Master Thesis
Software Engineering

May 2011

Cloud Computing - Trends and Performance Issues

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This thesis is submitted to the School of Engineering at Blekinge Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Software Engineering. The thesis is equivalent to 2 x 20 weeks of full time studies.

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ABSTRACT

Context: Cloud Computing is a very fascinating concept these days, it is attracting so many organizations to move their utilities and applications into a dedicated data centers, and so it can be accessed from the Internet. This allows the users to focus solely on their businesses while Cloud Computing providers handle the technology. Choosing a best provider is a challenge for organizations that are willing to step into the Cloud Computing world. A single cloud center generally could not deliver large scale of resources for the cloud tenants; therefore, multiple cloud centers need to collaborate to achieve some business goals and to provide the best possible services at lowest possible costs. However a number of aspects, legal issues, challenges, and policies should be taken into consideration when moving our service into the Cloud environment.

Objectives: The aim of this research is to identify and elaborate the major technical and strategy differences between the cloud-computing providers in order to enable the organizations managements, system designers and decision makers to have better insight into the strategies of the different Cloud Computing providers. It is also to understand the risks and challenges due to implementing Cloud Computing, and "how" those issues can be moderated. This study will try to define Multi-Cloud Computing by studying the pros and cons of this new domain. It is also aiming to study the concept of load balancing in the cloud in order to examine the performance over multiple cloud environments.

Methods: In this master thesis a number of research methods are used, including the systematic literature review, contacting experts from the relevant field (Interviews) and performing a quantitative methodology (Experiment).

Results: Based on the findings of the Literature Review, Interviews and Experiment, we got out the results for the research questions as, 1) A comprehensive study for identifying and comparing the major Cloud Computing providers, 2) Addressing a list of impacts of Cloud Computing (legal aspects, trust and privacy). 3) Creating a definition for Multi-Cloud Computing and identifying the benefits and drawbacks, 4) Finding the performance results on the cloud environment by performing an experiment on a load balancing solution.

Conclusions: Cloud Computing becomes a central interest for many organizations nowadays. More and more companies start to step into the Cloud Computing service technologies, Amazon, Google, Microsoft, SalesForce, and Rackspace are the top five major providers in the market today. However, there is no Cloud that is perfect for all services. The legal framework is very important for the protection of the user's private data; it is an important key factor for the safety of the user's personal and sensitive information. The privacy threats vary according to the nature of the cloud scenario, since some clouds and services might face a very low privacy threats compare to the others, the public cloud that is accessed through the Internet is one of the most means when it comes the increasing threats of the privacy concerns. Lack of visibility of the provider supply chain will lead to suspicion and ultimately distrust. The evolution of Cloud Computing shows that it is likely, in a near future, the so-called Cloud will be in fact a Multi-cloud environment composed of a mixture of private and public Clouds to form an adaptive environment. Load balancing in the Cloud Computing environment is different from the typical load balancing. The architecture of cloud load balancing is using a number of commodity servers to perform the load balancing. The performance of the cloud differs depending on the cloud's location even for the same provider. HAProxy load balancer is showing positive effect on the cloud's performance at high amount of load, the effect is unnoticed at lower amounts of load. These effects can vary depending on the location of the cloud.

Keywords: Cloud Computing, Legal issues, Trust, Privacy, Multi-Cloud, Load Balancing, Performance.

ACKNOWLEDGMENT

First and foremost, we would like to thank our supervisor, Prof. Lars Lundberg, for his patient and invaluable guidance throughout the thesis. This study, in its current form, would not have been feasible without his effort. Moreover, we would like to thank Logica AB for providing the environment required for this study. In particular, we would like to express our gratitude to Bengt-Åke Claesson, Gustav Widerström, and Daniel Gustafsson for the valuable discussions and feedback throughout this project. We would like also to thank Therese Hogblad from Telecomcity for providing us the lab environment for the experiment. Chris Addis, Alex Pop and the support team from RightScale for patiently answering our questions. And special thanks for everyone participated in our interview study. Of course, we are also thankful to Blekinge Institute of Technology for giving us the opportunity to attend the Masters' programs in Software Engineering. Especially worth mentioning here are the lecturers we met during our studies as well as the staff at the International Office, Library and in the administration. We also learned a lot from the Swedish way of life. These experiences will certainly enrich our future. Finally, we are deeply grateful for our families and friends. Thanks for supporting us no matter what adventurous plans we had and will have.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Cloud Computing, an old dream of computing as a utility, where dynamically scalable resources are provided as a service over the Internet (the cloud). It becomes a very interesting concept these days, and it is attracting many organizations to move their utilities and applications into dedicated data centers, so it can be accessed from anywhere through the Internet. As we know Cloud Computing is expected to re-define the computing. It can convert a large part of the IT industry, making software even more attractive as a service and redefining the way IT hardware is designed and purchased. The infrastructure of Cloud Computing is a combination of virtualization technologies and service oriented architecture (SOA) [1], so for any developers with new innovative ideas, there will no longer be requirements for large capital costs of hardware to implement their service, or the expensive person power to operate it. They do not need to be concerned about wasting of costly resources if the service expansion was too low as compare to their predictions, or if the popularity of the service becomes too high, they can easily scale their resources to meet the growth. Thus companies can get results as quickly as their services can scale, since using 1,000 servers for one hour costs no more than using one server for 1,000 hours [2].

There are four deployment cloud models; Public, Private, Community and Hybrid. In the Public cloud, the infrastructure is done to make the service available to the public users on the Internet. For the Private cloud the infrastructure is made exclusively for a private user (i.e. An enterprise organization) where the services can only be accessed locally and it can be managed by the cloud owner or a third party. The infrastructure for the Community cloud is shared by several organizations and supports a specific community that has shared concerns (e.g., Security requirements). It may be managed by the organizations or a third party. As for the Hybrid cloud the infrastructure is comprised of two or more clouds (private, community, or public) that remain unique entities but are communicating with one another by standardized technologies that enable data and application portability [3].

There are three types of cloud service models, 1) Infrastructure as a service (IaaS), in this model the provider will supply the servers, networking equipments, storage and backup, where the users have only to pay for taking the computing services. Amazon EC2 is a great example of this type. 2) Platform as a service (PaaS), in this model the provider only provides the platform to the users, where the users build their own application softwares. Google Engine provides this type of service. 3) Software as a service (SaaS), in this model the provider will offer the users a service of using their software applications. SalesForce.com is a well known SaaS provider.

Nowadays, many companies are providing Cloud Computing services. Cloud Computing offers major opportunities but it also offers some challenges [30]. The number of Cloud Computing providers is increasing day by day while there are a lot of technical and strategic differences between the providers. Hence, choosing the best suited provider has become a challenge. Therefore, there is a need to conduct a systematic research study to identify the major cloud providers available in the market today and to understand the technical and strategic differences among these providers.

Legal issues, trust and privacy are some of the major challenges of Cloud Computing [30]. They are driving any new innovations and developments in Cloud Computing, however there are a number of aspects and challenges in regard to the legal issues and policies of the Cloud Computing environment that needs to be addressed.

The evolution of Cloud Computing shows that it is likely, in a near future; the so-called Cloud will be in fact a Multi-Cloud environment comprised of a mixture of private and public clouds to form an adaptive environment. A single cloud center generally could not deliver

large scale of resources for the cloud tenants also it will be almost an impossible task for a single data center to fulfill all the desires and requirements of the customers, including the desire for special security criteria or even a desire for special computing unit or memory capacities [4]. Therefore, multiple cloud centers need to collaborate in achieving some business goals and to provide the best possible services for the lowest possible costs [4]. The Multi-Cloud environment will provide the ability for on-demand selection of cloud providers, with easy transfer, which can bests utilize resources to the maximum. However, Multi-Cloud environment has become a demand of many customers in the Cloud Computing domain; it is still an immature area, so the deployment of Multi-Cloud can cause some limitations due to the geography-specific data, processing, or hybrid architectures across private and public clouds.

Load balancing is the method by which load (number of requests, number of users, etc.) is distribute across one or more servers, network interfaces, hard drives, or other computing resources. There are many reasons to use load balancing, for instance, improving performance, reliability, flexibility, scalability and availability. Load balancing in Cloud Computing is different from the typical way of implementation and architecture of the classical load balancing; it is using commodity servers for the load distribution. Load balancing in the cloud is presenting a new set of technical and economic opportunities; on the other hand it has its own challenges [5].

1.1 Related work

In Minqi Zhou et al. [S3]. The authors in their work provided a study on some of the main Cloud providers in the market today, they based their study on six service categories; 1) Data as a Service (Daas), 2) Software as a Service (SaaS), 3) Platform as a Service (PaaS), 4) Identity and Policy Management as a Service (IPMaaS), 5) Network as a Service (NaaS), 6) Infrastructure as a Service (IaaS).

In G. Ras et al. [S9]. The authors in their work provided a use case study to evaluate the service providers based on their ability to meet the most common use cases between Gartner's clients.

In contrast to Minqi Zhou et al. [S3] and G. Ras et al. [S9], our study considers the analysis for each of the cloud providers presented in the study; moreover we identify the major cloud providers for each of the Cloud Computing services. We also considered new standards while selecting the dominant cloud providers. These standards are 1) Experts opinions 2) Market share 3) Variety of service type & products offering 4) Information availability.

In the year 2010 Pearson & Benameur [30] carried out a research study to assess how security, trust and privacy issues occur in the context of Cloud Computing and to discuss the ways in which they may be addressed. The paper addresses some of these issues, for example: Lack of user control and unauthorized secondary usage related to Privacy. Availability and backup related to Security. Lack of customer trust related to Trust. Routes transnational traffic of the data related to Legal aspects. We benefitted from this study in our thesis work to address the issues related to trust, privacy and legal issues, also to address the impacts of implementing Cloud Computing. However we have discussed more practices in relation to each issue, based on our literature studies and the information we got from the interviews.

In general, not much research addressing the benefits and drawbacks of Multi-Cloud Computing can be found. The one example that was identified is presented by Elton Mathias [51]. In his study he included one section (2.1.5.3) to address multi-cloud Computing, and the sections (1.3.5) and (3.2.1).

1.2 Aims and Objectives

- The aim of this research is to identify the major Cloud Computing providers, and to elaborate the technical and strategy differences between the different providers. This comparative study will enable the organization's management, system designers and decision makers to have a better insight into the strategies of the different Cloud Computing providers.

- The study will also aim to comprehend "what" the impacts of implementing Cloud Computing, since the implementation of Cloud Computing will have impacts on so many different aspects. We believe that legal, trust and privacy aspects are one of the most controversial in Cloud Computing, so we will focus our research on these three aspects.

- Multi-Cloud Computing environment is a newly emerging paradigm in Cloud Computing. There are a lot of ambiguities surrounding the definition of Multi-Cloud environment. In this research we will clarify what is the meaning of Multi-Cloud Computing by creating a definition of this paradigm also by investigating the benefits and drawbacks of a Multi-Cloud Computing.

- The last aim of this study will be dedicated to exploring the load balancing in Cloud Computing, and the focus of the study will be on the performance issue. The objectives will be to provide practical results for applying load balancing in Cloud Computing and it is impacting on the performance also it will provide a realistic review on a load balancing solution that is available in the market today.

1.3 Research Questions

Research question 1: Who are the dominant Cloud Computing providers?
Sub question 1: What are the major technical and strategic differences between the providers?
Research question 2: What are the impacts regarding legal aspects, trust and privacy in Cloud Computing?
Research question 3: What are the benefits and drawbacks of a Multi-Cloud Computing?
Research question 4: What are the impacts of load balancing on the performance of different Cloud availability zones?

1.3.1 Purpose of the research questions

Table 1 *Purpose of the research questions*

Research Question	Purpose
Research question 1	To identify the major Cloud Computing providers available in the market today.
Sub question 1	To address the differences between the providers from the technical and strategic perspectives.
Research question 2	To study the impacts of the implementation of Cloud Computing. The study will focus on the legal, trust and privacy aspects.
Research question 3	To create a basic understanding of Multi-Cloud Computing environment by investigating the benefits and drawbacks of a Multi-Cloud Computing.
Research question 4	To study the impacts of load balancing solutions on the Cloud Computing environment. The study will focus on the performance aspect of Amazon AWS cloud in a different availability zones.

1.4 Terminology

Table 2 *Terminology Used in This Thesis*

Term/Abbreviation	Definition
SLR	Systematic Literature Review. "A means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest" [6]
SLA	Service Level Agreement
RQ	Research Question
AUTHORS	Ali Al-Refai and Srinivas Pandiri
AWS	Amazon Web Service
AMI	Amazon Machine Image
AWS SDK	Amazon Web Service Software Development Kit
EIP	Amazon's Elastic IP addresses are static IP addresses designed for dynamic Cloud Computing and they are associated with the Amazon AWS account, not to a specific computing machine.
CDN	Content Delivery Network
API	Application Programming Interface
SaaS	Software as a Service
PaaS	Platform as a Service
IaaS	Infrastructure as a Service
MaaS	Management as a Service
GAE	Google App Engine
REST	Representational State Transfer
SOAP	Simple Object Access Protocol
HTTP	Hypertext Transfer Protocol
SOA	Service oriented architecture
CSP	Cloud Service Provider
API	Application Programming interface
VMs	Virtual machines
HTTPS	Hypertext transfer protocol secure
WCF	Windows Communication Foundation
MOM	Message Oriented Middleware
RDS	Relational Data Service
SQS	Simple queue service
ACL	Access Control List
S3	Simple storage service
EC2	Elastic cloud compute

2 RESEARCH METHODOLOGY

2.1 Research design

This study involves three different research methods:
Method 1: Interviews.
Method 2: Systematic literature review.
Method 3: Experiment.

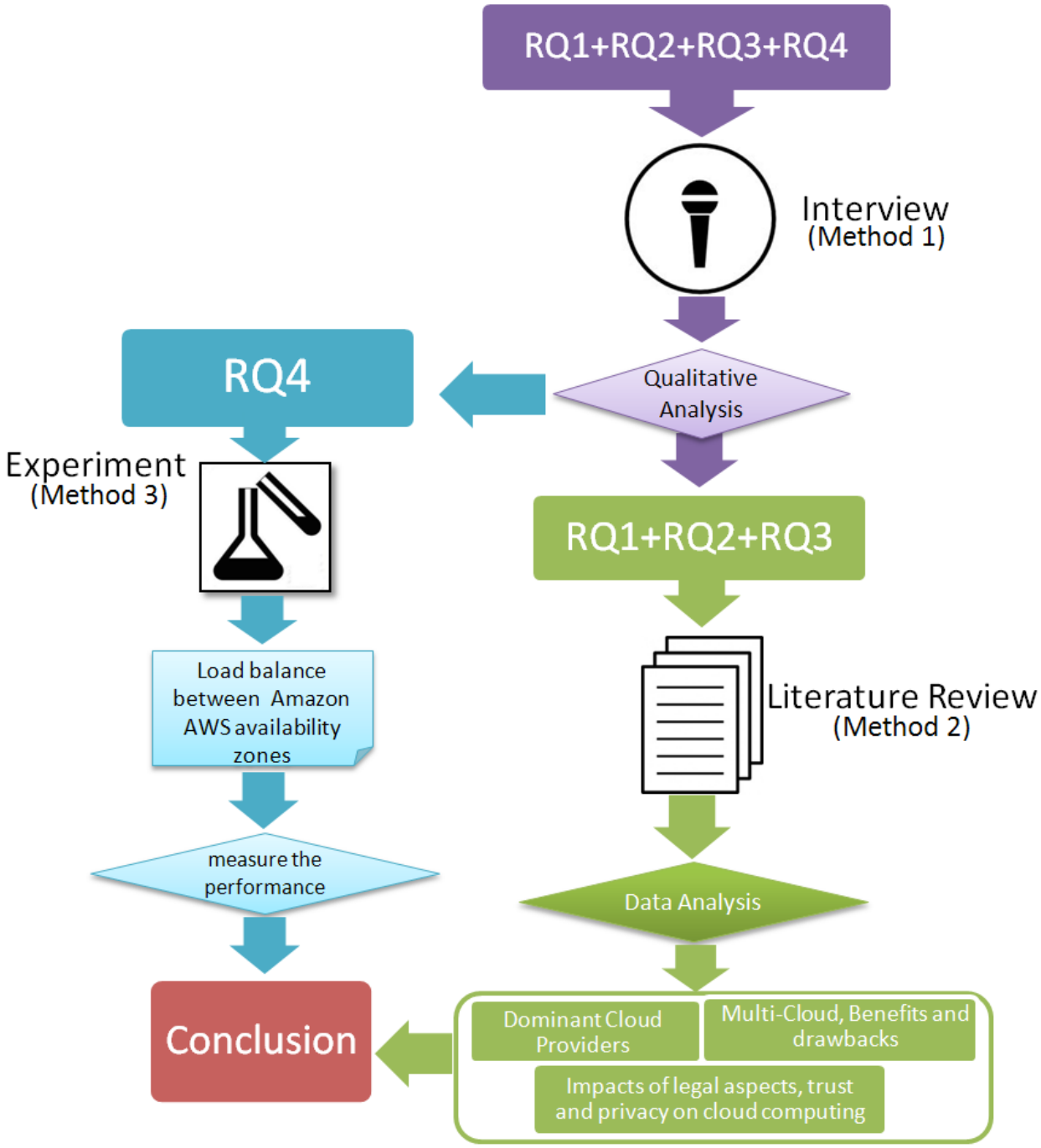

Figure 1 *Flow chart of Research design*

In order to answer the research questions of this thesis, the authors decided to use a mixed research methodology. Interview is to be used at first place. The formulation of the interview questions was based on the thesis' research questions, for that and in order for a better designing and conducting of the interview the authors spent a time of three days for some preliminary readings, they also held discussions with the teachers and the students who got expertise in the research domain. The discussion was mainly on the formulation and structuring of the interview questions and the size of the interviewees. Most of contacting persons suggested going for open-ended interviews in order to get the maximum information from the interviewees.

The motivation behind using interview is that the research area is too immature and there are a lot of ambiguities in regard to the research phenomenon, which may cause misunderstandings while answering the research questions. So by having the opportunity to interview highly expert's professionals who are working in the relevant field it will be so valuable to gain a quick insight on the interview areas and to get some preliminary results. Hence, it would be useful for the authors gain a common understanding of the research phenomenon and in developing the other research methodologies that they intend to use in a later stage of this thesis. The results of the interview will be presented in the Chapters 3, 4, 5 and 6.

In order to answer the first, second and third research questions a comprehensive literature study will be carried out to gather materials related to Cloud Computing providers, the impacts of Cloud Computing, and the Multi-Cloud Computing paradigm. The literature study will include articles, books and web references. It will provide a detailed study on existing dominant cloud providers, and to identify the major strategy differences between each of them. The study will investigate the impacts of the legal aspects, trust and privacy in Cloud Computing; it will also state a definition for Multi-cloud Computing and address's the benefits and drawbacks of multi-cloud computing. For conducting the Systematic Literature Review the authors follow Kitchenham's guidelines [6]. The authors believe that a systematic review supported by the data from the interviews is a necessary approach for this research in order to have comprehensive answers to the research questions. The results of the SLR will be presented in the Chapters 3, 4 and 5.

A quantitative research (i.e. Experiment) method will be used in order to answer the fourth research question. As already mentioned in the interview part the authors are going to conduct a number of interviews with experts in the research area, the interview findings will assist in the planning to conduct the research experiment. Generally, one or more variables are manipulated to determine their effect on a dependent variable [7]. The experiment is to be used in order to find out the impacts of load balancing on the performance of different clouds. The experiment result will be presented and discussed in Chapter 6.

2.2 Interviews

The interview is one of the research methodologies for obtaining the qualitative data. Interviews as part of the research makes it easier to collect data that cannot be collected quantitatively [8]. In this research the interview will be used as an assisting tool for obtaining the information about the research phenomenon and to get preliminary results. Interviews were conducted with respondents in the study (i.e. Questionnaire) and gave their views on the thesis research areas. Interviews were conducted in a semi-structured approach as it combines specific questions (in order to gather information, planned) and open-ended questions. The interviews were mainly conducted through telephone calls and partially through e-mails.

2.2.1 Formulation of interview questions

The interview was designed in an open-ended structure; this formulation of interview questions allows the respondent to formulate their own answers, by expressing their thoughts, using their own words, based on their knowledge and experiences. Such type of interview allows the researcher to query for in-depth explanations, so simple yes/no questions or fixed-response questions are typically not used. There is no right or wrong approach. The conclusion will be based on respondent enthusiasm, method of administering the questionnaire, the topic covered, expertise and time spent developing a good set of unbiased responses. The questionnaire is presented in Appendix E. The structure of the questionnaire consists of five categories; 1) General questions about the interviewee, 2) Related to research question 1, 3) Related to research questions 2, 4) Related to research questions 3, and 5) Related to research questions 4.

The interview questions were formulated to gather information regarding the following aspects:

- General information about the interviewee's expertise.
- The dominant Cloud providers.
- The technical and strategy differences between the providers.
- The legal, privacy and trust aspects regarding Cloud Computing.
- The definition of Multi-cloud computing.
- The benefits and drawbacks of Multi-cloud computing.
- Load balancing in Cloud Computing.

2.2.2 Population of the interview

There were no fixed criteria in selecting the participants of the interview; we have targeted experts who they have worked directly in the Cloud Computing area, either in a management or technical side. Finding the experts who are willing to participate in the interview was a difficult task because of different reasons i.e. (Busy schedule of the experts, the less expertise in the research domain, and the limited time of the study.), therefore it was very helpful for us to get a reference from Logica[1] in order to get contact with number of cloud experts in the market. We have interviewed six experts from three different organizations. They are located in the Netherlands, UK, and Sweden.

2.2.3 Interview execution

Respondents of the questionnaire were sent an e-mail and asked for a follow-up interview to collect data. Therefore the interviews are based on the willingness and availability of the interviewees. The participants of the interview were given the option to choose the most comfortable and convenient method of communication for them, for example e-mail, telephone, physical meeting or instant messaging tools [8]. Because of the open-end structure of many questions some of the respondents preferred to have a telephone interview while others preferred to have the questions emailed to them. No one preferred instance messaging or physical meetings. We conducted interviews with six persons, in that two of them filled up the questionnaire and send it by email, while we had telephone interviews with the rest of them. We used to record these interviews and later on we wrote it down on papers.

2.2.4 Interview data analysis

Working to analyze a big amount of raw data is not an easy task. Therefore using a systematic way would be the best approach to classify and assign meaning to pieces of different

[1] Logica is a global IT and management consultancy company. This study was supported by Logica-Karlskrona.

information. In this thesis the authors used the “Grounded Theory” for analyzing the interviews’ data.

2.2.4.1 Grounded Theory

Glaser and Strauss defined the Grounded theory (GT) is a systematic qualitative research methodology that emphasizing generation of theory from data in the process of conducting research [67] [68]. The theory is developed from the collected data instead of applying theory on data, so the data are coded and categorized and then again categorized and analyzed to develop a theory.

In this thesis we performed a predefined GT process (coding techniques) that consists of three series of steps, including Open Coding, Axial Coding and Selective Coding. Successful execution of these will generate a good theory as the result [68].

We used Microsoft Excel to systematically store records of all codes. It helps to apply and save code to any piece of data, sub-code, categorize, write notes and finally analyze the data. Each and every piece of information was added in the data sheets; they were also tagged to ease the traceability. All the data were then thoroughly analyzed and codes were re-checked to ensure validity. The below text will explain the three steps of GT according to our use in this thesis.

Step 1: Open coding

This is the first step, in this step we dismantle a big block of text data into a smaller piece and then we apply code on each and every piece of information. This was performed by a thorough reading of the data line by line, it is also aiming to insure that every piece of data is reviewed, analyzed and then tagged with a proper tag.

Step 2: Axial coding

Second step is to relate codes (categories and their properties) with each other. It has been observed that many codes and categories are interrelated [68].

In the second step we relate codes to each other, and so we link the similar codes to observe the interrelated between these codes and remove any duplicates or irrelevant data. This will cause a result of re-categorization of the data.

Step 3: Selective coding

The last step is to do a combination between the related categories; this step is called Selective coding [68]. In this step, a core category is to be chosen and systematically validating relationships between the categories. To ensure the validity of the data we did not include unclear statements if they do not relate to any category.

In the next page, Figure 2 is presenting a simple example of using Grounded Theory to analyze a qualitative data.

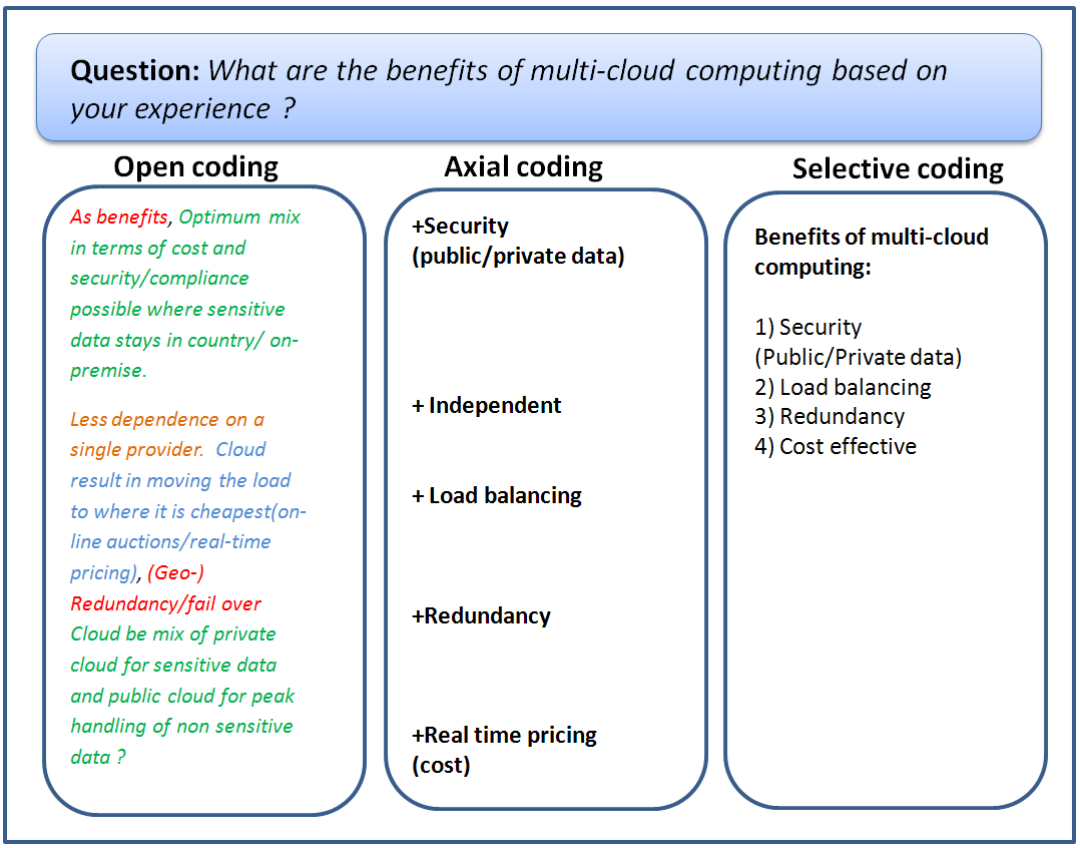

Figure 1 *Example of the Grounded Theory to analyze qualitative data*

2.3 Systematic Literature Review (SLR)

Systematic Literature Review (SLR) also known as Systematic Review is defined as "*a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest*" [6].

The main reason for conducting an SLR at some part in this research is to ensure a thorough and unbiased summarization for all the existing information regarding the subsequent areas. 1) The main cloud providers available in the market today, as well as the technical and strategy differences between those providers. 2) The impacts of Cloud Computing. 3) The phenomenon surrounding Multi-Cloud Computing.

In this research work, the authors decided to adopt the SLR procedure suggested by Kitchenham [6]. We first developed the SR (Systematic Review) protocol that prescribed controlled steps for conducting the review. The protocol included defining research questions, search strategy, study selection criteria, quality assessment, data extraction and data analysis. The protocol was revisited and refined after piloting each step of the review. The main research question for this systematic review is taken from research questions (1, 2 and 3). The purpose of the research questions is defined in (section 1.3.1).

2.3.1 Search strategy

In order to find the required articles, authors conducted a search for systematic literature reviews from five main databases namely: IEEE, ACM, SpringerLink, Google Scholar and Google Web.

IEEE Xplore was the most flexible and user friendly for all the databases. It has simple and flexible designed interface which enables users to add as many combinations as possible with the OR/AND/NOT command, from dropdown button and define search strings. Hence, the authors were able to combine the entire search phrase and used as a single search string. The "download citation" embedded in the IEEE's web interface was used to generate references for all IEEE Xplore papers, while materials from other databases were compiled and referenced manually or using Mendeley referencing tool. We ensure all references were aligned, and maintained IEEE referencing standards.

In ACM Digital Library, the search procedure appears to be a bit technical. Unlike the IEEE Xplore, the search tool does not command the use of more than one search phrase at the initial stage. However ACM was used to locate other research papers and articles that we could not find in IEEE Xplore.

Searching through the SpringerLinks database system requires a lot of caution. The search tool tries to identify every article with a title that has at least any of the word included in the search strings. Authors search with a specific keywords (i.e. Cloud Computing, Multi-Cloud, legal, trust, privacy, etc.,) In order to avoid the overflow of too many and unwanted materials.

Google scholar is a reliable search tool to browse/access the academic literature. It is a general free tool for academic literature that we have used in our search strategy. It has an easy-to-use and familiar user interface. Google scholar is open to a huge number of indexes including discreet files, pages and journal articles. However it does not provide the flexibility to create combinations of search phrases or the possibility of inclusion and exclusion of the search strings. Therefore in this research it was not used as the primary search engine tool.

In our search of the web contents we used Google web, Google web is a search engine that was considered to be the largest search engine on the Internet with over a trillion website indexes in 2008 [70]. Google web is also so good at putting the most relevant sites at the top of the results list [70]. It also provides a variety of file formats, so in thesis it was a very helpful tool in our search for other types of web contents (i.e. Websites, web-blogs, webinars, and video/audio contents).

We used three search strings for conducting SLR of research questions (1, 2, and 3), a different search string used for each research question in order to focus our findings. It is worth emphasizing that the interview results were very useful in the forming of the search strings by providing a clear understanding to some terms and their synonyms i.e. (Hybrid mixture cloud is sometimes referred to multi-cloud). Some of the search strings were altered at a later stage and the keywords were replaced by a focused and more precise one (i.e. Dominant cloud provider keyword to be replaced by Amazon or another cloud provider). The Inclusion of the word "computing" in the third search string is necessary to exclude the results that are not related to "computer science".

Table 3 *Search string for search strategy*

Search string	**Research Question**
(((((((((dominant) OR main) OR lead*) OR large) OR top) AND provider*) OR supplier) AND Cloud) AND Computing)	Research Question 1
((cloud) AND ({computing} OR {environment}) AND {legal} AND {trust} AND {privacy} AND {aspect*})	Research Question 2

({multi-cloud} OR {multicloud} OR {multi cloud*} OR {multiple cloud} OR {hybrid mixture cloud} OR {cloud of cloud*} OR {cloud management} OR {cloud management solution} AND ({computing} OR {environment}))	Research Question 3

2.3.2 Study selection criteria

2.3.2.1 Inclusion criteria

The objective of the study selection procedure was to sort out the papers (or any other sort of data materials) relevant to the objectives of the systematic review, in correspondence with the agreed goals of the research questions. The search strings as discussed in the previous section, were quite wide and therefore we were expecting to receive a large number of results, where not all of the results would be relevant to our objectives. To make sure that only the research sources that were relevant to this study were included in our research, a study selection was performed as outlined in Table 4 and 5. It is agreed on by the authors to narrow down the study results by following the selection criteria used by Smite et al [9]. The followed criteria will be modified to meet our research objectives.

The study selection was performed in two independent stages, in one stage it is targeting the published papers or journals and in the other stage it is targeting the web contents that are included (websites, web-blogs, webinars, and video/audio contents on the web).

Study selection of the published papers, was performed in four relevance analysis phases as outlined in Table 4.

The four phases were conducted as follows:

- The search strategy resulted in 153 studies (or articles/papers) that were further evaluated.
- The primary studies were first evaluated for the relevance upon titles. Editorials, prefaces, discussions, comments, summaries of tutorials, panels and duplicates were excluded and 79 articles were left for screening upon abstracts.
- The authors went through the abstracts and evaluated each article using three possible votes: “relevant”, “irrelevant” and “can’t say”. An article was included in the review if there was an agreement between the authors as in the following scenarios otherwise it will be excluded (both authors vote “relevant”, one author vote “relevant” other vote “irrelevant”, one author vote “relevant” other vote “can’t say”) in case that both authors vote “can’t say” the article will be re-evaluated using a help of the supervisor, a friend/colleagues or an expert teacher from the relevant field.
- The relevance and quality of the articles were evaluated based on the full text.

After the study selection process was completed 14 number of research papers and articles were left and consequently included in full text review as part of selecting the primary studies. Among these papers two papers are related to research question 1, seven papers are related to sub question 1, three papers are related to research question 2, and two papers are related to research question 3.

Table 4 *Studpublishingon criteria for published research papers*

Phase	Relevance	Criteria

1	By Search	Contains the search strings Publication date after 2000 Only English Only published papers
2	Title screening	Related to the research area, Not (editorials, prefaces, discussions, comments, summaries of tutorials, panels or duplicates)
3	Abstract screening	Related to Cloud Computing Related to Cloud Computing providers Related to a multi-cloud computing
4	Full Text	Including discussion on the following areas (cloud providers, cloud provider strategies, cloud providers techniques, multi-cloud concept, SLAs in Cloud Computing, and trust & privacy in Cloud Computing)

Study selection of the web contents (websites, web-blogs, webinars, and video/audio contents on the web), was performed in six relevance analysis phases as outlined in Table 5.

The Selection of studies was based on six phases that were conducted according the following relevance; (By search, URL, year, the number of visitors, index, and thoroughly study).

A total of 120 web contents were the results of the search strategy phase. These web contents were then evaluated according to the exclusion criteria and 20 web contents were left for the screening upon title and index, then they were further evaluated according to the study selection criteria as explained in Table 5. After the study selection process was completed a number of 12 web contents were left, and consequently included for full study review as part of selecting the primary studies. Among these web contents nine web contents are related to research question 1, three web contents are related to question 3.

The final list of the selected papers/articles and web contents will be presented in appendix B and C.

Table 5 *Study selection criteria for Web contents*

Phase	**Relevance**	**Criteria**
1	By Search	Contains the search strings. Google search engine. Including first 4 pages of the search engine results. Only English.
2	URL Standard organization	Not (low visited web pages, low rated blogs, social websites, Wikipedia, odd URLs)
3	Year	2005
4	No of visitors	Highly visited WebPages
5	Index	Related to Cloud Computing
6	Thoroughly study	Including discussion on the following areas (cloud providers, cloud provider strategies, cloud providers techniques, multi-cloud concept, SLAs in Cloud Computing, and trust & privacy in Cloud Computing)

2.3.2.2 Exclusion Criteria

These guidelines were followed while excluding studies from initial search results.

- Studies which do not relate to Cloud Computing.
- Studies which do not relate to Cloud providers.
- Studies which do not relate to impact of Cloud Computing issues (i.e. Legal aspects, trust and privacy).
- Studies which do not relate to Multi-cloud computing.
- If the full text of the study was not available.
- Exclude the studies which are in a language other than English and English translation is not available.

2.3.3 Quality Assessment Criteria

Mainly the inclusion and exclusion criterion (sections 2.3.2.1 and 2.3.2.2) worked as the quality assessment criteria. Nevertheless, we have to mention that we did not evaluate the quality of the included studies in terms of, for example, research methodology, subjects, research problem, validity threats or study was successful or not.

2.3.4 Data extraction

The data extraction is performed by reading the full-text of the studies; key concepts from each study were extracted according to the checklist shown in Table 6. Both authors used the following checklist as a template to extract data from the selected studies. The documented information was further used in the data analysis phase.

Table 6 *Data extraction checklist*

Category	Description
Title	Title of the published paper.
Authors	All the author's name credited with writing the paper.
Publication date	Year of publication.
Database	IEEE, ACM, SpringerLink, Google Scholar, and Google Web.
Source	Books, Journals, Articles, Webpages, White papers, Webinars.
Focus of the study	Main topical focus of the study. If the study has a broad focus and this data extraction focuses on just the objectives of the research questions.
Methodology	Main method of the study. For example: Theoretical approach, survey, case study, interviews, experiment.
Findings	Provide a description about the cloud provider, regarding technical and strategy aspects. Provide a description of the Cloud Computing impacts (legal, trust and privacy aspects) Provide a description on the Multi-Cloud Computing concept.
Additional findings and comments	Provide a description and summary of any other findings, Stated in the paper that are related to cloud providers and multi-cloud computing.

2.3.5 Data analysis

Data analysis is collecting and summarizing the results of the selected primary studies [6]. Data extracted from the reviewed articles was analyzed quantitatively and qualitatively according to the research questions. We first aimed to summarize the mainstream in the research related to major Cloud Computing providers. At the same time, we proposed a set of detailed research questions that require thorough analysis and narrative synthesis of the studies, thus leading our work towards a systematic review [9].

Data extraction resulted in several new categories and thus, qualitative analysis of the data was necessary to refine our classification scheme. This was performed iteratively, during the piloting of the review procedure and final improvements were performed at the end of the review, as the remaining data was extracted and analyzed. Qualitative data Grounded Theories were also used to characterize the focus of each study [68].

2.4 Experiment

Experiments in software engineering are part of a wider context i.e. Empiricism in software engineering [10]. The important reasons for undertaking quantitative empirical studies (i.e. Experiments and case studies) are summarized by Wohlin et al. [11] as, "to get objective and statistically significant results regarding the understanding, controlling, prediction and improvement of software development".

This experiment will be used in order to find out what is the impact of load balancing on the performance of different clouds (different AWS cloud availability zones) compared to each other when handling a specific number of requests in a specific duration time. As already mentioned in the interview part we are going to conduct a number of interviews with experts in the research area, our interview findings will assist us in our planning to conduct the research experiment. The experiment is to be conducted using an existing load balancing solution i.e. HAProxy. The experiment will be consisting of five steps:

1. Definition: The definition step helps to define goals and objectives of the experiment. This is one of the foundation phases of the experimentation.
2. Planning: The planning step includes determination of experiment context, formal statement of hypothesis, selection of variables and subjects, selecting experimental design, instrumentation and validity evaluation.
3. Operation: The experiment operation consists of preparation, execution and data validation.
4. Analysis and interpretation: The first step in the analysis is to use descriptive statistics to provide a visualization of data. The second step is data reduction and the third step is hypothesis testing.
5. Presentation and packaging: This step deals with documentation of experimental process and final results.

The above steps are clearly stated in Chapter 6.

2.5 Results reporting

After analyzing the data of the interview, SLR, and experiment, reporting the results in a proper format would be next. There will be a need to consider the audience of the results, and so the authors need to format the report accordingly. The intended audience of this report includes the thesis supervisor, industrial contact person, faculty reviewer, examiner, thesis opponents and other students. The results will be presented in the chapters 3, 4, 5 and 6 in this master thesis.

3 DOMINANT CLOUD PROVIDERS

In this Chapter the authors present the results of research question 1 and sub question 1 (see section 1.3 Research Questions). Based on the interview data we concluded the major Cloud Computing providers available in the market today, the providers' names are a conclusion of the interview responses to the question "who are the major cloud providers?" (See appendix E 1.1 Interview Questions), as a result we named 12 major Cloud Computing providers. As for SLR, there are many studies available online that are providing lists of the major Cloud Computing providers (the reader can refer to appendix A [P91] [P97] [P98] [P99]), but most of these studies are based on personal observations and do not follow a strict selection standards or a systematic research way, as well as the majority of these studies are studying market share as the only selection standard. We only found two research articles to include in our SLR study (appendix B [S3] [S9]) those are related to the research question 1 (a more detailed discussion on the related work is explained in section 1.1). As a result we named 38 major cloud providers from the SLR. To see the full list of the selected provider from interviews and SLR, the reader can refer to Appendix D. So, in this thesis we realize the identification importance of the major Cloud Computing providers, hence that information would be so much valuable for organizations' managers, systems designers, decision makers or any user of the cloud, since it will provide a detailed review on each of the major cloud providers compared with other providers.

Four standards were considered while selecting the dominant Cloud Computing providers, these standards are namely: 1) Experts opinions 2) Market share 3) Variety of service type and products offering 4) Information availability. A list of 5 providers was developed after considering the results of interviews and SLR.

Hence there are hundreds of cloud providers available in the market today, so in order to narrow down our search for the main cloud providers we have designed the above mentioned standards. Based on those standards we selected the following as major Cloud Computing providers: Amazon, Google, Windows Azure, Salesforce, and Rackspace. The figure 3 is presenting the dominant Cloud Computing providers that we include in our study.

Figure 2 *Dominant Cloud computing providers*

As for the sub question 1, the authors will be going to address the differences between the providers from the technical and strategy perspectives. In order to answer this question the authors used the results from the interview and SLR. In the interview, the respondents have been asked to give their thoughts on the technical and strategy perspectives of the cloud providers (See appendix E 1.2 Interview Questions), as for SLR it include the following research papers and web resources as a result of the research study; (appendix B [S1] [S4] [S5] [S6] [S7] [S8] [S13]) and (appendix C [W1] - [W9]). The collected will be used to answer sub question 1 as will be explained in the next paragraph.

Based on the collected data from interviews and SLR, the authors are going to carry out a comparative study in the technical and strategy aspects for each the aforementioned dominant cloud provider. The comparison will be focused on the following aspects: (Cloud services, Platform, Development tools, Database supported, Security, Data Storage & backup, SLA availability, Load balancing availability, market share, and Payment model). For comprehensive information on each of these providers, see Table 7.

3.1 Amazon AWS

Amazon AWS is one of the top leading cloud providers, it has the highest computing power compare to the others. As for the infrastructure perspective, Amazon is a public cloud so it can be accessed anywhere through internet [13] [14]. Amazon is considered to be the most developed Cloud Computing provider that is delivering highly innovative cloud features. In our interview with the cloud experts they all mentioned Amazon as the major and the most advanced cloud provider. Amazon has a set of cloud services provided under Amazon AWS, these services including computation, storage and other functionalities. Amazon AWS enables organizations and individuals to deploy applications and services on an on-demand basis [12] [15]. Amazon initially started offering a Cloud based Message Queuing service called Amazon Simple Queue Service (SQS). They eventually added services like Mechanical Turk, Simple Storage Service (S3), Elastic Compute Cloud (EC2), A CDN service called CloudFront, a flexible and distributed database service called SimpleDB. As for the availability of MySQL database they provide a service called Relational Data Service (RDS) [13] [16]. For a comprehensive overview of Amazon's products and services, see Table 7.

3.1.1 EC2

Amazon Elastic Compute Cloud (Amazon EC2) is a web service provided by Amazon to supply a manipulated computing power in the cloud, or in simple words, it is renting a virtual server that is running on a remote location [15]. These virtual servers called Amazon Machine Images or AMI, and they are running on top of Amazon's data centers. EC2 provides a library of pre-configured AMIs templates, these AMIs containing a set of libraries and associated configuration settings, so launching a new server is no longer difficult. Now it could only take as less as few minutes to launch a stack of high-performance servers, while in the classical way, this process could take up to a few weeks or even months. EC2 also provide a remarkable change when it comes to scalability, helping the developers to scale their resources to meet the service requirements, and so it become easier for the developers to scale the computing capacity (up and down) by adding or removing computing instances to meet the desire requirements of the developed service, with no need to spend a lot of investments to buy an expensive hardware or software applications, that could be wasted if the service popularity did not go well in the future, i.e. Online gaming. It could be also used to prevent any failover scenario.

As for security concern, EC2 provides a multilevel security strategies, security for the host operating system, security for virtual instance operating system or guest operating system,

security for a stateful firewall and signed API calls and security for the network communication.

Amazon EC2 is providing a true virtual computing environment allowing you to use web service interfaces to launch instances with a diversity of operating systems, load them with the custom application environment, manage the network's access permissions, and run the image using as many or few systems as you desire [16].

EC2 uses Xen virtualization to allow several machine images to execute on the same computer hardware concurrently. Each virtual machine, called an "instance", functions as a virtual private server. EC2 provides instances of different sizes, the size of the instance is based on the "elastic compute unite". EC2 offers instances of different sizes, starting from a micro instance with 2 EC2 units and 633 MB memory up to extra large instance with 8 EC2 Compute Units (4 virtual cores with 2 EC2 Compute Units each) and 15 GB memory. It also provides a wide range of instances with very high CPU and memory capacities [16].

Generally Amazon's charging for what the customer uses pay-per-use business model, with no subscription or extra fees. The primary charging aspects of EC2 are defined as following; 1) hourly charging: charging based on the time per running virtual machine. 2) Data transfer charging: charging based on the amount of data being transferred [16].

3.1.2 S3

The Amazon Simple Storage Service (S3) is an infrastructure storage service that provides the users of Amazon the ability to store their data. For that S3 is using the infrastructure that Amazon uses to run its own global network of Web sites. S3 is considered to be a virtual file system that provides constant storage capacity to applications [13] [14] [17] [19]. Generally there is no restriction by Amazon on the essence of the data that is hosted by S3, however all the users are subject to follow the "AWS terms of use" so their data contents must not violate the law. It is worth emphasizing here a popular case in late 2010 when Amazon AWS announced it would stop hosting the data of WikiLeaks, a website that is specialized in publishing secret documents. Amazon claimed that WikiLeaks had violated the "AWS terms of use", however WikiLeaks denied those claims. Nevertheless, some experts believed that Amazon's actions demonstrated censorship [16].

S3 data is stored as objects accompanied by metadata. The objects are organized into buckets, where every bucket has defined access permission [18]. The size of the objects can be up to 5GB and 2kb for metadata [15]. All the objects can be accessed using REST or SOAP calls [17].

3.1.3 Amazon Simple Queue Service

SQS is the message queue on the Cloud. It supports programmatic sending of messages via web service applications as a way to communicate over the internet [13]. Message Oriented Middleware (MOM) is a popular way of ensuring that the messages are delivered only once. Moving that infrastructure to the web is expensive and hard to maintain. SQS gives this capability on-demand and through the pay-by-use model [17]. SQL is accessible through REST and SOAP based API [17].

3.1.4 Amazon Cloud Front

CloudFront is another sort of storage service provided by AWS [12]. CloudFront provides a Content Delivery Network (CDN) services. When your web application is targeting the global users, it makes sense to serve the static content through a server that is closer to the

user. One of the solutions based on this principle is called Content Delivery Network (CDN) [13]. But this infrastructure of geographically spread servers to serve static content can be very expensive. Amazon is having a presence in its data center in different geographical locations all across the globe locations [13]. CloudFront utilizes S3 by replicating the buckets across multiple edge servers. Amazon charges you only for the data that is served through CloudFront and there is no requirement for upfront payment.

3.1.5 Amazon SimpleDB

SimpleDB is a database administration tool by Amazon. SimpleDB is used by the developers to simplify the storage and query of data items, the developers can use the web services of SimpleDB to store and query and data items. SimpleDB is a flexible, highly available and ease to use tool, so it helps to reduce the administrative expenses for managing and maintaining the database systems [17]. To provide high availability SimpleDB creates a number of data replicates that are distributed in a multiple geographical locations. SimpleDB provides a set of APIs to provide high security and to provide the users with domain-level control to control the access to their data [12].

3.1.6 Amazon RDS

Amazon RDS is a web service that provides a simple way for setting up, operating and scaling the relational databases in the cloud. Using RDS will give the user access to the functionalities of MySQL and Oracle database. One of the main advantages of RDS is the easiness of installing, configuring, managing and maintaining the database servers. RDS is supported with a set of API calls, these APIs provide RDS with the flexibility to scale the computing instances linked to the relational database systems. As for the pricing the model, RDS priced on “Pay-as-you-go model” so the users pay only for the resources they use [16].

3.2 Google

Google is a public cloud provider however it is not providing Infrastructure as a Service (IaaS); it provides Software as a Service (SaaS), and Platform as a Service (PaaS). Google App Engine GAE is Google's application development and hosting platform. GAE provides the service of building high-traffic web applications without having to manage high-traffic infrastructure. For any application that is built on GAE, it uses the same technology that powers Google's websites for speed and reliability [15] [20]. GAE virtualizes applications across multiple servers and data centers [20]. It differs from other cloud services like AWS, that it is a Platform as a Service while AWS is an Infrastructure as a Service. GAE is free up to a certain level of use resources. Fees are charged for additional storage, bandwidth, or CPU cycles required by the application [20].

Each App Engine resource is measured against one of two kinds of quotas, a billable quota or a fixed quota. Billable quotas are resource maximums set by the application's administrator, to prevent the cost of the application from exceeding your budget. Every application gets an amount of each billable quota for free. It is possible to increase the billable quotas for the application by enabling billing, setting a daily budget, then allocating the budget to the quotas. Pay-as-you-go, this billing criterion is used in GAE, so users will be charged only for the resources their app actually uses, and only for the amount of resources used above the free quota limit. The other charging criterion is fixed quotas where resource maximums set by App Engine to ensure the integrity of the system. These resources describe the boundaries of the architecture, and all applications are expected to run within the same limits. They ensure that another app that is consuming too many resources will not affect the performance of other apps [20].

GAE supports the following platforms: Java Runtime Environment and Python Runtime Environment. GAE supports the following services and tools: Memcache, URL Fetch, Mail, XMPP, Images, Google Accounts, Task Queues, and Blobstore [15].

Google App Engine lets customers run their web applications on Google's infrastructure. App Engine applications are easy to build, maintain, scale as traffic and data storage need grow. Uploading applications to App Engine and starting to serve, no servers are needed to maintain. Google App Engine uses a principle called defense in depth to secure the App Engine, and is not relying exclusively on a secure interpreter, or any other single security layer, to protect their users. However, its detail is not divulged [12].

Google also provides a number of cloud web services under the name Google Apps, the services from Google providing an independent version of several Google products under a custom domain name.

Google Apps provided in three major categories, 1. Google Apps (Free): This includes free of charge services like Gmail, Google Docs, Google Calendar, Google sites [21]. 2. Google Apps for Business: This includes services like AdSence, AdWords, Alert, Checkout, Voice, Wave, Knol, YouTube and others [21]. 3. Google Apps for Education: Offers a free set of customizable tools that enable faculty, staff and students to do their work more effectively, this service includes Email, Calendar, Talk, Docs, Videos, Sites, APIs, and Support. [23] Other services like Google Apps for Government & for Nonprofit.

3.3 Microsoft's cloud services platform (Azure)

Microsoft's cloud services platform (Azure) is providing a platform as a service and infrastructure as a service. Experts are classifying Microsoft's Azure to have the strongest position in enterprises. Microsoft's Azure platform is mainly consists of three components [15], these components will be described in the following sections.

3.3.1 Windows Azure

In simple terms, Windows Azure is Cloud OS; it runs the windows applications and storing the data on servers in data centers [15]. Windows Azure supports the languages such as .NET Framework and other ordinary languages supported on Windows systems like C#, Visual Basic, C++, and other languages including SOAP, REST, XML, Java, PHP and Ruby for building the applications [15] [22] [55]. It supports general-purpose programs, rather than a single class of computing [15]. Developers are using ASP.NET and Windows Communication Foundation (WCF) technologies to create web applications, applications that run as spate background processes, or applications that combine the two [55] [15].

Windows Azure offers an internet-scale hosting environment built on geographically distributed data centers. This hosting environment provides a runtime execution environment for managed code [22] [55]. Windows Azure stores the data in blobs, tables, and queues, and it accessed in a RESTful way by HTTP or HTTPS [15]. Presently Windows Azure is commercially available in 40 countries [22].

It offers the network functionalities; those are Windows Azure Connect [22] [55], Windows azure content delivery network (CDN) [22] [55]. Windows Azure Connect provides IP-based network connectivity between on-premises and Windows Azure resources, in simple and easy-to-mange way [22] [55]. Windows azure CDN provides best delivering of content to the end users. It enhances the user performance and reliability by placing the data closer to the user [22] [55].

3.3.2 SQL Azure

SQL Azure built with SQL server technologies, it offers the cloud-based relational database service (RDBMS) [15]. It is a highly available, scalable, multi-tenant database service hosted by Microsoft in the Cloud [23].

SQL Azure mainly consists of three components, one is SQL Azure Database is Cloud-based Database management system [55]. It helps to ease provisioning and deployment of multiple databases. Developers do not have to install, setup, and patch or manage any software, as all that is taken care about Microsoft to this platform as a service (PaaS). This means it doesn't require the physical administration. It has a High availability and fault tolerance is built-in it [23]. Second is SQL Azure reporting is an edition of SQL Server Reporting Services (SSRS) that is running in the cloud. It is mainly intended to use with SQL Azure Database, it allows creating and publishing standard SSRS reports on cloud data. Third, SQL Azure Data Sync allows synchronizing data between SQL Azure Database and on-premises SQL Server databases and also synchronizing the data across different SQL Azure databases in different Microsoft data centers [23] [55].

3.3.3 .NET Services

In earlier Windows Azure platform AppFabric is also known as .NET Services. It offers distributed infrastructure services to cloud-based and local applications. The .NET Services facilitate the creation of distributed applications [15]. AppFabric consist of three components one is Access Control [55], it provides a cloud-based implementation of single identity verification across applications and companies, and it means to secure your Cloud services and applications. The second component is Service Bus [55], it helps an application expose web service endpoints that can be accessed by other applications, whether on-premises or in the cloud [15]. Each exposed endpoint is assigned a URI (Uniform Recourse Identifier), which clients can use to locate and access a service; it means a secure connection between on-premise and Cloud services. Third, caching it is common for applications to access the same data over and over.

A fabric controller is software it monitored the all physical resources, VMs and applications in the data centers [15]. With each application, users upload a configuration file that provides evidence-based XML applications that need. Based on this file, the fabric controller to decide which new applications to be run, choose to optimize utilization of physical server hardware [15].

Microsoft's cloud services platform also offers some other services, those are Windows Azure Marketplace is an online service for purchasing the Cloud data and applications [22] [55]. The windows Azure platform appliance is a turnkey cloud platform; it offers the customers to set up their own datacenter, across hundreds of thousands of servers [22] [55]. This is designed for specially service providers, large enterprises and governments [22] [55]

3.4 Salesforce

It is one of the fastest growing cloud providers in the market; it is a leader for business applications.

3.4.1 Sales Cloud

All leading sales organizations are moving to the cloud [24] [26]. For fast, easy access to the tools, services and build strong relationships with customers, without the risk and expenses associated with traditional software [26].

Sales cloud is world number one sales application [24] [26]. It eliminates the fruitless tasks (minimize the administrative tasks) and focus on what matter most (selling). Sales cloud is trusted sales application for more than 92,300 Salesforce customers throughout the world [24]. Sales force design the sales cloud ten years ago to be as easy to use consumer websites like Amazon.com [24]. It connects the social networks and online communities and delivers the information up- to – minute directly to the organization (seller) [24]

It offers chatter, marketing and leads, email and calendaring, opportunities and quotes, partner management, Analytics, Appexhcange, force.com platform and mobile, it offer everything on sales cloud [24] [26].

In 2010 October salesforce.com-sponsored survey by Market Tools, more than 6,000 salesforce.com customers reported average improvements of 42 percent in forecast accuracy, 25 percent in sales win rates, 34 percent in sales productivity, 33 percent in lead conversion rates, and 29 percent in sales revenues [24].

3.4.2 Service cloud

Service cloud is platform for next generation (future) customer service; the feature everything from "knowledge as a service" to make your agents and customers smarter, a simple and easy to set up a call center, and Facebook/Twitter integration for real-time service conversations [26]. It provides services faster and more responsive across every channel (from the call centers to the social websites) [26].

It is easy to use and customizable because it's all in the cloud, and everyone access to an internet [57]. No need of expensive software and hardware resources [57]. It is flexible; suppose a customer improves the call center they can simply upgrade the service edition without any business disruption [57].

Service cloud is available in three editions. One is Professional edition; it provides basic service and supports any size team. It can also use the service cloud to join conversations about company, products, and services via twitter [57]. Second is enterprise edition is extend service to the Web with customization, automation, and integration [57]. Additionally it includes many force.com platform features [57]. Third is an unlimited edition as Premier Support for customizing Service Cloud app. With Unlimited Edition, the service cloud meets organization specific requirements [57].

The default minimum storage amount of all the customers is 1GB of data and 1GB of files. Professional and Enterprise Editions provide an equal amount of storage for each user that is 20MB of data and 600MB of file. Unlimited Edition provides 120MB of data storage and 600MB of file storage for each user [57].

3.4.3 Database.com or cloud

Database.com is a first enterprise cloud database and it is only built for the cloud [25]. Database.com is designed for next generation applications (social and mobile enterprise applications) [25].

It's open to any developers on any platforms, it supports any language (such as Java, c#, Ruby, Perl, and Objective C) and running on any platform (such as Google AppEngine, Microsoft Azure, Amazon Web services, Facebook and etc.) and any device (such as upload, iphone android and etc.) [25]. It supports open-standards APIs like REST, SOAP, and for authentication to support out and SMAL [25]. It is a social data model user can easily add

profiles, status updates, feeds, and groups to all of their custom apps [25]. It is more trustworthy and secure database [25]. It's open, proven and trusted (trust the 87,000+ business and governments) and certified by ISO27001, SysTrust and SAS70 Type II [25].

3.4.4 Force.com

Force.com is leading cloud platform for business applications [26]. Force.com developed the first service allowing for developers to build the multi-tenant applications hosted on salesforce servers [12]. It is 100% cloud, no need of software and hardware for developing the applications and websites. It offers the mobility, it means, it can run application from any platform or device and also have social feature such as add collaboration features on every app [26].

Force.com has four products one is Appforce, it builds enterprises apps (HR applications, financial applications and etc.). It is five times faster at about half of the cost of traditional software platforms and much more, without being a professional software developer. Because build apps 80% clicks and 20% code [26]. Second is Siteforce, it builds data- rich websites and web apps quickly. Siteforce includes site hosting, content management, a database, and a content delivery network; it's all in the cloud [26]. This means, it takes care of the infrastructure [26]. Third is VMforce, it makes everything fast and easy and build enterprise Java apps without worrying about provisioning, maintaining, or scaling hardware, app servers, or databases [26]. Fourth is ISVforce, it is the fastest way to bring commercial apps to market [26]. If the customers need to distribute their apps it provides the tools and resources [26].

Force.com provides the powerful and flexible security, it concern three aspects of security [56]. One is user security which watches how users are authenticated, second is programmatic security, it audits any customers to log in to the platform, and third is platform security, it is used for offering different access permissions to authenticated users within organizations [12] [56]

3.5 RackSpace

Rackspace is the leader in enterprise-level hosting services to businesses of all sizes and kinds around the world in Gartner's Magic Quadrant for Cloud Infrastructure as a Service and Web Hosting [27] [28]. It offers mainly Managed hosting, Cloud hosting and Email and apps [28].

Rackspace Cloud is a Cloud hosting it is the part of rackspace, and Cloud hosting is the next generation of hosting [28]. Cloud hosting offer different services those are Cloud sites, Cloud files, Cloud load balancers and Cloud servers based on a utility computing basis [28]. The Rackspace cloud provides the fanatical support for all the services [28]. Rackspace cloud have control panel it was custom built by and for their services [28].

Cloud sites are a great Cloud hosting platform similar to traditional web hosting only built on a scale out hardware infrastructure. It runs Windows, Linux or both [28]. Cloud Sites support the PHP 5, Perl, Python, MySQL, .NET 2.0+, ASP and Microsoft SQL Server 2008 application frameworks [28]. Most popular apps WordPress, Drupal, Joomla, and DotNetNuke run really good. A fixed monthly credit card payment gives users access to the service with an allocation of computing, storage and bandwidth resources. This allocation can be exceeded then following usage is billed on a utility computing basis [28].

Cloud files provide scalable, secure unlimited storage for files and media [28]. It's access Via File Manager or API Serve Content at Blazing with Akamai's content delivery network (CDN) [28]. Cloud files are built with OpenStack [28].

Cloud load balancers launched recently in 2011 [28]. Cloud load balancers provide the failover solution without a lot of effort and expenses [28]. Rackspace built its Cloud Load Balancers offering of solutions from Zeus Technology [28]. It features static IP addresses, built-in functions for high availability, a broad range of supported protocols and algorithms, access through both API and control panel, and session persistence [28].

Cloud Servers is a cloud infrastructure service that allows users to deploy "one of fifty cloud servers in minutes (instantly)" and create of "advanced, high availability architectures", similar to the Amazon Elastic Compute Cloud [28]. It's access control panel and open API [28]. You can manage server via iphone, ipad, and iPod touch [28]. Cloud servers" are actually virtual machines running on the Xen hypervisor for Linux and XenServer for Windows [28].

	AmazonAWS	*Google*	*Microsoft Azure*	*Rackspace*	*Salesforce*
Age of service	Since early 2006	Since July2008	Since October 2008	Originally launched as Mosso LLC on March , 2006	Since 1999
Cloud Type	Public Cloud	Public Cloud	Private Cloud, public Cloud	Public Cloud, Private Cloud	Private Cloud
Cloud Services	IaaS, PaaS	SaaS, PaaS	PaaS, IaaS	IaaS	SaaS, PaaS
Products and services	***Compute:*** Amazon Elastic Compute Cloud (EC2), Amazon Elastic MapReduce, Auto Scaling ***Content Delivery:*** Amazon CloudFront ***Database:*** Amazon SimpleDB, Amazon Relational Database Service (RDS) ***Deployment & Management:*** AWS Elastic Beanstalk ***E-Commerce:*** Amazon Fulfillment Web Service (FWS) ***Messaging:*** Amazon Simple Queue Service (SQS), Amazon Simple Notification Service (SNS), Amazon Simple Email Service (SES) ***Monitoring:*** Amazon CloudWatch ***Networking:*** Amazon Route 53, Amazon Virtual Private Cloud (VPC), Elastic Load Balancing ***Storage:*** Amazon Simple Storage Service (S3), Amazon Elastic Block Storage (EBS), AWS Import/Export ***Web Traffic:*** Alexa Web Information Service, Alexa Top Sites ***Workforce:*** Amazon Mechanical Turk	**Google Apps Engine:** Memcache URL Fetch Mail XMPP Images Google Accounts Task Queues Blobstore **Google Apps:** Gmail Google Docs Google Calendar Youtube Google Videos Picasa News Etc...	***Windows Azure:*** Compute, Storage, Virtual network, CDN, Appfabric, Marketplace, Appliance ***SQL Azure:*** SQL Azure database, SQL Azure data Sync, SQL Azure reporting, Appliance	***Cloud hosting:*** Cloud servers Cloud sites Cloud files Cloud load Balancers	Sales Cloud Chatter Service Cloud Force.com Data Cloud Jigsaw Heroku Remedyforce AppExchange
Data Hosting Locations	US-N. Virginia, US-N. California, EU-Ireland, APAC- Singapore Cloud Zones: EC2East, EC2 AsiaPacific, EC US-East, EC-US-West	Not available	Not available	1. Desoto, Texas, United States, 2.San Antonio, Texas, United States, 3.Thousand Oaks, California, United States	United States Singapore
Payment Model	On-demand pay as you go model They have two type special services 1. Amazon Flexible Payments Services(AFS) 2. Amazon Devpay	On-demand pay as you go model	On demand pay as you go, and subscription offer	(Pay as you go) model. Payment is by hour and they provide monthly cost estimation.	Using (PaymentConnect), it is a payment solution used by Salesforce, This payment solution is can be used by small businesses and large enterprises.
Technical Support	Limited technical support. They provide AWS Premium Support, and there are different packages of service methods and response times, as Platinum is the highest with 24/7/365 availability. The lowest is Bronze with limited service hours. They guarantee response accordingly for each package: Bronze- 12 hrs, Silver- 4 hrs, and Gold- 1 hr Platinum- 15 minutes.	Access to help center and phone support for customers on a 24 x 7on a priority basis. P1 Priority is answered within one hour for 24x 7. P2, P3 & P4 Priority support Requests are responded to during business hours of the location to which the Requests are assigned. P2 Requests will be responded to with an initial target response time of 1 business day or less.	Online service is available for technical support for all cloud product services	24x7x365 Chat/Phone/Ticket Support	Offers three levels of support. Basic Support is included with the license, so the customer can take advantage of self-help resources and Web support at any time. Premier Support offers 24x7 phone support, with fast response time and a priority queue to reach our technical experts. Premier Support with Administration provides all those benefits, plus access to a specialized team of certified administrators who will help to manage the client system.
Market Share	50%-60%	9%-10%	8%-9%	10%	8%
Availability guarantees with SLA	Amazon EC299.95%, Amazon S3 99.99% and Amazon CloudFornt 99.99%	100% uptime	99.9% uptime	Cloud servers 100%, Cloud files 99.9% Cloud sites 100%	99.9%+ uptime

Table 7 *Comparison between the cloud providers*

4 IMPACTS OF CLOUD COMPUTING

This chapter proposes several impacts regarding the trust, privacy and legal aspects in Cloud Computing. It reports the results of the SLR and the interview that are covering the research question 2. The reader can refer to (appendix E 2.1 interview questions). We also included research papers from the SLR study (see appendix B [S10] [S11] [S12]).

In this thesis we assess how legal aspects, trust and privacy issues occur in the context of Cloud Computing and discuss the ways in which they may be addressed. In light of the carried out a study, we address a number of the most important challenges of trust, privacy and legal aspects according to literature and experts view, then we discuss these challenges by giving a brief description for each issue and trying to find how they could be moderated. We believe that there are some interdependences and correlation between these issues, however we think it would be more helpful to study the impacts of each issue independently, in doing this we take into account the different delivery and deployment models for Cloud Computing.

4.1 Privacy

In Cloud Computing environment, privacy is an important aspect [31]. Cloud Computing, an increasingly prominent model these days, in which services, data, files and all records of the client are brought out on a rented hardware server that the client do not own or manage. These data are uploaded by the client to the cloud, which means that they typically results in the user data being present in unencrypted form on a machine the users does not own [58]. Cloud providers need to protect the privacy of personal data that they hold on behalf of organizations and users. In particular, it is essential for the adoption of public cloud systems that consumers and citizens are reassured that privacy is not compromised [30].

The privacy threats vary according to the nature of the cloud scenario, since some clouds and services might face a very low privacy threats compare to the others, because the less use of public contents. However, a more consideration on privacy need to be taken into account if the service handles personal information, in collecting, transferring; processing, sharing or storing it. As an example: social networks, calendars and personal pictures that are uploaded on a public site, are requiring a privacy to be taken into account, since the potential risk is high. These services could have some sort of embedded tracking and profiling of the user‘s privacy data. The public cloud that is accessed through the Internet is one of the most means when it comes to the increasing threats of the privacy concerns.

In the next text, we address some important privacy challenges; these challenges can be described as special in the Cloud Computing context.

1. Lack of user control: As soon as the user is using SaaS environment, then he or she will not have much control over their data. The storage of data becomes the responsibility of the service provider, so the control of data for the user become very limited, the users of the cloud do not own or control the machines, so there is a threat of theft, and misuse [30].

2. Unauthorized secondary usage: There is a possibility that the data of the client may be put in a not-permitted uses. It is part of the standard business model of Cloud Computing that the service provider may gain some returns from approving secondary uses of the users' data, usually in targeting of advertisements [30]. However, some secondary data uses would be very unwelcome to the data owner, such as for example the release of sales information.. Etc... At present there are no technological barriers to such secondary uses.

3. Data transportation: It becomes difficult to observe the data flows if the data location is changed regularly or exist in multiple locations at the same time. It is also necessary to verify

the conditions that would legalize such data transfers. If the data movements are geographically unlimited under some local laws, in Europe, data transfers to third countries often require an agreement or other preparations to be in place (e.g. EU "model contracts" or US Safe Harbor registration for data transfers to the US). It may become difficult to fulfill these arrangements if data locations are not stable. Across the data movement into the cloud and potentially across and between legal jurisdictions, including off-shoring of data processing, increases risk factors and legal complexity [32] [33]. Governance and accountability measures also become more complex as processes are outsourced and data cross organizational limits [34]. The risks that can arise from choosing the wrong business partner can be daunting and very difficult to assess, especially in cloud based environments, where even knowing the jurisdictions involved can be quite difficult [35]. Issues of jurisdiction (i.e. About whose courts would hear a case), which law applies and about whether a legal remedy can be effectively enforced need to be considered [36]. As considered also in the following subsection, a Cloud Computing service which combines outsourcing and off-shoring may raise very complex issues [37]. Hence, it can be difficult to ascertain privacy compliance requirements in the cloud.

4. Sensitive entrusted information: It is almost possible to host any type of data on the Cloud that includes highly valuable, confidential and sensitive data information like: (bank account records, company assets, health records … etc.), So is it really Entrusting to provide such kind of information to be hosted on a machine that you do not own or control! This information to a Cloud increases the risk of uncontrolled spreading of that information, or to be used by a third party with an interest in the information [31].

5. User access rights to information: By given the users of the same Cloud to share the permissions of data processing and the data storage facilities, they are by nature exposed to the risk of information leaking [31].

6. Data theft: There can be a risk of data stealing from the servers and databases in the cloud some of the employees of the cloud service providers itself or by data hackers breaking into the servers of service providers. Governments in the countries where the data is processed or stored may have some interest also to steal the data [59] [60].

7. Localization of information and applicable law: The physical location of the data is so important for defining the privacy rule that applies within that area or location, since the judicial legislation is varied from one country or territory to another. Thus, in Cloud Computing this issue is extremely important for the privacy protection of the users' [31]. In this case it becomes important to create a condition that helps the users of the cloud to maintain their privacy rights and for the cloud providers keep their commitments towards their customers' regardless the location of their data, therefore the cloud providers must operate in different jurisdictions in order to avoid the privacy limitation while operating in one jurisdiction location.

9. Contractual rules: Contractual conditions can have direct implications in the privacy and protection of the hosted data (e.g. Defining who actually "controls" the data and who only "processes" the data) [31]. There for it is highly recommended to carefully read the contract terms and conditions and in case of any drought to negotiate with the cloud provider, however some of the providers may offer the possibility of tailored contracts.

4.2 Trust

The linguistic meaning of trust can be defined as "reliance on something in the future" [40]. However the conventional meaning of trust in the context of Cloud Computing can be defined as the reliance relationship between the cloud user and the cloud provider.

There are many different ways in which online trust can be established: security is one of these (although security, on its own, does not necessarily imply trust [41].

Some would argue that security is not even a factor of trust: Nissenbaum [42] argues that the level of security does not influence trust. On the other hand, an example of growing security to raise trust comes from people being more eager to engage in e-commerce if they are assured that their credit card numbers and personal information are cryptographically protected [61].

Another factor of online trust is reputation. Reputation is maybe a company‘s most valuable asset [42] Trust can be lost quickly: as Nielsen states [43]: “Trust is tough to build and easy to lose: a single destruction of trust can demolish years of gradually accumulated credibility”.

Particularly, the issue of trust is one of the biggest problems for the development of Cloud Computing. For any Cloud Computing environment there is a need for mutual trust between the users and the service providers [29]. Evaluate trust in relation to Cloud Computing may be useful to distinguish between social and technological means of providing persistent and dynamic trust, as all of these aspects of trust can be necessary and neither is dispensable [44]. In the next part of this section we are naming a number of trust issues in Cloud Computing.

1. Lack of Customer Trust: When it is not clear to individuals why their personal information is requested, or how and by whom it will be processed, this lack of control and lack of visibility of the provider supply chain will lead to suspicion and ultimately distrust [30]. Customers may become skeptical of using cloud services where personally particular information is concerned, without an understanding of the obligation or involved in the agreement risks faced, and assurance that potential suppliers will address such risks. This is particularly the case where sensitive information is involved, for example financial and healthcare information [30].

2. Trust enhancement through assurance mechanisms: Cloud-computing concept cannot assure full, continuity and control of the Cloud clients over their resources. For these reasons, the establishment of suitable “checks and controls” to determine that Cloud providers meet their commitments becomes very relevant for Cloud users (for example, through adherence to generally-accepted standards) [31].

3. Visibility: Migration to cloud services hand over control to the service provider for securing the systems on which the organization‘s data and applications work. To avoid creating gaps in security, management, procedural, and technical controls must be applied commensurately with those used for internal organizational systems. The task is formidable, since metrics for comparing the security of two computer systems are an ongoing area of research [63]. Moreover, network and system level monitoring by the user is generally outside the scope of most service arrangements, limiting visibility and the means to audit operations directly. To ensure that policy and procedures are being enforced throughout the system lifecycle, service arrangements should contain some means for gaining visibility into the security controls and processes employed the service provider, as well as their performance over time.

4. Risk Management*:* With cloud-based services, some subsystems or subsystem components are outside of the direct control of the organization that owns the information and authorizes the use of the system. Many people feel more comfortable with risk when they have more control over the processes and equipment involved. At a minimum, a high degree of control provides the option to weigh alternatives, set priorities, and act decisively in the best

interest organization when faced with an incident. In choosing between an in-house solution and a cloud-based implementation, the associated risks need to be assessed in detail.

Assessing and managing risk in systems that use cloud services can be a challenge. Ideally, the level of trust is based on the amount of direct control the organization is able to exert on the external service provider with regard to employment of security controls necessary for the protection of the service and the evidence brought forth as to the effectiveness of those controls [62]. However, verifying the correct functioning of a subsystem and the effectiveness of security controls as extensively as with an organizational system may not be feasible, and the level of trust must be based on other factors.

5. Change in cloud ownership or economy fluctuations: The immaturity of the cloud market or the fluctuations of the global economy may affect some of the Cloud Computing providers or cause a change in the cloud provider ownership. For that reason, users of the cloud should not lose the trust or the confidence in their cloud provider, for that the cloud providers should assure the users that their data will not be disrupted in such a case [31].

4.3 Legal aspects

The legal framework is very important for the protection of the user's private data; it is an important key factor for the safety of the user's personal and sensitive information. There is one national legislation directory in the EU, while in the US there are different legislation directories divided based on specialization, information and geographical area. Legislation directories are also available in other countries worldwide [30]. The basic functionalities of these frameworks are related to all sort of technology and so their authority will be covering Cloud Computing as well. However, these legislation frameworks need to be continuously updated with latest technologies to be prepared and well aware of all the new technologies. The dynamically changing in Cloud Computing, has introduced a number of legal aspects that required a careful consideration when dealing with the data. In the next part we will discuss the legal aspects regarding to Cloud Computing.

First, knowing the routes of the transferred traffic will make it easier to understand the specific laws by which it can apply on the transferred data; otherwise it could be a very difficult task. However it will be difficult to understand the exposure of the transferred data without knowing the routes of the transferred data, so based on that it assure that the particular transferred data fulfills the legislations that applies on a given case [30].

Second, it is a common practice among the companies that when a company handles some confidential data to outsourcer, this company has the responsibility to assure that the outsourcer is protecting these data by applying a reasonable security in to it. In case of Cloud Computing this scenario becomes difficult, that the cloud service provider needs to apply a reasonable security into the data but the problem is that different companies may be involved in the supply chain of the cloud, so that makes it very difficult to ensure that the security terms are applied for all the providers of the supply chain. So in fact in such a case the customer only knows the final Cloud Service Provider and that does not necessarily to be the original provider, so in case of data loss, deletion or alteration to the stored data the initial provider does not guarantee to protect the data, and usually the supply chain providers do not include that in the SLA with the client, so usually in such case of data loss the customer will be the one who will receive the major loss [37].

Third aspect is litigation [46]; the different laws apply depending on the location of the information and where it exists, but in Cloud Computing the information could be located in multiple places at the same time, it may be difficult to know exactly where it is located or it may be in transfer, so the difficulty comes to locate the data , since there are multiple copies

that is located on a different geographical location in the cloud, that can be also used for backup by the service provider, so putting data in the cloud may have concerns on the privacy rights.

Although there have been some steps in developing a law for the cloud technology, there is still much ambiguity in regard to privacy rights in the cloud [47]. However, there are some existing legal regulations that are focused on the treatment of the user's privacy provided by the cloud provider. EU countries usually only permit the personally-identifiable data to be processed if the data subject is aware of the processing and its purpose, and put special limitations on the processing of sensitive data (for example, health or financial data), the explicit permission of the data owner being part of a satisfactory validation for such processing [47]. They generally stick on to the concept of data minimization, that is, they require that personally identifiable information is not collected or processed unless that information is necessary to meet the stated purpose. In Europe, data subjects can reject to allow their personally identifiable information to be used for marketing purposes [48]. Moreover, there may be requirements for the security and geographical location of the machines on which personally identifiable information is stored [49]. European law limiting cross-border data transfers also might forbid the use of Cloud Computing services to process this data if the data would be stored in countries with weak privacy safety laws [50].

Moreover, it is difficult to impose trans-border data flow rules within the cloud. Cloud Computing can exacerbate the problem of knowledge of the geographic location of where Cloud Computing activities are coming, as due to its dynamic nature this can be very difficult to find out. Finally, not least because many Cloud Service Providers rely upon the secondary use of data as part of their revenue, it will be necessary for consumers and Cloud Service Providers make legally binding agreements as to how data provided to Cloud Service Providers may be used. It is likely that in the near future such agreements might be enforceable in a technological sense. This will help improve trust and moderate the effects of the ambiguity of security borders. In general, the legal condition in regard to Cloud Computing is subject to change: legislation has not yet been updated to address the challenges above and courts have not yet experienced many cases particularly associated with Cloud Computing [30].

5 MULTI-CLOUD COMPUTING

In this chapter, the authors present the results of research question 3. It reports the results of the SLR and the interview. The reader can refer to (appendix E 3.1-3.4 interview questions). We also included research papers and web resources from the SLR study, see (appendix B [S2] [S14]) and (appendix C [W11] [W12] [W13]). Based on the authors' own knowledge in the domain and in light of the results of interviews and SLR, the authors present a definition of Multi-Cloud Computing.

Later in this chapter the authors will present the deployment of Multi-Cloud Computing and to address the major benefit and drawbacks of a Multi-Cloud environment.

This chapter is bringing a new contribution by addressing a new definition of Multi-Cloud Computing, as well as it is presenting the deployment, benefits and drawbacks of the new model. It is believed that Multi-Cloud will be the next logical step after Hybrid-Cloud and there are many indicators that are showing more requirements for such a model; however there are a lot of questions, ambiguities and lack of information in the literature regarding to Multi-Cloud. In this chapter the authors are trying to answer some of these questions.

5.1 What is Multi-Cloud Computing

5.1.1 Definitions of Multi-Cloud Computing

The following definition of Multi-Cloud Computing emerged as a result of this thesis:

Multi-Cloud Computing is an advanced model of the Hybrid-Cloud Computing, it is formed from a combination of more than one cloud (private, community, or public) or group of clouds that are not necessarily sharing the same infrastructure, architecture standards, geographical location or security settings.

The aforementioned definition was addressed by the authors, based on the experience of the authors in the domain and the results collected from the interview and the SLR.

The following paragraphs show the readers how this definition was derived and developed.

The interview with the experts contains a question (see interview questions (3.1-3.4) in Appendix E) this question focuses was on the respondent's definition of Multi-Cloud Computing, the benefit and drawbacks of Multi-Cloud according the respondents' opinions and the Multi-Cloud solutions that are available in the market today are used by the respondents' organization.

According to the interview questions, respondents defined Multi-Cloud Computing in different ways as will be followed in the next paragraph:

"Multiple clouds working together as a whole to provide a single service, which to me is very similar to grid computing".

"Multi-Cloud Computing as a multi hybrid cloud, i.e. To use a private Cloud for the secure data, and a public cloud for the less secure data".

"Multi-Cloud Computing for us is a multiple public cloud, hybrid cloud, or multiple private clouds".

However there are not so many resources available in the literature that is discussing Multi-Cloud Computing. In the SLR of this thesis we found only two research papers, see (appendix B [S2], [S14]) to define Multi-Cloud Computing and few other web resources (webinar, and blogs) (appendix C [W11] [W12] [W13]). The following paragraph is addressing the definition found in literature.

According to [54] Multi-cloud means, "Deploying the applications across the different clouds". Multi-cloud is a further step towards the fulfillment of the cloud paradigm, it can present a utilization of private and public cloud into one cloud that inherits the features of both clouds. The main objective of a Multi - Cloud over the other Cloud models is the possibility of using one single cloud that is working together in an integrated manner and used for all purposes, this will allow cloud users to avoid the difficulties of using or learning new interfaces every time they use new cloud.

Designing, developing and managing in the Multi - cloud is different than single-clouded. It takes advantage and strengths of each cloud and combines it into one single cloud [52].

5.1.2 Deployment of Multi-Cloud Computing

Some companies have been working now for some time, on a project to form strategic alliances to make hybrid multi-cloud deployment [52]. Many organizations (including cloud providers and cloud enablers) are looking to the hybrid multi-cloud as the technology revolution of the future and therefore they are trying hard to make this option easily accessible.

There are many challenges that are pulling back the development of multi-cloud computing environment, security is one of the major challenges, in fact the security issues are not only particular to Multi-cloud but it is a general issue for any cloud model. The security issues are related to authentication, encryption, in particular with respect to issues arising from multi-tenancy and concurrency. Other challenges like privacy, trust and legal issues are also of a huge importance toward any development of the multi-cloud environment , therefore they need to be thought about it [51] [53] [54].

The usage of Cloud Computing is growing very fast, and this reflects on the offers of the cloud platforms. Each cloud provider presents different characteristics, different solutions and pricing plans. The emergence of cloud marketplaces of companies that want to buy and sell hosted server capacity online; indeed, startup companies are already pushing the creation of such marketplaces [51]. The evolution of the Cloud Computing shows that it is likely that, in a near future, the so-called cloud will be, in fact a multi-cloud platform composed of a mixture of private and public clouds to form an adaptive environment. The Cloud will also have to be able to cope with changes in resources offer and users requirements.

A number of providers like RightScale, FlexiScale and Eucalyptus are working on the integration of cloud providers to build a multi-Cloud platform [52].

For making the use of multi-cloud computing, there are some issues that need to be considered first. The characteristics of the cloud are a main concern when it comes to collaboration between a heterogeneous network and resources. Since each Cloud is offering a set of characteristics that is not necessary to be the same on the other cloud. For a public IaaS provider like Amazon EC2, it is offering a wide environment to be used by the users in order to give the user the ability to configure the Cloud according to their needs and requirements that is included for example: firewall configurations and public IPs. However for private clouds like OpenNebula or Eucalypus, the users do not have such an open environment but it all depends on the policy of the cloud administrator who manages the Cloud. Issues like this

and other differences between the cloud characteristics, makes these issues in the concern where ever there is a need for a design a Multi-cloud environment.

It is worth emphasizing here, that Eucalyptus solves some problems regarding multi-Cloud communications by providing a virtual network overlay that both isolates network traffic of different users and allows two or more clusters to appear belong to the same Local Area Network. This feature helps the creating of multi cloud environment mixing private and public resources [51]. In the next two points we are going to point out and discuss the major benefits and drawbacks of Multi-cloud Computing.

5.1.3 Benefits of Multi-Cloud Computing

- As a service provider, you got the option to run your service on an alternative vendor [53]. For example: customers required that the application to be running on more than one Cloud provider.

- Used by the multiple geographic markets [53] [54], to reduce latency and provide customers with the best response time. So companies can look for to establish cloud deployments in each local market.

- Disaster recovery [53]. Multi-cloud helps the recovery planning normally requires backup systems in multiple physical locations with no shared resources. Architecting cross-cloud server and storage resources in separate locations achieves that goal.

- Unique requirements [53], Multi-cloud provides the user with the ability to select the provider who best meets the requirements of each of the applications according to the customer's desires, so the customer can choose to move to the cloud and get the ability to select from different cloud providers the cloud that better the requirements of his application.

- Hybrid Cloud Strategies, as a customer you get the ability to use the functionalities of both public and private clouds, a mixture of various technologies that supports private clouds, a cloud within a private data center; you might also want to use a public cloud for other applications.

- Optimum mix, in terms of cost and security, it is possible to keep the sensitive data to stay in country or on-premises.

- Provide the possibility to use more features that is not possible in a single cloud environment, i.e. data cross geographical boundaries [53].

- Provide special features, i.e. Content Delivery Network [54].

- Multi-cloud gives the user more freedom of choice and not to be bonded to a specific cloud [54]. I.e. one cloud provider could provide a better feature for specific region.

- Providing scalability [54], for private and public clouds, with multi-cloud it is easy to scale the resources up and down since the user got more choices and not to be locked to a single vendor where it could not be very easy for some clouds to scale.

5.1.4 Drawbacks of Multi-Cloud Computing

- Multi-Cloud Computing is a new area and there are a lot of ambiguities around it; and immaturity of the concept makes customers skeptical about multi-cloud.

- There is no common standard and not a clear understanding of the multi-cloud computing, which could lead to a market misunderstanding.

- Amazon AWS is the dominant provider in the market of about 60% of the market shares, while other providers are having slightly small dominance in the market, so that can cause the smaller providers to follow the characteristics and strategies of Amazon in order to design a Multi-cloud environment [54].

- Multiple Service Level Agreement's, and pricing methods. So it is almost impossible to design an SLA or a pricing method that will fit for all providers [54].

- Data movement in a Multi-cloud environment is expensive and difficult.

- Additional layer needed for managing distribution [54].

- Each Cloud vendor is having it is own set of strategies and characteristics, and so they have different cloud architectures and functionalities, there is a lot of complexity in practice to design a fully multi-cloud environment [54]. The main differences to differ the cloud characteristics are:

  i) APIs (i.e. different resources, format, and versions).
  ii) Abstractions (i.e. network architecture differs: VLANs, Security groups, NAT, ACLs, etc.).
  iii) Storage architecture: (i.e. local/attachable disks, backup, and snapshots).
  iv) Hypervisors and machine images.
  v) Supported features (i.e. spot pricing, RDS, attachable IPs or disks), not just by cloud type, but by cloud instantiation or version.

6 LOAD BALANCING IN CLOUD COMPUTING

Load Balancing is a technical procedure by which it is aiming to share out the workload over one or more computing resources (i.e. computer servers, network interfaces, hard drives, etc.) to achieve best possible resource utilization, maximize throughput, minimize response time, and avoid overload.

According to [71] Server Load Balancing (SLB) is defined as "a process and technology that distributes site traffic among several servers using a network-based device". A load balancer is a device (software or hardware) that distributes load among several computing resources and making these resources appear as one [71]. However, the large and powerful computing and network equipments of the data centers, does not necessarily guarantee that these devices are safe from the risks of hardware failure or performance limitations when the workload become high.

Load balancing in the cloud computing environments is different from the typical techniques and architectures of load balancing. The scalability and complexity of the cloud systems and data centers makes centralized transfer of tasks to a particular server infeasible that it is unlike the classical architecture of servers, there are no physically dedicated servers in cloud computing rather it is a number of virtualized servers sharing the same resources. So such a new architecture is requiring an establishment of a new load balancing techniques that provide effective distributed solutions [72]. The implementation of load balancing in the cloud is achieved by using a number of commodity servers to perform the load balancing [5], [72]. This technology provides a new set of opportunities, at the same time it has it is own challenges.

In this chapter the authors decided to perform an implementation experiment on one of the cloud load balancing solution available in the market (i.e. HAProxy). This experiment on the cloud environment will be used in order to find out what is the impact of load balancing on the performance of different clouds; in this experiment we are using Amazon cloud of multi-availability zones (see section 6.2.1.1 Cloud availability zones). The studied cloud zones will be compared at a number of similar scenarios. The primary goal of this experiment is to illustrate significant conclusions regarding the problem at hand [11].

In general, the experiments are used when there is a need to control the behavior of the tested environment directly. It is very important that the experiment is very well planned and designed so that it can achieve the expected benefits and advantages of it; however it is most likely that a poor designed experiment will not achieve the expected benefits and advantages or it may result a wrong and scattered conclusions [11]. The main objective of an experiment is mostly to evaluate a hypothesis or relationship [11]. To know more about the motivations, aims and objectives for using experiment in this thesis work, (see section 1.2). In this thesis we are following the experiment process suggested by Wohlin et al. [11]. These processes include; definition of the experiment, planning the experiment, operation, analysis & interpretation, and presentation & package. We will go through these processes during this chapter.

6.1 Experiment Definition

The object of study is performance. The subjects are the Amazon AWS cloud instances and HAProxy load balancer. The purpose of the experiment is to find out the performance behavior of the Amazon AWS cloud instances that are located in a different availability zones and to examine the impacts of load balancers under a different testing scenarios. In

this experiment performance is described by the amount of accomplished tasks by a computing instance compared to the time and resources used. Depending on the context, good performance may include one or more of the following:

- Short response time for a given task.
- High throughput[2].
- Low utilization of computing power (CPU utilization).

The goal definition framework of the experiment is followed according to Wohlin et al. [11], and it is described as:

Purpose. The purpose of this experiment is to provide an experimented data for the scenarios under test, so the outcome information could be utilized by the cloud users who are interested in performance enhancement of their cloud through considering load balancing solutions and techniques.

Quality focus. The quality focus is performance in cloud computing.

Perspective. The perspective is from the researcher's point of view.

Context. The experiment is run in a real environment (i.e. Amazon EC2 cloud, HAProxy load balancer).

6.1.1 Experiment Objectives

The primary goals of the load balancing experiment performed in this study are:

1) To determine the performance behavior of the Amazon AWS cloud instances that are located in a different availability zones.

2) To examine the performance impacts of load balancers under a different testing scenarios.

For these purposes we focus on retrieving a small web page (i.e. 105 bytes of text data) from backend servers via the load balancer. Particular testing scenarios will test the performance of cloud under test by measuring the number of HTTP requests that can be served per second.

In order to achieve our goals for this experiment, two main performance aspects were evaluated:

- Traffic handling performance (requests per second) of the Cloud instances.
- CPU utilization for each instance under test.

6.2 Experiment Planning

6.2.1 Experiment context

Experiments were performed to benchmark an Amazon Elastic Compute Cloud (EC2) instances that is running behind HAProxy load balancers. HAProxy was used in the experiment because of it is widely used, open-source software application, high-availability, and the support of load balancing features on the cloud [64]. HAProxy scales its request handling

[2] Throughput represents the maximum simultaneous requests or transactions per second that the web application is capable of handling it successfully.

capacity in response to incoming application traffic. It detects unhealthy instances and automatically redistributes traffic to healthy instances. HAProxy was benchmarked with HTTP LAMP server (Linux, Apache, MySQL, PHP) using the HTTP performance benchmarking tool ApacheBench[3].

Four types of instances were used in three availability zones, LAMP server (Linux, Apache, MySQL, and PHP), RightScale load balancer, MySQL database server and ApacheBench benchmarking tool. We used a server template provided by the RightScale management platform, the used instances for each template were on the same platform, memory size, instance size, architecture, and image operating system. All the instances were running in the Amazon AWS-US-East Cloud, the tests were performed in three availability zones, 1a, 1b, and 1c.

The below list is of the tools and instances used in this experiment, for more details on the instance configurations see table 8.

1) LAMP server (Linux, Apache, MySQL, PHP).
2) RightScale load balancer with Apache/HAProxy 11H1.b1.
3) Database Manager with MySQL 5.0.
4) Benchmarking tool - ApacheBench.

Table 8 *Instances details and configurations*

Platform	***Cloud***	***Availability zone***	***Memory***	***Instance size***	***Architecture***	***Right Images OS***
Linux/Unix	AWS-US-East	us-east-1a us-east-1b us-east-1c	1.7 GB	c1.medium (5 EC2 Compute Units)	I386	CentOS_5.4

In an initial setting, two LAMP HTTP servers running on a medium size EC2 instances were connected with two HAproxy load balancers. All the previous instances are running on the same cloud zone. We have to insure that the LAMP server is up and running and the connection was successfully established with HAProxy, then we run the sample web page using the benchmarking tool ApacheBench, using such tool will make it easy to control the number of requests for each testing scenario and it will also provide a numerical feedback on the performed tests, for more details on the load generating script (see appendix G).

In order to keep control of the experimental environment, all the servers' configurations were identical in terms of memory, platform, and allocated EC2 Compute Units; furthermore all the instances were using the same security settings. In order to manage the requests for different servers that is running the same contents we are going to use Round-Robin DNS load balancing algorithm, it works by responding to DNS requests for a list of IP addresses of several servers. For that we used a DNS management tool (i.e. DnsMadeEasy) to distribute the load equally between the load balancers, while each HAproxy instance was assigned a unique Amazon Elastic IP EIP (see Terminology from the definition of Elastic IP).

As for the procedures for testing the performance of the application servers without the use of load balancing, then the same setup was used and the HAproxy instances were checked out by terminating it and assigning the EIPs to the application servers. Figure 4 shows the basic structure of the experiment where it is demonstrating load balancing in the cloud using Round-robin technique.

[3] ApacheBench - a command line computer program for measuring the performance of HTTP web servers [65].

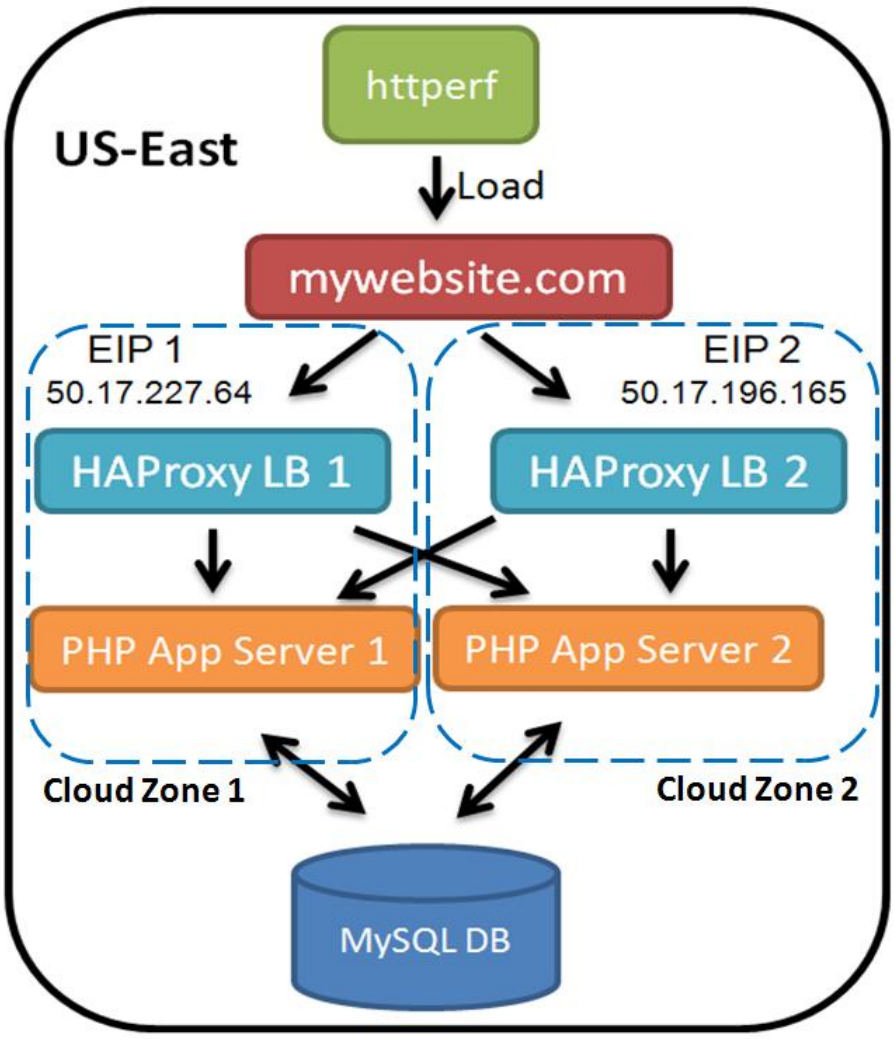

Figure 3 *Load balancing in the Cloud using Round-robin technique*

6.2.1.1 Cloud availability zones

As mentioned in the opening section of this chapter Amazon EC2 is composed of regions and availability zones. Regions are distributed and located in separate geographic areas (i.e. US, EU, etc.). Availability zones are independent localities within a Region that are designed to be isolated from failures in other availability zones. This architecture provides a high possibility of failure independence and stability, so if the servers in one availability zone become fail that failure will not affect the other availability zones in the same region [73]. By launching servers in separate Regions, the applications could be designed to be closer to specific customers or to meet legal or other requirements [74]. However Amazon EC2 does not guarantee 100% availability. According to Amazon EC2 SLA the customers can file a claim if their annual uptime percentage drops below 99.95% [74], for that they only consider the term "Region Unavailable" means that more than one availability Zone in which you are running your servers, within the same Region, is "Unavailable" to you [74]. Figure 5 [73] is demonstrating the concept EC2 availability zones.

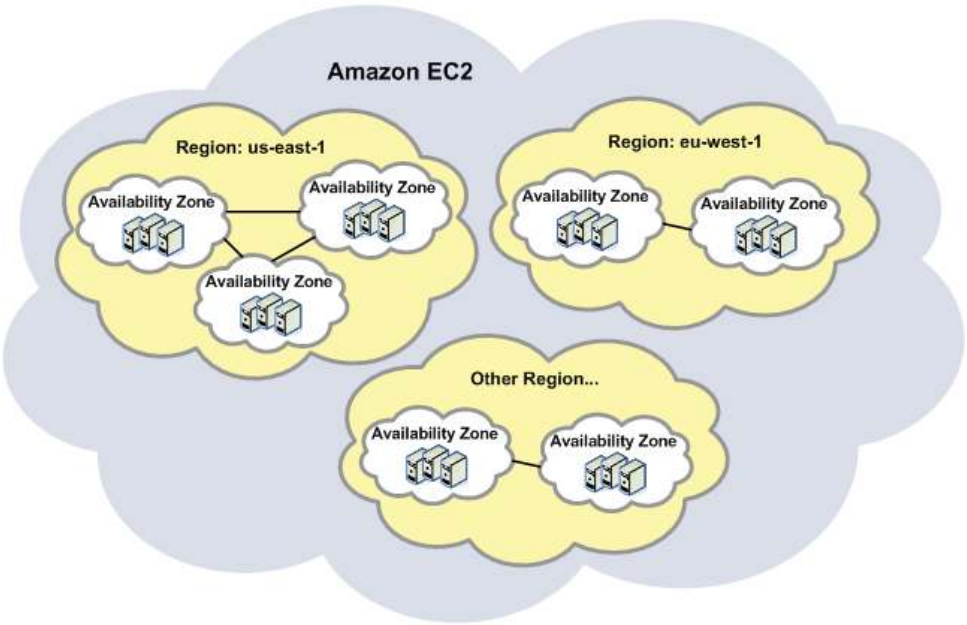

Figure 4 *EC2 Regions and Availability zones*

6.2.2 Hypothesis Formulation

Definition: We assume from the definition presented earlier that load balancing over multiple cloud increases performance. In this case and for all given tasks; increasing performance means short response time, high throughput, and low utilization of the CPU. One or more of the previous attributes will be considered an increase in performance.

In our particular case, servers running behind a load balancer on different clouds of different geographical locations were compared with servers running without load balancing in a single location cloud. To make things easier we will call the first scenario (Cloud behind LB) compared with the second scenario (Cloud without LB).

This informal statement of the hypothesis can be stated formally as follows:

Null hypothesis, H0: Performance remains the same using Cloud behind LB or Cloud without LB.
Alternative hypothesis, H1: Performance increases in Cloud behind LB versus Cloud without LB.
Alternative hypothesis, H2: Performance decreases in the Cloud behind LB versus Cloud without LB.

H0: Performance (Cloud behind LB) = Performance (Cloud without LB)
H1: Performance (Cloud behind LB) > Performance (Cloud without LB)
H2: Performance (Cloud behind LB) < Performance (Cloud without LB)

6.2.3 Dependent and Independent variables

Those variables that are studied to see the effect of the changes in the independent variables are called dependent variables [11]. All variables in a process that are manipulated and controlled are called independent variables [11]. The dependent variable of this experiment is performance; however the independent variables are the Load (HTTP requests) and the Cloud environment itself (i.e. number of server instances, the size of the instance, the

locations, etc.). The experiment consists of a set of tests (trials) where at each test there will be some controlled changes in the independent variables, these changes will be studied for each test to see the effects on the performance (dependent variable). These tests will be repeated for a number of times on a cloud of a different availability zones.

6.2.4 Selection of subject

The selection of subjects is closely connected to the generalization of the results from the experiment [11]. As the subjects were the Amazon EC2 clouds (US-East) from the availability zones (1a, 1b, and 1c). The selected subjects were sampled from Amazon EC2 clouds and the public clouds in general. The selections of subjects were organized through simple random sampling (SRS), in this case Amazon EC2 as the frame, so each element (cloud zone) has an equal probability of selection [36] [75].

6.3 Experiment Execution

Two main performance benchmarking categories were performed:

1) Traffic handling performance.
2) CPU utilization for each instance under test.

6.3.1 Traffic handling performance

To measure whether deployment of HAProxy load balancer causes any gain (boost-up) or loss (bottleneck) in throughput, we ran the same amount of load with and without deployment of HAProxy both in the same cloud availability zone and in a different cloud zones. First we ran the test in the zone (us-east-1a), then we ran again the same test in the zones (us-east-1b and us-east-1c).

To measure the traffic handling performance for using HAProxy load balancer, we monitor the effects of each case scenario, so particularly we are focusing on the gain and loss of the throughput for each case scenario. To implement this scenario, first we ran the test in the zone (us-east-1a), then we repeated the same test in the zones (us-east-1b and us-east-1c). By repeating the same test on a different cloud zones we can insure to get an actual performance results for each of the a cloud availability zones, these results will be used in order to create a conclusion on the behavior of the different cloud zones. There were some technical difficulties to create the same test for a multiple clouds, since HAProxy does not support Multi-cloud load balancing, however we have found a load balancing solution available in the market (i.e. Dynect) that can provide load balancing for multiple-clouds, but due to the limited budget of this thesis, we were not able to buy the license of that solution.

6.3.1 CPU utilization

To measure the performance of the CPU utilization factor of the virtual servers, we ran three load tests (using ApacheBench) every 5 minutes. The test is run on individual servers and will be repeated on the same server setups but running behind the HAProxy load balancer. The purpose of these tests is to monitor the effects of the traffic handling performance (section 6.3.1) on CPU utilization for testing scenarios. In this case degrades or stability of CPU utilization will indicate positive performance however increasing CPU utilization indicates negative performance.

The graphs in Figure 10 shows the runtimes for these tests. For an ideal server these values would be constant and the graphs would display a horizontal line (more fluctuations mean less performance quality). The intention of this test is to monitor the consistency of the CPU performance on different scenarios: how reliable are the run times of the service over time?

And what are the performance differences for an application running on different cloud zones? Due to differences in (infrastructure , data connectivity links, geographical latency .. Etc.) It would be impossible to get an accurate result. So to create a cloud instances performance test, the load benchmarking tests should be all run from a single point with an identical infrastructure environment. For that we have used a Cloud Computing management environment (i.e. RightScale), RightScale is a web based Cloud Computing management platform for managing cloud infrastructure from multiple zones and providers[53]. Figure 6 shows the web dashboard of RightScale, the dashboard is easy to use for launching instances of multiple providers and multiple availability zones.

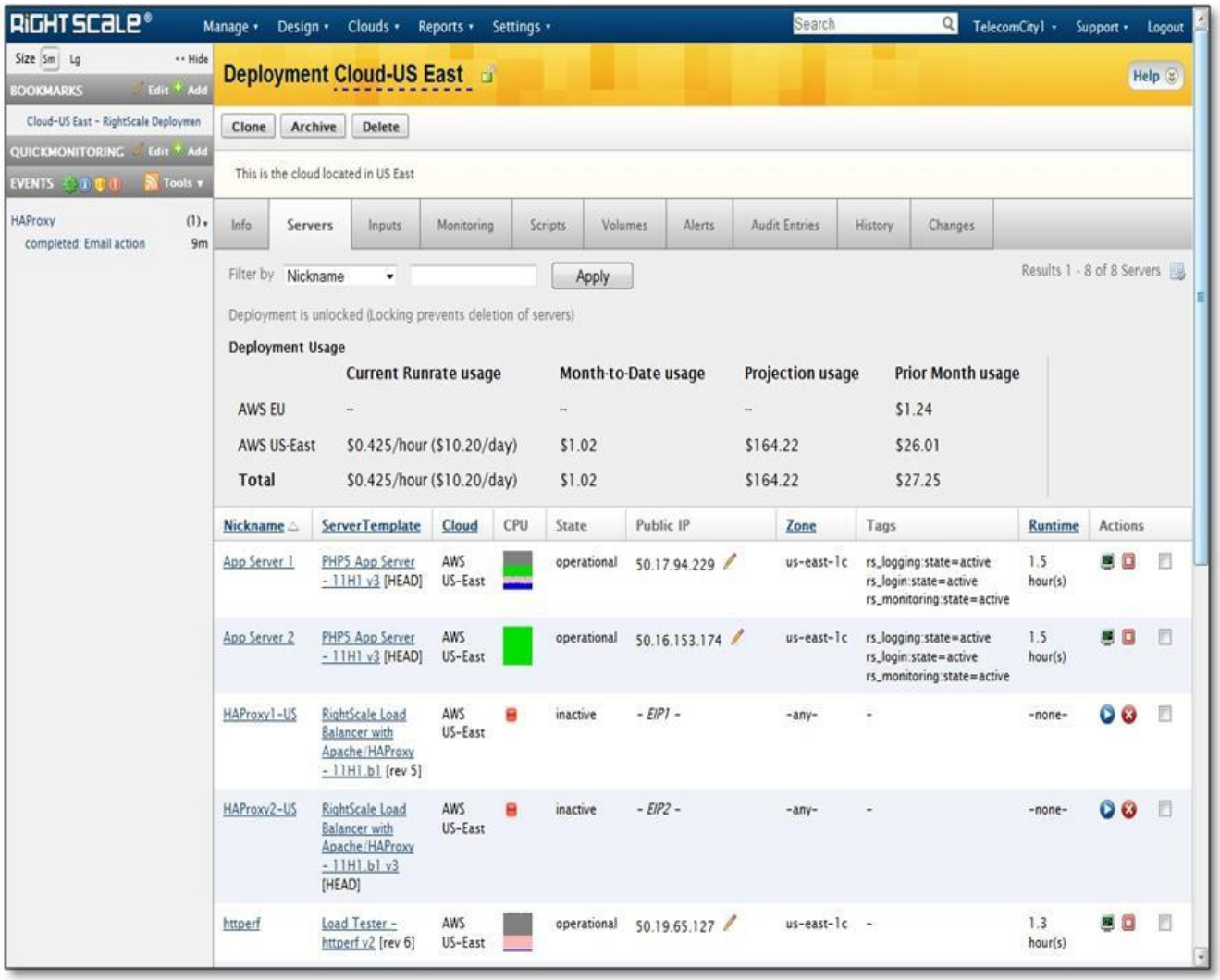

Figure 5 *RightScale's dashboard*

6.4 Experiment Results and Analysis

6.4.1 Traffic handling performance

The zone (us-east-1a) is not showing any significant effects on performance due to HA-Proxy deployment at low to moderate loads. However, at higher loads HAProxy causes significant increase in performance. Figure 7 shows a graphical display of the tests performed in

this zone. It shows a comparison between individual servers and the servers behind a load balancer.

In this zone, the setup at a certain load up to 256 connection requests per second, at that level of load the observed total throughput of the two individual servers without HAProxy is slightly lower than the throughput of HAProxy-enabled servers. Further than 256 connection requests per second, throughput remains stable at around 400 connections per second for the non-HAProxy setup. However there has been a remarkable increase of performance for the server behind HAProxy of about 125%. It happened when the load exceeded 256 requests per second. The increase of performance was steady and quick. At around 1024 request per second the number of served HTTP connection was stopped at around 900 connections per second. There was no major increase in performance of the load beyond 1042 up till 60000 requests per second, it was relatively stable.

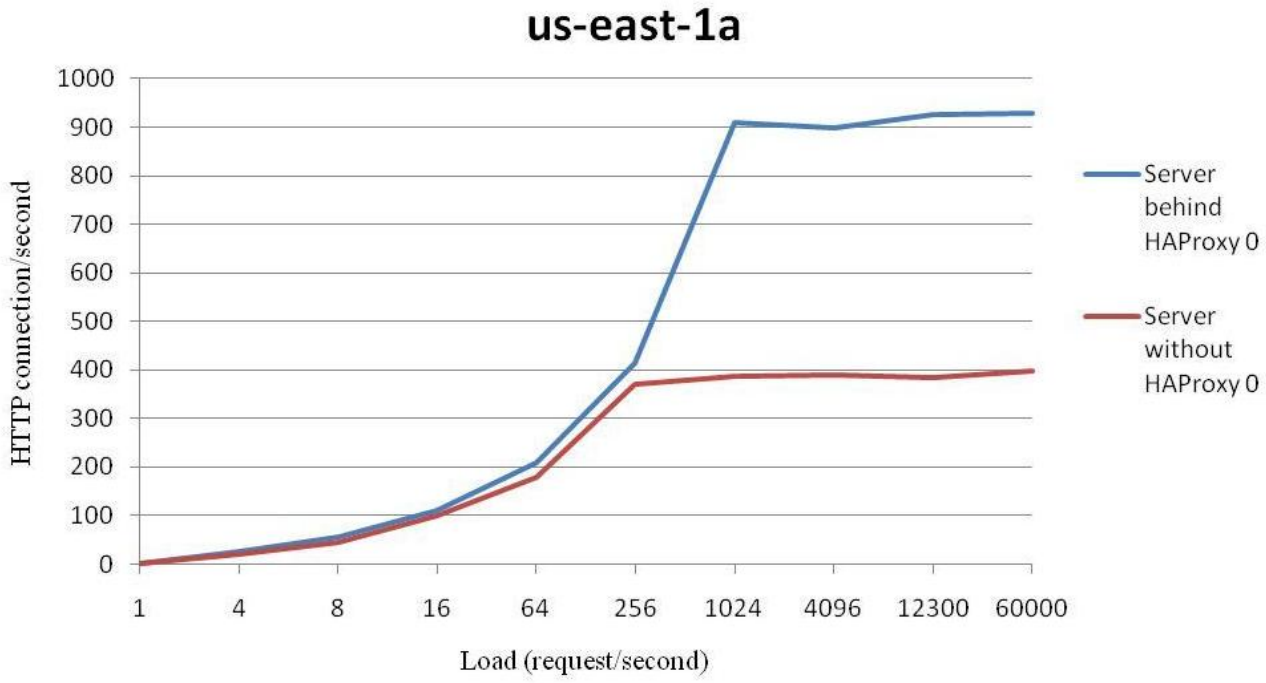

Figure 6 *Comparison between individual servers and servers behind load balancer (a)*

The zone (us-east-1b) is not showing any significant effects on performance due to HA-Proxy deployment at low to moderate loads. However, at higher loads HAProxy causes significant increase in performance on the other side higher loads causes negative effects on the non-HAProxy setup. Figure 8 shows a graphical display of the tests performed in this zone. It shows a comparison between individual servers and the servers behind a load balancer.

In this zone, the setup at a certain load up to 256 connection requests/second, at that level of load the observed total throughput of the two individual servers without HAProxy is almost identical to the throughput of HAProxy-enabled servers. Further than 256 connections requests/second, throughputs remain increasing up to around 400 connections/second for the non-HAProxy setup and 500 connections/sec for HAProxy-enabled servers. At a higher load (i.e. 1024 request/sec) the performance of individual servers quickly degrades of about 20%. The throughput number of served connection was stable at around 400 connections/second for the higher number of load up till 60000 requests per second. However there has been a remarkable increase in performance for the server behind HAProxy of about 80%. It happened when the load exceeded 256 requests/second the increase of performance was sudden

and quick. At around 1024 request/second the number of served HTTP connection was stopped increasing at around 800 connections/second. There was no major increase in performanceofr the load beyond 1042 up till 60000 requests/second, it was relatively stable.

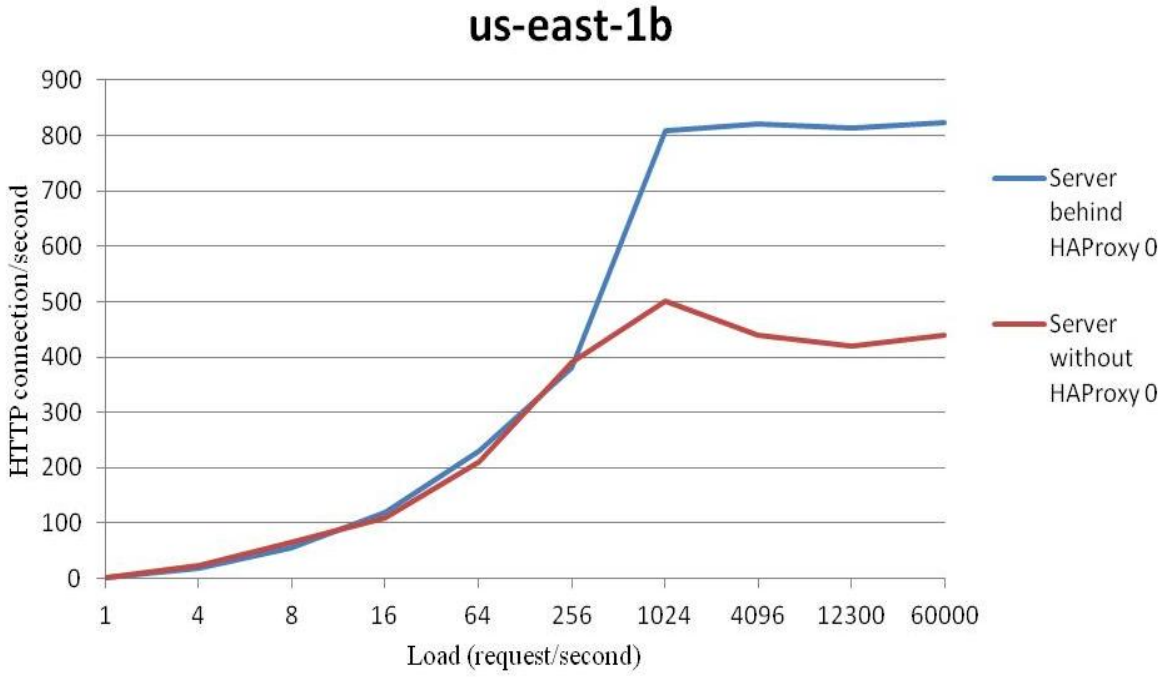

Figure 7 *Comparison between individual servers and servers behind load balancer (b)*

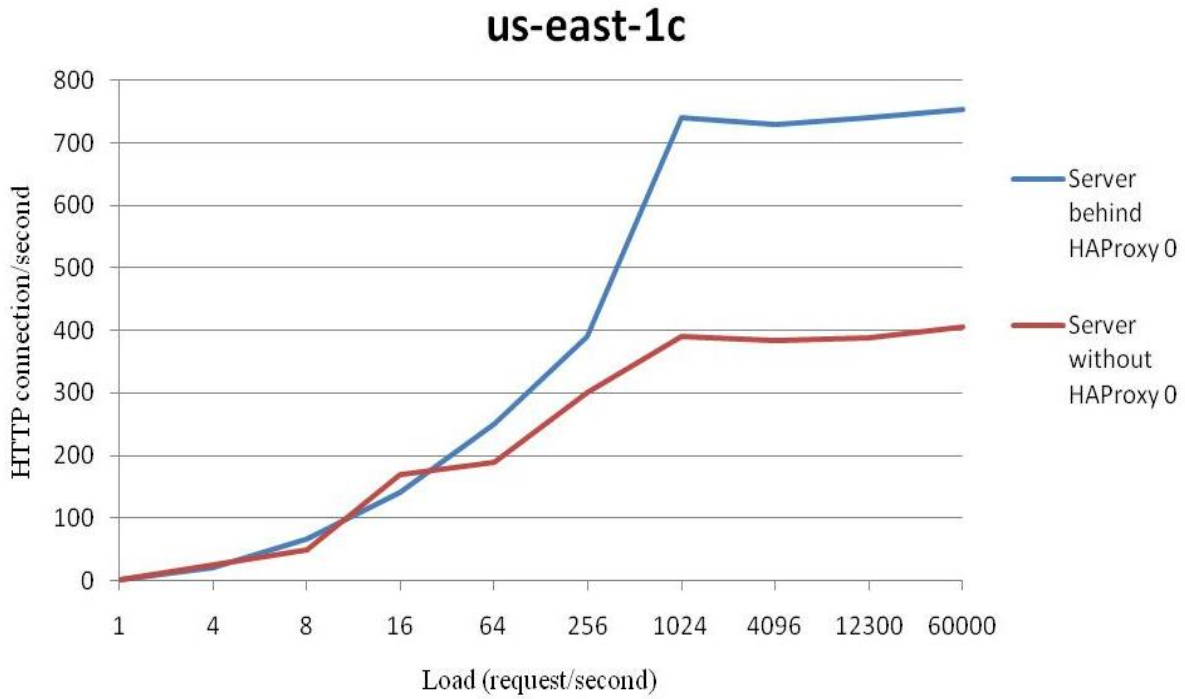

Figure 8 *Comparison between individual servers and servers behind load balancer (c)*

The zone (us-east-1c) is not showing any significant effects on performance due to HA-Proxy deployment at low number of loads. There has been slightly positive effect on performance at moderate load (i.e. 64 – 256 request/second). However, at higher loads HAProxy causes significant increase in performance on the other side higher loads causes negative effects on the non-HAProxy setup. Figure 9 shows a graphical display of the tests performed in this zone. It shows a comparison between individual servers and the servers behind a load balancer. In this zone, the setup at a certain load up to 256 requests/second, at that level of load the observed total throughput for HAProxy-enabled servers was showing a slight increase in performance of about 10% compared to the two individual servers without HA-Proxy. Further than 256 connection requests/second, throughput remain increasing up to around 300 connections/second for the non-HAProxy setup and 500 connections/second for HAProxy-enabled servers. At a higher load (i.e. 1024 request/second) the performance of individual servers quickly stopped increasing. The throughput number of served connection was stable at around 400 for the higher number of load up till 60000 requests/second. However there has been a remarkable increase in performance for the server behind HAProxy of about 90%. It happened when the load exceeded 256 requests/second the increase of performance was sudden and quick. At around 1024 request/second the number of served HTTP connection was stopped increasing at around 800 connections/second. There was no major increase in performance of the load beyond 1042 up till 60000 requests/second, it was relatively stable.

6.4.2 CPU utilization

The graphs shown in figure 10 are showing the CPU run timemeasuress for the performed tests. For measuring the performance of the CPU utilization, we ran a total number of 3 load tests for each server in each availability zone. Each test consists of a different number of HTTP request generated by ApacheBench. We started with a small number of HTTP requests load generating, waiting for 5 minutes between each test in order to get unbiased results that is not effected with any previous test. The HTTP requests as to be followed (100, 1000, 15000, 30000, 60000) request/second. The results of the performed test are not showing any major changes on the the CPU utilization factor of the virtual servers. This will indicate a positive effect on the performance under the performed testing scenarios.

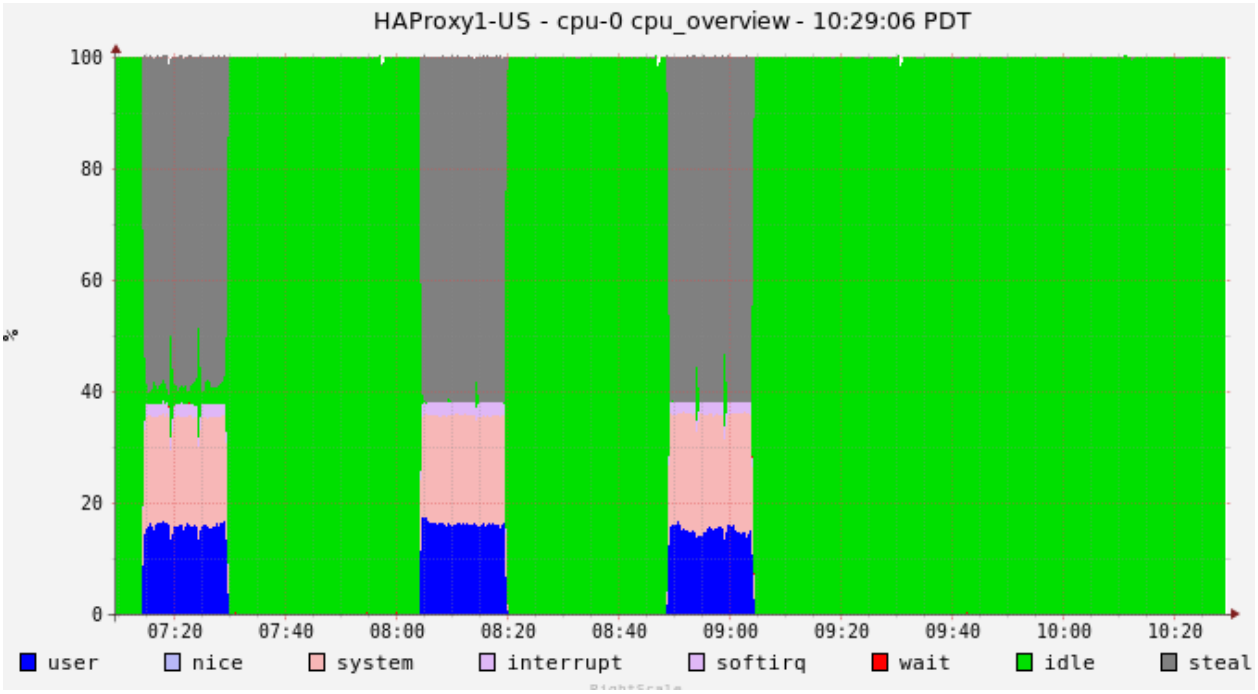

Figure 9 *CPU's performance monitoring*

7 DISCUSSION

This section gives a discussion on major findings of this master thesis.

The thesis was of an exploratory type, the goal of the study was to elaborate and identify a number of controversial trends and performance issues of Cloud Computing. In particular, we identified and compared the major Cloud Computing providers in the market today; we also comprehend the impacts regarding legal aspects, trust and privacy in Cloud Computing. We clarify the benefits and drawbacks of Multi-cloud Computing. Finally we examine the impacts of load balancing on the performance of Cloud Computing.

In order to answer the research questions, we followed mixed methodologies namely as interview, systematic literature review and experiment. Interview was aimed to provide answers for RQ1, RQ2, RQ3 and RQ4; the interview was used as an assistance tool for obtaining the information about the research phenomenon and to get preliminary results on the research questions. The results of the interview were used at a later stage by other research methodologies. The systematic literature review was then conducted; the SLR was aimed to answer RQ1, RQ2 and RQ3. SLR was carried out to gather materials related to Cloud Computing providers, the impacts of Cloud Computing, and identification of the Multi-Cloud Computing model. We created two independent study selection criteria one for research papers other for web contents, a list of the selected resources is presented in (appendices B and C). Experiment was aimed to answer RQ4 to find out the impact of load balancing on the performance of different clouds.

Several cloud providers were named in the interviews in answer for the question "Who are the dominant cloud providers today?" See interview questionnaire (Appendix E) and list of major cloud providers from interviews (Appendix D). All the interview respondents named Amazon at the top of the list; however they got different motivations for their answers but in general they all agree that Amazon is considered to be the most developed Cloud Computing provider that is delivering highly innovative cloud features. For this question we selected two research papers as a final result of the SLR study, (the reader may refer to [S3] [S9]).

A list of providers was developed after considering the results of interviews and SLR (12 providers suggested by interviews and 38 providers from SLR, see appendix D), yet many of the interview findings are consistent with the findings of the SLR. To create a final conclusion of the major providers, we considered four standards for the selection of the dominant Cloud Computing providers, and so all the listed providers were studied according to these standards, the standards are namely: 1) Experts opinions 2) Market share 3) Variety of service type and products offering 4) Information availability. Based on the aforementioned standards we selected the following as major Cloud Computing providers: Amazon, Google, Windows Azure, Salesforce, and Rackspace. The technical and strategy differences were then studied for the selected providers; this section is giving an answer for the sub question 1. Each of the major providers studied independently by investigating the major services, technical and strategy differences among the providers (i.e. Products and services, data hosting location, payment model, technical support, market share, etc.). For further details see Table 7.

The impacts regarding privacy, trust, and legal aspects in Cloud Computing were reported from SLR and interviews; this is used to answer RQ2. For this question we selected three research papers as final results of the SLR study and the data from interviews – the reader may refer to ([S10] [S11] [S12]) and (appendix E 2.1 interview questions).

The results of this study addressed some challenges of privacy in Cloud Computing (i.e. Lack of user control, unauthorized secondary usage, Data transportation, etc.). Privacy is a critical threat for the context of Cloud Computing, as explained in the result of this study it is

very important to understand the privacy challenges for any cloud environment which they may vary according to the cloud scenario. The privacy challenges could be categories into three major areas: 1) access of data 2) security of data 3) control of data.

There are many ways in which trust could be established in the Cloud Computing environment, however building a reliance relationship between the cloud user and the cloud provider could be a problematic issue for the development of Cloud Computing. Therefore it is important to name and clearly define the trust issues in Cloud Computing. A number of trust issues are included (Lack of customer trust, Visibility, Risk Management, etc.).

The impacts of legal aspects in Cloud Computing were studied based on three main factors 1) The routes of the transferred traffic 2) Data management and security in supply chain cloud providers 3) Legal view of the data located on multiple geographical locations.
It is clear that there are still ambiguities with regard to the legal aspects in Cloud Computing, this was reflecting a conflict interview responses and limited amount of information from SLR regarding to this question – the reader may refer to ([S10] [S11] [S12]) and (appendix E 2.1 interview questions).

The study also answered RQ3 related to Multi-cloud computing, first and in order to create a definition for Multi-cloud computing, we asked six interview respondents to define Multi-cloud computing, only one respondent was familiar with the term and had some practical knowledge, second respondent was familiar with the concept but never worked on such a model, third respondent have heard of the term but not familiar with it, other respondents never heard of the term. We have also selected some related resources from SLR – the reader may refer to ([S2] [S14] [W11] [W12] [W13]) and (appendix E 3.1 - 3.4 interview questions). There are not so many resources available in the literature that is discussing Multi-Cloud Computing. The aforementioned resources are not addressing plain and definite definition of Multi-cloud computing. All the resources are only listing the objectives, benefits and drawbacks of the Multi - cloud model but we could not find any specific definition to define this model and it is characteristics. A definition was addressed by the authors, based on the experience of the authors in the domain and the results collected from the interview and the SLR. For more information on how the definition was derived and developed see section 5.1.1. The other sections of chapter 5 were to list the benefits and drawbacks of the model based on the collected information from interviews and SLR.

Load balancing in Cloud Computing environments is different from the typical techniques and architectures of load balancing. The experiment that is presented in chapter 6 is studying a deployment of one load balancing solutions. The aim of performing this experiment is to answer RQ4 related to the impacts of load balancing on the performance of Cloud Computing. The results of the experiment indicate that the performance of the cloud differs depending on the cloud's location. It also noticed significant effects on performance due to HA-Proxy load balancer deployment; these affects can vary depending on the location of the cloud and the load of connections. In general these affects are much more visible at higher amount of load with some differences depending on the cloud's locations. Consequently, the results of the experiment are consistent with our hypothesis, see section 6.2.2.

7.1 Validity Threats

Validity threats must be tackled in order to determine the key elements that affect the accuracy of the results. This section highlights a series of threats, related to our study. The actions performed by the authors to reduce and divert refute, affect the validity of any threat.

7.1.1 External validity threats

External validity refers to the generalizibility of the treatment/condition or outcomes [11].

1. Interview: The external validity is concerned with the ability to generalize the results. The interview was limited in scope as there were only 6 respondents from three companies, and all of the respondents are located in one geographical area (i.e. Europe). Therefore the results are not generalizable. However, in this study the interview results were used as a helping information tool for obtaining the information regarding the research questions, and it was not used as a main research method for answering the research questions.

2. SLR: We have conducted the systematic literature review between the years 2005-2011. By this we have found all the studies from the year 2005-2011 and we have not considered the studies before the year 2005. This can be a threat of missing some studies before 2000. In order to mitigate the above threat we have again run the search in order to find out the studies in the previous years. We could not find any studies related to the search terms and our research study about Cloud Computing and multi-cloud computing.

3. Experiment: There could be some limiting factors on the performance results, due the Internet connection or the geographical location. In order to mitigate the above threat we used to run the same test at different times and to avoid changing the test implementation location.

7.1.2 Internal validity threats

Internal validity refers to whether an experimental treatment/condition makes a difference or not, and whether there is sufficient evidence to support the claim [11].

1. Interview: Some time the low quality of the phone calls and/or the difficulty of understanding the interviewee accent, could lead to a threat of misinterpreting the interview information. In order to mitigate the above threat we used to record the interviews and hear it again or ask a help from friends in order to understand any doubtful words.

2. SLR: Publication business is an internal validity threat which explains about the publications in which the researchers of some papers might have not discussed about the negative factors as much they have discussed about the positive factors in the publications. In order to avoid this threat we have built systematic review protocols and adopted them in a systematic way. Both the researchers have performed the search based on the defined criteria individually. During this process if a researcher finds problem in assessing the acceptance or rejection of the article searched then both the researchers are required to discuss this consequence and make a decision based on mutual understanding between the researchers.

3. Experiment: This threat can have a huge impact on the experiment results if the data collection tools and other instruments are poorly designed. To ensure that the research instruments are well designed and deployed, one pre-test was executed with a direct supervision from the solution provider (RightScale support), the support technician was well aware of the experiments' objectives, and therefore he gave us direct supervision to assure that instruments and data collection tools are well designed.

7.1.3 Conclusion validity threats

Conclusion validity is related to the issues that affect or limit the ability to draw the correct conclusions from the research [11].

Conclusion validity is related to the reliability of the research study results [36]. It is also concerned with issues that affect/limit the ability to draw the correct conclusions from the research [11].

The sampling techniques used for identifying the respondents can pose a threat to the validity of the interview results since the sample is small in number.

Interview is very hard to make conclusions by conducting interviews. In our study interview is helping information tool for research questions and we have conducted SLR for RQ1, RQ2 and RQ3 and experiment for RQ4 for achieving substantial results. Hence there is no reason in treating it is a threat.

8 CONCLUSION

8.1 Revisiting Research Questions

8.1.1 RQ1

Research question 1: *Who are the dominant Cloud Computing providers?*
Sub question 1: *What are the major technical and strategic differences between the providers?*

Cloud Computing becomes a central interest for many organizations nowadays. More and more companies start to step into the Cloud Computing service technologies, to provide services for public and private use, partially because of the nature of Cloud Systems, i.e. reduced upfront cost, expected performance, high availability, infinite scalability, tremendous fault tolerance capability and so on.

Most of the studies on the cloud providers are based on personal observations and do not follow a strict selection standards or a systematic research way. There is a need to study the cloud providers in more details and in unbiased way. A list of 50 major cloud providers was created, (see appendix D). The list was focused to include the five major providers only. The focused list was made according to 1) Experts opinions 2) Market share 3) Variety of service type and products offering 4) Information availability. The five major providers are (in a random order): 1. Amazon 2. Google 3. Microsoft 4. Sales Force 5. Rackspace.

A comprehensive comparison and detailed study was created for the technical and strategy differences among the top five major providers.

All the results of this question are presented in Chapter 3.

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8.1.2 RQ2.

Research question 2: *What are the impacts regarding legal aspects, trust and privacy in Cloud Computing?*

Legal aspects, trust and privacy are some of the most controversial trends in Cloud Computing. The legal framework is very important for the protection of the users' private data; it is an important key factor for the safety of the users' personal and sensitive information. It is likely that in the near future the legally binding agreements might be enforceable in a technological sense. This will help improve trust and moderate the effects of the ambiguity of security borders. In general, the legal condition in regard to Cloud Computing is subject to change.

The privacy threats vary according to the nature of the cloud scenario, since some clouds and services might face a very low privacy threats compare to the others, the public cloud that is accessed through the Internet is one of the most means when it comes the increasing threats for privacy.

Lack of visibility of the provider supply chain will lead to suspicion and ultimate distrust. The issue of trust is one of the biggest problems for the development of Cloud Computing. There is a need to develop a trust relation of the users and the service providers, neither is dispensable.

The results of this question are presented in Chapter 4.

8.1.3 RQ3.

Research question 3: *What are the benefits and drawbacks of a Multi-Cloud Computing?*

In this study we created a definition of Multi-Cloud Computing as "an advanced model of the Hybrid-Cloud Computing, it is formed from a combination of more than one cloud (private, community, or public) or group of clouds that are not necessarily sharing the same infrastructure, architecture standards, geographical location or security settings".

Multi-Cloud Computing is a further step towards the fulfilment of the cloud paradigm; it presents a deployment of private and public cloud into one cloud that inherits the features of both clouds. Using one single cloud that is working together in an integrated manner and used for all purposes.

The evolution of Cloud Computing shows that it is likely, in a near future; the so-called cloud will be in fact a Multi-cloud environment composed of a mixture of private and public clouds to form an adaptive environment.

Despite the indicators that show a growing demand for such model, there is still lack of research on multi-cloud computing.

Lists of benefits and drawbacks of Multi-Cloud Computing are presented in Chapter 5.

8.1.4 RQ4.

Research question 4: *What are the impacts of load balancing on the performance of the Cloud (within different availability zones)?*

Load balancing is a technical procedure by which it is aiming to share out the workload over one or more computing resources. Load balancing in the Cloud Computing environment is different from the typical load balancing. The architecture of cloud load balancing is using a number of commodity servers to perform the load balancing.

The performance of the cloud differs depending on the cloud's location. These differences could be slight or significant.

For Amazon's EC2 clouds of a different availability zones, there could be some differences in performance on each cloud zone even they are running at the same geographical location.

The HAProxy load balancer could be an effective tool for enhancing the performance of the cloud environment, but these affects can vary depending on the locations of the cloud and the amount of load. Most probably they are affective at higher amount of load.

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APPENDIX A: PRIMARY STUDIES OF SLR

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APPENDIX D: LIST OF MAJOR CLOUD PROVIDERS IN INTERVIEW AND SLR

List of major cloud providers from interviews:

1. Amazon
2. Windows Azure
3. Google
4. Rackspace
5. IBM
6. Terremark
7. GoGrid
8. Gartner Magic
9. Quardent
10. Joyent
11. TATA
12. Salesforce

List of major cloud providers from SLR:

1. Amazon Web Services (AWS)
2. Mosso
3. GoGrid
4. Skytap
5. Sun Network
6. Verizon
7. AT&T
8. Azure
9. Google App Engine
10. Force.com
11. EngineYard
12. Ping Identity
13. TriCipher
14. DataDirect
15. Strikeiron
16. MediaTemple
17. Hosting.com
18. Hosting365
19. Gridlayer
20. Joyent
21. Flexiscale
22. 3Tera
23. AppNexus
24. NewServers
25. Terremark Enterprise Cloud
26. Carpathia Hosting
27. CSC
28. Datapipe
29. GoGrid
30. IBM
31. Layerd Tech
32. NaviSite
33. NTT Communications
34. OpSource
35. Rackspace
36. Savvis
37. SoftLayer
38. SunGard

APPENDIX E: INTERVIEW QUESTIONS

CLOUD COMPUTING QUESTIONNAIRE

This questionnaire is done as part of the master thesis titled 'Survey in Cloud Computing' By Ali Al-Refai and Srinivas Pandiri from Blekinge Institute of Technology.
Please take a few moments to complete this questionnaire.
Your responses will help us to meet our target of this research.
All the responses will be kept confidential. Please complete this questionnaire and return it to email …

THE INTERVIEWEE BACKGROUND

1. What is your role in the company? Is it technical or management?

2. How long have you worked in Cloud Computing?

3. How long have you worked in the IT sector?

RELATED TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers today?

1.2 Based on your experience, what are the major technical and strategy differences between the providers?

RELATED TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy in Cloud Computing?

RELATED TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?

3.2 What are the benefits and drawbacks of Multi-Cloud Computing based on your experience?

3.3 What are the multi-cloud solutions currently available in the market?

3.4 Which solution or method is used by your company for multi-cloud computing?

RELATED TO RESEARCH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the Performance in Cloud Computing environments?

ADDITIONAL COMMENTS

APPENDIX F: INTERVIEW TRANSCRIPTS

INTERVIEWEE 1

THE INTERVIEWEE BACKGROUND

1. **What is your role in the company? Is it technical or management?**
   Software service offering it's related to technical and management

2. **How long have you worked in cloud computing?**
   1.5 years

3. **How long have you worked in the IT sector?**
   For 24years

RELATE TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers (please try to estimate relative market shares)?
Amazon, Microsoft azure, Sales force, Google

1.2 Based on your experience, what are the major technical and strategy differences between the providers?
Amazon Microsoft are more providing platform as service and infrastructure as service Sales force and Google are more providing the application as a service(software as service)

RELATE TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy due to using cloud computing?
Yes I see challenges losses of data, I don't have real solution may be in 6months

RELEATE TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?
I heard about the term, I am not familiar with the scenario. We had one customer using with logica private cloud solution, performance

3.2 What are the benefits and drawbacks of multi-cloud computing based on your experience?
They don't need to allocate resource pay resource utilization, very low base performance, accelerate another provider scale up, geo-location.

3.3 What are the multi-cloud solutions currently available in the market?
I don't know, we are investigating

3.4 Which solution or method is used by your company for multi-cloud computing?
No

RELATED TO RESEARH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the performance in cloud computing environments?

No
Major challenges:
Contract legal issues
Monitoring
They are interested move to cloud computing

ADDITIONAL COMMENTS

INTERVIEWEE 2

THE INTERVIEWEE BACKGROUND

1. **What is your role in the company? Is it technical or management?**
   My role is somewhere in between. I am responsible for partner strategy in cloud and developing propositions plus coordinating client engagements.

2. **How long have you worked in cloud computing?**
   For just over one year

3. **How long have you worked in the IT sector?**
   For 11 years

RELATE TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers (please try to estimate relative market shares)?
Amazon for IaaS (40%), still very small market and depends a lot on how you define it. Microsoft for PaaS (20%), still very small market and depends a lot on how you define it. Salesforce.com, Google and Microsoft for SaaS (different offerings so hard to state market share) but SF is clearly the leader with MSFT picking up

1.2 Based on your experience, what are the major technical and strategy differences between the providers?
For Microsoft cloud is key to their future and they make a big bet, being forced to do so by Google as their license revenue is under threat. For Amazon cloud is not core business. Google focus on a niche and excel at user experience where as Microsoft covers the whole range and have a strategy based on the right mix of on-premise and cloud. Salesforce is clearly a leader but do not really go broad. Microsoft has strongest position in enterprises.

RELATE TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy due to using cloud computing?
These are concerns around all clouds. In the case of cloud provided by a set of different organizations a single contract and SLA will be essential.

RELEATE TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?
I had not come across this concept yet so I had to read the material you provided to understand what it is: multiple clouds working together as a whole to provide a single service, which to me is very similar to grid computing.

3.2 What are the benefits and drawbacks of multi-cloud computing based on your expe-

rience?
Optimum benefits mix in terms of cost and security/compliance possible where sensitive data stays in country/on-premise, less dependence on a single provider, could result in moving the load to where it is cheapest (on-line auctions/real-time pricing),(Geo-) Redundancy/fail over, could be a mix of private cloud for sensitive data and public cloud for peak handling of Non sensitive data?
Drawbacks: Multiple contracts and bills, SLAs may be different for each provider and Additional layer needed for managing distribution.

3.3 What are the multi-cloud solutions currently available in the market?
I am not aware of any but for example Microsoft has the concept of backup data centers so your data and application is always available even if a data centre goes down. But if we look at it as a new form of grid computing than it exists already for example in large research organizations (Governmental or European).

3.4 Which solution or method is used by your company for multi-cloud computing?
Need to speak RTIS people

RELATED TO RESEARH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the performance in cloud computing environments?
No experience

ADDITIONAL COMMENTS

INTERVIEWEE 3

THE INTERVIEWEE BACKGROUND

1. **What is your role in the company? Is it technical or management?**
   It is a management and sale role; I head up business development for right scale with EMEA, Middle East and Africa.

2. **How long have you worked in cloud computing?**
   4years

3. **How long have you worked in the IT sector?**
   For 16years

RELATE TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers (please try to estimate relative market shares)?
I think when we look at cloud computing and particularly cloud providers, cloud is typically divided into software as a service, platform as a service and infrastructure as a service. If we focus on the infrastructure as a service part, where you just provide role access to servers, networking and storage. We really see that as the main cloud provider market. You have Amazon who dominant player within the market, then you probably have people like Rack Space, Azure, IBM, Terremark, GoGrid. You have a lot of companies particularly if like at the Gartner Magic Quadrant which is released before Christmas who are web hosting companies and Gartner has sort of web hosting company within pure cloud providers, and we believe the

Gartner Magic Quadrant really isn't as viable as it would be but because what would start a lot of web hosting companies claiming that they have cloud but really what it is, is just re-packaged of their existing web hosting. So if you want me to rank them from the market perspective, pure infrastructure market, you have Amazon who we see having about 50-60% of the market share then you have Rack-Space probably sort of high than 10% way behind them, and then you have sort of 9-8% Azure and IBM, Terremark perhaps same as IBM and then you a lot of smaller companies who smaller and smaller percentage, like GoGrid, Joyent.

1.2 Based on your experience, what are the major technical and strategy differences between the providers?

Amazon strategy is very much will build a very public cloud, they will step into the SLA they, and they are very much 98% of their customers have to give Amazon credit card paying as they go. Where the other providers far more sort of traditional webhosting vendors who moving to the cloud space so they all think potentially high level of service, high sort of support around there cloud offering. But the features and functionalities they are support I would say good 18 months behind Amazon. What we see at the moment that those companies like Azure, IBM, Terremark, RackSpace to a certain extent they are not innovating as fast as Amazon, they are 18 months behind and Amazon innovating and bringing new products a lot quicker than those guys. This is very much focus on the infrastructure as A service, you also have things like platform as a service where you have Google and Microsoft playing along with, you know Amazon is just into that market. Platform as a service is basically delivering rather than access to the infrastructure delivering access to the development environment.

RELATE TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy due to using cloud computing?

Different rules and regulations when it come to different geographies is that , take data protection within UK , data protection of people data means that data can't be housed outside the UK and in worst case can't be housed outside EU, so from our platform perspective what we were able to do is anyone in the company who logs through the platform because the platform can be configured to make available all the clouds that we work with or shut the cloud which not allowed to put data in. so we configure the product to the regulations, if required we had a number of UK customers who do that already, they don't make available Amazon, although we have access to it every one do, but we never see Amazon US cloud available to lunch services. So the product supports the ability to control usage and how and where you lunch servers where you use infrastructure. and that part of the management piece and control piece, what we also seeing is that people will say ok, from a self service perspective from using the cloud, you are only allow to use search and configuration, certain pieces of functionalities of different cloud since that is something can be controlled through the RightScale platform

RELEATE TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?

We are a cloud management platform, so we are a platform that allows customers to get into a specific cloud with their applications quickly and then to manage those ap-plication in the cloud where ever the cloud is through our platform. We see all the different cloud or multi cloud as cloud recourse source. We believe people will choose their application in the cloud based on the characteristics of the application. So multi-cloud computing for us is a multiple public clouds, hybrid cloud, or multiple private clouds. So the concept of being able to manage your internal infrastructure in a cloud format that what people calling private cloud. There are number of technologies that enable you to first lay your infrastructure and then layer on top of it private cloud enabling technology. We provide people with enabling technology and integrate into a number of these, some start saying I will start using both public and private cloud which is where the term hybrid cloud come from, which is a multi cloud strategy, we also see

people using multiple public cloud, so IBM, RackSpace, Amazon AWS, because they need their application to be available in various different locations, one provider can't provide all those locations. Another people are doing multiple private cloud, the sort of aspect of the public cloud, they need different locations, to manage their infrastructure. That's our thinking of multi-cloud computing

3.2 What are the benefits and drawbacks of multi-cloud computing based on your experience?

Benefits: multi cloud allow you to deliver application across all the features you need them to, maybe deliver certain application they need high level of security, maybe the public cloud can't offer and may demand certain level of data protection, because the data is sensitive they can't leave the organization so you use a private cloud for that piece and some other data have geographical boundaries this happened a lot with the UK , there is a lot of government and ex government organizations that is not allow to their personal private data to be housed outside the European community, you can look at London data centers or Amazon data centers in Holland to host this they wouldn't put this data in Amazon in the US, sort of security. Also some cloud have different functionalities that other cloud, some application may need CDN features or contact delivery network feature which only some cloud access, but the big one I think really is people want choice and multi cloud allow to have that choice, it allows them not to be locked to one vendor, we see people start with one cloud as long as that cloud gives them all sort of features and price they stay with that cloud, they may do some private cloud work but we are not seeing a lot of multiple public cloud projects. They only thing that people do is around location, but people always ask for it because people want to have the choice, if they need to move to that cloud or if they want use the ability to threaten one cloud provider so he drop his price or get more price competitive because they could move their application into another cloud. So from our perspective we see a lot of people talking about multi-cloud from the multi-public cloud perspective. One more thing on the benefits is, what we also seeing a lot of people do is, use the public cloud as a "bursting mechanism" for private clouds, what I mean by that, one some people who have an application highly scalable and they only have a certain amount of computing power internally within the private cloud, so if they need for some part of the application to grow up the processing power internally we see people "bursting" into the public cloud. On the drawbacks, we as a company very successful see... all these cloud are different, they have different functionalities a lot of them have different APIs, so there is a lot of complexity, so simply one cloud can't offer what the other cloud can offer, even though a multiple public cloud strategy would work but Rackspace couldn't offer you all the functionalities that Amazon offer you. They also can't offer you the same number of service. Multi cloud is still to deliver the kind of ease of portability, and that's why people r looking for RightScale as a cloud measure platform to bring a layer of abstraction that allow you make the move between clouds a lot easier. Another drawback, from multi cloud we are seeing at the moment there is no great solution for moving data in and out of clouds it tends to be very expensive, to bring the data in defiantly expected to bring the data out , data transfer costs expensive, there are challenges around running multiple clouds based infrastructure , you know if you have a social gaming application that needs a large database behind its database caching layer and web application servers, load balances , it is very difficult to moving that application that starting in a private environment and to move it from one public cloud to another public cloud. so I think one of the biggest challenges and biggest drawbacks is how do they work with the data in a multi cloud work and database. Multiple contracts and bills, SLAs may be different for each provider and Additional layer needed for managing distribution.

3.3 What are the multi-cloud solutions currently available in the market?

3.4 Which solution or method is used by your company for multi-cloud computing?

RELATED TO RESEARH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the performance in cloud computing environments?

RightScale from a load balancing perspective uses a number of products. Everything from Zues to HAproxy and load balancing from Amazon, our platform is a manage-ment platform and it has a configuration management part to it, so from our perspective are we providing a load balancing service across all the clouds, if our perspective is it deploy that, in that manner yes we are. we giving visibility and manageability across the clouds, we can build capability , if a product cloud is hitting a maximum of number of servers utilize and the performance of those servers are hitting CPU utilization is hitting 70% then we can perform an action to lunch server somewhere else, yes , we call that load balancing. we rolled based engine and we are able to create automatic reactions scaling up, scaling out, or reducing the number of your servers based on a particular alerts or schedules so from that perspectives there is a load balancing capability do we have full reusa-bility into all the servers that are lunched in Amazon, Amazon don't tell we have 100 servers left, but what they can say , there is nothing available when you are trying to lunch your server, so we can measure automatic reaction to that so you lunch it somewhere else.

ADDITIONAL COMMENTS

The big challenge is not connecting to these clouds, because these clouds building out their APIs, building out their functionalities, that just a matter of doing the work. The difficult part is not to merge a server, what is the difficult piece is to lunch the server in contacts to the environment or a system or a deployment as we call it, so I need to scale out 5 servers and I need all of them to come up in a particular region of Amazon, I need them to check the load balancer, I need them to check the database and start running the application and running the work loads, for us that where the difficulty of multi cloud exist, you have to be able to create what we call server template that multi cloud aware so the ability to say ok, I will take this template which is base machine image and then the rest of the server being described in the scripting mechanism, to say I need that server to move from Amazon to RackSpace, and I need to see that movement happened in a time of 10-15 minutes. so that's the challenge that there is a lot of work around configuration management area, you see people like ourselves using our methodology around server template we also support people like (Shift and PUPIT) and they work around the configuration management piece to manage the configuration around the cloud, so we see that as the biggest challenge. Going to servers, being able to maintain those servers, manage them through the life cycle. That allow you to say... ok... I want to fail over between different clouds, I want to use multiple clouds, I want to use some clouds for some tasks, other tasks, I potentially want to grow from one cloud to another cloud, allot we are saying that in the hybrid world growing from private cloud to a public cloud and then shrink back to a private cloud. For us the biggest challenge is around the configuration management and being able to bring up these servers in an automatic fashion where they already know where there job when they arrive and then they carry on with the work, and the infrastructure have the ability to flax around you business challenges , that's for us how RightScale is run, we are responsible for the biggest water scaling event in the cloud, people like (Hmoto, Grow) who grow there servers a hundred times every day for the first five days of lunch, and people like Zinga who are running now 20,000 servers in the cloud , where u got people to administrate these servers and they are scaling 20,000 to 30,000 required a time. for us that where we are focusing format the multi cloud perspective is how , that is difficult to do in one cloud, I am sure you are pretty aware of that , Amazon they have 4 regions which are actually 4 separate clouds (2 in US, 1 in EU, 1 in Asia), so if lunch you server on Amazon machine image and let say you lunched in EU and you want to lunch it in Asia, you have to take the AMI (the machine image) and change the AMI so it work, so the cloud have un bun

dle and re bundle, where in RightScale you don't have to do that because the way we build the server template and the configuration management so it is a challenge doing multiple cloud in one cloud like in Amazon perspective. the challenge is how we make these server templates and portable not just cross Amazon but also in RackSpace, portable across private clouds and other public clouds that's coming , so a lot of challenges for us, and that's we are spending a lot of our time. The future demand of multi cloud is growing , in UK we see a lot of interest in private cloud and people say the private cloud will be the way forward , our view the world will go hybrid cloud, as we have said at the start we see all these different clouds, public clouds, and cloud hosted in other providers or clouds hosted in your own datacenter in a private cloud , we see the people using all of them and want to use all of them because of the characteristics of the applications, so the world will be hybrid world. And hybrid immediately will be multi cloud. Within companies purely public environment.

INTERVIEWEE 4

THE INTERVIEWEE BACKGROUND

1. **What is your role in the company? Is it technical or management?**
   Technical
2. **How long have you worked in cloud computing?**
   5 years
3. **How long have you worked in the IT sector?**
   For 14 years

RELATE TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers (please try to estimate relative market shares)?
On the public market: Amazon and Google Private Cloud: Microsoft Azure

1.2 Based on your experience, what are the major technical and strategy differences between the providers?
Microsoft has always targeted the corporate sector with their products first and then the private sector will follow. Google and Amazon is the complete opposite, they always target the private sector first with cheap prizes or even free products at times.

RELATE TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy due to using cloud computing?
This also is a subject that looks for an answer, I truly believe that each sector (bank & finance, Retail, government and so on) have to present their specific needs, rules and legislation that is unique to them. Each Cloud provider then must determine which of these demands they can fulfill and "guarantee" a secure solution for. That package then will give you the design. Important to remember, as of now due to all the different laws and rules out there. Some applications and platforms are not meant to be in the cloud!

RELEATE TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?
My definition of cloud is data storage as close as possible to the end consumer with as little latency as possible.

3.2 What are the benefits and drawbacks of multi-cloud computing based on your experience?
Benefits: low costs for storage, licenses and hardware. Always accessible for the end user no matter what device they use. Legal issues between different countries regarding data transfers, money transactions and so on.

3.3 What are the multi-cloud solutions currently available in the market?
Private/corporate, Public and hybrids. It all depends of the customer's needs and wants

3.4 Which solution or method is used by your company for multi-cloud computing?
We provide a Private cloud solution

RELATED TO RESEARH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the performance in cloud computing environments?
Load balancing solutions is crucial today in "normal" storage infrastructures and it will not lose its importance in the cloud. Load balancing gives you the benefit of a constant load rate and a pleasant user experience. In the cloud load balancing is the key to a proper design and a proper scaling rate.

ADDITIONAL COMMENTS

INTERVIEWEE 5

THE INTERVIEWEE BACKGROUND

1. **What is your role in the company? Is it technical or management?**
2. **How long have you worked in cloud computing?**
3. **How long have you worked in the IT sector?**

RELATE TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers (please try to estimate relative market shares)?
IBM, Sales force, Amazon

1.2 Based on your experience, what are the major technical and strategy differences between the providers?
What are sales in the market? Different business models and delivered

RELATE TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy due to using cloud computing?
I don't know, different situations

RELEATE TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?
No cannot may be you mean that, someone want to utilize different clouds then heard it,
We see it future Terminology is different, it will take some time. We are so many perspectives,

maturity of the customer, Common services

3.2 What are the benefits and drawbacks of multi-cloud computing based on your experience?
Multi-cloud provide building more business utilitarian directly end customer they want to have multi cloud computing, dependent on the prices cost of development, It more complexity, Hybrid cloud is different to multi cloud, Customer satisfaction know I can't say after some time

3.3 What are the multi-cloud solutions currently available in the market?

3.4 Which solution or method is used by your company for multi-cloud computing?

RELATED TO RESEARH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the performance in cloud computing environments?
I am not a Technical expert.

ADDITIONAL COMMENTS

INTERVIEWEE 6

THE INTERVIEWEE BACKGROUND

1. **What is your role in the company? Is it technical or management?**
   Solution architect, Technical

2. **How long have you worked in cloud computing?**
   4-5 years (private Cloud, infrastructure)

3. **How long have you worked in the IT sector?**
   21 years

RELATE TO RESEARCH QUESTION 1

1.1 Who are the dominant cloud providers (please try to estimate relative market shares)?
The first one is Amazon then I would say Google not a infrastructure as service, software as service and platform as service. IBM, Microsoft azure. I don't know how they are big, defiantly they are number three. Then I know example TATA as invest as cloud infrastructure as a service solutions. I don't think Amazon is public at. I would say those basically are top leading dominant providers. But many startup changing them including logica but top 4 are basically these providers. Tata Indian Consultancy Company put it in Singapore.

1.2 Based on your experience, what are the major technical and strategy differences between the providers?
Well different answers, Google they provide services are workable solutions I can believe

email, platform as service. Amazon as a computing power, other vendor Microsoft is providing platform as service biggest side, should it care about underlying infrastructure so it reaches from Amazon we can put everyone on it deployment on the related .and the way up to compa-

ny like Microsoft services provisioning extension model we don't need care about extension environment to care about everything use just by email box on the board with in the number of parameters on the platform. the common platform for all them for multi location of the world Amazon ding that Microsoft doing that Google resources requirements in different regions basically they have target about different needs about market. These are the leaders in the market.

RELATE TO RESEARCH QUESTION 2

2.1 Based on your experience, what are the impacts regarding legal aspects, trust, and privacy due to using cloud computing?

I think it is the biggest challenge, because one there is who does you actually talks to? And how do you guarantee that the cloud provider has security and privacy etc, we still in the normal outsourcing in the services, we still lagging behind in virtualization because there is a mistrust on the high provider technologies yet with major companies and then I think the public companies .. Microsoft has addressed slightly differently, but there is mistrust on this publicly available and then the security guard says well, good nice try but not good enough. But you should put the right thing in the cloud; it is a very useful place to put things

RELEATE TO RESEARCH QUESTION 3

3.1 How would you define multi-cloud computing?

I would define multi-cloud computing as a multi hybrid cloud, we connect different types of clouds depending what you are going to use for. For example you could use one public version like Amazon for the development stuff but you keep with the private cloud like Logica for your most secure and perhaps things that aren't mature enough for the public cloud, like your legacy applications, already secure stuff like the mainframe etc. and you perhaps will blend it with the different types of clouds depending on which regions of the world you are targeting to use your application from, for example one cloud provider could be better like RakeSpace for USA. And you would use for example IBM for Asia for example. So, I think the key to using a cloud is to have a multiple clouds and make it transparent for you. So you can actually change if you find something better because that is the purpose of the cloud it supposes to be transparent for you. Multi hybrid cloud is transparent and can easily replace if needed.

3.2 What are the benefits and drawbacks of multi-cloud computing based on your experience?

It's defiantly not matured yet; it's still a lot of companies that have new ideas and putting new stuffs all the time, no common standard. So you can't take any server form Logica and put it on IBM cloud for example, it's still very early and if you know recognize those limitations you can take advantage of it ,if you don't know about it just read what you see in the paper I was article in Computer Sweden in couple of days ago, They clearly haven't understand what is the usage of Amazon cloud basically, so I think that could lead to market misunderstanding or what cloud is, and so I think we need to get together and have a formal standard in cloud basically because that will help. the solution to this today is off course to make some kind of common cloud management on top of multi cloud, and that will be probably come, because perhaps 24 companies issues like open the data center etc.. Single standard when an announce the last week the same companies some kind of cloud interpretability, it's a part of cloud vison2015 we need to more interopera-bility between resources.

3.3 What are the multi-cloud solutions currently available in the market?

That there no many solutions, only couple of solutions are multi-cloud capability like

cloud.com used as IAAS platform that as a capability being multi-cloud that could like backend system on VMware based and Microsoft based hypervisor and then take your own public stuff for on for example Ubuntu of the cloud stack then there is multi-cloud manage-

ment products like Right scale to access can manage multi-cloud , Logicas IAAS is cloud going to be multi-cloud capable within the next year, general state with one of our biggest customer 3 months ago integrate with Amazon and number of other clouds it's not public not available at but for my knowledge none of these top place we talk about as multi-cloud unable multi stating there is solution in the world. we can't to be at Azure, platform with another cloud we can't integrate Amazon is developer plat form is a third party is outside on top generality of multi-clouds, no top, your cloud able to give it multi-cloud look a feel. Without standard we do it hard that's why we need standard

3.4 Which solution or method is used by your company for multi-cloud computing?

RELATED TO RESEARH QUESTION 4

4.1 Based on your experience, how can load balancing solutions improve the performance in cloud computing environments? From the technology perspective, it's not the tricky thing to do, to have your application scaled out or send out over multi -clouds depending on the region loads etc. and so what you would do, if you do it right, you could say that for example if a user from north America it's my application he would be directed to the nearest cloud, and that improve performance because it is using the data center closer to it and of course the availability will be also that if use a cloud provider you would catch up with another cloud provider somewhere in the vicinity basically. This is been done for long time and there is companies that are internet based for web applications do this already today without cloud like (Akamai). And then they have to same concept they have data center around the world and basically when user usually hits the URL of a user, you hit the cash of Akamai somewhere near their data center, they have two in the US , one Asia and one or two in Europe, Basically you do the same thing with your own application with the multi- cloud product, so it been used for years it is just for the cloud it is bit different and one thing what about here, of course the cloud providers they give you a three for transferring Things in an around there cloud by the network sea and if you don't know about it will be very costly for you, but technologies wise it gives all those features with scalability, performance, availability but you should also use it with a single cloud because for examples RackSpace for example, they have two availability zones and you load balance between them as well, so I don't see load balancing only being limited to one cloud at time but also in each of the clouds.

ADDITIONAL COMMENTS

I would actually talk about Application Operation if I would to have a another topic in your questionnaire because in a multi-cloud environment the one thing that brings it together is Application Operation, and that is not application maintenance, this is to keep to the system running and monitoring, proactively maintaining its resources etc., and next a challenge as well like with the multi-cloud environments since they all standards, all service are different between different clouds, the way you install it is different to maintain it different, but the good thing is that it would be easy to test the deployment, because you can just start 10 more servers, use it, and terminate them off, you tested it, so from operational point of view it is easier but on the other hand it's a new world and there is no that many that have done a multi-cloud Application Operation and also the way you do the application in the cloud changes because in a normal deployment, a traditional outsourcing world, you would install the application on a server and the application resides on that server for .. let say three years, in a cloud environment you would instead of batching or updating yourself, you just install a new server with a new version of the application, switch all users and terminate over, so it brings out a new set of operational skills for the applications guys which is the things that you put into the cloud, because that's why you go there because you need to have your application server, so I would also think you should also look at the application perspective of a cloud because this is an interesting to discuss.

APPENDIX G: LOAD TESTER LOG FILE

```
[root@domU-12-31-39-09-24-41 working]# ab -n 100000 -c 10 -g test_data_1.txt www.swelinks.com/servername.html
This is ApacheBench, Version 2.0.40-dev <$Revision: 1.146 $> apache-2.0
Copyright 1996 Adam Twiss, Zeus Technology Ltd, http://www.zeustech.net/
Copyright 2006 The Apache Software Foundation, http://www.apache.org/

Benchmarking www.swelinks.com (be patient)
Completed 10000 requests
Completed 20000 requests
Completed 30000 requests
Completed 40000 requests
Completed 50000 requests
Completed 60000 requests
Completed 70000 requests
Completed 80000 requests
Completed 90000 requests
Finished 100000 requests


Server Software:        Apache/2.2.3
Server Hostname:        www.swelinks.com
Server Port:            80

Document Path:          /servername.html
Document Length:        105 bytes

Concurrency Level:      10
Time taken for tests:   140.811468 seconds
Complete requests:      100000
Failed requests:        0
Write errors:           0
Total transferred:      45600000 bytes
HTML transferred:       10500000 bytes
Requests per second:    710.17 [#/sec] (mean)
Time per request:       14.081 [ms] (mean)
Time per request:       1.408 [ms] (mean, across all concurrent requests)
Transfer rate:          316.25 [Kbytes/sec] received

Connection Times (ms)
              min  mean[+/-sd] median   max
Connect:        0    2   6.6      0      59
Processing:     2   11  17.3      4    1594
Waiting:        1   10  15.2      3    1594
Total:          2   13  18.1      5    1594

Percentage of the requests served within a certain time (ms)
  50%      5
  66%     14
  75%     23
  80%     24
  90%     31
  95%     44
  98%     54
  99%     60
 100%   1594 (longest request)
```