University of Economics, Prague
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Bachelor's thesis

Costs of cloud IAAS in businesses

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4th May 2016

Acknowledgements

I would like to thank my thesis supervisor Ing. Miroslav Lorenc, Ph.D. for advice and pleasant cooperation on an interesting topic. I would also like to thank the e-shops which provided me with information about their infrastructure. Finally, I would like to thank my parents for their support during my studies.

Declaration

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Citation of this thesis

Kučera, Adam. *Costs of cloud IAAS in businesses*. Bachelor's thesis. University of Economics, Prague, Faculty of Business Administration, 2016.

Abstrakt

Cloud computing přináší malým i velkým podnikům mnoho možností, které mohou využít pro snížení nákladů na svou IT infrastrukturu. Tato práce popisuje klíčové koncepty cloud computingu a jeho hlavní výhody a nevýhody pro firmy. Práce porovnává různé poskytovatele IAAS služeb a nabízí framework, kterým mohou podniky porovnávat nákladovost své původní IT infrastruktury s náklady Infrastructure as a Service.

Klíčová slova Cloud computing, IAAS, IT infrastruktura, IT náklady, e-commerce

Abstract

Cloud computing brings many possibilities for businesses, large or small, which they can leverage for reduction of their IT infrastructure costs. This thesis presents the key concepts of cloud computing and its main advantages and disadvantages for enterprises. It compares different cloud IAAS providers and presents a framework for comparison of classic on-premises infrastructure costs and Infrastructure as a Service costs.

Keywords Cloud computing, IAAS, IT infrastructure, IT costs, e-commerce

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Introduction

Sun Microsystems follow the dictum “The network is the computer” (Kimch, 2013) since the immemorial days of computing and nowadays the materialization of this concept can be observed. Cloud computing is basically one huge network of computers which others use in many almost unthinkable fashions.

Since its birth, cloud computing became very appealing to many businesses – and one of the main reasons is the cost reduction it allows. Nowadays, energy makes up a quarter of the expense of running a data center and cloud computing offers a way to lower such costs. It also brings the businesses an option to tap as many computing cycles of nearly any magnitude as they want or require.

Thanks to cloud computing, businesses can also move their focus from keeping their current infrastructure running and working to what they really should do, innovating and solving new problems. They now have the resources to do so, as thanks to cloud computing, the infrastructure expenditure moved from capital to operational.

A big advantage of cloud computing is also the fact that it is available as a service for almost anyone, any type of business, large or small. (Babcock, 2010)

Because of this reasons, cloud is often referred to as a “disruptive technology”, which (Christensen, 2013) is described as follows:

> “Disruptive technologies often enable something to be done that previously had been deemed impossible.”

That means that the influence of cloud computing on the world and on the world of business in particular is and will be tremendous.

This thesis aims to investigate this potential of cloud computing and apply it on particular small and medium enterprises in the Czech republic. Its ambition is to propose a cloud usage in such businesses and to calculate its costs. The main goal is to compare it with the costs of the original infrastructure and to see what is more advantageous.

This thesis is structured as follows: Firstly, in chapter 1 the thesis goals are presented, then in chapter 2 a theoretical background for cloud computing and requirements of businesses for IT infrastructure are presented, then in chapter 3 the methodology for mostly practical part is presented and in chapter 4 the cost comparison of cloud solution and classical infrastructure is made. Finally, in Conclusion the results of the thesis are summarized.

Chapter 1

Thesis goal

The goal of this thesis is to understand the possibilities cloud computing infrastructure-as-a-service (IAAS) products offer to small and medium enterprises (SME), especially e-shops. The thesis aims to investigate basic principles of cloud computing and its key advantages which it holds for SME. The thesis then aspires to compare the most important IAAS products on the market and choose those most suitable for SME and their requirements.

The objective of this thesis is also to investigate several real enterprises and their infrastructure, quantify their needs for computational resources and analyze the typical workload present on their infrastructure. The output of this analysis will be then applied to the chosen IAAS product and its costs will be calculated.

The main goal of the thesis is to compare cloud products and traditional on-premises infrastructure and suggest which solution is more suitable for SME, based on costs, options it offers and advantages it brings.

Chapter 2

Theoretical part

In this chapter, the concept of cloud computing and its key characteristics are presented. Then the advantages and disadvantages of cloud for businesses are examined and described. Afterwards different cloud deployment and service models are shown. Then the concept of Infrastructure-as-a-service is understated, following with the description of different IAAS products existing on the market. Afterwards the requirements of SME for IT infrastructure are summarized and finally an outline of already existing work related to this thesis is presented.

2.1 Cloud computing and its characteristics

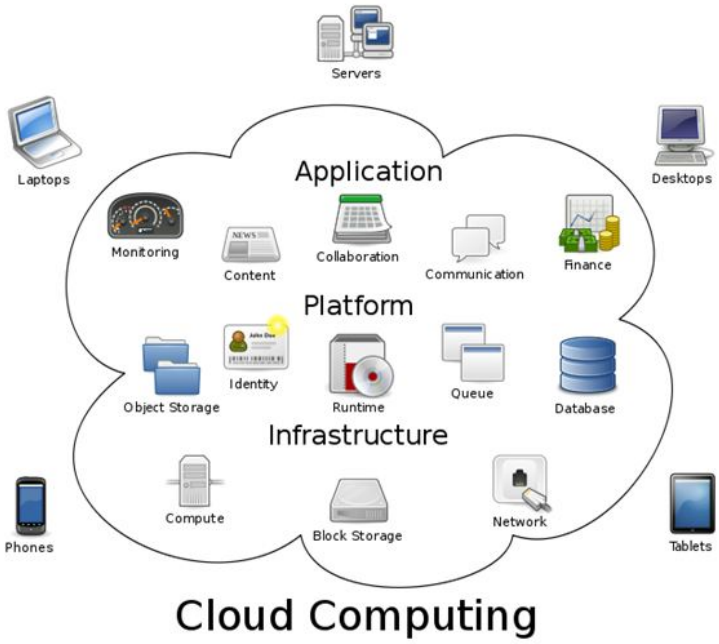
Cloud computing is not anymore just a buzzword floating around tech conferences, it is an already established term with a huge economic potential that already arose around it. Every year, the consulting company Gartner publishes the Hypecycle of emerging technologies which evaluates different computing innovations in terms of their current popularity and business acceptance. In 2015, cloud computing already left the hype cycle to so-called "Plateau of productivity", which means, that it is already widely accepted among businesses on all markets. (Rivera & Meulen, 2015)

Cloud computing is often referred to as a revolutionary and disruptive change comparable to the invention of the Internet, which can transform whole markets. The basic notion of cloud computing enables anyone to have instant access to almost unlimited computational power from anywhere in the world, just a swipe of a credit card away. The businesses worldwide can use this access for a wide variety of purposes, some of which may be the gamechanger on the specific market. (Babcock, 2010)

Cloud computing also promises the companies that it can replace almost the whole IT infrastructure needed for running the company for dramatically reduced costs. This is appealing to almost any business entity in the market using IT. (Marston, Li, Bandyopadhyay, Zhang & Ghalsasi, 2011)

The most important and popular usages of cloud computing are portrayed on Figure 2.1.

Figure 2.1: Applications of cloud computing in businesses



Source: (Scudder, 2011)

In this section, the basic characteristics of cloud computing will be described, so that the reader can understand why it has such a potential. Firstly, this section briefly describes the history of the cloud computing, then the definition of cloud computing is set and then key aspects of cloud computing – technical, qualitative and economic – are presented.

2.1.1 History of cloud computing

Several factors had foreshadowed the emergence of cloud computing: increasing storage capacities, decreasing prices for 1 MB of storage space, development of multiprocessor computation and the increase of network throughput. John McCarthy was the first herald of cloud computing, who in 1961 said: "Computing may someday be organized as a public utility just as the telephone system is a public utility." (Wenger, 2011)

The idea of cloud computing itself started to be around in mid-2000s. The key role in cloud development was played by Amazon and the emergence of cloud services could be dated to 2002, when they started renting their data centers to external customers. Later, in 2006, they launched their EC2 services which already resembled the cloud today. After that, other major vendors entered the market, such as Google, IBM, Sun, HP or Microsoft. (Magoules, 2013)

The term "cloud" was first used by Google CEO Eric Schmidt at Search Engine

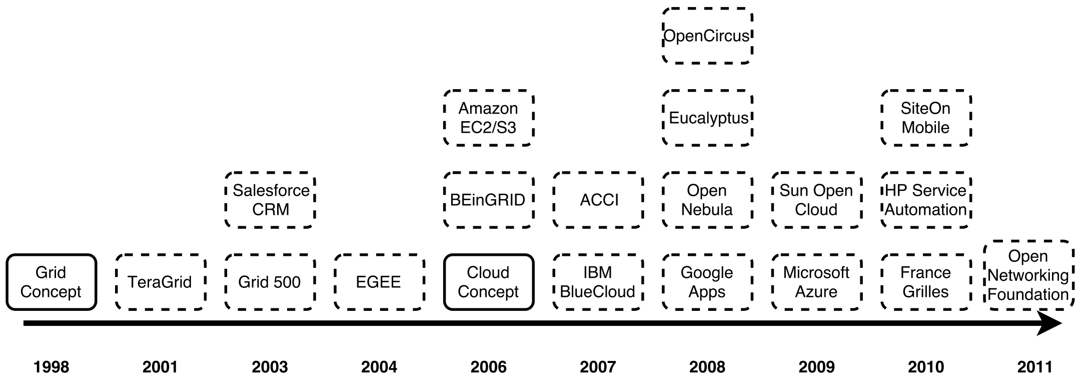
Strategies Conference in 2006 (Schmidt, 2006). However, he just named a concept which was already used in their company.

An interconnected network of computers acting as one had been around even before. It is known as grid computing, where computers around the world are connected over the network together. The difference between cloud computing is that cloud computing has all computers in one data center.

Cloud computing is also interesting for researchers. One of the first research projects called Academic Cloud Computing Initiative (ACCI) was launched in 2007 by Google, IBM and several universities and its goal was to address emerging challenges in cloud computing. In 2008, HP, Intel and Yahoo! together announced opening of a new laboratory called Cloud Computing Test Bed, where researchers from around the world could deepen their knowledge in the area. (Arutyunov, 2012)(Magoules, 2013)

Key milestones in the history of cloud development are depicted on Figure 2.2. It shows when the main grid and cloud computing businesses and organizations were founded.

Figure 2.2: Key milestones of cloud development



Adopted from (Magoules, 2013).

Key factors enabling the emergence of the cloud

There have been several key factors which enabled the cloud computing concept to emerge and which were evolving during past decades. Without them, cloud computing could not be what it is now. (Magoules, 2013)

- **Establishment of data centers** – The number of data centers grew significantly in past years, faster than ever before. This was enabled also thanks to the Moore's law[1], as the data centers are currently mostly built just from typical cheap computer parts. As data centers serve as a key technological property for cloud, they were also essential for its birth.

[1]The number of transistors per square inch on integrated circuits doubles every 18 month. It can be also applied to memory, network or prices of technology. (Beal, 2016)

- **Network performance growth** – Network performance also took major leaps in several past years. Expansion of wireless networks and 4G mobile networks made the Internet available to almost the whole planet. People can already generally access fast networks from anywhere and anytime and this enables wide usage of cloud computing services around the world.

- **Inexclusivity of PC as a terminal** – Since the emergence of the first smartphones, there appears to be an increasing number of devices used as terminals to access web services, something only the PC was used for. The growing number of these terminals brings difficulties with synchronizing data between these devices and therefore it is suitable to have this data saved in cloud.

2.1.2 Definition of cloud computing

National Institute of Standards and Technology (NIST)[2] defines Cloud computing as follows:

> "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." (Mell & Grance, 2011)

This definition focuses mostly on objective description what cloud computing is and what are its main characteristics. They are examined more in detail in the next paragraphs, however, to compare the definition, Gartner tries to define cloud computing from industry's point of view:

> "A style of computing where scalable and elastic IT-enabled capabilities are provided as a service to external customers using Internet technologies." (Gartner, 2016)

NIST also describes five essential characteristics, which are typical for a service to be called cloud computing:

- **On-demand self service** – a user can rent and set cloud resources without communication with the cloud provider staff

- **Broad network access** – cloud resources can be accessed from anywhere via the Internet network.

- **Resource pooling** – provider's resources are pooled in one or multiple data centers and dynamically assigned to users. Virtualization is very significant in this process.

[2]NIST is an agency based in the USA.

- **Rapid elasticity** – a user can almost instantly change the extent of rented computing resources.
- **Measured service** – everything in the data center is measured, for reporting, optimizing and billing purposes.

From the NIST definition we can derive main characteristics of cloud computing:

- *"Ubiquitous, convenient, on-demand"* indicates, that cloud computing products are used as packaged Web services, which can be used even by IT nonprofessionals. Web services are described more in detail in section 2.1.5.
- *"shared pool of configurable computing resources"* expresses the basic notion behind cloud computing: virtualization, which enables multiple different systems to be run on one computer. Virtualization is explained in section 2.1.5.
- *"rapidly provisioned and released"* describes cloud elasticity, which is one of the key factors of cloud's appeal for businesses. The concept of elasticity is elaborated in section 2.1.6.

From business' (and user's) point of view, cloud computing can be seen as a service which can be leveraged for various use-cases for lower prices than those which would be incurred in a traditional on-premises data center. However, the basis of any cloud computing product is still a data center[3] and therefore the key components of cloud are fast broadband communication, web standards, multicore servers and the ability of managing large clusters of computers as a single machine. (Babcock, 2010)

NIST illustrates the typical cloud provider with the Figure 2.3.

2.1.3 Cloud system architecture

When people refer to the cloud they usually mean the large pool of computational resources which can be instantly accessed via some kind of a network interface. This pool is basically a layered system, where each layer has different purpose and represents a different view of the cloud. These layers can be called a *cloud system architecture* and they are shown on Figure 2.4.

Hardware layer consists of hardware resources, such as server racks, CPUs, memory units, hard drives or network infrastructure. These hardware units are usually built using typical and cheap parts, so they can be easily replaced.

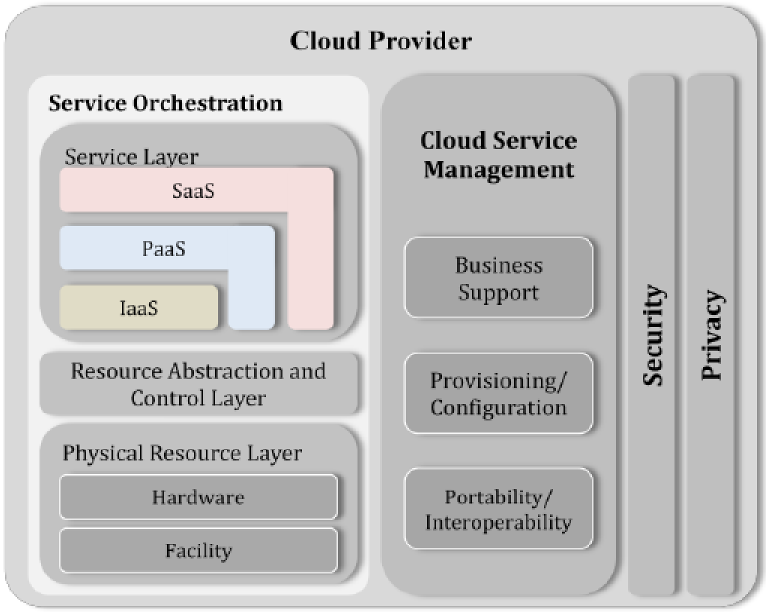
Unified resources layer shows these resources as one large unified resource thanks to virtualization (see section 2.1.5). This resource can be further offered to individual customers.

The platform layer brings extensions to the resources, such as specialized tools or deployment platforms which the customers can use on their rented resource space.

Finally, the application layer contains the very applications which will be run in the cloud. (Magoules, 2013)

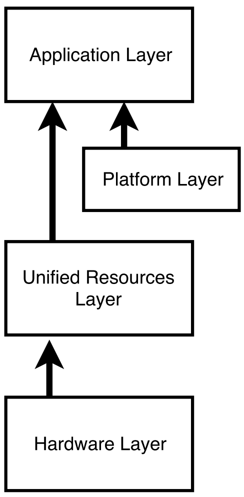
[3]Cloud data centers are examined in subsection 2.1.4.

Figure 2.3: NIST Conceptual reference model of a Cloud provider



Source: (Liu et al., 2011).

Figure 2.4: Cloud system architecture



Adopted from (Magoules, 2013).

2.1.4 Cloud data center

A cloud data center is significantly different from a traditional on-premises data center, which usually exists in any large company.

These on-premises (or legacy) data centers are usually overengineered and overinvested in hardware, desperately trying to avoid any machine failure. The machines in classic data centers tend to be expensive servers intended for special tasks and robustness and they also might be quite old, as they run legacy systems which are complicated to migrate somewhere else.

On the other hand, cloud data centers take an advantage of typical computer parts, which have been perfected through mass production for general public – and which are accordingly cheap. The cloud data center tolerates hardware failures and when they happen, it routes the workload around them and the faulty part is quickly replaced with another cheap piece of technology. Cloud data center represents thousands of fast interconnected computers of same (or similar) configuration acting as one huge machine. (Babcock, 2010)

2.1.5 Technical characteristics

These technical aspects describe the basic technology on which cloud computing is built.

Virtualization

Virtualization is the key technological concept, which enables the use of cloud computing. It is basically an act of dividing a psychical machine through software into the equivalent of several virtual machines. The concept of virtualization is known since 1960s, but with cloud computing it reached its plateau.

A computer to be virtualized (or set of interconnected machines acting as one, which is the case of cloud computing) is running a special operating system called hypervisor which enables virtualization. It is a quite complex piece of software and there are several big companies having their own hypervisors, such as VMWare, Microsoft, IBM or Oracle.

A hypervisor allows the user to create independent virtual machines on the computer, configuring how much resources they can use (setting storage space, limiting processor and memory usage). These virtual machines behave exactly as a normal machine and the user can deploy any operating system or application on them. When the operating system requires a resource, e.g. it wants to save some data to the hard drive, it does not communicate directly with the hardware controller of the component, but it sends the request to the hypervisor. Hypervisor knows, which part of the computer's hard drive was assigned to the virtual machine [4] and translates the request.

This means that on one physical machine there can be almost unlimited number of independent virtual machines which are unaware of each other and each of them can have different configuration and even a different operating system. Thanks to virtualization, there can be hundreds of different operating systems running next to each other.

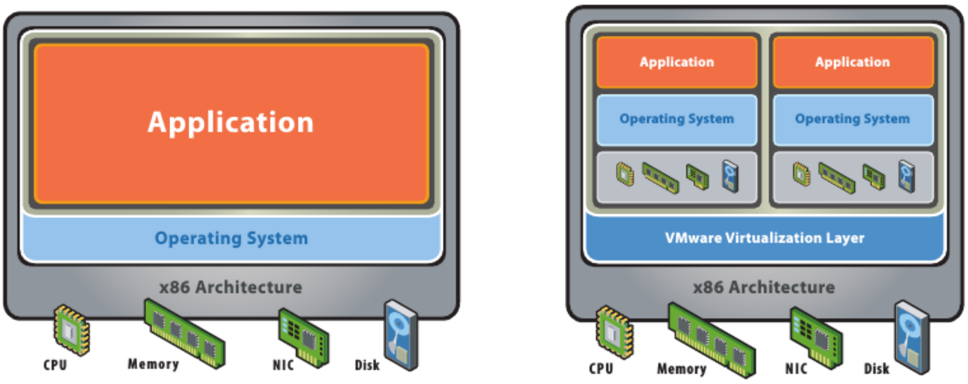
[4] Or on which interconnected computer it is, in which server rack, in which data center...

The concept also allows very easy migration of virtual machines, as they are basically represented as just one file for the hypervisor. Systems can be therefore copied to another locations (e.g. from an on-premises data center to the cloud) and it also means that the virtual machines can be easily reconfigured on-the-go.

Thanks to virtualization, cloud providers can offer their customers almost unlimited freedom in configuration of their virtual machines. They can also implement Service Level Agreements that sets standards for resources availability (they are described in subsection 2.5.1). (Babcock, 2010) (Marston et al., 2011)

The concept of virtualization is depicted on Figure 2.5. On the left side there is a single machine with a single operating system, on the right side is the same machine using virtualization, which now can host multiple different operating systems and applications and all have access to the same shared pool of resources.

Figure 2.5: Concept of virtualization at VMWare



Source: (VMWare, 2006).

Management through web services

An important factor for the boom of cloud computing was the development of web services and emergence of Web 2.0. This is relevant for two reasons: complex web services enable a simple configuration of cloud products and also many applications of cloud computing are in the field of modern web services.

One of the main ideas behind cloud computing is that rented cloud machines are available from any device anywhere in the world and it requires the ability to configure them easily even from mobile devices. This is enabled thanks to modern web services.

There is also a huge number of popular web applications which use cloud as a key technological factor. For example Netflix, a video-streaming service and a perfect example of modern Web 2.0, which recently expanded to almost all countries in the world (Netflix.com, 2016), is relying deeply on Amazon Web Services cloud. Other well known usages are e.g. Airbnb, Nokia, Zynga and others (Amazon, 2016c), but there are famous companies also using Google Cloud Platform (Google Cloud Platform, Inc, 2016) or Microsoft Azure (Microsoft, 2016a).

Security

Security of cloud computing belongs to the biggest concerns of businesses when it comes to their possible usage of the technology. In surveys, it is always raised as a first concern about cloud computing in businesses. (Marston et al., 2011) Cloud computing is not perceived as insecure, however CEOs of companies are not feeling safe about giving away their data to some cloud provider. They are also concerned about the reliability of the service, as they need a non-stop accessibility of their systems (however this can be solved with proper SLA, see subsection 2.5.1).

The problem of giving data away is not only about having it on a server with a different owner – the same problem arises when they outsource IT services. They see the threat in the nature of virtualization, because in cloud computing, the data will reside on a shared server alongside other firms' operation. When you move data to the cloud, you cannot be completely sure where are the data psychically located – on which server, which disk array or even which data center.

Cloud providers try to tackle these concerns with additional security procedure. One of them is constant migration of virtual machines, which means that e.g. every 30 minutes the machine is copied to another server in data center and the original one is stopped and deleted. Researchers from MIT (Talbot, 2009) tried to analyze IP addresses of servers and then put their virtual machine on the same server as targeted one, so if they developed a rootkit to get to the data of targeted virtual machine, it would be theoretically possible to harm the machine, however when machines migrate several times in an hour, it makes it almost impossible.

The security concerns are the main reason why large companies build their own private clouds, so they can profit from cloud computing benefits and stop worrying about possible data disruption. Private clouds are described in section 2.3.

Smaller companies cannot afford an investment into a private cloud, so they move only some workloads into the public cloud and keep the confidential data in their own infrastructure. (Babcock, 2010)

Multi-tenancy

One of the key concepts of cloud computing is that the hardware resources are shared among many different users. This allows a better resources utilization and also a cost reduction. The cloud provider can also benefit from economies of scale and e.g. build large data centers in areas with cheap electricity. On the other hand, multi-tenancy is one of the main reasons which is raising security concerns about cloud. (Magoules, 2013)

2.1.6 Qualitative characteristics

Qualitative properties describe mostly those characteristics of cloud computing which all of the providers offer in some way and which are key for the quality of a cloud service.

Elasticity

Elasticity or scalability of cloud computing is one of the key features with huge appeal for businesses. It is based on virtualization and it represents the way how cloud customers can easily scale the amount of resources they use.

Thanks to virtualization, it is possible to extend or reduce the number of resources used by a virtual machine and as the total amount of cloud provider's resource is usually perceived as infinite, the user can get almost "infinite" resources as well.

The main advantage of scalability is that the customer pays only for what he uses. In the traditional data center, servers have to be prepared to handle any possible workload and anything above their capacity will cause the servers to halt. This means that they are oversized and overdimensioned and their average utilization is very low, even under 20 %. That is very inefficient and it creates a lot of unnecessary costs.

On the other hand, in cloud computing, a customer can exactly specify her needs for every workload and rent just the capacity, which is required to handle it. This leads to major savings and it is also the main reason, why cloud computing is interesting for businesses. (Babcock, 2010)

Availability

Customers of cloud providers always expect a reasonable availability of their service, considering mostly the response time and throughput. This is usually guaranteed via a Service Level Agreement (see subsection 2.5.1). (Magoules, 2013)

Reliability

Customers expect that the data they put into cloud will never be lost and they also want the service to be available all the time[5]. The cloud provider therefore has to operate redundant servers and whole data centers to conform to these expectations. Is is common that a provider has data centers in geographically different locations to prevent failures in case of a natural disaster. (Magoules, 2013)

Agility

Agility describes the customer's demand to be able to instantly change and reconfigure the rented cloud resources. This is strongly connected with Elasticity and Management through web services. (Magoules, 2013)

2.1.7 Economic characteristics

Economic aspects describe the main reasons why commercial entities use this paradigm in practice and indicates, how the cloud business model works. (Magoules, 2013)

[5]Which means 99.99 % of the time and such.

Pay-as-you-go

Customers of cloud computing only pay for the resources they actually use, in opposite to traditional approach, when they have to pay for the whole server all the time. This allows even small enterprises to have cheap access to whatever amount of computational resources they need.

Operational expenditure

This is connected to the previous aspect, as customers have none or highly reduced operational expenditures when using cloud compared to legacy solutions. Cloud providers also significantly lower the operational expenses by leveraging the economies of scale.

Energy-efficiency

Cloud data centers unite thousands of servers together which are administrated centrally, which leads to significant energy savings. Some cloud providers even use the excessive heat from the servers, e.g. for heating purposes. Moreover, it is a good marketing advantage to be considered a "green company".

2.2 Advantages and disadvantages of cloud computing for businesses

Cloud computing brings several important advantages in contrast to traditional on-premises computing, which are described in the following list: (Marston et al., 2011)

1. Capital requirements reduction – With cloud, there is no need for businesses to obtain expensive IT infrastructure, they can get it very fast and cheap from cloud providers.

2. Access to unlimited number of resources – The amount of resources, which can be rented from the cloud provider, is almost unlimited.

3. Scalability – Cloud computing enables its users to almost instantly scale the amount of resources in usage. This brings great deal of flexibility and cost-reduction to the businesses.

4. Lowering barriers of innovation – In the IT industry, the infrastructure might be the biggest investment and therefore thanks to cloud it is easier for new companies to succeed.

5. Brand new services – Thanks to accessible computational power, new use cases and services emerge in the market, which use cloud computing heavily.

6. Green computing – Many firms (and the public) care about the environmental costs of data centers and cloud computing offers a clean alternative, as cloud

data centers are usually powered by clean (and cheap) electricity and their energy management is very effective.

Cloud computing however has several disadvantages and concerns which are raised mainly by CIOs of influenced subjects: (Babcock, 2010) (Arutyunov, 2012)

1. Security – The biggest concern of businesses about cloud computing is security, as companies are not willing to give away the data, which are in their possession. This is even more perceptible, when the data is very sensitive (e.g. for financial companies). On the other hand, cloud providers are successfully trying to disperse the concerns.

2. Vendor lock-in – As there are many cloud providers in the market, they often use various formats, which are incompatible with each other. This means that it is hard to migrate from one provider to the other. However, (Babcock, 2010) expects this concern to disappear when more customers get into market and raise the pressure on the providers.

3. Connectivity – When using cloud services, you have to maintain a good Internet connection and it is usually not possible to work with cloud offline.[6]

2.3 Cloud deployment models

There are different ways how cloud can be deployed in a data center and these deployment models determine who has access to the cloud resources. These ways can be divided in four main groups: (Magoules, 2013)

- **Public cloud** – The provider of the cloud services offers the access to the whole public over the Internet, the public can rent cloud resources from the provider and generally there are thousands of customers sharing one pool of cloud resources. The diagram of a public cloud can be seen on Figure A.1 in the Attachments.

- **Private cloud** – Private cloud offers the same functionality as public cloud, so its users can quickly get and return scalable and elastic computational resources, however access to the cloud is limited. Usually a large company can run or rent a private cloud for its purposes and letting only its employees to access it. The diagram of a private cloud can be seen on Figure A.2 in the Attachments.

- **Hybrid cloud** – Hybrid cloud combines public and private clouds and even traditional IT infrastructure. In Hybrid cloud, usually there are some parts of resources available to the public and some serve as a private cloud. The users can decide which workloads they want to put on which cloud. The diagram of a hybrid cloud can be seen on Figure A.3 in the Attachments.

[6]The exceptions are e.g. SAAS products, such as Google Drive, which need to be online only at some time or for some functions. (Casey, 2016)

- **Community cloud** – Cloud when several organizations and entities share cloud resources. They usually have similar aim or mission and therefore cooperate, often for scientific purposes. Grid computing (mentioned in subsection 2.1.1) can be considered as a community cloud. The diagram of a community cloud can be seen on Figure A.4 in the Attachments.

2.4 Cloud service models

Using a cloud basically means renting a portion of computational resources for a limited amount of time. However, there tends to be different ways of how to use and access these resources. These three basic different ways are called cloud service models. They are depicted on Figure A.5 in the Attachments. (Magoules, 2013)

The dashed border bounds the three different services themselves. Every gray box represents a layer in cloud computing and the arrows show how they communicate with each other (bottom to top). In white ovals in the boxes there are examples inside each of the layers.

Software as a service (SAAS) represents the hierarchical top of cloud services. User of such a service has an access to already made software, usually through a simple web browser interface and he does not know anything about the underlying hardware, servers, operating systems, networks or platforms. Pioneer of SAAS was Salesforce.com, an accounting software company, however there is a lot of well known SAAS products as well, such as Google Docs or Office360. SAAS portfolio is growing very fast, as most of Web 2.0 services function on this model.

Platform as a service (PAAS) offers its user an elastic cloud platform on which she can deploy applications she demands and manage them. It can be imagined as an operating system with unlimited computational resources. The PAAS user does not know anything about underlying hardware and she does not care about the version of platform (operating system), she only uses it to host applications on it. Typical examples of PAAS products are Google App Engine, Force.com or MTurk.

Infrastructure as a service (IAAS) represents the lowest tier, when the user rents just the infrastructure and deploys whatever applications or operating systems she wants. As this thesis is mostly about IAAS, it is more thoroughly described in the next section.

2.5 Infrastructure as a service

Infrastructure as a service (IAAS) is one of the three service models where cloud computing can be used. The other ones are Software as a service (SAAS) and Platform as a Service (PAAS), IAAS represents the lowest tier of these three.

In IAAS model, a service provider offers its customers an infrastructure which can be used as customer demands. The infrastructure consists of various computing resources providing computational power, storage and network. The user is able to run and deploy different operating systems and applications. The customer can therefore manage the whole software, however she does not manage underlying infrastructure and communication between computing resources. (Mell & Grance, 2011)

2.5.1 Service level agreement

BusinessDictionary.com defines a service level agreement (SLA) as follows:

> "Contract between a service provider and a customer, it details the nature, quality, and scope of the service to be provided." (BusinessDictionary.com, 2016)

SLA is a one of the key pillars for the IAAS providers, as it specifies the quality of the service offered and it is usually the only assurance of the customer about the reliability of the ordered service. Usually, an SLA between the cloud supplier and the customer sets the maximum allowable time for an application to respond to the users and the customer can therefore demand certain SLA level for certain applications. Cloud providers also use this SLA levels to detect a possible problem, so if the response time is threatened, automatic management systems can assign the customer with more resources so the servers can handle the response time problem. (Babcock, 2010).

However, there is no cloud service provider who can certainly offer continuous 100 % quality of service (QoS). All specifications in SLAs are merely based on predictions as there can be unexpected events such as nature disasters or human mistakes which can threaten QoS. Therefore there are often many exceptions in the SLA, listing events, when the provider is not financially responsible for a failure in the service deliverance. (Tamir, 2014)

When the availability of the service goes bellow the specific percentage value (which is usually listed in the SLA), the cloud provider often refunds the users with a credit which can be used to buy more of its services.

2.5.2 Usage of IAAS in businesses

Structure of expenses – CAPEX to OPEX

On of the main reasons behind cloud computing appeal to businesses is the character of its costs.

If a business owns an on-premises infrastructure, it has to be proportioned for the worst case expected workload and this infrastructure has to be maintained all the time. It represents both capital expenditure (CAPEX) and operational expenditure (OPEX).

On the other hand, using cloud computing does not require any CAPEX, all the costs are OPEX. These costs are much more easier to handle as they are usually paid just by current revenue. Therefore, a new business or start-up (or basically any SME) can lower its basic capital requirements by simply starting using cloud. (Patrignani & Kavathatzopoulos, 2016)

Private clouds or public clouds

Benefits for SME from previous paragraph might not be so appealing for large businesses, who can often afford the trade-off between higher capital requirements and their complete control over the data and the infrastructure. However, even they can benefit from cloud computing, either by using private clouds or using public cloud just for several use-cases (e.g. those described in following sections).

Large businesses can transform their current infrastructure into a private cloud, so they can benefit from the advantages of it and still be sure they have the data in the house. Such a private cloud may never achieve the economies of scale of the public clouds, but that is not the goal. It is viable if it will be only cheaper and more effective than the original legacy system. (Babcock, 2010)

Handling peaks in traffic

It is not necessary to have the whole infrastructure in cloud, a business can leverage cloud just sometimes when it is needed. Most of the time in the year, on-premise servers might be handling the demand for IT resources quite fine, but there are cases, when the demand is much higher. It can be when accounting is closing of a quarter, when there is a new product to be launched or when an onslaught of customers begins shopping before Christmas.

These peaks in traffic can be easily handled by moving them to the cloud. Such moved workloads have been given a name: “cloudbursts”.

This also brings new challenges for businesses, because now the IT manager has to decide which workload can and should me moved to the cloud and which should stay. However, leveraging cloudbursting decreases the costs and also increases the customer satisfaction, as it prevents the failures during the traffic peaks.

Cloudbursting is one of the most common cloud use-cases in businesses. (Babcock, 2010)

Servers utilization

Server utilization is connected to cloudbursting technique. If a company dimensions their on-premises infrastructure according to the traffic peaks, it will inevitably mean that most of the time the servers will be utilized very low and the full capacity will be used only during those rare peaks. This is very cost inefficient and also harming the environment, as the company uses more electricity to power the servers than needed.

Cloud computing solves this problem as the company can use only the resources it actually needs.

Other use-cases

The other typical cloud use-cases are listed here: (Babcock, 2010)

- Software testing – Software under development undergoes different types of testing and many of these test are automatic and quite computationally intensive. It represents a typical workload, which is safe and efficient to be moved into the cloud.
- Software stagging – That is a process, when new software is configured with other applications, which it should be run with. Similarly to the previous point, it can be moved to the cloud.
- Big data analysis – Every business generates large amounts of different data, which can be analyzed to improve the company's performance. For an e-shop it can be the data of customer's click-path through the website. This data can be analyzed in cloud so the core functions of the e-shop have enough resources on the original infrastructure.

2.6 IAAS products existing on the market

Several IAAS products exist on the market and it is not the goal of this thesis to cover them all, it will rather try to describe those currently most popular and important. To determine them the 2015's Magic Quadrant for Cloud Infrastructure as a Service, Worldwide analysis from Gartner will be used. (Olavsrud, 2015)

Products described in this section are later compared in section 4.1.

2.6.1 Amazon Web Services (AWS)

AWS is currently the largest provider of IAAS in the world, at the time of the analysis it actually offered more computational power than all other listed providers combined. Therefore it also offers a wide range of different IAAS products, which can be suitable for almost anyone. Two main products of AWS are Elastic Compute Cloud (EC2) and Simple Storage Service (S3). (Magoules, 2013)

Via Amazon EC2, a user can create virtual machines called *instances*. These instances function as a standalone server and the user can specify which hardware the instance has and which software it runs. Amazon offers several categories of instances, which differ in their performance etc., e.g. Burstable performance instances[7], General purpose instances[8], Compute optimized instances[9], Memory optimized instances[10], GPU instances[11] and more. Each category is then subdivided into different configurations,

[7] Instances optimized for handling cloud bursts, i.e. unexpected spikes in workload

[8] Instances with balanced compute, memory and network resources.

[9] Instances with high computational performance.

[10] Instances with large and fast memory.

[11] Instances that offer high computational power on graphic cards.

such as processor cores, memory size, network performance, storage size etc. EC2 also offers a lot of additional services for security, access control and more. (Amazon, 2016a)

Amazon S3 allows the users to rent a highly durable storage infrastructure, which can be used for any kind of data. It provides fast ways to access the data and it is safe as it stores the data redundantly on multiple places. User pays only for storage she actually uses. There are several types of S3 for different kinds of data: standard storage for frequently accessed data, storage for infrequent access and storage for long-term archive data. (Amazon, 2016b)

2.6.2 Microsoft Azure Infrastructure Services

Microsoft Azure is the second largest provider in the market and offers more than twice as much capacity than other providers (excluding AWS) mentioned by the analysis. The key customers of Azure are those who are already strongly dependent on Microsoft infrastructure.

Azure offers similar products to Amazon, a user can also choose from wide variety of instances, which are divided into multiple categories. They are very similar to EC2 instances, including Basic, Standard, Optimized, Performance-optimized, Network-optimized and Compute intensive category. Virtual machines rented from Azure support easy deployment of other Microsoft applications, such as Microsoft Sharepoint or Microsoft Dynamics, so it is very advantageous for current Microsoft users to use this infrastructure.

Microsoft also offers storage place which is very similar to S3 and it will not be described more in detail.

Large parts of Azure documentations are available in Czech and many other world languages.(Microsoft, 2016b)

2.6.3 Google Cloud Platform

Google also offers IAAS services, but its main distinction between the previous two is that it specializes rather on PAAS and therefore is more favorable for those using both service models at once.

Speaking about IAAS, Google Cloud Platform is still a bit different from previous two, as it is possible to built a virtual machine just as the user wishes. In addition, Google also offers traditional preset virtual machines of different types. Google operates standard machines and also machines optimized for CPU or memory usage. Google also offers so called "Effective use discount" which encourages the user to utilize the machines as much as possible. As in the previous cases, Google offers persistent disk storage as well. (Google, 2016)

2.6.4 CenturyLink Cloud

CenturyLink is the general communication services provider, however they acquired two IAAS companies in recent years and merged them to create their own IAAS service

– CenturyLink Cloud. According to the analysis, this cloud can be leveraged for self-service usage or virtualized systems, but it does not offer enough computational power for computationally intensive applications.

CenturyLink is on the first look different from the previous three big cloud players, as it is also offering typical web hosting and other communication solutions. It does not offer any preset virtual machines so the user has to set up her own configuration. CenturyLink however offers thiner range of services and friendly user interface and therefore might be more understandable for inexperienced users. (CenturyLink, 2016)

2.6.5 VMWare vCloud Air

VMWare is a traditional player on virtualization field (see section 2.1.5), however in 2013 they also started their own public IAAS. Logically, it is recommended to use this cloud if the company already relies on another VMWare products.

VMWare is a big player in private clouds (see section 2.3), however they also offer public cloud instances. They do not offer any prefabricated types of them, so the user has to choose her own configuration. The offer is not that wide as with the other providers, but if a user already uses VMWare or if she wants a trusted virtualization provider, VMWare can be the right choice. (VMWare, 2016)

2.6.6 IBM SoftLayer

IBM also started their IAAS through acquisition of SoftLayer web hosting, which focused on small and middle sized businesses. Therefore even now it is their main target segment, as they offer good mix of pure cloud services (e.g. elasticity) and bare-metal servers[12].

IBM nowadays is mostly an IT services provider for business and the same impression comes from their SoftLayer cloud. Cloud IAAS are just one part of their offering and they only offer Custom Virtual Machines, which the user has to configure by her will. SoftLayer therefore suitable mostly for companies who already have established contact with IBM and can easily fit it into their infrastructure. (IBM, 2016)

2.6.7 Rackspace Open Cloud

Rackspace's main focus is offering private clouds (see section 2.3) for companies, which wish to have this safer environment. However they also offer basic and simple public cloud services.

Rackspace is one of the oldest cloud providers and similarly to Amazon, Microsoft or Google it offers a variety of different virtual machines the user can choose from: Standard, Compute optimized, Memory optimized and I/O optimized. Rackspace users can also benefit from the fact, that its cloud is running on OpenStack, which is an open-source cloud solution, which is often used in private clouds, etc. If the user is in such private cloud, it can be an advantage. (Rackspace Public Cloud, 2016)

[12] Traditional servers whose operating system is not run through virtualization, but it is installed traditionally on the hard drive (Rouse, 2006).

2.7 Requirements of SME for IT infrastructure

As this thesis is focused on IAAS in SME, and e-shops in particular, the aim of this section is to summarize basic requirements of these subjects for the IT infrastructure. This requirements are backed up by data collected in section 4.2 and by (Patrignani & Kavathatzopoulos, 2016).

- **Website** – Website is the key to e-shops and therefore they require a place where they can host it. The requirements for place differ mostly in number of visitors at time it can handle.
- **Working infrastructure** – SME require an infrastructure to host e-mails and other operational management tools, such as Customer Relations Management Systems or Accounting Software.
- **E-commerce tools** – E-shops rely hardly on online advertising and they require tools from which they can manage it.
- **Analysis tools** – These tools allow the e-shops to analyze their customers using data they collect from their audience.
- **Law compliance** – SME have to comply with the laws of the countries they are active in, which is usually connected also with the IT infrastructure.
- **IT infrastructure of employees** – Including computers, printers, etc.

2.8 Related work

There are several other papers and theses which deal with cloud computing in small and medium enterprises. This section aims to summarize them.

(Patrignani & Kavathatzopoulos, 2016) present a roadmap for SME which they can follow if they want to adopt cloud into their IT infrastructure. They also specify the main issues SME can face when migrating their resources to cloud.

(Prodan & Ostermann, 2009) offer a framework for evaluating different cloud providers and comparing them between each other, this framework will be leveraged in chapter 4.

(Phu, 2014) compares cloud services for enterprise printing servers using a framework based on return on investment (ROI) and net present value (NPV) metrics. Similar framework will be also used in this thesis.

(Cajthaml, 2013) compares cloud services and on-premises infrastructure from more technical point of view than this thesis.

(Antos, 2015) focuses on SME as this thesis, he however evaluates their usage of cloud SaaS applications.

(Schadler, 2009) aims to measure expenditures of different cloud e-mail providers using comparative costs analysis.

Finally, (Li, Li, Liu, Qiu & Wang, 2009) build an universal and detailed framework for calculating cloud computing costs mostly for cloud providers and this thesis will leverage some if its part as well.

Chapter 3

Methodology

This section aims to briefly describe the methodology used in the whole thesis, mostly in the upcoming practical part (chapter 4). The methodology depicts how the results presented in this thesis were obtained.

Theoretical part serves as an introduction to the cloud technology itself. It is based on other literature and it aims to summarize what the cloud technology is, what are its key aspects and what advantages and disadvantages it brings to small and medium enterprises. Then it focuses on what IAAS products are and it also summarizes the most important products on the market. The goal of the theoretical part is to give the reader insight into cloud computing and its possibilities for SME.

Practical part consists of three main parts. Firstly, existing IAAS products are compared, then IT infrastructure from Czech SME are presented and finally a cost comparison between on-premises and cloud infrastructure is performed.

Comparison of cloud providers and their IAAS products (see section 4.1) is based on existing work. (Prodan & Ostermann, 2009) compared many providers using thorough analysis of each one of them and the findings of this analysis were marked down into a table. The similar approach was used in this thesis, although the table was simplified as this thesis focuses mostly on business perspective and not technicalities. Every IAAS product listed in section 2.6 was examined and the findings were summarized in the table. The resulting table can be seen on Figure 4.1.

From the table, three most suitable providers were chosen, using many metrics and their importance for SME. These three providers were then compared by costs for one possible use case and the cheapest (and the most suitable) provider was chosen.

Case studies subsection aims to show some data about IT infrastructure from concrete SME in the Czech republic. This data serve mostly as a background for the next subsection, where the cost comparison itself is made. The subjects presented here were given a questionnaire about their IT infrastructure, concerning the number of visitors of their websites, the costs of the infrastructure and also the costs of human resources taking care of it. Most of the questions were about numbers and prices, so the respondents were given an opportunity to either specify the exact number or to choose from an interval. To get a better understanding of the subjects, they were also later asked about their number of employees.

The original version of the questionnaire (in Czech language) can be found in the attachments. (see Figure A.6, Figure A.7, Figure A.8 and Figure A.9).

Cost comparison is the final subsection which fulfills the main goal of this thesis. In this subsection, the costs of on-premises infrastructure and a cloud IAAS product are compared. The methodology of this subsection also represents a framework, which can be leveraged to calculate the usefulness of cloud computing for any other website.

Firstly, the current infrastructure of the examined subject and its costs are presented. These costs will be later used in the final comparison.

Then, an analysis of subject's audience data during the examined period is made. The basic statistical measures of this data are calculated and the data are also presented on a timed graph and also on a histogram. From this analysis, a capacity which is required to be handled by cloud virtual machine is calculated, so that approximately in 10 % of days there would be a need for provisioning of another virtual machine.

Afterwards, two cloud virtual machines are specified. The first serves as a reference machine and offers similar performance as the current infrastructure. The second one is dimensioned using the capacity from the audience data analysis.

Finally, the costs of these three machines are calculated using prices from provider's websites and compared and the cheapest solution for Subject 1 is presented.

CHAPTER 4

Practical part

In this chapter, firstly, the cloud providers listed in section 2.6 are compared. Then the data collected from small e-shops and websites from the Czech republic about their infrastructure are presented. Finally, based on the comparison and the data, a cost comparison of one of the SME is performed using a framework, which can be later leveraged by another readers. Methodology of this procedure is more thoroughly described in chapter 3.

4.1 Comparison of cloud providers

This section aims to compare different cloud providers according to aspects, which are most important for SME, particularly those in the Czech republic. The basic findings of this section are summarized in Figure 4.1. Every aspect will be described more in detail and then the most suitable cloud provider will be chosen.

4.1.1 Operating systems

All of the compared providers nowadays offer both Linux and Windows operating systems and therefore all of them can easily serve the SME needs. The providers differ slightly in specific distributions they offer and also in a price the customer has to pay for Windows licenses[13], however these are not major differences and they does not influence the selection of the best solution.

4.1.2 Locations

Locations row in the table shows where the data centers of the providers are located. There is a similar pattern in all of them, as all of the providers are based in United States, they also have the most of data centers there. All of them also offer at least some data centers in Europe and Asia. The numbers in brackets represent the number

[13]Microsoft Azure naturally offers the widest support for Windows products.

of data centers in given locations. Those in Europe are always located in the western part (United Kingdom, The Netherlands, Germany, etc.).

For a SME located in the Czech republic, those in western Europe must suffice. However, SME and e-shops in particular usually do not require top response times and their infrastructure could probably just as easy run in other data centers. Therefore locations offered by all of the providers are fine.

Figure 4.1: Comparison of IaaS cloud products

	Amazon EC2	Microsoft Azure	Google Compute Engine	CenturyLink Cloud	VMWare vCloud AIr	IBM Soft Layer	Rackspace Open Cloud
Operating systems	Linux, Windows	Linux, Windows	Linux, Windows	Linux, Windows	Linux, Windows	Linux, Windows	Linux, Windows
Locations	US (4), South America (1), Europe (2), Asia (4), Australia (1)	US (8), South America (1), Europe (2), Australia (2), Asia (9)	US (6), Europe (1), Asia (1)	US (10), Europe (3), Asia (1)	US (7), Europe (2), Asia (1), Australia (1)	US (14), Europe (5), Asia (4), Australia (2), South America (1)	US (3), Europe (1), Asia (1), Australia (1)
# Hardware Configurations	39	30	18 + custom	custom	custom	custom	19
# Compute units	1-40	1-32	2-32	1-16	1-16	1-16	1-32
Memory [GB]	0.5 - 244	0.75 - 448	0.6 - 208	up to 128 GB	up to 240	up to 64	1-240
Hard disk [GB]	up to 48000	to 6144	unlimited (Google Storage)	unlimited (Block Storage)	up to 6144	up to 100 (primary disk)	to 1228
Load Balancing	yes	yes	yes	yes	yes	yes	yes
Public IP	5 (per region)	5	unlimited (IPs in use)	1 per 1,75€ per month	3	unkown	1
EUR per hour	0.12	0.14	0.07	0.12	0.22	0.14	0.14
EUR per GB traffic	0	0	0.07	0.04	0 (payments for bandwith)	0	0.1
EUR per GB storage	0.03	0.02	0.02	0.11	0.05	0.13	0.0002
SLA	99.95%	99.95%	99.95%	99.99%	99.99%	100%	99.9%

All information are taken from product websites, they are valid for April 2016. The sources can be found in section 2.6.

4.1.3 Number of hardware configurations

The number of hardware configurations offered by a provider represents a flexibility the user has when renting a virtual cloud machine. Some of the providers (Google, CenturyLink, VMWare and IBM) offer a customized solution, so the user can pick whatever resources she needs and build a virtual machines from them. Others (Amazon, Microsoft and Rackspace) offer only a set of preset virtual machines, which is usually divided into subgroups according to their potential usage:

- *General purpose machines* with decent computational power which can be used for all basic use-cases.
- *Memory intensive machines* which should be used for tasks requiring high and fast operational memory.
- *CPU intensive machines* which should be used for computationally intensive tasks.

- *Input/Output intensive machines* which should be used for tasks which require a lot of input and output to and from the hard drive (e.g. Big Data operations).

The requirements of the SME are not very high and therefore the *General purpose machines* should suffice (or a custom one which is dimensioned similarly).

4.1.4 Number of compute units

Number of compute units represents the number of CPUs which the virtual machine can use. This is particularly useful for intensive computational operations which require a lot of parallel computations. However, that is not the case SME usually require and therefore all providers suffice.

4.1.5 Memory size

Similarly to Number of compute units, the memory size represents how large memory size can a user get for her virtual machine from a provider. The providers vary in the maximum memory[14], however these numbers are really high for the need of a SME and therefore any provider would suffice.

4.1.6 Disk size

Hard disk size represents the amount of storage space a user can get on hers virtual machine[15]. Most of the providers offer quite high storage space, which should be enough for a SME needs. IBM offers a disk just of size 100 GB, however it is just a primary disk for a virtual machine[16] and this space can be later expanded.

Google and CenturyLink offer unlimited disk space, which is paid per GigaByte. The unlimited offer exists at most of the providers as well, but sometimes as another service (e.g. Amazon S3). If a SME needs an infrastructure for saving large chunks of data, it can get it from all of the providers.

4.1.7 Load balancing

Load balancer is a software tool, which measures the amount of resources being used on individual virtual machines and if one of them is overloaded, it shares its workload with the other virtual machines. This is quite important tool for SME and e-shops in particular, while it can help them overcome days with high traffic (e.g. Christmas) and split it between several virtual machines.

All of the providers offer a load balancer, but they differ in price.

[14] Microsoft Azure offers twice more memory than any other provider.

[15] Thanks to virtualization, this storage space can be spread around several physical hard drives.

[16] Primary disk is running the operating system and the essential applications.

4.1.8 Number of public IP addresses

IP address is a number assigned to every device in a network; public IP address can be accessed from anywhere in the world via Internet[17]. Therefore if a user wants a public service running in the cloud (web, application, etc.), she needs to run it on a certain IP address. Providers differ in the number of free IP addresses they offer, additional IP addresses can be accessed for a small fee.

SME usually do not need to run large number of applications in the cloud and therefore the offered numbers suffice, however it is better if they are for free and also having more than one IP address might be an advantage.

4.1.9 Price per hour

Price per hour is one of the most important factors for SME, as the goal of this providers comparison is to reduce SME costs. For price comparison in the table, a typical instance was chosen: **a virtual machine with 2 CPUs and 8 GB of memory**. Such a machine has reasonably high performance and should suffice for most of the SME. Moreover, prices usually scale similarly, so comparison of prices of smaller machines would lead to very similar results.

From the comparison it can be seen that by far cheapest provider now is Google Compute Engine, followed by Amazon EC2 and CenturyLink Cloud. Using Google Compute Engine instead of these two for this type of machine can save a SME more than 430€ a year, and even more compared to others.

However, some of the providers already offer a SSD disk in their offer, which Google Compute Engine does not and adding one immediately makes it more expensive.

4.1.10 Price per GB transfered

Providers usually charge the user for traffic[18] to and from the Internet on the virtual machine. Some of the providers offer scalable prices, which means that the user does not pay for the first several GigaBytes a month and only has to pay for the following ones. Amazon offers first GB free and then other one for 0.08€ per GB, Microsoft offers first 5 GB for free and then next GB per 0.07€.

From this we can see that the offer from most of the providers is quite similar. Moreover, if SME run just their website in the cloud, their monthly traffic should not be very significant.

4.1.11 Price per GB stored

Price per GB represents how much user has to pay the provider to permanently store 1 GB of data. We can see that Rackspace offers by far the cheapest solution, followed

[17] And there is limited number of IP addresses.
[18] Amount of data transfered via network.

by trio Amazon, Microsoft and Google. However, it is not expected from SME to store a lot of data, because they mostly need just a website or a small application.

4.1.12 Service level agreement guarantee

Service level agreement sets a level of guaranteed uptime of the provider's service. If the uptime goes below this level, the users are refunded with free usage hours of cloud[19]. We can see that all of the providers offer similar SLA, which should suffice for SME.

4.1.13 The most suitable provider for SME

From the previous comparison above, three most suitable providers were chosen: Amazon EC2, Microsoft Azure and Google Compute Engine. To determine which one of them will be the best, tools called Price Calculators were used. These tools are offered by providers on their websites. (Amazon Web Services, 2016) (Microsoft Azure, 2016) (Google Cloud Platform, 2016)

In a Price Calculator, it is possible to specify a product configuration, which the user would like to use and specify its utilization during the month. The calculator then computes a price, which will be payed for such configuration. The specification used is shown in Table 4.1.

Table 4.1: Configuration of the virtual machine under comparison

Virtual machine	
Location	Western Europe
Operating System	Linux
Number of CPUs	2
Memory size	4 GB
Disk size	100 GB
Disk type	SSD
Persistent storage	
Additional Storage	1000 GB
Data transfer	
Traffic	1500 GB

Source: Author

Results of calculation

The configuration specified in Table 4.1 was tested for all Amazon EC2, Microsoft Azure and Google Cloud. The results of the calculations are shown in Table 4.2.

[19]There are different levels of "bellow" where different refunds apply.

Table 4.2: Monthly prices of service for three providers

Product part	Amazon AC2	Microsoft Azure	Google Cloud
Virtual machine	103.33€	105.41€	122.61€
Persistent storage	28.72€	20.24€	35.45€
Data transfer	119.58€	109.68€	155.33€
Summation	**251.63€**	**235.33€**	**313.39€**

Source: Author

It can be seen that even though Google Cloud was one of the cheapest in the original comparison, adding a SSD disk makes him more expensive than the others. Also non-scalable data transfer price makes Google more expensive.

Microsoft Azure and Amazon EC2 offer similar prices, but Microsoft Azure is a little cheaper. Considering that Microsoft Azure also offers Czech support for its products , it can be stated that Microsoft Azure is the most suitable cloud IAAS provider for (Czech) SME.

4.2 Case studies – SME and their infrastructure

This section presents the data from four SME subjects in the Czech republic about their current IT infrastructure and its costs. Three of them are e-shops, each of them focused on a different market segment and one of them is a portal about online computer games. More information about the subjects can be found in Table 4.3.

Table 4.3: Information about the examined SME

ID	#Employees	Brief description
Subject 1	1 + 10 part-time[20]	A Czech web portal operating several websites about online computer games from Blizzard Entertainment. The portal provides the users with news about these games and its main source of income is web advertisement on the websites.
Subject 2	1 + 2 part-time	An e-shop with fantasy and sci-fi books and also collection figures and board games, based in the Czech republic.
Subject 3	18 + 6 part-time	A fashion retailer selling original clothing and design from all around the world based in the Czech republic, operating both e-shops and retail stores.
Subject 4	cca 30	One of the major video games retailer in the Czech republic, operating both e-shops and retail stores.

Source: Author

The subjects from Table 4.3 were asked about their IT infrastructure and its costs, the findings are summarized in Table 4.4. Methodology of obtaining the data is described in chapter 3.

Table 4.4: IT infrastructure of SME and its costs

	Subject 1	**Subject 2**	**Subject 3**	**Subject 4**
Daily visits (in thousands)				
Average Day	7	0-5	5-10	10-20
Bellow Average Day	5	0-5	0-5	5-10
Above Average Day	15	0-5	5-10	20-30
Infrastructure				
Type	Dedicated server	Web hosting	Remote ERP Web hosting	Dedicated server
Monthly rent costs	74€	0-185€	350€	185-370€
Monthly support costs	0-185€	0-185€	0€	0-185€
#IT support employees	0	0	0	0

Source: Author

4.2.1 Daily visits

Number of daily visitors to subjects' websites is important to determine the traffic the website is getting. From the traffic it can be inferred which cloud virtual machine will be suitable for the subject.

One of the most important usages of the cloud for e-shops or web portals is scalable provisioning of virtual machines. Thanks to that, SME do not have to buy servers for their highest traffic peaks, but they can rather rent these servers only during these peaks when they need it. Therefore we have not only average audience data, but also bellow average and also above average (e.g. before Christmas for e-shops).

It can be seen that for three of the subjects above average days have quite higher traffic than average days. For them it would be useful to dimension their server only for average days and traffic spikes send on another cloud machine.

4.2.2 Infrastructure

Subjects were also asked about their infrastructure. Two subjects just rent a whole server from a provider. These dedicated servers usually cost less than similar virtual machines, however they also have to be dimensioned for much higher traffic, so for these two a reasonable switch to a cloud solution could be better. Other two subjects rely on a classic web hosting solution, in which the customer just gets space for his website and

[20]Number of part-time editors differs a lot during the year, usually around 10.

e-mail infrastructure. Web hosting is usually cheaper and it is debatable whether the cloud would be better for that.

Subject 3 also uses an Enterprise Resource Planning system (ERP), which is responsible for 80 % of the infrastructure costs. Moving ERP to the cloud would definitely be cheaper, however not all ERP providers offer the clients with option to run the system on server of their own choosing.

In Table 4.4 it can also be seen that prices for hosting solutions scale with traffic and also that the maintenance prices are not very significant. Moreover, neither of the companies is having a full time employee taking care of the IT infrastructure.

4.2.3 Case studies summary

The table shows that neither of examined subjects is relying on the cloud computing yet, but the insights from the data give clear view about the traffic subjects have to handle and the costs they pay while handling them.

It is not a goal of this thesis to draw conclusions from just four subjects about all SME, however, in the next section, one of the subjects will be evaluated and its infrastructure costs will be compared with cloud costs. This section therefore stands as a support for this evaluation and with proper data, every reader can make evaluations about the costs on her own.

4.3 Costs comparison of Cloud IAAS and on-premises infrastructure

In this section, an analysis of the visitors traffic throughout the year 2015 will be made using the audience data obtained from Subject 1 from previous section. For this traffic, virtual machines from Microsoft Azure, the best candidate for cloud IAAS provider, will be chosen and their costs throughout the year will be calculated. This calculation will be then compared with nowadays used on-premises infrastructure costs.

4.3.1 Current infrastructure

Specifications of infrastructure which is currently used by Subject 1 and its costs are summarized in Table 4.5. This specifications will be used to choose a suitable virtual machine offered by Microsoft Azure and it will be later used for cloud costs calculations. As seen in subsection 2.5.2, it is not necessary to dimension the virtual machine for the highest peaks, but during those peaks, extra virtual machines can be rented and "cloudbursting" can be leveraged. If the peaks are not very often, it should lead to a cheaper solution.

The aim of the thesis is to compare both, so one of the virtual machines will be dimensioned according to this settings.

Table 4.5: Current infrastructure of Subject 1

CPU	Intel Xeon E3 1225v2
#Cores	4
Frequency	3,2 GHz
RAM	16 GB
Disk space	2 TB
Monthly price	37 €

Source: Author

4.3.2 Audience data analysis

In this subsection, the audience data obtained from Subject 1 will be examined. The data show how many page views were recorded on Subject 1's websites every day in 2015. The data are plotted on Figure 4.2, where it can be seen how the user traffic evolved during the year[21]. These data will be used for calculations in the following subsection.

The data have to be used for the estimation of the number of page views per day. Based on this estimate, a proper cloud virtual machine can be chosen. It is therefore necessary to decide, what would be the optimal number of visitors the virtual machine can handle, and which number of visitors would be transfered to another virtual machines using cloudbursting. To determine this number, a histogram of daily page views can be used, which is shown on Figure 4.3. From this histogram it can be seen that many days fit into "usual amount of page views", but that there are also several exceptions (these peaks can be also seen in the previous figure). It suggests that optimal amount of visitors handled by single virtual machine should be somewhere around 15000.

To pinpoint this number exactly, the data statistics can also be used. The most important ones are summarized in Table 4.6. The average amount of visitors is 11436 and the standard deviation is quite high, 4441.7, which is almost half of the average itself. That implies that the audience numbers can vary a lot and it can be seen also from the audience histogram.

The standard deviation is a measure of data variance and therefore a sum of average and standard deviation can be taken as a candidate for the virtual machine capacity C.

This sum C is as follows:

$$C = \bar{x} + \sigma = 15878 \tag{4.1}$$

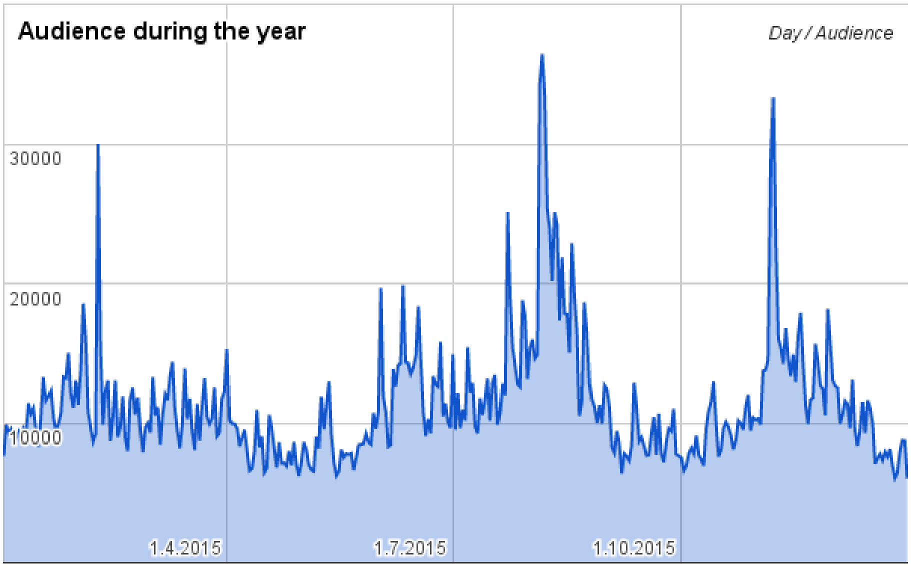
There are only 36 days in the dataset which exceed this value, which is, relatively speaking:

$$\frac{36}{|x|} = \frac{36}{365} = 9.86\% \tag{4.2}$$

[21]The original dataset can be found on (Kučera, 2016).

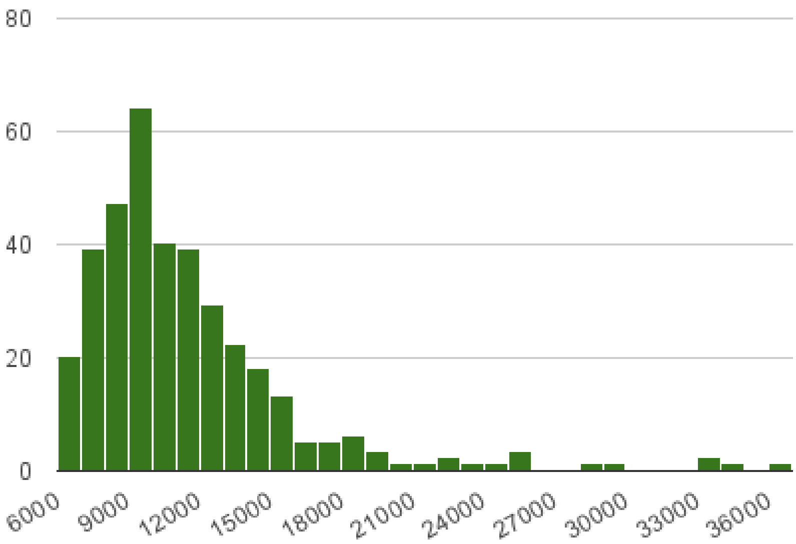
Therefore, with this capacity C in less than 10 % of days there would be a necessity to use cloudbursting and only one virtual machine with capacity of 15878 page views per day would suffice. Thus this capacity value $C = 15878$ will be used for the costs calculations.

Figure 4.2: Page views during 2015



Source: Author.

Figure 4.3: Histogram of page views during 2015



Source: Author.

Table 4.6: Statistics of page views during 2015

Size of dataset $\|x\|$	365
Median M	10304
Average $\bar{x}$	11436
Standard deviation σ	4441.7
Skewness γ_1	2.458
Kurtosis γ_2	8.600

Source: Author

4.3.3 Virtual machines specifications

In this subsection, two Microsoft Azure virtual machines will be specified. First will be called *Reference machine*, it will be built based on the original on-premises machine presented in subsection 4.3.1 and it will just serve the purpose to show the difference between costs in cloud and on-premise. The second virtual machine, called *Cloud machine*, will be chosen based on the calculations from the audience data in subsection 4.3.2, as this machine will leverage cloudbursting and therefore does not have to be dimensioned for high peaks.

Reference machine was set up so that it is as much as possible similar to the original on-premises machine.

Cloud machine was chosen according to the several sources suggesting the sizes of cloud machines for a certain page views count. (Jeff Barr, 2013) from Amazon summarizes all options users have for different applications. In similar cases to ours, (Darshan Shankar, 2013) and (Stan Hanks, 2014) suggest that Amazon Micro instances should suffice, so in this thesis' case, similar Microsoft Azure instances will be used. Any business can also firstly try smaller (or bigger) instances and then move to a different one with few simple steps, as suggested by (Eric Hammond, 2011).

The specifications of virtual machines are summarized in Table 4.7.

Table 4.7: Specifications of virtual machines

	Reference machine	*Cloud machine*
Azure instance	Standard A4	Basic A1
#Cores	8	1
RAM	14 GB	1.75 GB
Disk space	605 GB	40 GB
Hourly price	0.4048€	0.043€
Monthly price	301€	32€

Source: Author

4.3.4 Comparison of cloud and on-premises costs

In this subsection, the concluding costs comparison will be finally made. In total, three different costs will be compared:

- **On-premises costs** of original infrastructure of subject 1.
- **Reference machine costs**, which is a cloud machine with similar specification as previous item.
- **Cloud machine costs**, which is dimensioned to handle only "usual amount" of daily page views and which will leverage cloud bursting. The days, when the cloud bursting will be required will incur additional costs which still have to be calculated.

Total yearly costs of renting all of three machines are obvious, as their monthly or hourly costs are already known. Therefore only cloud bursting costs have to be calculated yet.

Costs of cloud bursting in case of ***Cloud machine***

The *Cloud machine* is dimensioned to handle only capacity C calculated in subsection 4.3.2. It was also calculated that in around 10 % of days – in 36 of them in 2015 – this capacity would not suffice. Therefore in these days cloudbursting would have to be used. That basically means that another (similar) virtual machine should be rented to handle the traffic peak.

To calculate the exact amount of extra costs, the number of extra "virtual machine days" has to be calculated. Any virtual machine can handle C daily pageviews, so it has to be checked how many days fit into intervals $[C, 2C)$, $[2C, 3C)$ and so on.

Looking at the data, it can be noticed that in total 32 require 2 virtual machines and 4 days require one. This results are summarized in Table 4.8.

Table 4.8: Virtual machines required per days in 2015

Interval	#Days	#Virtual machines
$[0, C)$	329	1
$[C, 2C)$	32	2
$[2C, 3C)$	4	3

Source: Author

It can be assumed, that the additional virtual machine(s) would have to be rented for the whole day, even though in reality they might be required only for a shorter period of time. The resulting costs would therefore be even smaller.

From previous subsection, it can be seen that daily costs of a virtual machine used in the *Cloud machine* scenario are 1.032€. The total yearly costs of the *Cloud machine* usage would therefore be:

$$329 * 1.032€ + 32 * 2 * 1.032€ + 4 * 3 * 1.032€ = 417.96€ \tag{4.3}$$

Costs comparison summary

Costs of all three cases were calculated and now it is time to finally compare them. The findings are summarized in the Table 4.9.

Table 4.9: Cost comparison of yearly infrastructure costs

On-premises costs	*Reference machine costs*	*Cloud machine costs*
444€	3612€	417.96€

Source: Author

From the table it can be seen that using the *Cloud machine* scenario incurs the lowest costs. The scenario leverages cloudbursting, which means that the current website would have to be updated to support it. Concretely, a software watching the server usage and provisioning new virtual machines when needed would have to be implemented. However, such an implementation is just an one-time cost and the solution would be still cheaper in the long term.

On-premises server is not however much more expensive. If the Subject 1 had used A0 basic Microsoft Azure instance instead of A1, the difference would be much more marked[22], however it is debatable (but possible) that instance would suffice.

To conclude, cloud computing would be cheaper for Subject 1 (based on data from 2015), however the savings are not very significant. For a bigger SME, who dimension their servers for much higher peaks and workloads, the savings could be much higher.

4.3.5 Practical part conclusion

In this chapter, firstly, several cloud IAAS providers were compared according to a different characteristics of the products they offer. Based on this comparison, three providers were chosen who were more thoroughly compared using a costs analysis of one of their products. From this analysis, Microsoft Azure was chosen as the most suitable cloud IAAS provider for Czech SME.

Afterwards, the results of the questionnaire between Czech e-commerce subjects were presented. The results contain the data about their current IT infrastructure and its costs. From the results it was concluded that none of them already relies on cloud computing and the results served as a basis for next section, where these infrastructure costs were compared with possible cloud costs.

[22]In that case, the total yearly price would be 148€.

Finally, the cost comparison between cloud IAAS and on-premises infrastructure of Subject 1 was made. The costs of the current infrastructure were compared to a simple cloud solution and also to a cloud machine resembling the original one. From this comparison, it was concluded that cloud solution would be cheaper for Subject 1, however the difference is not very significant.

To sum up, usefulness of cloud computing for SME is not that high, but the bigger the needs for IT infrastructure in a SME are, the higher the usefulness is. A reader following the approach in the final comparison section, with proper data available, can easily perform a similar analysis for any other subject.

Conclusion

The rise of the cloud computing is bringing enormous changes to most of the business, and e-businesses in particular. Any business now can access almost unlimited amount of computational power for reasonable prices which now belong to operational and not capital costs. Cloud computing brings equality for businesses in terms of infrastructure accessibility and any business, large or small can profit from the advantages it brings.

The topic of this thesis was chosen mostly because of this reason – because of the appeal of cloud computing and its present and future importance in e-commerce. One of those appeals is the cost reduction it can bring for businesses, and such diminution for infrastructure costs in particular applies to almost any business. Investigating these costs and calculating the advantageousness of cloud is engaging for all enterprises, who seek the cost reduction.

This thesis goal was to investigate the potential of cloud computing it offers for SME and to examine different IAAS products on the market. The thesis also aimed to review several real enterprises in the Czech republic and obtain a notion about their current IT infrastructure. The ultimate goal of the thesis was to compare costs of this infrastructure with potential costs of such infrastructure in the cloud.

In the Theoretical part, concept of cloud computing was described, so that the reader can understand its specifics and recognize the advantages and disadvantages of this technology.

In the consecutive Practical part, it was found, that most suitable IAAS provider for SME is Microsoft Azure, followed by Amazon EC2 and Google Cloud Platform.

Afterwards, four different small e-commerce enterprises from the Czech republic were presented and the data about their infrastructure were shown. The knowledge gained from this data was used for the final goal calculation.

Finally, costs of cloud computing infrastructure were calculated, using the data obtained from one of the investigated subjects. It was concluded, that cloud computing is the cheapest solution for small businesses, however the cost difference is not that significant.

The framework used for costs calculations can be leveraged by any other reader, who can, with proper data, obtain the costs of her own business infrastructure. It can be suggested, that larger businesses with more expensive IT infrastructure can benefit from cloud computing more.

However, there are few limitations to the outcomes of the thesis. As the cost comparison was made only on one subject (as it requires a lot of potentially sensitive data), the results for other enterprises might differ and the cloud computing might be more expensive for them. Moreover, the amount of traffic was ignored in the calculations, assuming that it is not significantly high for Subject 1. Other businesses with higher traffic requirements might need to include it in the calculations. Finally, the case study part about real enterprises included only four subjects and therefore it is not possible to draw important conclusions from the data.

One of the possible extension of this thesis would be to include these costs in the calculations. It would be also possible to compare the costs of much wider portfolio of virtual machines and on-premises computers, as just three of them were compared here. Finally, a study involving much higher number of e-commerce SME could be performed and some claims about this market segment could be presented.

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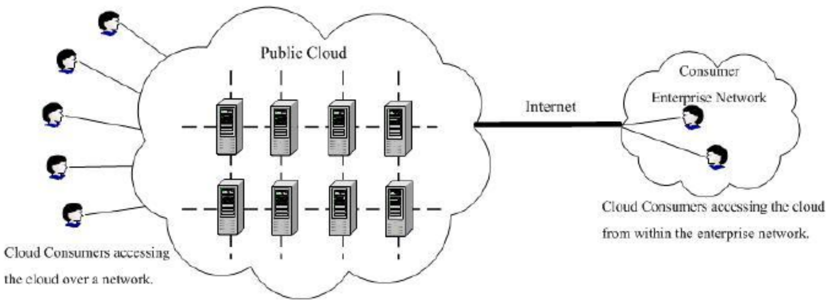
Appendix A

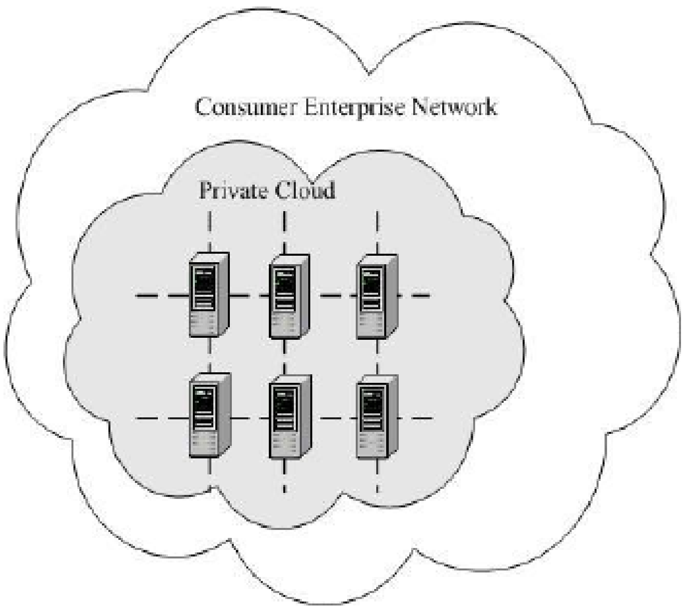
Attachments

Figure A.1: Diagram of a public cloud



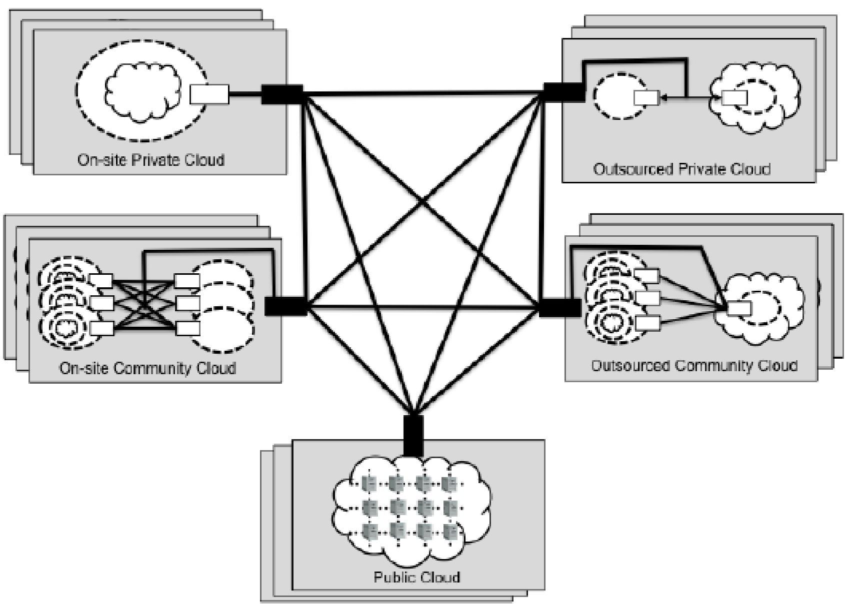
Source: (Liu et al., 2011).

Figure A.2: Diagram of a private cloud



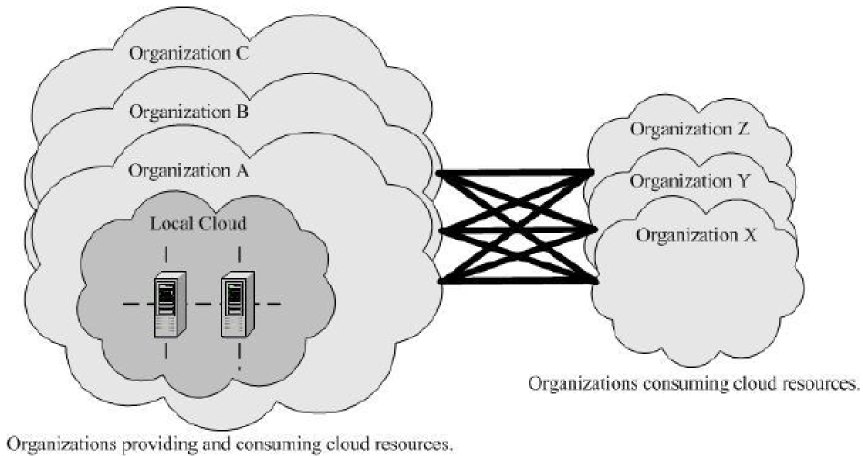
Source: (Liu et al., 2011).

Figure A.3: Diagram of a hybrid cloud



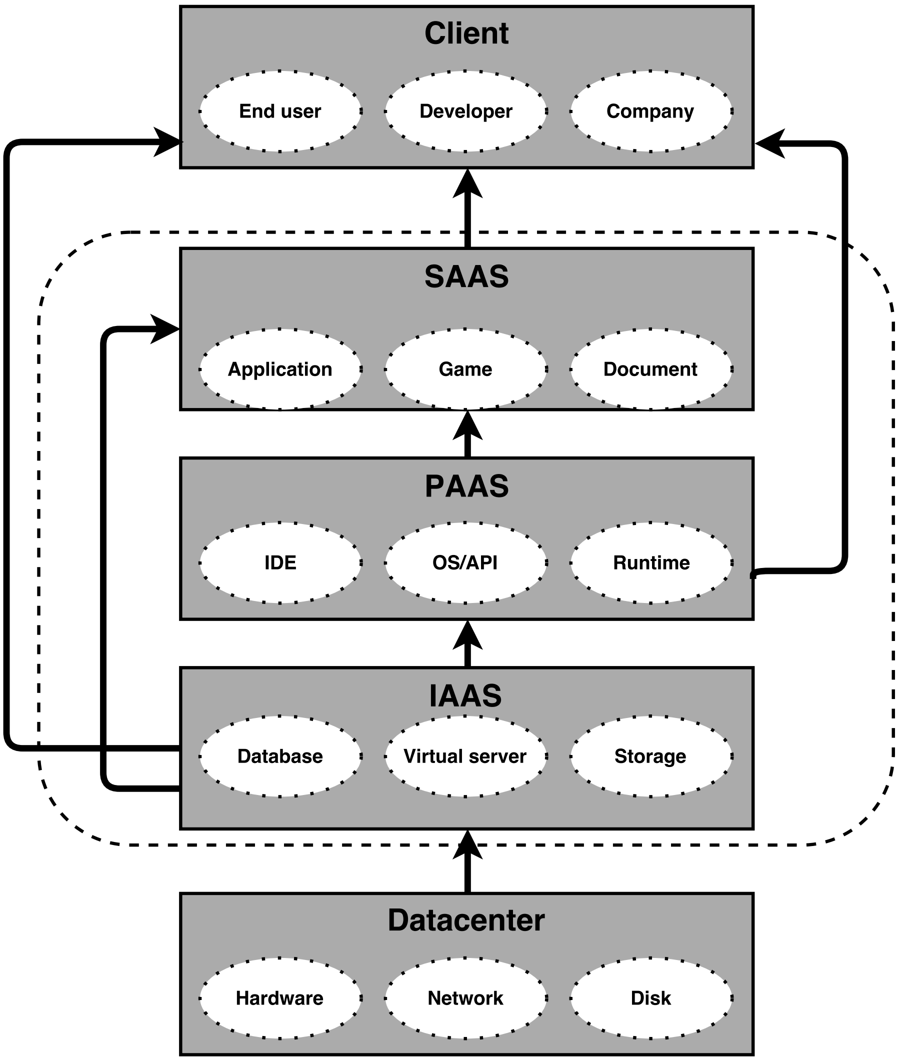
Source: (Liu et al., 2011).

Figure A.4: Diagram of a community cloud



Source: (Liu et al., 2011).

Figure A.5: Diagram of cloud services



Adopted from (Magoules, 2013).

Figure A.6: Questionnaire for Czech SME – page 1

Nákladovost on-premises hostingového řešení

Tento formulář slouží k získání dat pro praktickou část bakalářské práce zaměřené na nákladovost cloudových služeb využitelných v podnicích. Data získaná pomocí tohoto formuláře budou využita pro praktickou část práce, kde bude porovnáno nákladovost vlastního on-premises řešení, kdy firma provozuje své servery a řešení, kdy firma využívá cloudových služeb jako je Amazon AWS.

Předem děkuji všem respondentům za vstřícnost při vyplňování.
Adam Kučera.

1. **Jaká je přibližná denní návštěvnost Vašich webů dohromady (počet návštěv) v průměrném dni?**
   Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
   Označte jen jednu elipsu.

   - 0 - 5 000
   - 5 000 - 10 000
   - 10 000 - 20 000
   - 20 000 - 30 000
   - 30 000 - 40 000
   - 40 000 - 50 000
   - 50 000 a více
   - Jiné: ....

2. **Jaká je přibližná denní návštěvnost Vašich webů dohromady (počet návštěv) v podprůměrném dni? (např. během letních prázdnin)**
   Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
   Označte jen jednu elipsu.

   - 0 - 5 000
   - 5 000 - 10 000
   - 10 000 - 20 000
   - 20 000 - 30 000
   - 30 000 - 40 000
   - 40 000 - 50 000
   - 50 000 a více
   - Jiné: ....

Source: Author

Figure A.7: Questionnaire for Czech SME – page 2

3. **Jaká je přibližná denní návštěvnost Vašich webů dohromady (počet návštěv) v nadprůměrném dni? (např. ve špičce před Vánoci)**
Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
Označte jen jednu elipsu.

- ◯ 0 - 4 999
- ◯ 5 000 - 9 999
- ◯ 10 000 - 19 999
- ◯ 20 000 - 29 999
- ◯ 30 000 - 39 999
- ◯ 40 000 - 49 999
- ◯ 50 000 a více
- ◯ Jiné: ....

Hardwarová infrastruktura

4. **Jaké technické řešení využíváte pro hostování svých webů?**
Označte jen jednu elipsu.

- ◯ Pronájem hostingových služeb *Přeskočte na otázku 7.*
- ◯ Pronájem virtuálního serveru *Přeskočte na otázku 7.*
- ◯ Pronájem dedikovaného serveru *Přeskočte na otázku 7.*
- ◯ Vlastní server(y) *Přeskočte na otázku 5.*
- ◯ Cloudové řešení typy Amazon AWS nebo Microsoft Azure *Přeskočte na otázku 7.*
- ◯ Jiné: .... *Přeskočte na otázku 7.*

Vlastní servery

5. **Kolik vlastních serverů využíváte?**

....

6. **Jaká je přibližná pořizovací cena jednoho takovéhoto serveru?**
Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
Označte jen jednu elipsu.

- ◯ méně než 10 000
- ◯ 10 000 - 14 999
- ◯ 15 000 - 19 999
- ◯ 20 000 - 24 999
- ◯ 25 000 - 29 999
- ◯ 30 000 - 34 999
- ◯ 35 000 - 39 999
- ◯ 40 000 a více
- ◯ Jiné: ....

Source: Author

Figure A.8: Questionnaire for Czech SME – page 3

Náklady technického řešení hostingu

7. **Jaké jsou průměrné měsíční náklady na toto řešení bez personálních nákladů?**
   Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
   Označte jen jednu elipsu.

   - 0 - 4 999
   - 5 000 - 9 999
   - 10 000 - 14 999
   - 15 000 - 19 999
   - 20 000 - 24 999
   - 25 000 - 29 999
   - 30 000 - 34 999
   - 35 000 a více
   - Jiné: ....

Personální zajištění

8. **Využíváte pro technickou správu svých serverů vlastní zaměstnance?**
   Označte jen jednu elipsu.

   - Ano *Přeskočte na otázku 9.*
   - Ne *Přeskočte na otázku 12.*

Personální zajištění

9. **Kolik zaměstnanců se stará o servery?**

   ....

10. **Komentář k předchozí otázce**

   ....
   ....
   ....
   ....
   ....

Source: Author

Figure A.9: Questionnaire for Czech SME – page 4

11. **Jaké je přibližné platové ohodnocení těchto zaměstnanců?**
Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
Označte jen jednu elipsu.

- 10 000 - 14 999
- 15 000 - 19 999
- 20 000 - 24 999
- 25 000 - 29 999
- 30 000 - 34 999
- 35 000 a více
- Jiné: ....

Přestaňte tento formulář vyplňovat.

Cena outsourcingu

12. **Jaké jsou přibližné měsíční náklady na správu Vašich serverů?**
Pokud Vám nevadí uvést konkrétnější číslo, uveďte do položky Jiné.
Označte jen jednu elipsu.

- 0 - 4 999
- 5 000 - 9 999
- 10 000 - 14 999
- 15 000 - 19 999
- 20 000 - 24 999
- 25 000 - 29 999
- 30 000 - 34 999
- 35 000 a více
- Jiné: ....

Používá technologii Google Forms

Source: Author

Appendix B

List of abbreviations

ACCI Academic Cloud Computing Initiative

AWS Amazon Web Services

CAPEX Capital Expenditure

CEO Chief Executive Officer

CIO Chief Information Officer

CPU Central Processing Unit

CRM Customer Relations Management

EC2 Elastic Compute Cloud

EGEE Enabling Grids for E-science

ERP Enterprise Resource Planning

GB Gigabyte

GPU Graphic Processing Unit

HP Hewlett Packard

IAAS Infrastructure-as-a-Service

IBM International Business Machines Corporation

IP Internet Protocol

IT Information technology

I/O Input / Output

MB Megabyte

MIT Massachusetts Institute of Technology

NIST National Institute of Standards and Technology

NPV Net Present Value

OPEX Operational Expenditure

PAAS Platform-as-a-Service

PC Personal Computer

QoS Quality of Service

ROI Return on Investment

SAAS Software-as-a-Service

SLA Service Level Agreement

SME Small and medium enterprises

SSD Solid State Disk

TB Terabyte

US United States

S3 Simple Storage Service

4G Mobile networks of fourth generation