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OPEN SOURCE CLOUD COMPUTING FOR SUSTAINABLE IT DEVELOPMENT

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ABSTRACT

Cloud computing changes the way IT services are delivered, introducing technology which supports efficient usage of computing resources. This paper examines the effect that cloud computing is having on several environmental aspects, which represent real challenge for the sustained growth of ICT infrastructures. Cloud computing delivers means for minimizing energy consumption for manufacturing and operations of computer equipment, while open source software enables efficient use and reuse of resources, through building on top of existing technology. This hybrid IT system is found at the core of big service providers worldwide, because of its many benefits, elaborated throughout this paper. One of the most important feature of open source cloud systems is the great perspective it has on reducing energy, electronic waste and pollution. However, the environmental aspect isn't the only measure for sustainable development. Cloud computing brings many exciting benefits and that is why this paper elaborates the parameters needed for calculating a total cost of ownership, for evaluating the complete design and implementation of open source cloud systems.

Keywords: Cloud computing, open source, emerging technologies, sustainable IT solutions, energy efficiency.

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1. Introduction

1.1. Goals and methodology

Today, emerging technologies are creating not only the trends and directions in the IT industry, but are also shaping the economic and financial market structure, on a global scale. Computing operations are needed in every field of a modern society. Apart from using the computers as tools for day-to-day ordinary activities, computers are heavily present behind the scenes, from gathering large amount of data, structuring and storing it, analysing relevant information and producing knowledge-based expert systems. This global trend has a heavy impact on the worldwide energy consumption. The substantial amount of information systems and data which is being fetched and consumed by individuals, companies and institutions, creates challenges for developing sustainable IT systems, from multiple points of view:

- integration of different applications,
- efficient reuse of hardware resources – having applications run at different time spans on the same hardware,
- maintaining security and compliance,
- ensuring safe and achievable migrations to other systems and upgrades.

Hardware manufacturing is bringing more efficient processors and faster memory, which uses less energy. However, regardless of the speed and efficiency of a computer, minimizing hardware utilization must be the priority of any IT project, since it achieves less electronic waste and less energy consumption. Using virtualization, cloud computing achieves this goals, by maintaining the computing speed and performances of dedicated physical systems.

Software development, on the other hand, is one of the fastest-growing industries in the Republic of Macedonia. Software is everywhere, and with the massive adoption of mobile devices and smart phones, development of new packages, protocols and applications is constantly on the rise. With open source software products (referred to as OSS throughout this paper), local developers can use semi-finished products, in

order to build on top of them and create additional values and professional software which can be implemented anywhere.

This paper relates to sustainability through several aspects:

- Impact of ICT on the environment;
- Energy efficiency in high-end systems;
- New and creative approaches to sustainability.

In order to measure and determine the impact that open source cloud systems, and cloud technology in general, have on the above-mentioned elements, this paper determines to analyse such systems and propose best practices for IT systems deployment in an all-round systematic approach.

Taking into consideration the challenges in front of future ICT solutions, these aspects of interest add even more dimensions in choosing the right technology for the right purpose. Therefore, the following steps are comprising the research methodology used throughout this paper:

- Decomposition of the feasibility of open-source cloud technology for mission-critical applications, through a total cost of ownership analysis;
- Elaborating the benefits that cloud systems have from an environmental and efficient energy point of view;
- Stressing out the importance of open source software systems for designing and building sustainable solutions;
- Determining the possibility for boosting the local ICT development and creating services and products applicable locally, regionally and globally, in both the private and the public sector.

The approach for achieving those goals starts with the analysis of recent research in this field, in the next chapter. After that, a total cost of ownership business model is created, since when discussing about open source cloud systems and their impact on the environment, one must consider how feasible it is to implement such systems in complex and mission-critical projects. After dismantling the open source cloud systems, focus is given to their environmental aspects, proceeded by research on how

sustainable development can be achieved and maintained. Eventually this paper represents an all-round perspective on the application, usability and efficiency of open source systems deployed for creating cloud computing environments.

1.2. Problem description

As more and more technology is becoming a necessity, companies and institutions should focus on optimal usage of these IT solutions for their own purposes, instead of implementing and integrating them into a complex and unsustainable environments. Particularly nowadays, when one institution often has multiple applications distributed across different hardware – it is becoming very difficult to resist the public cloud opportunities and put the data, which is their most valuable resource, somewhere on the Internet. This trend creates regulatory and compliance risks, since putting data abroad, makes it dependent on local laws and regulations.

The globalization as well has taken its toll, since these services are often made available for a lower price from big vendors. Spending money to big vendors for licenses and support, instead of using local resources for customizing, furthermore burdens the local economy, particularly since there are sufficient resources in the Republic of Macedonia for designing and implementing sustainable IT solutions.

In the Republic of Macedonia there is no hardware manufacturing industry for standard desktop and rack mountable computer systems or servers. Inefficient usage of hardware resources burdens the economy from that perspective as well, since more hardware is imported. The average lifetime of computers has been constantly dropping, because of three important IT equipment manufacturing trends:

- Bringing the products to the market is extremely important, influencing big companies to create easy-to-manufacture hardware parts;
- New technologies are increasing performances of computer systems constantly, reducing the time for which a computer system becomes obsolete;
- Internet applications are expanding worldwide, which usually require more computing resources in terms of processing power, memory usage and bus speed.

Bearing this in mind, efficient use or reuse of the same hardware for multiple applications must be introduced in Macedonia, exchanging local knowledge and expertise for hardware equipment, which is being imported and is generating large quantities of electronic waste. That is why it is very important for the companies and public bodies to understand the importance of virtualizing computer resources and deploying cloud solutions.

When referring to cloud computing, it is considered as both private and public cloud infrastructures. The differences and impacts on energy consumption by the private/public clouds are not in the scope of this paper.

2. Related research

The field of cloud computing has been receiving a lot of research in the last few years, both on a theoretical and application level. Not only research institutes, but also commercial organizations are stressing more and more the economical and environmental impact of green technologies, such as "the cloud". Cloud computing itself, has been defined from different aspects , with one of the most comprehensive and profound definition being from Baliga et al. [2] as a "model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction". Within this paper, the main focus on cloud technology is on its virtualization capabilities for reducing manufacturing, operation, communication and maintenance resources, deliberately neglecting the service and business perspective. Many researches [2], [4], [5] are trying to emphasize the potential cloud systems have for contributing to the sustained development of the IT industry. Moreno and Xu [5] are discussing the performance degradation issue, which must not be ignored, since cloud technology and virtualization are only feasible if they meet the functionality demands of the applications being serviced and delivered. Heavy research has been made on the many aspects for the impact of the modern IT industry on world's pollution and waste accumulation. Even new terms such as e-waste [5], e-pollution and Green-

IT [7] have been introduced, even though the IT industry is still rather young for exact calculations to be made for the long-term impact on the environment. Jeffery and Neidecker-Lutz [7] in their Expert report for the European Commission underline the dedication of EU for extending the development and usage of cloud IT systems, as one of their long-term goals for boosting IT innovation, technological development and controlling the impact that the IT industry has on the environment. In their research study, they recommend that The EC should promote the European leadership position in software through open source approaches in cloud computing, as it simplifies the adoption to different environments.

Open source software, has been constantly present in the researches and in the educational environment in general, even though not drawing the enormous attention cloud computing is accumulating in the last five years. The great importance of open source software for cloud computing is brought forward in many researches, some of which naming open source "the great enabler for cloud computing" [6].

3. Total cost of ownership advantages of open source cloud systems

Calculating the expenditures and the ratio of investment in new ICT solutions can be a challenge, particularly for dynamic and distributed systems, with a large base of users and stakeholders. When a decision should be made between various options, the comparison must include all important parameters, in order to avoid hidden and unpredicted costs. In this paper, the total cost of ownership (refereed to as TCO throughout this paper) business model is proposed for evaluating technical solutions from different perspectives from their life cycle, starting from acquiring, through deploying, testing, operating and maintaining, and to upgrading and managing end-of-life support issues. This approach, originally proposed by Gartner Group Inc. [2], encapsulates most aspects needed for supporting decisions for implementation of robust and scalable ICT solutions. Even though the mentioned cost-decomposition model is used as a reference, the proposed criteria in this chapter defer from it, since

2. http://www.gartner.com/technology/research.jsp

recommendations are given for issues that should be taken into consideration for total cost of ownership of open-source cloud projects in particular, having in mind the sustainable development and usability of such systems.

We assume that we need to design and implement a flexible and scalable virtualized system, for various applications, not dependent on a particular vendor and being able to support different customers connected over the Internet. The following aspects are recommended in this paper to be considered for system evaluation and for each of them a complete prospect on open source cloud system is given.

Total cost of ownership elements, for creating a cloud environment:

- **Hardware purchase and maintenance**: Cloud computing systems are software entities, which should be run on an appropriate hardware. Even though this parameter is considered independent from the technology, one important issue, which must be stressed, is that using open source technology, cloud infrastructures can be created out of commodity hardware with no special requirements. This can impact the cost of the cloud project and the scalability as well, because if the servers start to take heavy load – additional servers can be added with ease. Also, reuse of the hardware can be made and old hardware which is deprecated within the organization can be adapted to fit in the cloud deployment.
- **Infrastructure: electricity, cooling, fire-protection**: This element can add significant expenditures for building the cloud infrastructure, but deploying a cloud environment will have great impact on the requirements for these systems. Using cloud technology, if ten different applications are required, running in ten different environments – there is no need for ten separate physical servers. Instead, those applications can maybe run only on two or three servers, depending of the load imposed on the applications. The bigger the number of physical servers, the more electrical and cooling energy is wasted, because servers are consisted of passive elements which add to the energy consumption and heat – and having few servers to do the job, will increase the

density of active computer parts (CPU, RAM memory, etc.) compared to the passive parts. Having fewer servers will also decrease the risk of a fire in the data-centre. Another benefit from utilizing cloud principles is that once an application is not used, it can be suspended, without using any energy whatsoever. When it resumes, the virtual server running the application will not have to boot all over again, performing useless operations and consuming energy – but it will run from the point when it was suspended.

- **Software acquisition, installation and maintenance**: Never the less, one must consider that greater expertise is required for deploying an open source software package. Existing of-the-shelf software products have big companies behind them offering integration and maintenance support. This is not an issue with open source, but using this type of software can surely boost the local economy, since license money are substituted with money for local companies and experts. With open source cloud system, the time-to-deployment can be reduced since there is no vendor lock-down. Choosing partners or support companies and being locked-down by one particular company are two very different things, which should be considered in the TCO evaluations.
- **Licenses**: Open source software has a distinctive advantage when it comes down to this expenditure. It will never expire or become license burden for the organization, since in terms of usage it is completely owned by the organization. When using an open source cloud solution, the organization is completely free to choose the company or team of experts, which will support the solution. There will be no limit on behalf of users or resources used on the cloud infrastructure, nor in terms of duration of the usage of the system.
- **Integration with other systems**: Since it is open source, the cloud environment can easily be integrated with existing or new software systems such as ERP, CRM, Trouble Ticketing, Billing, again without being dependent on a particular vendor or company.
- **Scalability and Software upgrades**: Scalability is the main advantage of

cloud environments, since they can easily be extended to a larger number of servers, even on a different geographical location. Software upgrades however, are big asset for proprietary systems; however, there are companies, which offer commercial support, patches and upgrades for open source systems as well.

- **Security**: This is a major issue for cloud based systems and it has been the greatest drawback for higher penetration of cloud computing in the business and government sector. As cloud technology is expanding with exponential rate, the security features of these systems are yet to find solid ground. This is a field to which scientific researches have been focused recently and it is expected that more applicable security measures will become an inseparable part of cloud deployments.
- **Backup and disaster recovery**: Using virtualized computer resources facilitate and speed-up the process of backing up and restoring data. With cloud systems, the Mean-time-to-recovery (MTTR) of systems and applications is expected to be much lower, since hardware failure issues are usually efficiently dealt with.

The global IT spending has risen 3% in 2012 compared to 2011, with public cloud services seeing substantial growth [12]. Computer hardware for business users is getting a negative growth, which implies to greater usage of server virtualization and cloud computing.

This chapter proposes means for calculating direct and indirect costs for an open source cloud system and cloud systems in general. These principles are mostly adaptable to designing and implementing both private and public cloud solutions, taking into consideration all relevant criteria.

4. Benefits of open source cloud computing

Throughout this paper, Cloud computing is considered as a location-independent, online applications which are available on demand.[3] But how does cloud computing

3 Definition by Joe Weinman from ATT, http://www.greentelecomlive.com/2009/03/16/full-interview-att's-joe-weinman/ [16]

achieve these advantages over commodity and legacy dedicated IT infrastructures? Cloud computing relies on three very important technological principles, which are having big impact on energy consumption and hardware utilization:

1. **Virtualization**: The ability to run different and independent operating systems on the same hardware. The importance of this principle is that applications can share resources and consume them only when they are active.
2. **System and application provisioning**: The ability to quickly and adequately add new instances on demand, making computer at disposal, at the same time maintaining security and scalability of traditional non-virtualized systems.
3. **Elasticity**: The cloud system gives impression that it is having an infinite set of resources[4]. This leads to the necessity to be able to expand, whether in terms of processing power, RAM memory or disk storage, over different types of systems and give impression that it is one coherent platform. Open source is particularly important for this principle, since open standards and interfaces are easily scalable and can be integrated to work with each other.

To explain these three concepts, a simple example is given: One website resides on cloud implementation of multiple web servers. It has small amount of users in night hours, only few virtual instances will run to accommodate their needs and to save energy as much as possible. Once the demand for the website and its contents increases, new virtual appliances will be automatically added to distribute the load and serve new clients. As storage on the website increases, the disk space can easily scale over different systems, which can be on different geographical locations, communicating and creating unified disk storage over network protocols.

There are three main models for cloud systems, on behalf of the service level being delivered to the end customer:

- **Infrastructure-as-a-service** (IaaS): Hardware infrastructure, delivered as a service;
- **Platform-as-a-service** (PaaS): Hardware infrastructure, together with

4 Cloud computing and its interest in saving energy [15], page 4.

installed operating system delivered as a service. Customer is installing his own applications.

- **Software-as-a-service** (SaaS): Everything, which is needed for an application to be used by the end customer – delivered as a service. This incorporates the infrastructure and the platform, for which the customer doesn't have to be aware of.

Cloud computing has achieved massive popularity worldwide, mainly because the fact that the whole ICT industry is transforming into a service-oriented manner. As technology reaches enormous development, with new scientific fields being opened on a daily basis, corporate IT administrators, both in the public or private sector, are finding it more difficult to track and deploy best practices into their environments. On the other hand, environmental aspects have burdened heavily the development of the IT industry worldwide in terms of pollution and large energy consumptions, putting efficient resources consumption (both in terms of hardware and in terms of energy) top of the priority list. If the technological development requires energy consumption for manufacturing and operations, which compromise our environment for the years to come, than this is an illegitimate method for increasing GDP, since it is in total violation of the sustainable development principles [1].

Open source software incorporates open standards, which is very important for interfacing different applications. Open standards are the foundation of sustainable technological development, since they create space for application and system developers to build over and upgrade existing systems, also ensuring that produced documents, databases or archives will be accessible and usable in the future, regardless of the vendor who designed the means for their creation.

Through this paper, a determination has been put forward that cloud computing is very important for energy efficiency and other environmental aspects. Constructed out of open source software it can represent a real sustainable system, not only from an environmental point of view, but technological and economical.

5. Environmental impact

Large-scale computing environments and data centers are high energy consumers, due to the need for their continuous operations and the big span of performance demands they should be capable of withstanding. This is why significant efforts have been made in recent years for introducing technologies, which will enforce higher energy efficiency and reduce electronic waste, electrical power and carbon emissions. Challenges for creating a "greener" computing environments are growing, since today there are more than ever users of computer devices and network services, new applications and websites are constantly added on-line and large amounts of data, needed to be processed and stored, are being accumulated over time.

The approach in this paper is to address the benefits of cloud computing and how this new way of delivering services can actually minimize energy costs not only for end users, but for the infrastructures providing the on-demand services. The environmental impact of cloud computing is measured and dismantled from three different aspects, having in mind this important technological fundamentals:

- **Minimization of electronic waste.** Cloud technology, among the rest, delivers hardware as a service. This means that end users should not invest in buying their own hardware, as they are using applications from their cloud provider. But even if companies or institutions build their own private cloud infrastructure, using this technology they will reduce the needed hardware, since multiple computational environments can run on one computer hardware. With open source cloud computing technology of course, hardware can be effectively reused, since virtualization technologies are independent of hardware manufacturer or particular system types.
- **Energy efficiency: heat savings, electricity savings.** As explained in previous chapters, cloud computing represents a new way not only of service delivery, but also of using system resources. With this concept, **computing on demand** is introduced, enabling usage of system resources only when there is necessity for the applications from the end users. Cloud systems reside on

complex hardware, which is using large portions of electricity, generating thermal energy, which needs to be cooled-off. The systems included, were explained in the Total cost of ownership analysis and in this chapter, a comparison would be made between cloud-based and traditional IT environments. For creating the power consumption model, computing resources are divided into four main groups [15]:

- Processing, the use of CPU power;
- Storage, the power consumed by accessing/writing data on magnetic hard disk;
- Communication;
- Passive energy consumption.

Multiple techniques exist for minimizing the power consumption in both idle and dynamic state, but analysing their impact is beyond the scope of this paper, as it focuses on the impact of virtualization and usage-on-demand principles of IT resources.

- **Carbon emissions.** As it has been stressed out in the Carbon Disclosure Project Study [11], the carbon emissions reducing potential of cloud computing opens huge possibilities, representing a "thrilling breakthrough" [11]. This allows companies to lower their costs, reduce energy usage and increase efficiency by lowering carbon emissions at the same time. The use case in the aforementioned research project indicates that one ordinary company, by porting only one HR application to the cloud, can reduce CO_2 emissions by 30,000 metric tons over five years [11].

6. Open source cloud contribution to sustainable development

Cloud computing and open source forge a mighty coalition, prepared to deliver on several different fronts from reducing costs, increasing efficient, minimizing risks for vendor lock-downs and increasing computing capacities, while using less overall hardware resources. However, one perspective is very important and that is the long-term environmental impact and sustainable development of this technology. Today, a

sound system design must rely on scalable and flexible solutions, since the IT industry introduces more and more technology every day. New systems need to be replaced or to be integrated with existing ones, extra data is added and more users must be managed.

As was mentioned above in this paper, open source software is beneficial for flexibility, modifications and customizations, avoiding vendor lock-ins. Having a sustainable technological development means being able to be more adaptive to change and new technologies. When using open source at the core of the system infrastructure, whether it is a corporate or governmental environment, owning the software code and the possibilities for independent modifications and customizations, add significant advantages on the long term. This business model ensures that if the applications are having high usability level at the moment, they can be adapted, without great difficulty, to the needs of tomorrow. This is the very essence of sustainable development and the principle for keeping pace with technological development without big capital expenditures, in general.

In terms of sustainability and energy efficiency, another great benefit of cloud computing is that it tends to move computer resources and energy usage from ordinary homes, to remote data centers where renewable energy resources are more available and carbon emissions are reduced in the urban living environment.

But who uses open source technology for building "clouds"? OSS has been used extensively for designing cloud infrastructures, with many big service providers including Google, Yahoo!, Amazon and eBay[5] building their production environments on top of open systems. Even though that this implies that open source cloud computing can deliver on the highest possible level, proprietary vendors of virtualization infrastructures and private cloud solutions are having great success in persuading mid-range and even large-scale service operators to use their technology. Arguments are most often in direction of non-existent professional support or unsustainable complexity of the overall system. However, the TCO considerations and

5. Study by SUN Microsystems [6], page 5 – Open Source in the Cloud.

other arguments raised in this paper – result in pointing out the ability and benefits of open source software. It is clear that major IT companies and service-oriented companies are delivering huge support for open source cloud computing, making it a core system at the heart of the IT industry.

Now that technology is a key instigator for economic growth, meeting today's ICT needs and creating an environment in which future needs can easily be managed is one of the key challenges for sustainable development. Particularly as it is proven in the short history of the ICT industry, that predictions and assumptions on the long-term development of computer systems are very hard to make.

Another very important aspect of open source is the opportunity for development of the IT industry on a national level. The development of open source applications can have a very positive effect on the local IT industry. This is because the business model for selling applications as SaaS incorporates fee for customization and maintenance, and not so much for licenses for the product. With open source, there is the possibility for creating a complete end product, using tools and pieces developed and supported by users and communities worldwide.

7. Conclusion

Technological development is one of the most critical factors for increasing the GDP worldwide. While striving to achieve a more rapid growth, it must not overstep the boundaries of sustainable development. Cloud computing delivers means for minimizing energy consumption for manufacturing and operations of computer equipment, while open source software development enables efficient use and reuse of future human and machine resources for building on top of existing technology. It is therefore highly recommended that the government of the Republic of Macedonia takes into consideration support actions for these modern and rapidly developing global trends.

Cloud computing is dedicated to enable users to pay IT resources per-usage and extend as they grow, making it a vastly popular trend in the IT industry. Most cloud

infrastructures are built on top of open source systems, which empower them to extend with greater dynamics, constantly generating features and additional values from and for the user community. When designing and implementing an open source cloud computing project, it is very important to create a Total Cost of Ownership model, for effectively considering all aspects of the system's implementation and operation life cycle.

As the 21st century is aiming to be dedicated to information processing and communications, green technology approaches are necessary to support sustainable development and to enable technological growth, which will not endanger the future environment.

After all, the ultimate goal of this paper is to inspire further research, both in the theoretical and in the application domain, for higher inclusion of open source software for implementing sustainable and flexible solutions, which can be of great interest for the ecosystem and economic development of the Republic of Macedonia.

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