific NDC deployment. In the next section an analysis will follow making this comparison useful also for generic cases. The total licensing costs of the actually deployed platform and for the following alternative scenarios will be compared:

A. Closed source virtualization software and guest OS. VMware ESX Server is considered as virtualization software and Windows 2003 Standard as the guest OS. Virtualization licensing for Microsoft products used in this case is the one during the initial phases of the projects implementation, i.e. middle 2007.

B. Closed source virtualization software, i.e. VMware ESX Server and F/OSS guest OS, a mix of community supported CentOS and RHEL supported OS.

C. Closed source virtualization in the form of Windows 2008 Datacenter edition, with the latest licensing terms, which permit unlimited virtualization copies (Microsoft, 2008).

The software licenses costs are based on the publicly available information. Additional CAL for Windows servers and other software licensing costs are not included, while a mix of 20% enterprise level supported guest OS are considered in the form of RHEL Advanced Server and Windows 2003 Enterprise.

Table 3. Actual software costs for implementing the virtualized platform.

	NDC case Study	Case A	Case B	Case C
Licensing Costs	8.192,00$[3]	52.980,00$	52.980,00$	17.994,00$
Guest OS licenses	0	17.994,00$	8.192,00$	0
Total Software Licensing Cost	8.192,00$	70.974,00$	61.172,00$	17.994,00$

While significant controversy exists about Total Cost of Ownership (TCO) estimations, (e.g. IDC 2007), it is accepted that personnel are a significant amount of TCO. In this section personnel costs is not included, since we would like to

[3] Since not all vendors readily provide costs in currency other than US dollars, the USD has been used as the common pricing reference.

emphasize on licensing costs. However our practical experience and empirical evidence shows that for the platform implemented, irrelevant of the virtualization technology selected, and regardless of whether servers where physical or virtual, one additional senior system engineer would be required per year. Furthermore, it should be noted that the Windows 2008 Datacenter edition virtualization option became available lately and that the latest changes in licensing policies from major vendors have greatly reduce the guest OS software licenses cost. However it should be also highlighted that in scenario C and A, neither CALs nor additional needed application software licenses, from IDE to databases, are included, that would have significantly increased the platform's software Total Cost of Ownership (TCO) figures. These conclusions are not presented here as a generalized case, but as the experience from this specific case study. In forthcoming section cost reductions from using F/OSS virtualization are analyzed in a more general manner.

4.3 Empirical workplan/timing related benefits

Experience from the NDC shows that for small to medium sized infrastructures (20-40 servers, 20 publicly available end user services) required personnel is based mostly on the number of servers and services and the administration automation and management tools used, and not on the specific kind or flavor of the software used. Thus, for such environments the differentiating factor can be licensing costs and possible procurement delays and not personnel costs. Empirical evidence shows that from the initial IT level decision to purchase a software license until the actual purchase date up to three weeks can pass roughly; one for each stage of the tender, the management approval and the license purchase and server installation phase. Time delays can be even larger when virtualized approach is not employed and a physical server is required to be purchased. While this estimated time can be significantly shorter from an organization to organization case, it is not an uncommon occurrence, especially in governmental and large organizations in general. Furthermore, this delay would be experienced every time a platform expansion was underway, or new specification emerged from the agile development method.

Thus, for the NDC case study this time has been minimized to the initial 3 weeks for the initial software license purchases. If a project has been built using closed source software it would require at least two times extra guest OS and application software licenses purchases, in order to expand the platform, and the subsequent project delays. While the above can be predicted in some degree with extra licensing purchases and other methods, it is also true that F/OSS virtualization gives a significant flexibility for the project execution, especially when agile methodologies are employed and budget constraints are in place. Finally, using F/OSS virtualization delays on the purchase of hardware and software can be easily absorbed.

5. Comparing F/OSS virtualization licensing to alternatives

Implementing a virtualization platform using exclusively F/OSS has possible significant software licensing costs reductions, since the total cost of a virtualized platform can depend heavily on the software licensing model used. In this section a generic case and comparison of virtualized platforms implementation using F/OSS and commercial software will be presented. As already stated the total cost of ownership (TCO) has been used and defined in a number of different ways and with controversial sometimes manners (IDC, 2007). Moreover, TCO reductions using virtualization arise from different directions. In the analysis of this section two main metrics will be evaluated. First the **total cost of licensing and software support** for building a virtualized infrastructure in a comparison to non-virtualized infrastructure using both commercial and F/OSS software. This will include:

- Software licensing costs per virtual or physical server including support
- Virtualization software cost per server

This was not a task that could be undertaken in a general manner until recently due to the changing licensing structures especially for virtualization implementation from all vendors. As a second metric **the total software licensing and maintenance costs** will be estimated for a one year period. These, apart from the software licensing and support costs include the costs of:

- Hardware maintenance costs per physical server.
- Administration personnel costs for supporting the virtual and physical servers. This is assumed the same in both occasions.

Hardware acquisition costs are not presented, since we would like to concentrate at comparing the software costs among different virtualization solutions. Lastly two additional variables are taken into account are:

- The consolidation degree of the infrastructure, i.e. the average number of virtual servers per physical server.
- The total number of physical and virtual servers.

We study the following scenarios:

A. No virtualization is employed and closed source OS software is used.

B. Virtualized infrastructure using closed source software, i.e. VMWare ESX with the conditions existing at early 2007. At that point of time vendors did not generally made any specific provisions for virtual machines licensing.

C. Virtualized infrastructure implemented using fully F/OSS. A 20% of the total servers are running mission critical applications and should be vendor supported. The rest are using a community supported compatible edition.

D. Implementation using closed source virtualization infrastructure software and F/OSS guest OS software.

E. Implementation using the present scheme of commercial virtualization software and OS licensing for Windows 2008 Datacenter Edition.

F. No virtualization is employed however the infrastructure is built fully using F/OSS

We consider that hardware maintenance costs are 10% of the initial hardware cost each year and due to increased infrastructure complexity one hardware systems engineer is required for every 20 physical servers. Furthermore, we consider that a systems engineer is required for administering every 10 physical servers. While these figures are arbitrary, they are reasonable and they cannot change the section's overall conclusions. Finally a consolidation degree of 8 virtual servers per physical is assumed. Two processor die servers are assumed in general except the last row of table 3.

Table 3. Software Licensing Costs

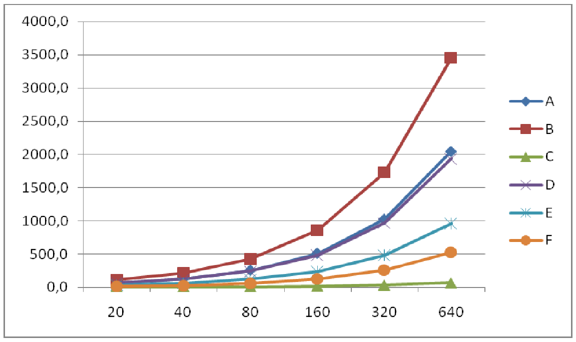
Number of Servers	A (K$)	B (K$)	C (K$)	D (K$)	E (K$)	F (K$)
20	40,0	66,5	8,2	42,9	18,0	16,4
40	80,0	124,1	8,2	76,9	30,0	32,8
80	160,0	248,3	8,2	153,8	60,0	65,5
160	319,9	496,5	16,4	307,7	120,0	131,1
320	639,9	993,1	32,8	615,3	239,9	262,1
640	1279,7	1986,1	65,5	1230,7	479,8	524,3
640[4]	2047,5	3460,3	65,5	1937,1	959,7	524,3

Table 4. Total software licensing and personnel maintenance estimated costs

Number of Servers	A (K$)	B (K$)	C (K$)	D (K$)	E (K$)	F (K$)
20	180,0	155,5	97,2	131,9	107,0	156,4
40	360,0	299,1	183,2	251,9	205,0	312,8
80	720,0	598,3	358,2	503,8	410,0	625,5
160	1439,9	1196,5	716,4	1007,7	820,0	1251,1

[4] In this row servers with four processor dies are assumed

320	2879,9	2393,1	1432,8	2015,3	1639,9	2502,1
640	5759,7	4786,1	2865,5	4030,7	3279,8	5004,3



Picture 2 – Software Licensing Costs

Based on the above the conclusion is that implementing a virtualization platform using a mix of community supported and vendor supported F/OSS can achieve significant IT spending cost reductions. Furthermore, the platform cost scales gracefully in accordance to the number of servers, making possible the full utilization of the virtualization potentials, i.e. flexibility. This trend is still true when additional TCO factors are taken into account, although somehow diminished. The Windows 2008 Datacenter edition cost is underestimated since no application or CAL licensing costs are taken into account. However, it is apparent that a significant variable factor is the number of required IT personnel for supporting the overall IT infrastructure apart from the significant licensing costs reduction, thus making critical the issue of server system manageability (Creeger, 2008).

6. Conclusions

In this paper we presented the case study of the NDC F/OSS virtualization platform deployment. This platform was created as a mean for NDC to provide its service to the end users while at the same time developing in a structured staging environment a large scale open access infrastructure, in a short period of time and using agile development methods. Benefits derived from F/OSS virtualization not only included quantitative benefits of power consumption and possible cost reduction through consolidation, but also F/OSS virtualization specific ones.

When the properties of virtualization were combined with the freedom of F/OSS a significant level of flexibility was achieved, allowing the overall project to be implemented with high quality while meeting all aforementioned constraints. Similar requirements and conditions exist in a variety of projects, situations and organizations thus making F/OSS a practical candidate for deploying virtualization platforms in short time and with significant budget constraints. Lastly the quantitative results presented regarding licensing costs, achieved and projected, indicate that F/OSS virtualization exhibits significant and scalable benefits regarding licensing costs, when ones considers a similar degree of man power costs.

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