QUALITY ATTRIBUTES INVESTIGATION FOR SAAS IN SERVICE LEVEL AGREEMENT

ASHRAF NABEEL MOHAMMEDTAIB ALMALLAH

JANUARY 2015

QUALITY ATTRIBUTES INVESTIGATION FOR SAAS IN SERVICE LEVEL AGREEMENT

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF
ÇANKAYA UNIVERSITY

BY
ASHRAF NABEEL MOHAMMEDTAIB ALMALLAH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
THE DEPARTMENT OF
MATHEMATICS AND COMPUTER SCIENCE / INFORMATION TECHNOLOGY PROGRAM

JANUARY 2015

Title of the Thesis: **Quality Attributes Investigation for SaaS in Service Level Agreement.**

Submitted by **Ashraf Nabeel Mohammedtaib ALMALLAH**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University.

Prof. Dr. Taner ALTUNOK
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Billur KAYMAKÇALAN
Head of Department

This is to certify that I have read this thesis and that in my opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Dr. Sinan Can AÇAN
Co-Supervisor

Assist. Prof. Dr. Ö. Tolga PUSATLI
Supervisor

Examination Date: 19.01.2015

Examining Committee Members

Assoc. Prof. Dr. Fahd JARAD	(UTAA)	
Assist. Prof. Dr. Abdül Kadir GÖRÜR	(Çankaya Univ.)	
Assist. Prof. Dr. Ö. Tolga PUSATLI	(Çankaya Univ.)	

STATEMENT OF NON-PLAGIARISM PAGE

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Ashraf, ALMALLAH
Signature :
Date : 19.01.2015

ABSTRACT

QUALITY ATTRIBUTES INVESTIGATION FOR SAAS IN SERVICE LEVEL AGREEMENT

ALMALLAH, Ashraf Nabeel Mohammedtaib
M.Sc., Department of Mathematics and Computer Science
/ Information Technology Program
Supervisor: Assist. Prof. Dr. Ö. Tolga PUSATLI
Co-Supervisor: Dr. Sinan Can AÇAN

January 2015, 52 pages

The cloud computing has been growing and becoming a new service model in business; in parallel, more service providers appear in the market. Hence, both quality and reliability of cloud computing services become essential topics as Quality of Service (QoS) requirements play major roles in service/provider selection. However, there is a significant concern for the QoS attributes considered in a service level agreement (SLA) while selecting service provider. Clarifying QoS attributes and related metrics for software as a service (SaaS) in SLAs are aimed in this work as the research question. It is partially observed that SaaS concerns more quality attributes than other services; also, availability of services is more considered in all SLAs. In this work, possible QoS attributes and metrics to be considered in SLAs for SaaS are presented. Main benefit of this work is defended as the QoS attributes are to be given major importance in the negotiation and evaluations of SLAs of cloud service. As major limitations, law/regulations, government/company policies and budgeting are not discussed. All these were led to answer the research questions by present 12 quality attributes with related metrics for SaaS.

Keywords: Cloud Computing, Quality of Service, Service Level Agreement, Software as a Service.

ÖZ

HIZMET OLARAK SUNULAN YAZILIM IÇIN HIZMET SEVIYESI ANLAŞMASINDA KALITE ÖZNITELIKLERININ ARAŞTIRILMASI

ALMALLAH, Ashraf Nabeel Mohammedtaib
Yüksek Lisans, Matematik-Bilgisayar Anabilim Dalı / Bilgi Teknolojileri Bölümü
Tez Danışmanı: Yrd. Doç. Dr. Ö. Tolga PUSATLI
Eş Danışmanı: Dr. Sinan Can AÇAN

Ocak 2015, 52 sayfa

Bulut bilişimin gelişimine ve yeni bir iş modeli olarak kendine yer bulmasına paralel olarak, piyasaya daha fazla servis sağlayıcı giriş yapmaktadır. Servis Kalitesi (SK) gereksinimleri, servis sağlayıcı seçiminde büyük rol oynadığı için, bulut bilişimde kalite ve güvenilirlik önemli konular haline gelmiştir. Bununla beraber, servis sağlayıcı seçiminde değerlendirilen hizmet seviyesi anlaşmaları (HSA)'nda tanımlanan SK özelliklerinde endişeler bulunmaktadır. Bu çalışmada, servis olarak yazılım (SOY) için belirlenmiş SK özelliklerini ve ilgili ölçütleri aydınlığa kavuşturmak hedeflenmiştir. SOY'ın diğer sevislere göre daha fazla kalite niteliği ile ilişkili olduğu, ayrıca servislere erişilebilirliğin bütün HSA'nda tanımlandığı gözlenmiştir. Bu çalışmada, SOY için olan HSA'nda içeriğinde düşünülmesi gereken SK özellikleri ve ölçütleri sunulmuştur. Bu çalışmanın temel faydası, anlaşma ve servis sağlayıcının HSA'nın değerlendirme safhalarında SK özelliklerine büyük önem verilmesi gerektiğini ortaya koymasıdır. Yasalar, düzenlemeler, devlet/kurum politikaları ve bütçe konuları ele alınmamıştır. Çalışma sonucunda araştırma sorusuna cevap olarak SOY için 12 özellik ve ilgili ölçüt sunulmuştur.

Anahtar Sözcükler: Bulut Bilişim, Servis Kalitesi, Hizmet Seviyesi Anlaşması, Servis Olarak Yazılım.

ACKNOWLEDGMENT

I want to show my thanks and gratefulness to my supervisor, Assist. Prof. Dr. Ö. Tolga PUSATLI, and co-supervisor, Dr. Sinan Can AÇAN for their supervision and support during my thesis. Besides, I want to say thanks to my committee members Assoc. Prof. Dr. Fahd JARAD and Assist. Prof. Dr. Abdül Kadir GÖRÜR for your important suggestions and comments through my thesis discussion.

I want to dedicate this thesis to who sacrificed their whole life for me, my parents. I could not finish this work without your influential help and support. Also, I would like to thanks my sisters for encouraging me through my work, thank you. In addition, I would like to say special thanks to my love, my wife for your assistant through our life. I dedicate this work to my passion in living my daughters. Also, to my friends, thank you for your help and support.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURES

LIST OF TABLES

TABLES

LIST OF ABBREVIATIONS

BPaaS	Business Process as a Service
CSMIC	Cloud Service Measurement Initiative Consortium
DNS	Domain Name System
HaaS	Hardware as a Service
IaaS	Infrastructure as a Service
IDC	International Data Corporation
ITO	IT outsourcing
IOS	International Organization for Standardization
KPI	Key Performance Indicator
NIST	National Institute of Standards and Technology
PaaS	Platform as a Service
QoS	Quality of Service
SaaS	Software as a Service
SLA	Service Level Agreement
SLO	Service Level Objectives
SMI	Service Measurement Index
SOA	Service Oriented Architecture
StaaS	Storage as a Service
WSDL	Web Service Definition Language
WS-Agreement	Web Service Agreement specification
WSLA	Web Service Level Agreement
XaaS	X as a Service
XML	Extensible Markup Language

CHAPTER 1

INTRODUCTION

1.1 Motivation

In the last decade, the cloud computing has come to be an important technology trend. It offers a different level of services such as infrastructure as a service, development platform as a service and software as a service. It takes the attention from the academic area and commercial businesses. Also, the cloud computing opened a new service and established new data centers for hosting the cloud services such as Amazon, Google, and Microsoft.

Moreover, cloud computing offers a new cloud computing model. It promise sharing the services over the Internet and a new way to focus on how to change the way of people work and improve the usage of resource efficiency with reduced spending on their hardware and software resources. Thus, the US government estimated to spend 20 billion USD for moving to the cloud computing in 2011 and start the Federal Data Center Consolidation Initiative (FDCCI) to eliminate 800 data centers for the next years [1]. Also, the business possible of cloud computing is interested by several research companies such as International Data Corporation (IDC), which reports that the cost spent on the cloud service and the technology of that service would increase and reach 55.5 billion USD in 2014. IDC expects to see an increase in data centers and cloud service providers. Providers such as Microsoft Azure, Google, Amazon, Salesforce and IBM have already begun to increase the number of cloud computing services and data centers [2].

Today, because of the increasing in the cloud service providers (seller) companies such as Amazon, Google, Microsoft and others, whose trying to provide different cloud services depend on different cloud costumers (buyer) needs and requirements. Due to the expansion happening in the cloud service providers, selecting a cloud service cannot be easy for the cloud customers. In addition, the quality and reliability of cloud computing service become an important issue [3].

It means that customers such as organization and IT decision maker measure the services depend on the quality level of service to achieve the reliability. However, it is not easy for the customer to choose a service from the cloud service providers without determine specific quality attributes. The quality attributes become an important factor while selecting a service from cloud service providers. Therefore, the cloud customer should know about the main requirements and quality attributes of a cloud service to start a good Service Level Agreement (SLA). SLA is the key issue to select the most suitable cloud provider that satisfies the business requirements and goal. Service Level Agreement is a formal agreement signed between a cloud provider and a customer that explain the responsibility; manage expectation and describe quality attributes of delivered cloud service. The cloud customers look for an SLA before moving their business to the cloud infrastructure to get the assurance of the resources delivered and got the benefits of the cloud. Also, the cloud providers want an SLA to describe the trust and quality of service they offer to the cloud customers. Also, to choose and negotiation on the requirements attributes for such a cloud service, investigation starts to consider the main attributes and metrics to select the most suitable cloud service provider to meet business objectives and goals. Additional, the quality attributes that present in the cloud SLA are different because there are different cloud service models, each model has its own characteristics and QoS attributes. So, QoS attributes must be specified for each type of cloud service models. For example, the quality of the Software as a service (SaaS) is different from other services in the same cloud provider.

1.2 Thesis Objectives

The objectives of this thesis are to specify the possible SaaS Quality of Service (QoS) attributes which should be considered in the SLAs when selecting a service from cloud service providers. Also, it will help the small organization and IT decision maker in the negotiation and establishing a good development model for the SLA in a cloud computing environment. Investigate and describe main QoS attributes which considered when the organization starting to move their business to the cloud computing. It will further look at the main metrics for each measurable attribute of a SaaS service. These QoS attributes will be related to the SLA of cloud computing to achieve effective performance evaluation and to expect the level of the cloud service to be delivered.

1.3 Scope of Thesis

This thesis was conducted to review and investigate about the important QoS attributes which must be considered by the organization to build an efficient model for developing cloud SLA specification. First, it reviewed general understanding of the SLA content and structure. Second, it discussed the investigations about the non-functional attributes (QoS) which can be existing in the cloud SLAs while selecting a cloud service from different public cloud service providers. The proposed QoS attributes will be selected from the standard of Service Measurement Index (SMI) framework designed by the Cloud Service Measurement Initiative Consortium (CSMIC) for SaaS service. Furthermore, it based on content analysis of literature studies. The proposed QoS attributes will be 12 attributes. Moreover, the study discussed the measurable and non-measurable metrics related to the QoS attributes. The description about these QoS attribute will be related to SaaS service. Finally, these QoS attributes will be classified into four categories related to user, business, strategy and system.

1.4 Research Question

- What are the QoS attributes that specify in the cloud for SaaS in SLAs?
- What are the related metrics for the attributes that can be measured?
- Should there be any considerations for customers before going to cloud environment such as privacy or vendor lock-ins?

1.5 Thesis Structure

The next chapters in this thesis will be organized as follows. Chapter 2 Background and Literature Review give an overview about the cloud computing in general and main technologies that based on it. Also, describe the cloud computing Service Level Agreement and SMI framework. Moreover, discusses different research about SLA and related studies to this thesis. Chapter 3 results of quality attributes, this chapter will be related to the SLA QoS attributes for SaaS. Chapter 4 Conclusion, in this chapter, summarizes the finding, limitation of the study, future work for the next study and the conclusion of the study.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 Background

This section gives a background about the cloud computing and Service agreements in general.

2.1.1 History

The change from local data storage and programs to cloud computing comes to be underway in seriously and proceeds faster than expected. Shrink wrap programs still has the control in software market and are not going to disappear. However, the focus on cloud innovation looks to be ascending nowadays. Some substantial part of computing activity is moving away from the person's computer. The change was triggering effect all levels of the computation system, from the individual user to the software developer, IT manager even hardware builder [1, 3].

In a sense, everything that has seen nowadays is just the second generation of the cloud computing. About many years ago a similar revolution became with the conception of the service and the sharing of resources that offers a way to access the computing machine for the users who do not have a mainframe. Many users at the terminal access over the telephone lines. When the personal computers come during 1980 to 1990, the feature of that appeal was the guaranty of independent programs and data from the central computer center. People used and controlled their private data and personal environment and select software to do their tasks. However, the personal computer also had another weakness such as collaboration and sharing data [4].

In short, also cloud computing has been rising many issues about privacy, security, availability and reliability across all of the deployment, architecture and service model are the major concerns in cloud computing. However, realizing the promise of cloud computing faster application development, scalability, greater efficiency and dynamic IT infrastructures and gives too much time to innovation rather than care of IT up and working. Cloud computing comes when thinks about what IT needs and will be the next revolution over the Internet [1, 4].

2.1.2 Definition

According to the 16th and the definition of the official NIST, describe the cloud computing as, "*cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*." [5].

The final definition of NIST for the cloud computing is explaining from the high level. Vaquero et al describe the cloud computing after reviewed twenty expert definitions as "*clouds are a large pool of easily usable and accessible virtualized resource (...). These resources can be dynamically reconfigured to adjust to a variable load (scale), (...). This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the infrastructure provider by means of customized SLAs.*" [6].

Cloud computing has many definitions. We view cloud computing as a kind of sharing and distributed system that consists of a lot of interconnected computers system. It helps the customer to easily scaled, deployed and configured infrastructure within minimum time and effort, existing one or many of computing resources depends on service level agreements started through negotiation between cloud customer and provider.

2.1.3 The cloud computing architecture

The cloud computing system can classify in two main different sections “the front end” and “the back end”. The front end is the customer or any client’s devices that required accessing for the cloud computing services. The back end is the cloud computing services, which consist of hardware, computer system, storage, and servers. All of these make up the cloud system. The cloud computing system needs software that used to connect with various cloud customers accessed a single cloud server which called middleware. It is used to control the system, manage traffic and customer demands to make sure that the system running will and efficiently [7].

2.1.4 Features and advantages

The NIST definition of cloud computing described five essential characteristics that the cloud computing system must offer:

- *On-demand self-service*: It is a top characteristic in cloud computing. It is about customer’s needs; customers can configure and setting up computer resources using cloud service catalogs without requiring human interaction with the service’s provider. For example, the customers can scale the service up/down as a business requirement needs [5].

- *Resource pooling*: Resources such as network bandwidth, process and storage of the service provider are pooled together in the system to serve multiple cloud users using multi-tenant model. Examples of resource are processing, storage, network, and virtual machines [8].

- *Broad network access*: The cloud services accessed by the cloud customer over the network using the standard methods regardless of time and place. For example, the cloud services access from multi-geographic location such as mobile phone, pc, laptop and personal digital assistants [9].

- *Rapid elasticity*: Resources can be quickly and elastically provisioned and released at any time. Cloud customers can response to demand automatic or

manual in quite efficient way using online control panel. For example, an organization success on cloud computing. Then, it can quickly change or add resources to existing one [10].

- *Measured service*: Cloud computing systems are automatically controlled, measured and monitoring based on metric capability such as the amount of network bandwidth, processing, storage and for how long the user activity. Resources can be controlled, monitored and reported to cloud providers and users to utilized service. Cloud customers charged depend on pay as you use [11]. For example, the cloud customer will be only pay for used services such as the bill of internet service provider.

While those were essential characteristics of cloud computing as the NIST classified. Also, there are many advantages and benefits of cloud computing that are promised:

- *Lower cost*: There is no need to pay extra money on the own infrastructure and pay per use such as hardware, software and licensees fee because the cloud computing lets you focus on your work and works at higher efficiencies with more utilization. For example, the business of an organization can grow without needs to buy new hardware of new software [11, 12].

- *Reliability*: The efficiency of cloud computing networking and its power to give load balance and failure of the system makes it more reliable than traditional approaches [13].

- *Backup and recovery*: Since all the data and information putted in the cloud, backup and recovery is much easier than the traditional methods. Furthermore, most of the cloud service providers are adopting enough methods to handle recovery of the information [14].

- *Outsource IT management*: The cloud computing deployment enables hire someone else to control and manages computing infrastructure while focusing on business. In a sense, it will reduce IT staff cost, and other IT problems go away [13].

- *Quality of service*: The quality of service (QoS) is something to guarantee the services under contract between the cloud provider and customers. For example, the cloud provider should have an agreement describe the QoS its attributes. The organization checks the QoS attributes that suitable for the business requirements [6].

- *Simplified maintenance and upgrade*: The cloud computing system is not as a traditional computing system, so cloud users can apply upgrades and accessed the last version of the software. The process of backup and recovery of data becomes easily because now the data residing in the cloud and not on the physical storage [13].

- *Deliver new services*: It is possible add new classes of application and offers new services [14]. For example, many services such as software, hardware, networking, computing, storage, big data, business platform and desk software can deliver to as a service. Those services enable the small organization to compete with large businesses.

- *Low barrier to entry*: The cloud computing changed the dynamics of open new business. In the cloud computing, anyone can be a large company [13]. For example, a new organization started a big project and decided to buy a cloud service such as a customer relationship management (CRM). It is possible to buy such software from many providers and used for organization employees to supports business.

Because of this long list of features and benefits the people are becoming excited from the idea of cloud computing. Cloud computing is not a solution, however. Cloud computing may be does not work well in all applications [13].

2.1.5 Cloud computing challenges

As explained in section 2.1.4, cloud computing is a service model that gives many benefits to its customers. However, as any new service, the selection of cloud computing is not coming without challenges.

- *Limited control and flexibility*: The risk of cloud computing is found in its major advantage. Since you move to the service running on a remote system business may lose or have restricted control over some function and processes of the hardware and software [14].

- *Security and privacy*: In the cloud computing security can be one of the biggest concerns in the cloud computing. Particularly using a remote cloud based infrastructure, cloud customers essentially leaves away private data and information, things that might be sensitive and secret [7]. Then depend on the cloud service provider to manage, protect and save the private data from security issues, thus the cloud provider's reliability is risky. Cloud customers should be warned before moving to cloud computing. In the same way, privacy can be another huge issue. Cloud customers have to depend on the cloud provider to provide methods that protect data and information from unauthorized access such as enable encryption and storage for sensitive data [10].

- *Dependency and vendor lock-in*: One of the main disadvantages of cloud computing is the total dependency on the cloud provider. The transformation from cloud provider that have subscribed with him to another is difficult and sometimes impossible. This is another issue why should be warned and wisely when chooses a cloud provider [13]. Also, there is a data lock-in. it means not easy for the cloud customers to extract data from one cloud side to another [15].

- *Technical difficulties and availability*: There will be system problems and downtime in the cloud computing and all the system might face problems from time to time [14]. Unavailability is possible even for the best cloud

service providers. Cloud service providers must manage the expectations and have the service level agreement (SLA) to get service credit when downtime happens. For example, Google Company had partial outage in the AppEngine for 5 hour in 2008. Additionally, keep in mind that the whole system depends on the internet connection, thus any network or connectivity problem cut the service [15].

- *Sensitive information*: When an organization starts to use the public cloud. It should aware about the private and sensitive data and information. For example, an organization would like to use the Google Spreadsheet for a list of employee's salary. Now the organization's financial plan may be unsecure and under hacker attack [16].

- *Increased vulnerability*: The cloud computing solutions are risky on the public internet and make the companies vulnerable to both external hack attacks and infrastructure failures. Such event can affect internet domain name servers or prevent access to cloud [14]. The security on the internet is not adequately secured and saved even for the big players. For example, an attack occurred on "Akamai Technologies" in June 15, 2004, caused a domain name outage and Google Inc., Yahoo Inc. and many other sites affected from [17].

Despite of the disadvantages of cloud computing, however is still strong and has a great future because its users become more and more player interested in it [15].

2.1.6 Classification of cloud computing service models

The cloud service models classified into: IaaS (infrastructure as a service), PaaS (platform as a service) and SaaS (software as a service). The three cloud categories models are generally present in a new academic research area and have different levels of details and objective depends on the way they are usually using. The cloud service models can deploy in public, private or hybrid cloud deployment models. Additionally, the three service software, platform and infrastructure models together

also known as (SPI model) [5]. **Figure 1** shows Classification of SPI cloud computing service models.

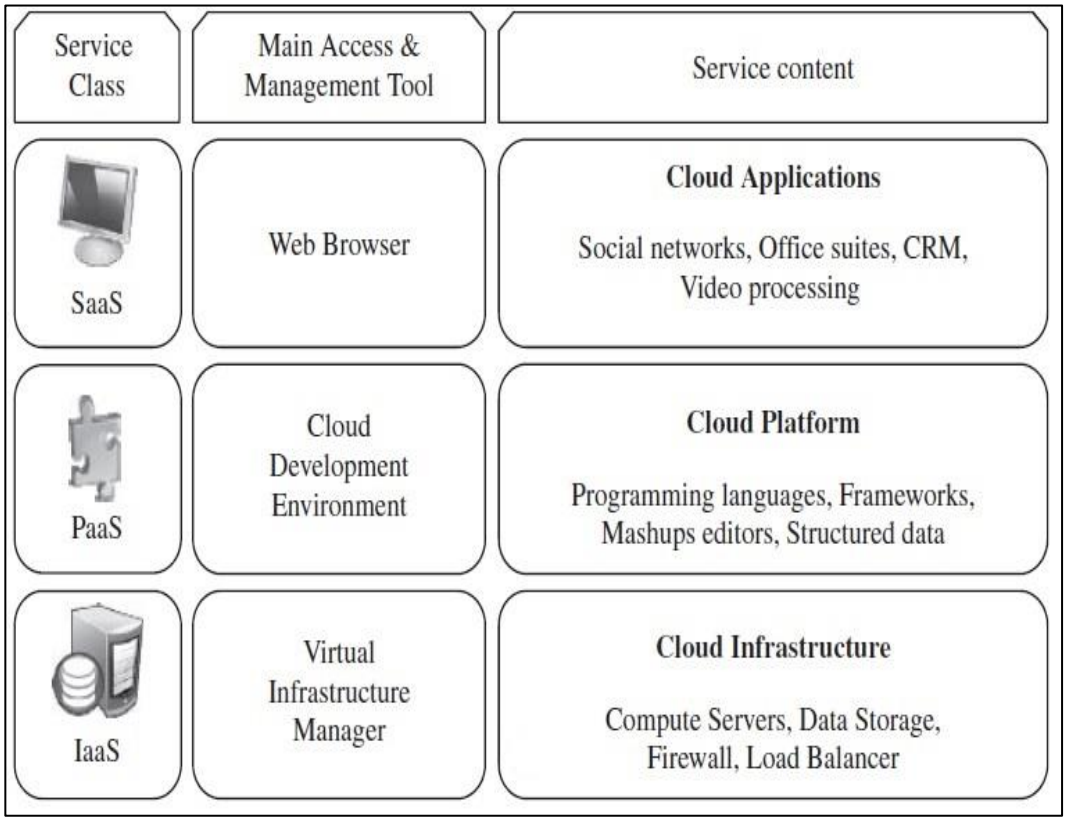

Figure 1 Classification of SPI cloud computing service models [10]

The cooperation between UCSB-IBM academia and industry IBM T.J. Watson Research Center tried to extend the SPI model by using the principle of a service-oriented architecture (SOA). The main contribution of this classification is to give an educational view of the cloud computing service model. The first three layers of UCSB-IBM cloud ontology are similar to the SPI model. Simply the authors decompose the cloud infrastructure into three services. They are Computation (IaaS), storage (Data as a Service) and communication (communication as a Service). Also, mentioned that there are software kernel and hardware as a service (HaaS) under the cloud infrastructure [18]. Figure 2 shows UCSB-IBM cloud computing model.

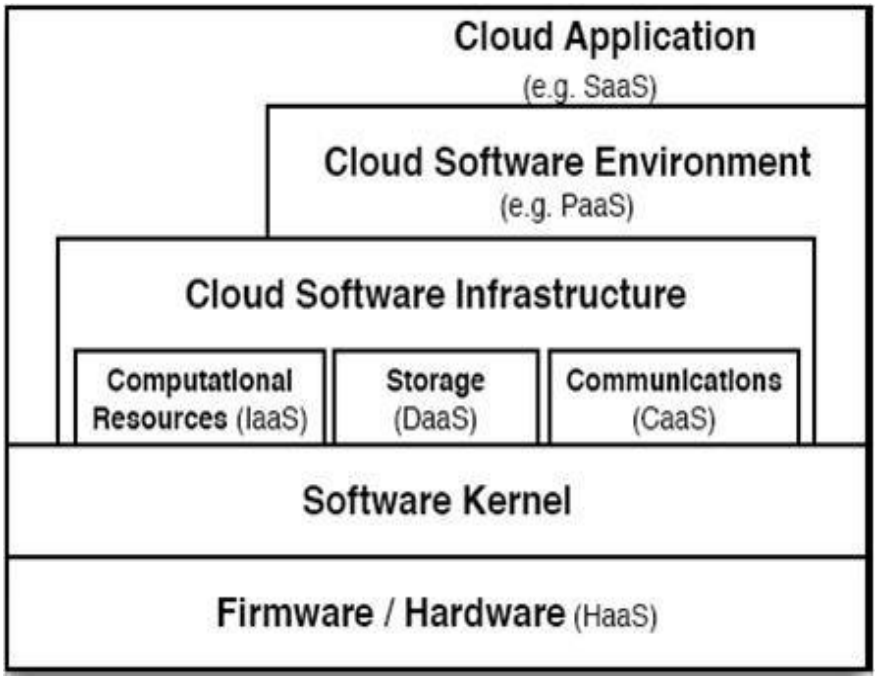

Figure 2 Classification of UCSB-IBM cloud computing service model [18]

In the section 2.1.6, we explained the two classified models of cloud computing service models. In the rest of the section, we will focus on SPI models because they are the main models of cloud computing services and usually mention in academic research.

- **Software as a service model (SaaS):**

Software as a service model gives the capability to the cloud customer to use the cloud computing services such as business application (e.g. customer relationship management CRM) and web browser (e.g. Gmail). The applications can access through the internet from thin client or mobile device. The cloud customer does not control or manage the underlying cloud infrastructure include network, storage, virtualization, OS, and so on just use the application with possible limitation on the application configuration setting [10].

There are some particular essential characteristics that the software as a service offers [19]:

- The application accessed via web browser and managed from center location.
- The cloud customer does not have to upgrades and patches.
- The software delivered in “one to many” model. for example google app can used by many users.
- The application manages and controls by the cloud provider

There are examples of software as service providers such as Salesforce offers CRM and sales applications, Google Apps and Adobe acrobat connect for online communication and collaboration [11], Microsoft office 365 and SAP HR [20]. Also, SaaS faced the similar problems of the cloud computing. Furthermore, the world's leading information technology research “Gartner” said the revenue of SaaS increased by 17.9 % from 2011 to reached 14.5 billion USD in 2012. Also, grow in 2015 will be to 22.1 billion USD. Therefore, many companies invested in SaaS and the primary resources that SaaS offers finance/ERP, communication, CRM, HR, online workspace and other.

- **Platform as a service model (PaaS):**

Platform as a service model (PaaS) offers an environment to the cloud customers for application design, testing and development using the cloud infrastructure. The PaaS suitable for the developers, it offers new software platform for developers using APIs, programming languages, middleware services, libraries and tools that the cloud provider provided. The cloud customers do not control or manage the underlying cloud infrastructure including network, servers, operation system and storage. Therefore, the cloud customers have the ability to control over the deployed application and configuration settings for the application in a cloud environment [20].

There are some of the basic characteristics that platform as a service (PaaS) provided [11, 19]:

- Development tool for build, develop, test, deploy, host and control applications in the same development environment.
- Web based user interface to build, modify and test applications.
- Multi-tenancy service that can be used by many concurrent users.
- Built in scalability of developing software such as load balancing and failover.
- Integration with other infrastructure such as web services and databases.
- Collaborate with development team supported via project planning and communication tools.
- Providing tools such as management interface and API.

Despite these characteristics PaaS has downfall side and lack of portability among cloud providers. That lack is if the cloud customer design application with one cloud provider and want to move to another cloud provider; he will not able to do that easily and may do it with a high price. Also, when the cloud provider went out of business, the cloud customer will lose his application or if the application needs for customization of the underlying hardware and software [19].

Platform as a service (PaaS) offers many services such as Amazon SQS for data integration [13], Google AppEngine for development [11], Amazon simpleDB for database and Google BigQuery for data analytics [16, 20].

- **Infrastructure as a service model (IaaS):**

According to the SPI classification model, the IaaS model capability given to the cloud customers used outsource equipment to support computing, storage, networking, hardware, server and other cloud resources. Therefore, the cloud customers have the capability to deploy and execute the software, which can include operating system and application with a level of control. The cloud customer cannot manage or control the underlain cloud infrastructure. However, the cloud customer

has the ability over the operating system, data, middleware, runtime and applications, and may be limited control over select networking components (e.g., host firewalls) [5, 8]. The main resource that IaaS depended on is the virtualization technology which let the cloud customers to deploy and execute own operation system based on virtualization. The virtualization is the main concept of cloud computing which enable deployment, distribute, scalable and software maintenance [21].

There are some core characteristics which explained what IaaS is. In general IaaS has accepted to offer with the following [19, 11]:

- The resources distributed as a service.
- Dynamic scale is allowed.
- Has pricing model and variable cost.
- Include one multiple users on a single instance of hardware.

In addition, the challenges that IaaS faced today are security policies, governance and the physical location of the data. The security is a considerable issue within the IaaS especially that the rest of the cloud models work on top of it layer. However, companies have good reputable will retain data secure and safe [16].

Within IaaS, there are three main resources that cloud Infrastructure provision are computing, storage and network [13, 22, 10]. **Table 1** describes the most service resources offering by the big player in cloud computing. While some cloud service provider companies focus in one of these IaaS cloud resources (computing, storage, networking, hardware, and server), still large companies such as Amazon has offerings many services in IaaS area such as Amazon AWS as a network resource, Amazon EC2 as computing resource and Amazon S3 as storage resource [22, 23].

Table 1 Example of cloud computing service providers for IaaS resources.

IaaS resources	IaaS cloud provider companies
• Computing service	• Amazon EC2 • Microsoft Azure • HP cloud computing
• Storage service	• Amazon S3 • HP storage • Rackspace files
• Network service	• Amazon ELB • Rackspace networks • Virtela networks

IaaS works well in a number of cases and has the same benefit of cloud computing. For example, when demands are changeable at time or for the company is growing rapidly and scaling infrastructure would be a problem. Also, IaaS is not the best option for other cases such as where regulatory compliance becomes outsource of data storage and processing difficult for the company [19].

Additional, SaaS offers application accessed online which already developed, while PaaS represents a platform that help a developer to develop new applications. Also, PaaS depends on IaaS. As well as many of the academic research focus on these three models and other expand the classification to XaaS where X could be hardware, storage, OS, network [13].

2.1.7 Cloud computing deployment models

A cloud computing deployment model defined the location and management of the cloud's infrastructure. There are four cloud deployment models as the NIST definition: public cloud, private cloud, hybrid cloud and community cloud [5].

- *Public cloud:* The cloud infrastructure is provided services to the general public group or to an industry group and the computing resources can share between the cloud customers. It is owned and controlled by a third party or

an organization which is selling cloud services. It find in off-premise and support multiple users, connectivity over the internet and suitable for less security information [12]. For example of the public cloud are Amazon EC2, Google App Engine, Microsoft Azure and HP cloud [20].

- *Private cloud:* The cloud infrastructure is provided services to the one organization and operated just that organization. It is owned and controlled by the organization or a third party. Private cloud may be located in on or off-premise and support single user, connectivity over the internet or a private network and suitable for more security information [11]. For example of the private cloud financial company such as eBay [20]. For example, when the data of an organization are significant and sensitive the private cloud is the best. However, the private cloud is more expensive.

- *Hybrid cloud:* The cloud infrastructure is a mixed between two or more different cloud infrastructures (private cloud and public cloud) where each of them has unique identifies, despite they are bound together as one unit [5]. The idea of this approach is to use the public cloud for general computing and private cloud for data and other sensitive information. For example, an organization would like to put the insensitive data and operation in a public cloud to get the lower cost beneficial. Also, it puts the sensitive data in a private cloud to get the control [20].

- *Community cloud:* The cloud infrastructure is provided services for a specific user group or several organizations which has the same concern such as mission, security, requirement and needs. It is owned and operated by an organization or third party, and the infrastructure may be located in on or off-premise [13]. The benefit of the cloud community is building a cloud infrastructure for government agencies.

Figure 3 shows how cloud infrastructure and how can be deployed in public, private and hybrid clouds.

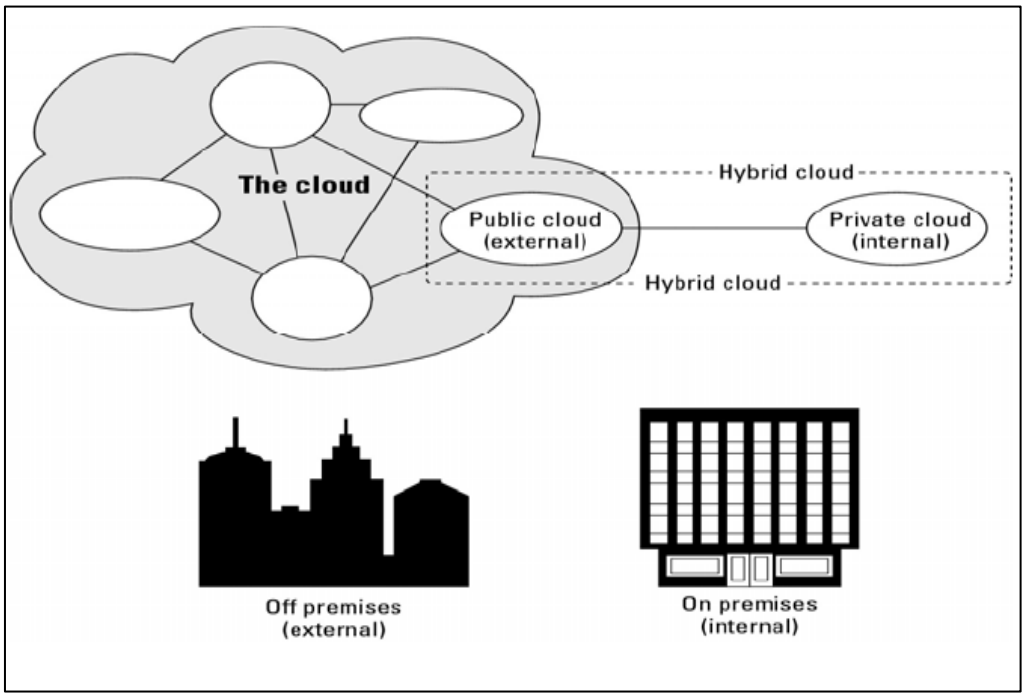

Figure 3 Three types of cloud computing development models [13]

2.1.8 Enabling technologies

The main technologies that cloud computing based on are discussed in this section; they are virtualization, web service and service oriented architecture and web 2.0 [12].

- **Virtualization as underlying technology:**

The cloud computing technology could not be real without the term of the underlying technology known as virtualization. It allowed the cloud computing to virtualize systems by sharing resources and pooling among different users with more efficient using of the computing resources. The cloud computing depends on the virtualization to virtualizes many resources of computing such as operation system, platform, storage and network [24]. The advantages of the virtualization are: to enable you to merge your servers and serve more with minimum using of the hardware and it allows supporting more users using the same piece of hardware and run applications faster. These features that virtualization offered gives the cloud computing the ability to offer multi-tenancy, scalability, rapid elasticity and measured cost service [24].

Also, there are two kinds of virtualization; full virtualization and para-virtualization. In short, Full virtualization is a complete installation of the system (BIOS, drive, so on) run on another machine. Para-virtualization is a software that one physical machine to support multiple virtual machines [8]. For example for three applications running in non-cloud which needs for three independent servers, while in the cloud needs less of that such as two servers [12].

- **Web service and service oriented architecture (SOA)**

In short, web service and service oriented architecture also considers as base technologies for cloud computing because cloud services are designed as web services follow the standers such as Web Service Definition Language WSDL, SOAP and UDDI. SOA helps to manage web services into the cloud, also include set of cloud services [12].

- **Web 2.0**

The Web 2.0 is the second version of Web 1.0 that use the technology of the web design and web to enhance information sharing, creativity, collaboration between users [12].

2.1.9 Grid computing

Grid computing is a system that general protocol to combine distributed the resources of computers in a network to work on a project and to use in the same organization to process heavy computational tasks. The difference between the grid computing and cloud computing is in resource utilization, however the grid computing, not for public service and relate to the infrastructure service. Also, it used for massive computational jobs while the cloud computing offers many plans and model for different business. For example, the Sun Microsystem provides Grid system for employees of companies to share and pool the computer resource up to 80% workstation at a time [16]. **Figure 4** explains all technologies that enable the cloud computing invention.

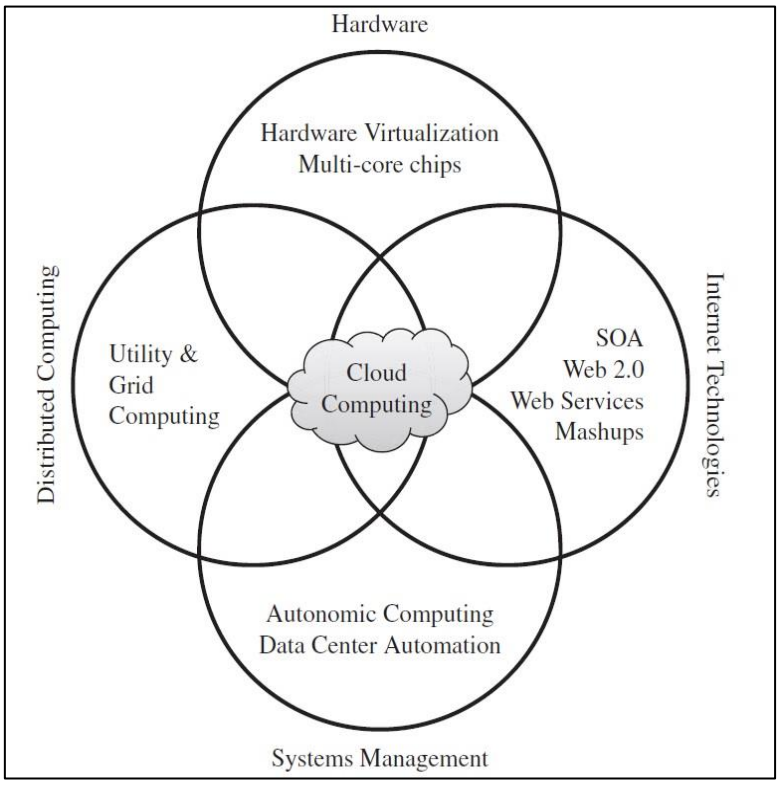

Figure 4 Different technologies that enable the cloud computing [10]

2.1.10 Overview of service level agreement (SLA)

The development of grid computing and SOA spot the light on how applications and services are managed and used. This management includes metrics and obligations of the services, service provider and service customer are keeping together. When the customer wants to start using one of these services, he must ready to negotiation with the different service providers. Therefore, after the negotiation completed the agreement is ready to sign between the customer and services provider. This agreement between two parties knows as Service Level Agreement (SLA) [25].

SLAs are an essential term in cloud computing. SLA is a formal agreement signed between a cloud provider and a cloud customer that describes the parameters and performance of the services. This agreement is written by IT service provider in the formal contract that defines the minimum obligations and the scope of services existing between a service provider and the customer [26].

Also, in order to provide the respect to these agreements and to achieve the desired level of providing service, the both parties must agree upon. However, establishing a good agreement is difficult for both parties because there are difference of requirements and needs. The attributes and metrics in the SLA determine the quality of the services (QoS) attributes such as availability, response time, security, latency and throughput [27]. **Figure 5** explains the typical structure of the SLA.

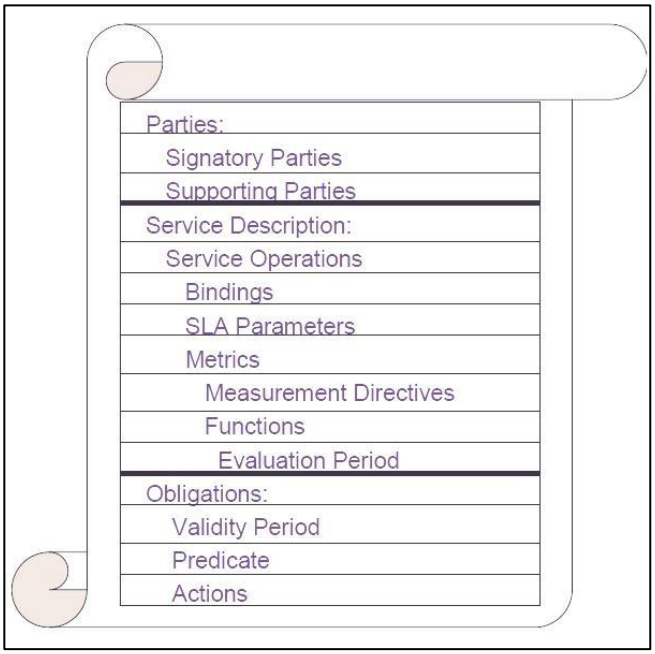

Figure 5 Typical structure of the SLA [28]

Service level objectives (SLOs) are a part of the SLA. It determines measurable performance metrics such as availability, throughput and response time. These single requirement metrics are called SLO. The SLO also referred to the SLA parameter or SLA attributes [29]. SLO is the goal of the cloud service provider such as how to achieve the uptime percentage (e.g. 99.9% uptime). SLO may greatly depend on the providers' offers, the business needs and competitive situation. The cloud service providers, as well as offer different kind of service level agreement for the same service. These different levels depend on the QoS and cost. A standard SLA should include the following SLO and metrics: availability, response time, outage of the system, reason for outages, failover from disaster recovery, how the system proactive from outage and maintenance [30].

The following are the main components of the SLA [31, 32]:

- *A Description of the provided service:* This section contains the description of the type of the service that will provide, the technical issues linked with the service and any qualifications of the service such as configuration of the server's and the client's, operation and maintenance.

- *Parties:* Represent the cloud provider and cloud customer.

- *The performance and QoS level of the service:* It contains the cloud availability metric and how the system will respond to the expected service outages. In responsiveness stage state whether the service will continue in normal operation.

- *The procedure dealing with a problem:* This section will include information about the contact person when there is a problem in the service and the steps that must be quickly followed to resolve the problem.

- *The time for response to the problem and solution:* This defines the time that taken by someone who started the investigation about the problem that was reported. Maybe there is also a time limit to solve the problem.

- *How to monitor and report the service:* This monitor and report the quality levels of the services and describe who will responsible for monitoring these qualities and how and how often.

- *Penalties when the service provider obligations are not met:* This part is to determine the credits that are given to the customers when the service obligations are not met. As an example is to give the customer the right to terminate the contract or ask to retrieve some money. The Amazon EC2 said that "*if the annual uptime Percentage for a customer drops below 99.95% for the service year, that customer is eligible to receive a service credit equal to 10% of their bill*." [10].

- *Extra clauses and constrains:* This part contains some clauses talking about the SLA will not be not cover and valid is such a case of natural disasters such as flooding, fire or war.

In fact, not all the components are present in the SLA, nevertheless the good SLA cover those points as a part of the SLA agreement [31].

The SLA life cycle identified the following six phases in general shown in **Figure 6**; these stages are [33, 34]:

1. *SLA Template & Development:* Here is where the SLA presents the service identification, customer requirements, identification of service characteristics, parameters which offers by cloud providers and the SLA template developed.

2. *Negotiation:* This section where the negotiation started and specific the parameters which are going to be covered, the price for the service provider and the contract executed.

3. *Implementation:* In this section where the SLA generated. This phase may need rearrange of the resources that service in the next stage to meet the SLA parameters.

4. *Execution:* In this section and after the SLA generated, is the preparation for execution, monitoring, reporting and maintaining.

5. *Assessment:* This section where the overall assessment is done to the SLA, QoS and performance. In this stage, may reassessment to SLA template may be done.

6. *Termination & Decommission:* This section is to terminate the SLA of the service for reasons such as violation in service, expiration of the contract and cancel finished commission services.

The SLA template should contain the six phases of the SLA, which are listed above as well as the scope of the agreement, appropriate penalties and problems solving

and the duties of the two parties [34]. The SLA is a difficult process, however after the SLA is realized the specific parameters of the customer that may be monitored to make sure there are no violations in providing service. Then, when the violation is happened the appropriate solutions which are determined in the SLA should be implemented including penalties and credits [35]. The goal from the SLA are to make a best framework that select the service level and business priority [36].

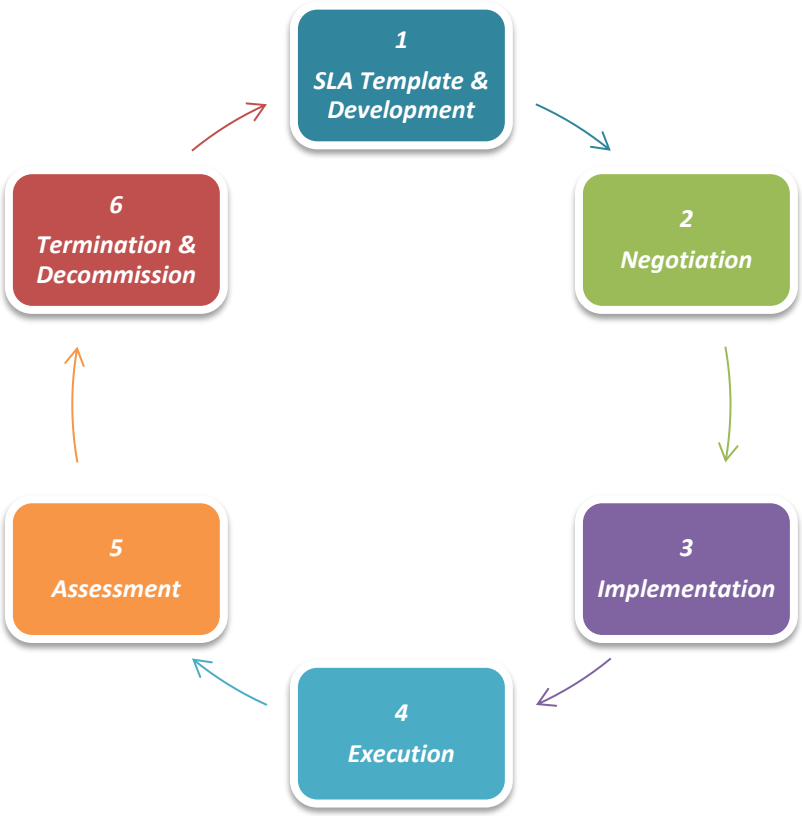

Figure 6 The Telemanagement (TM) Forum's service level agreement life cycle [35]

SLA for IT can be classified into three types:

1. *Basic:* It is a single SLA which has well defined metrics that are evaluated. These metrics are usually doing manually [34].

2. *Medium:* It is a multi-levels SLA the qualities depend on the cost of the service. The goal from this is to make balance in services quality and cost [34].

3. *Advanced:* This kind of SLA is a dynamic update of resources to achieve demand as the business needs [34].

2.1.11 Standards and designation of SLAs in cloud computing

As far as we know that there is no standard in the area of the SLAs for the pay as you use services which are called "Cloud computing service". The most standard and main specification which is used to describe the SLA in cloud computing environment are Web Service Level Agreement (WSLA) and Web Service Agreement specification (WS-Agreement) [34]:

- *The Web Service Level Agreement (WSLA)*: The WSLA language is a specification implementation. WSLA framework was designed and developed by IBM in 2001. The WSLA language depends on Extensible Markup Language (XML) and XML schema for determining and monitoring web services. It is let to make of machine readable SLA for web services [25]. WSLA framework used to describe the services in three main sections: parties, SLA parameters and SLO [37].

- *The Web Service Agreement specification (WS-Agreement)***:** A Web Service Agreement specification (WS-agreement) is developed by the Open Grid Forum (OGF) with a view to create an official agreement between service customers and service providers and monitor this agreement [27]. The WS-Agreement similar to the WSLA used the extensible language XML and XML schema to describe the overall specification of an agreement. In addition, the WS-Agreement must determine the guarantees, the negotiation and the penalties of the agreement dynamically [34]. Also, there are three sections that describe the agreement using the WS-Agreement: name, context and terms [27].

2.1.12 Service measurement index (SMI) framework

The standard framework of Service Measurement Index (SMI) is a new cloud computing standard method. The first version presented in 2011 by Cloud Services Measurement Initiative Consortium (CSMIC) using International Organization for Standardization (IOS). It identified a set of business Key Performance Indicators (KPI's) that offered a method to measure and compare a cloud service. Also, the SMI until now is under developing. In this version 2.1, one of it is objective is to be a standard method for organizations measure cloud service based on their requirements. It consists of seven top level categories: performance, agility, assurance, financial, accountability, security and privacy, usability [38]. In addition, each category defined 3 or more attributes as a set of KPI's. The total number of attributes is 58. Some of KPI's are for one service, despite the others can be for all services (IaaS, PaaS, SaaS, and BPaaS). There are no architecture and compare for a cloud provider in the first framework, however, for most attributes, they made a review contain Measure Identification, Purpose of Measure, Measurement Definition, Other Information. **Figure 7** shows the categories and attribute of Service Measurement Index (SMI).

Figure 7 The categories and attribute of Service Measurement Index (SMI)V2.1 [38]

2.2 Literature Review

This section will present the review of related works and studies about the SLA in a cloud computing environment and QoS attributes for the cloud computing services. Several studies have already done around the area of SLA for cloud computing. They were related to SLA trust management, conceptual framework for cloud SLA depending on WS-Agreement and WSLA, managing SLAs in cloud computing, systematic analysis of cloud computing SLA, the conceptual platform of cloud SLA, framework for comparing different cloud service and the quality of attributes for cloud service depending on the QoS of SMI standard or QoS of SOA. All these topics research discussed from different kind of view the SLA in a cloud computing environment. The next section will follow as the research that related to cloud SLAs QoS attributes.

2.2.1 The studies related to the cloud SLAs in general

This section of related work will give a better understanding to the field of the SLAs. **Qiu et al.** [39] presents a systematic analysis of service level agreement in the public cloud. The aim of this study is to give better understanding in the area of service level agreement and to suggest a good study on the SLA. The study addressed a content analysis on thirty SLAs to find the declared attributes and unstated attributes. Then, follow with a case study on a selection of public cloud services.

The study collects the data of 29 SLAs from individuals and organization for public cloud service providers. The authors used sampling method to make sure that the samples of SLAs are for public cloud services. The analytical study was for the three service models (IaaS, PaaS, and SaaS). It included 17 SLAs for IaaS, 5 SLAs for PaaS and 7 for SaaS. To make the collected data representative, the authors snapped the samples from large and small companies. Also, for the infrastructure samples, the authors classified them into three categories, IaaS/infrastructure, IaaS/computing and IaaS/storage. After the collection of data, the analysis stage starts by identifying a list of all attributes that must be stated in an SLA agreement. These attributes will be used as a template to check the SLA sample and find the missing attributes in cloud

computing SLAs. **Figure 8** shows a summary of the attributes that collected and analyzed for the SLA template.

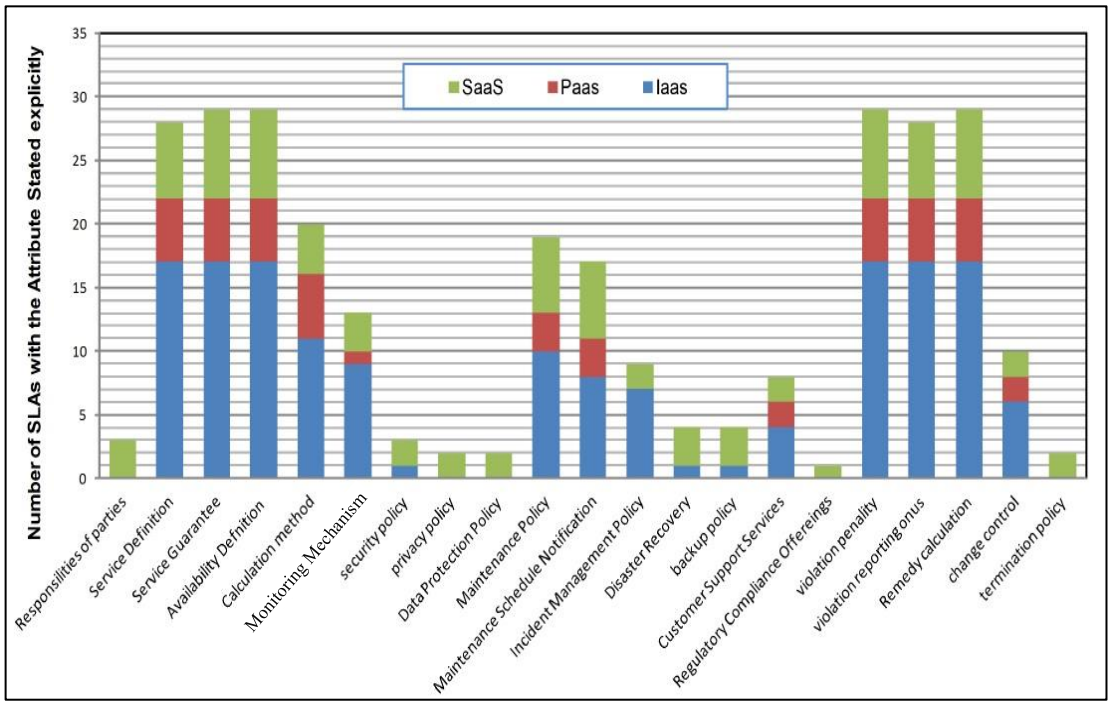

Figure 8 Summary of the attributes presented in cloud SLAs [39]

A summary of the attributes given in Figure 8 that there are attributes which were stated in all SLAs regardless of the cloud services offer such as availability. Also, there are some attributes unmentioned in the SLAs study such as responsibility of parties. All SLAs analyzed in this study guarantee at least one attribute. The most attributes that guarantee from the service provider side is the availability. For example, some of SLAs mention that the service will be available to customers at least 99.9%, still one of the SaaS SLA guarantees the security of the network beside the availability. The most common attribute such as availability has different definitions depending on the cloud service delivered. The availability metric for IaaS is usually defined by uptime and downtime, although other SLAs may use error rate because the type of the services is different. Moreover, even if the availability defined in most of the SLAs examined, simply not all the SLAs provide monitoring mechanism service for violation and proactive, still all of the SLAs describe the penalties for service. A few of cloud service providers give description about termination policy. However, All the SLAs describe the amount of service credit.

Also, all the cloud service providers mention that any interruption in the service caused by service maintenance will not count as downtime of the service. The customer support service is not covered in the entire cloud service provider. The commonly missed attributes are security, privacy, protection and backup. One of the 29 SLAs that exam in this study states the standard about the structure of their SLA. Also, changes the term and termination policy are stated only in two SaaS SLAs. In average, the SaaS SLAs has more attributes especially related to disaster recovery, maintenance, data protection and change term. The calculation method for the same attributes may be differing from one cloud service provider to the other. **Figure 9** shows the average attributes for the five cloud computing services.

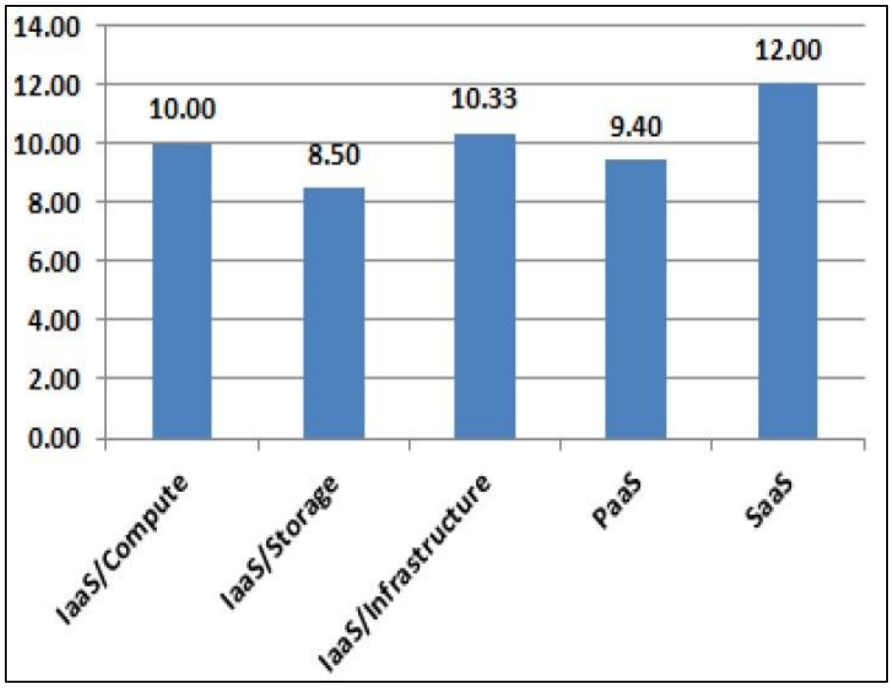

Figure 9 Average numbers of attributes in five cloud computing services [39]

Another study, **Alhamad M. et al.** [40] tried to propose a trust model for cloud computing based on the SLA using the WSLA. In this model, the authors attempted to fill the gap between the cloud provider and cloud customer. It helps the cloud customer in assessing and selecting the most reliable cloud service providers for their critical business and private information. This model used the best trust techniques and SLA management to offer an efficient model to choose the best cloud providers from different cloud providers to deliver both the functional requirements and non-

functional requirements. The proposed architecture consists of four main sections: SLA agent, cloud service directory, cloud providers and cloud customer, and SLA agent. The SLA agent is the basis of this model because it does the main tasks: grouping cloud customer, design metric for SLA, choosing and negotiation with cloud provider and monitoring both parties. This study does not consider the process of finding and selecting a service in detail. The authors present a protocol that shows that activity that this model included, only without implementation. All in all, the authors used the service level agreement metrics and user requirements as the main input for this model. This model can also use for different cloud computing services.

Moreover, **Alhamad M. et a**l. [41] presents a framework for the cloud computing based on the SLAs. Due to the expansion that happened in the cloud computing services, make the customers of the service asked about which metrics and criteria should be defined in the SLA at the stage of SLA development. Also, the authors discussed the negotiation strategies between the cloud customers and cloud provider.

The study investigated the main requirements which should consider in order to integrating with a cloud computing service. The cloud framework depends on the main specifications which are described the SLA in web service, WSLA, and WS-Agreement. The authors said that there are two kinds of requirements function and non-functional. It takes the non-functional requirements which are availability, scalability, cost, configuration of service, security and privacy from the perspective of the customer. Furthermore, depending on these non-functional attributes presents the proposed metrics for cloud framework for services such as IaaS, PaaS, SaaS and storage as a service (StaaS). Then, discussed the possible negotiation strategies which are: the first strategy is direct between the cloud provider and the cloud customer. The second strategy is indirect, use the third party. The last one more than one agent is needed to select a service. This framework limits to the non-functional attributes and present them from side of the cloud customer. The authors in this framework tried to help the cloud customers to start an effective negotiation model for SLA in cloud computing.

2.2.2 The studies related to quality of service attributes

This section will focus on the studies that related to quality of attributes based on different standards. **Grag et al.** [42] proposed a complete framework for comparing and ranking IaaS cloud services. It is not easy for the service customer to choose a service from the providers without relying on specific requirements. This framework will help the cloud provider to fulfill customer's requirements, satisfy the SLA and enhance the QoS. The challenge of QoS attributes that each service has special requirements and characteristics. This framework used the CSMIC SMI version 1.0 for evaluation of a cloud service, however in this study the authors takes the CSMIC work one step forward to the SMI cloud framework. There are many challenges to define a model for evaluating QOS and ranking cloud service providers. The first one is the measurement of different attributes. Many attributes are changeable over the time and without having specific measurement models, it will be difficult to compare different cloud service provider. So the framework uses the historical measurements to provide specific value of an attribute. The second one is related to rank the cloud service provider depending on two kinds of attributes: functional and non-functional. This is a problem of multi-criteria decision making (MCDM). To solve this problem, the authors proposed an Analytical Hierarchical Process (AHP) based ranking mechanism. Moreover, the authors define 12 attributes and appropriate metrics that related to IaaS model. The SMI Cloud framework helped the cloud customers to choose well could provider and start proper SLA for their requirements. Also, it gives an assessment of cloud services in term of KPIs and customer requirements. Furthermore, this framework is limited to the quantifiable QoS attributes and based on SMI standard.

Siegel and Perdue [43] presented a literature study about cloud service measures for global using the SMI standard framework. They studied some attributes such as cost, security, privacy, data loss and flexibility from two directions the literature and popular research about cloud capability. Also, this study mentioned the missed of a common conceptual framework for measuring cloud computing services. The IT service and Information Technology Infrastructure Library (ITIL) outsource identified some standards of resources. These can use by the customers and

providers. However, the cloud service resources were not discussed by any of the standards or discussed from separate standard.

Moreover, the study gives description about the SMI attributes and template that provides an explanation about each measure attribute. It includes sections about the attributes such as name of the measure, quantitative or qualitative, related SMI attributes and so on. The authors start their work with examples about the cost and security attribute because they are the most attributes should be considered before moving to cloud computing. The SMI framework is changeable over years. The measure and attribute will be developed reviewed, and tested. Also, the SMI attributes will be increased through researching feedback and global community use to the CSMIC researchers.

Frey el al. [44] worked to cover the KPIs for SLAs in cloud computing. Because of the complexity and dynamics in the cloud computing environment, selecting SLA for the cloud can be difficult. This study proposed KPIs attributes for SLA in the cloud computing and explain possible SLO as well as how to monitor them. This study helped the cloud customer in negotiation and starting of SLA for cloud services. Also, given general information about the SLA and how monitor and manage.

The study addressed the structure of the SLA and what the characteristics of SLO. Then, proposed four general services KPIs that suitable for all the services: availability of the service, security, helpdesk, and monitoring. Furthermore, the study discussed and defined the KPIs for the network as a service, cloud storage, backup service and cloud infrastructure. The study defined six KPIs for the network service. For the cloud storage, the study classified into to two types, Storage as a service and data storage. For storage service defined eight KPIs and for backup defined five KPIs and for infrastructure also defined eight KPIs. In addition, this study limits to define the basic content and KPIs to get started on the cloud SLAs.

Monterio and Vasconcelos [45] proposed a review on the important attribute for the cloud computing using SMI framework. The difference of cloud computing providers and the shortage of standards are barriers in cloud computing technology. This study has given a brief introduction about SOA and the concept of cloud computing. Also, described the general architecture of cloud brokerage and SMI framework. Then, proposed the use of a cloud service broker using the open source Aeolus project and Deltacloud. Moreover, they developed a provider ranking algorithm that made an informed decision on selection of a cloud provider.

The study methodology started (step 1) with preparing a list of requirements that should be agreed by the cloud service broker, collected (step2) the most important attributes in the SMI framework. After the collection of requirements and attributes the ranking table will be created (step 3). The final (step 4) used the rank table to offer some decision between different cloud service providers. Also, a survey created to take the community feedback on important attributes to be used in step 2. This survey contained 39 ranking questions which related to 24 attributes and seven categories and may be more than one question for the same attribute. Then, the average for each attributes calculated depending on the mathematical formula. **Figure 10** shows the result collected after the analysis of this survey. This survey shows that all the attributes had the same balanced in importance, except the performance and security and privacy have about 50%. For the attributes above 40% such as cost, operability and certification, given us hint that the customers want to ensure a cloud provider operation and meet their requirements. So making the broker on a cloud provider service will be best for delivering service according to Monterio and Vasconcelos.

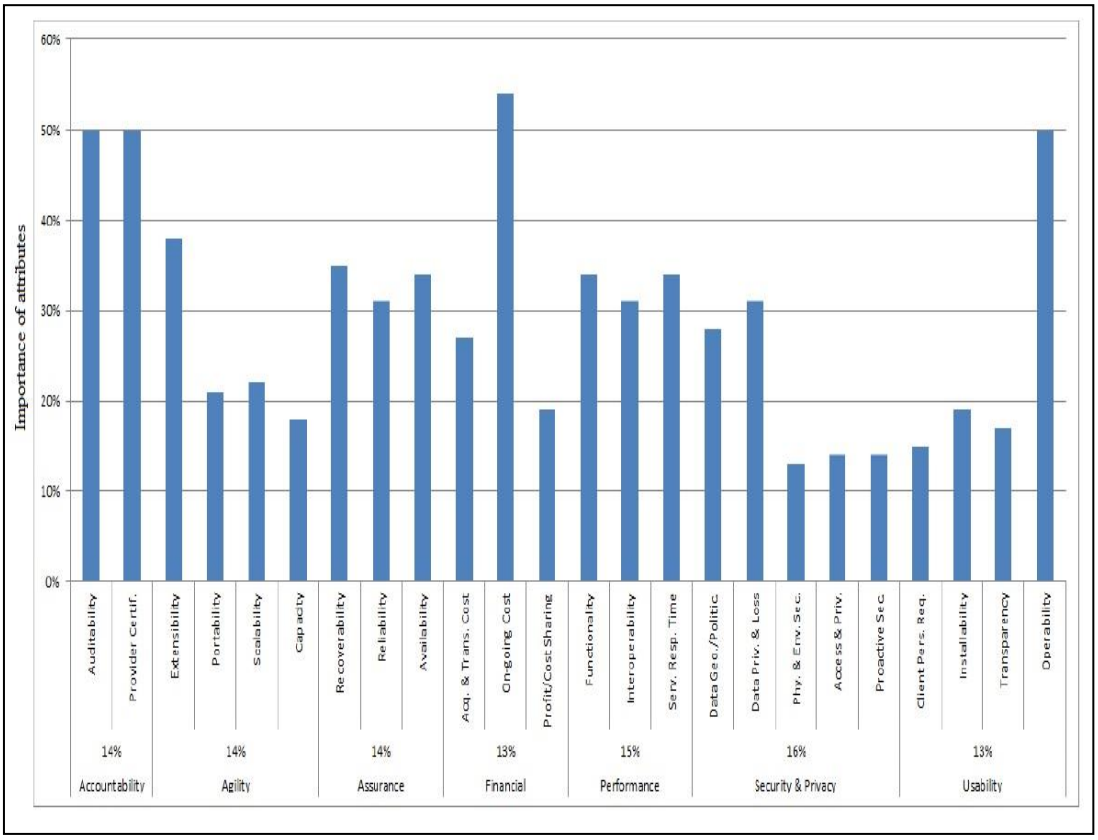

Figure 10 Survey result on the important SMI attributes [45]

Khanjani et al. [46] tried to describe the quality attributes for SaaS. The quality attributes of SaaS are considered to be an important for cloud customers and providers. Therefore, the authors tried to investigate and described the main quality attributes for SaaS. The study included 33 QoS attributes which categorized into three kinds of attribute, the user side attributes, the provider side and both side attributes. The study excluded the business perspective. The study described the 33 QoS attributes in general. Then, it prepared short definition for each attribute. The attributes described from three sides: user perspective, provider perspective and both, though some of the attributes did not classify and the authors did not state this. **Table 2** describes the attribute and metric classified according to the user, provider and both of them.

Table 2 Classification of quality attributes from the user and provider perspective [46].

User side	Provider side	Both sides
Customizability	Serviceability	Composability
Suitability	Robustness	Availability
Accessibility	Data Integrity	Reliability
Learnability	Data privacy	Resiliency
Commonality	Adaptability	Accuracy
Multi-tenancy	Extensibility	Efficiency
Operability	Flexibility	Service response time
Multi-tenancy	Scalability	Stability
	Changeability	Functionality
	Composability	
	Maintainability	

The last study we have reviewed is presented by **Burkon** [47]. This study focused on the quality of service attributes for SaaS. It showed the difference between SaaS and traditional IT outsources. Also, proposed a set of quality attributes related to SaaS management. The SLA in the IT outsourcing context used to define the quality of delivered service. Also, in the SaaS the SLA used for the same purpose. It showed that there is a lack of studies in the SLA for SaaS environment. The proposed QoS attribute for SaaS used the SOA concepts. The set of categories for SOA are covering the web services. The author used the category of the quality attribute and QoS dimension for metrics.

Moreover, the study described ten categories for the SaaS. The nine categories emerged from the research paper on QoS attributes for SOA, and they are availability, performance, reliability, scalability, security, interoperability, modifiability, usability and testability. Also, the author added one more category to the list which is support. Also, for each category defined one or more QoS dimensions. The author identified 28 QoS dimensions. Some of the QoS dimensions may be important for cloud service provider. However, the cloud customer should take all of them.

2.3 Summary

Among the studies reviewed in this chapter, [39] [40] and [41] discussed the SLA quality attributes based on the standardized of web services such as WS-Agreement. Other studies collected the quality attributes from different cloud provider SLAs and analyzed them to find the commonly mentioned and unmentioned attributes in the SLA. The Another study [42] presented 12 important QoS attributes for IaaS service related to SMI standard and went one step forward this standard to propose Cloud SMI framework. Furthermore, one study [43] discussed the QoS attributes such as cost, security, privacy, data loss and flexibility from two directions the literature and popular research about cloud capability in general for all resources of cloud infrastructure. Another one [44] proposed KPIs attributes for SLA in the cloud computing related to three resources of IaaS and explain possible SLO as well as how to monitor them. Moreover, [45] presented a survey on the SMI quality attributes. The last two studies [46] and [47] also discussed the quality attributes, through for SaaS service. One of them [46] proposed a definition for 33 quality attributes and metrics depend on the literature review and classified them into three terms. The last study [47] also, proposed ten quality attributes and related metrics, only depending on the literature studies on SOA quality attributes. In addition, the most quality attributes that have been presented based on different standards and literature review of web services. Also, a few studies discussed various quality attributes in SLA for SaaS service based on the SMI framework.

CHAPTER 3

QUALITY ATTRIBUTES

Once the components of SaaS QoS attributes and SLA in the cloud computing became clear. Now the important set of SaaS QoS attributes will present.

3.1 QoS Attributes

Before getting into the core chapter of the study, we should know the fundamental structure of the selected attributes should be described to organize the study. The Service Level Objectives (SLOs) refers QoS attributes in SLA [39]. Also, The QoS attributes refers to non-functional requirements [46]. The QoS is significant in the Cloud SLA because it can be one of keys success of an organization in cloud computing. Also, it will give the ability to avoid system failure [44].

The quality attributes in this study will be proposed based on the standard of SMI framework. The SMI framework managed the attribute into seven high-level Categories and attributes associated with each category. The SMI defines 51 attributes for all cloud services [43]. In this study, in order to organize the study, the attributes classify into four categories depend on user, business, strategy, and system. The selected attributes will be 12 for SaaS service based on research studies in chapter two and depend on SMI framework. They are usability, suitability, performance, reliability, availability, recoverability, scalability, flexibility, extensibility, security and privacy, maintainability, and portability. Furthermore, related metrics for SaaS service will be specified for most of the QoS attributes to be more understandable.

3.2 Classification of QoS Attributes

1. *User specific attribute*: These QoS attributes that effect directly to the user functionality. These QoS attributes are usability and suitability.

2. *Business specific attribute*: These QoS attributes that affect the business of the organization. Moreover, they will touch by the user. These QoS attributes are performance, reliability, availability, recoverability.

3. *Strategy specific attribute*: These QoS attributes that related to the capacity of a cloud provider to increase in the offered service depend on user requirements. These QoS attributes are scalability, flexibility and extensibility.

4. *System specific attribute*: These QoS attributes are security and privacy, maintainability, and portability. The failure occurs in those qualities will not immediately effect on the user's qualities.

3.3 QoS Attributes for the SaaS

In this part, we will present the core set of QoS attributes for SaaS service. These QoS attributes obtained from the properties of SaaS.

3.3.1 User specific attributes

- **Usability**

Usability is the facility of using the cloud computing services. It is the scope to which software can be used to prepare the organization goals and satisfaction. Also, usability is the way that the users can be able to work with the SaaS services. The typical software based on user interface and user interactive model; for example, is the SaaS service easy to learn and used. Also, simple user interface [41]. It will measure by metrics such as accessibility, learnability, and operability.

Accessibility refers to how the SaaS service can be usable by different users and disabilities. For example, is a SaaS service having the ability to dealing with voice and touch? Or do you need specific usage of service to be access over the internet. It is the expecting users' needs.

Learnability refers to the time and effort required by the users to learn and understand the new SaaS service. Also, the better learnability of software should take less of time and effort to learn it by users. It is a significant issue in the usability [46]. For example, how much the time should spend on the learning a new service to enable users use the software?

Operability refers to the ability of the SaaS service to be operated efficiently by users. It considers one of the essential parts of SaaS service. This metric take above 50% and considers a high percentage beside others QoS attributes in its category [45]. It considers as important metric. For example, is a SaaS service will operate 24h in a day per week?

Efficiency in SaaS refers to the good usability. A SaaS service should provide productivity and increase work efficiency. The efficiency can be achieved to the organization by following the metrics above.

- **Suitability**

Suitability indicates how the SaaS service matches the requirements of users. The SaaS should be meeting the user's needs and objectives. The user gives the essential and non-essential requirements. Also, this requirements may be changed depend on the user's needs. The metric for this attribute is the suitability of service. For example, if an organization wants an email service from cloud provider. It should determine the essential requirements of service such as inbox, draft, send and attachment and the non-essential requirements such as attachment bigger that 20M, encryption and signature. If the cloud service provider offers all the essential and non-essential requirements, then suitability is 10, and if one of the essential requirements not offers by cloud provider, then the suitability cannot measure. Still,

if one of non-essential requirement is not met then the suitability will be less than 10. The mathematical formula used to explain how can measure the suitability of service.

$$\frac{no.of\ non\ essential\ features\ provided\ by\ cloud\ provider}{no.of\ non\ essential\ features\ needs\ by\ cloud\ user} \times 10$$

Nevertheless, all the essential requirements should be satisfied otherwise the result will be zero [42].

3.3.2 Business specific attributes

- **Performance**

Performance refers to the amount of work that done and performed by the system to satisfy the user. Furthermore, if the systems did the entire task and satisfied the user requirement, then the service has high performance. Also, each service has different performance in the term of functionality. However, the most important metric used for SaaS service is the service response time. Also, the response time has above 30% in and considers a high percentage in its category [45]. For example, does the service do what the works need?

Service response time considers the most frequently metric that should be at the SaaS service [46, 47]. It refers to the require time between a SaaS service is requested, and the service response is available. Response time for SaaS service measures by application response, it is the time from the user request an operation in the application to the application response time complete. It presented in milliseconds.

- **Reliability**

Reliability refers to how the SaaS service run over the time without failure according to the given functionality during a given time. For example, what is the percentage of failure the service under a user's conditions?

The actual metrics is the error rate. However, the study [47] depended on uptime history as a metric for reliability.

Error rate refers to the number of request with error represented by percentage in practice. The higher reliable service is with minimal error [39].

- **Availability**

Availability is one of the QoS attribute in all cloud SLAs because the service credit depends on it. Also, all the examined studies talked about it. Availability refers to the proportion of time that the user can use the SaaS service. The related metric for the availability is uptime.

Uptime relates to the percentage of time the user can use the service. It presented as a percentage such as 99.95% and for the complex service the uptime should be measured for each component of the service. However, some of uptime percentage with 99.99 (four nine) and others (five nine), the last digit in the percentage can be critical. **Table 3** shows the available percentages and the downtime depending on these percentages.

Table 3 Availability percentages and downtime per year [48].

Availability %	**Classification**	**Downtime Minutes/year**	**Downtime Hour/year**
99.90	Reliable	526	8.77
99.95	AWS(cloud)	263	4.38
99.99	Highly availability	53	0.88
99.999	Error insensitive	5	0.09
99.9999	Error tolerant	1	0.01

- **Recoverability**

Recoverability can be the ability of service to resume a normal state of operation after unexpected error or disruption. For example, organizations nowadays want to manage and protect their data in SaaS because they use the cloud service for recovery can be reasonable since the cloud providers can backup data in safely locations geography and accessible from anywhere.

In addition, these QoS attributes (reliability, availability, recoverability) got almost 35% in its category and the recoverability was the highest one in the study [45].

3.3.3 Strategy specific attributes

- **Scalability**

Scalability refers to the ability of a SaaS service to decreased and increased capacity and functionalities depend on the user's need. It considers as necessary QoS attribute for SaaS service because it can easily grow up and shrink down based on organization requirements. Also, the scalability can be more economic for energy and compute. For example, a big organization such as Google runs the Gmail service in datacenter compare to small organization runs on their server, so the Gmail will save energy and compute 100 time more than in own server [49]. The metric related to the scalability is elasticity. Also, a question for the future is will be an enhancement on the SaaS service such as internet access or subsystem.

Elasticity defines by the ability to change consumption of SaaS service resources to meet demand in the peak time and pay only for resources used. For example, an organization pays for a service X and when the usage decreased or increased the cloud provider should change the service and price. However, it all depends on the agreement between cloud provider and consumer.

- **Flexibility**

Flexibility relates to the ability to add or change predefined services from SaaS service. It describes how the cloud service provider can quickly respond to the new challenges such as Tsunami disaster in 2011; the Japanese computer companies needed to move immediately to another area [46].

- **Extensibility**

Extensibility refers to the ability of SaaS service to handle and add new services or functionality to existing service in the future. It is useful when an organization grows; increase in the number of users or the functionality of existing SaaS service. However, the enhancement to the service should not result in main design or architecture. For example, the user interface for the service may be replaced with minimum change to the business components.

The QoS attribute scalability has around 22% and the extensibility got above 35% in its category in the study [47].

3.3.4 System specific attributes

- **Security and privacy**

The security and privacy consider in one category in the SMI framework standard because the security and privacy are important issues in the cloud computing. Also, the SMI supports security standards created by the Cloud Security Alliance. In this category, the QoS attributes related to provider's control on access to right users, data privacy, data integrity while transmission, and physical security issue such as damage and unauthorized access. The main question related to security and privacy falls into:

- Is how the cloud provider's SaaS service will meet the security and privacy requirements of an organization vs. another provider?

- Is the data safe from damage and hacker?
- Is the data of SaaS service partitioned from other?

Security considers a significant concern in the cloud computing because the cloud customer's data such as financial, employees' information, etc. stored outside the organization on a remote server. Moreover, there are other things related to security such as a natural disaster or end of the business. The security issues that should consider in the SaaS service or the metric depend on the organization requirements and needs. However, this study will focus on main metric related to SaaS service such as certification, backup and recovery.

Certification considers as important for a big organization or the heavily SaaS service such as service with credit card transaction. The SaaS service should be certified to get the right quality, and the security can perform the right level of quality to the service. It verified by a series third party auditing standard. For example, Statement on Auditing Standards 70 (SAS 70) which confirms that the cloud service provider has the fit set of procedures and policies to provider security services. Also, for credit card transaction there is Payment Card Industry Data Security Standard (PCI DSS) certification [50].

Backup and recovery metrics related to IaaS. However, they can impact on SaaS service. In many cases, the disruption is caused by natural disaster or other causes. Nevertheless, the cloud service provider should focus on application and data backup and recovery. There are a sub-metrics related to backup and recovery such as backup interval, backup type, recovery time, backup media and backup archive [44].

Backup interval specifies the time interval in which backup is created, if it is continuous or regular. *Backup type* refers to the type of backup such as incremental or full. Also, the scope of the backup is it for individual system or all the service components. *Recovery time* specifies the time of successful data recovery from failure cases and how the recovery process is fast. *Backup media* refers to the media storage type such as magnetic tape. *Backup archive* refers to how long the backup will keep and how will delete.

The backup and recovery time for disaster depends on the skill and experience staff of a cloud provider [50].

Privacy refers to the critical data of an organization such as social security number and credit card information for employees and customers. The related metrics are data privacy, data integrity and data geographic.

Data privacy refers to the restriction on use and access of user data by cloud provider, and any failure to protect the user data should be reported to the user. For example, protection requirement for critical data such as encrypted form.

Data integrity means the ability to change data by authorized transaction only to give the user that data are accurate, reliable and valid. It refers to the quality of data. For example, the cloud provider should implement encryption plan such as CloudArray's robust encryption.

Data location refers to the limitations on SaaS service location depend on geography or governments policies. For example, cloud customer should know where the data store and in which location because every geographic location has regulations on data privacy such as in Turkey it's open to discussion [51].

In this study [45], the data privacy has above 30% and data geographic around 27% in its category.

- **Maintainability**

Maintainability refers to the ability of cloud service provider to perform modification such as programing faults, enhance the performance on the SaaS service to keep service performance well. It considers as one of important benefit of SaaS [46]. It made the SaaS service easy to maintain because the cloud providers do the new software testing rather than users. However, there are some questions related to maintainability:

- Is the SaaS service will not go down while maintain and if not for how long.

- What is the time taken to maintain?

- **Portability**

Portability refers to the ability to change from one cloud service provider to another. For example, an organization's work is grown and the cloud service provider cannot keep up this growth. Is there any way to run the SaaS service on different environments?

3.4 Results

The summary about the QoS attributes and related metrics describes in **Table 4**

Table 4 Summary of QoS attribute for SaaS service and related metrics

QoS attributes	Definition / related metrics
Usability	Accessibility, learnability, and operability.
Suitability	Suitability indicates how the SaaS service matches the requirements of users. **Note:** check The mathematical formula in section 3.3.1.
Performance	Service response time
Reliability	Error rate
Availability	Uptime
Recoverability*	Recoverability can be the ability of service to resume a normal state of operation after unexpected error or disruption.
Scalability	Elasticity
Flexibility*	Flexibility relates to the ability to add or change predefined services from SaaS service.
Extensibility*	Extensibility refers to the ability of SaaS service to handle and add new services or functionality to existing service in the future.
Security and privacy	Certification, backup and recovery, data privacy, data integrity and data location.
Maintainability*	Maintainability refers to the ability of cloud service provider to perform modification to keep service performance well.
Portability*	Portability refers to the ability to change from one cloud service provider to another.

* These attributes are non-measurable and the best of our knowledge these attributes do not have related metrics.

CHAPTER 4

CONCLUSIONS

4.1 Findings

1. Penalties/ service credit: all the cloud SLAs explain the penalties when the service down. However, few of them describe how gets the service credit. For example, Amazon will cut 10% of bill if the uptime per year less than 99.95%.

2. PaaS and SaaS SLAs not public: the PaaS and SaaS SLAs are not available for public and only available for subscriptions customers.

3. Functional and non-functional requirement: there are two kind of requirements in which cloud customer can have. The function requirement described what the service should do such as business role and administrative function. The non-functional requirement described what the service supposed to be such as availability.

4. SaaS have more QoS attributes: PaaS and IaaS have less QoS attributes than SaaS because the cloud customers not responsible for any things and only used the service. Some of the attribute that related to SaaS are disaster recovery, data security, maintenance and change term.

5. The metrics for same QoS attribute may be different: in fact, there are different service models in cloud computing and each of them has its own characteristic. For example, in IaaS the availability defines by uptime and downtime. However, it not suitable for storage service such as Microsoft Azure storage describes the availability based on error rate instead of uptime. Moreover, some of QoS attributes depended on the customer such as suitability. However, some of QoS attributes independent such as flexibility.

6. The QoS attributes: the QoS attribute availability considered in all SLAs because the service credit depends on the availability percentage. Also, availability is important for the cloud customers business and for the cloud provider to retain his credibility. Also, Security and privacy they are considered a hot attributes for cloud computing services. Almost all the academic research discussed them for every cloud computing services.

7. The SMI attributes: the SMI define 51 attributes for all the cloud computing service models to enable cloud customers to select how much attributes they need for their requirements. However, not all of them suitable for SaaS service and depends on the cloud customers' needs. For example, the cloud customers may needs small numbers of QoS attributes for their application such as availability and reliability.

4.2 Limitations

In fact, this study did not discuss the cloud SLAs and penalties or service credit in details. Also, it did not examine real cloud SLAs and validate it in business; however it depends on academic studies and literature survey. Then, this study did not discuss functional quality attributes. Moreover, the QoS attributes were investigated related to the SaaS service and based on the literature review of past studies in section 2.2. The study discussed the measurable and non-measurable metrics. However, some of measurable can be qualified in the future. Also, the QoS attributes that have been presented are limited to SMI framework that design by CSMIC. However, the study did not discuss the financial attributes and the price of the cloud services. Also, this study did not address the discussion of laws or regulations governing by government policies.

4.3 Future Work

The future work based on this study can adapt in three directions. First, study different quality attributes for another service such as IaaS and PaaS. Second, may study in depth real SLAs agreement for published cloud service provider. Third, future work may be complete framework for SaaS in SLAs.

4.4 Conclusions

The fast investment in the cloud computing technology and the rapid growth in the public cloud service provider especially in SaaS service have made it difficult to select a cloud service provider. The cloud customers faced real challenging to decide which cloud provider will fulfill their requirements. This thesis investigated on the important QoS attributes and metrics that should consider in the cloud SLA while choosing a cloud SaaS service. The following are the answer to the research questions. The QoS attributes have been classified into four categories. As mentioned in chapter three section 3.1 the 12 QoS attributes and related metrics help the cloud customers to understand and learn how to choose or adapt some of them to fulfill his business requirements. However, there is lack of information about quality attributes such as portability or vendor lock-ins. So these issues remain as challenges for customers, who plan to go to the cloud. Moreover, QoS attribute and metrics can use to increase the reliability and improve the quality level of the service between the cloud customer and provider.

REFERENCES

1. **Kundra V., (2011)**, "*Federal Government Cloud Strategy*", Whitehouse Government Puplishing, Washington, pp. 1-37.

2. **Hassan M. M. and Huh E. N., (2012)**, "*Dynamic Cloud Collaboration Platform*", Springer eBooks Publisher, ISBN:978-1-4614-5146-4, pp. 1-12.

3. **Buyya R., Yeo C. S., Venugopal S., Broberg J. and Brandic I., (2009)**, "*Cloud Computing and Emerging IT Platforms: Vision, Hype, And Reality for Delivering Computing as the 5th Utilit*", Journal of Future Generation Computer Systems, vol. 25, no. 6, p. 599–616.

4. **Hayes B., (2008),** "*News Cloud Computing*", Communications of the Association for Computing Machinery, vol. 51, no. 7, pp. 9-11.

5. **Mell P. and Grance T., (2011)**, "*The NIST Definition of Cloud Computing*" NIST Special Publication 800-145, Gaithersburg, pp. 1-3.

6. **Vaquero L. M., Rodero-Merino L., Caceres J. and Lindner M., (2009)**, "*A Break in the Clouds: Towards a Cloud Definition*", ACM SIGCOMM Computer Communication Review Conference, vol. 39, no. 1, pp. 50-55.

7. **Ahluwalia S., (2011)**, "*Life on Cloud- the User's Perspective*", Techie.com Publisher, Chicago, pp. 3-37.

8. **Carlin S. and Curran K., (2012)**, "*Cloud Computing Technologies*" International Journal of Cloud Computing and Services Science, vol. 1, no. 2089-3337, pp. 59-65.

9. **Man B. H., Gerald G. H. Y. and Benjamin T. W. H., (2011)**, "*A Fresh Graduate's Guide to Software Development Tools and Technologies*", National University of Singapore, Singapore, pp. 5-18.

10. **Voorsluys W., Broberg J. and Buyya R., (2011)**, "*Introduction to Cloud Computing*", John Wiley & Sons Publisher, New Jersey, pp. 3-37.

11. **Williams M. I., (2010)**, "*A Quick Start Guide to Cloud Computing*", KoganPage Limited Publisher, London, pp. 1-99.

12. **Furht B. and Escalante A., (2010)**, "*Handbook of Cloud Computing*", Springer publisher, New York, pp. 1-19.

13. **Sosinsky B., (2011)**, "*Cloud Computing Bible*", Wiley Publishing Inc., Indianapolis, Indiana, pp. 23-42.

14. **Apostu A., Puican F., Ularu G., Suciu G. and Todoran G., (2013)**, "*Study on Advantages and Disadvantages of Cloud Computing – the Advantages of Telemetry Applications in the Cloud*", Conference on Recent Advances in Applied Computer Science and Digital services, vol. 12, no. 978-1-61804-179-1, pp. 118-123.

15. **Armbrust M., Fox A., Griffith R., Joseph A. D., Katz R. H., Konwinski A., Lee G., Patterson D. A., Rabkin A., Stoica I. and Zaharia M., (2009)**, "*Above the Clouds: A Berkeley View of Cloud Computing*", Berkeley Publishing, California, pp. 1-23.

16. **Velte A. T., Velte T. J. and Elsenpeter R., (2010)**, "*Cloud Computing:A Practical Approach*", McGraw-Hill Publishing, New York, pp. 3-87.

17. **Marinescu D., (2013)**, "*Cloud Vulnerabilities*", TechNet Magazine, http://technet.microsoft.com/enus/magazine/dn271884.asx. (Data Download Date: 28 September 2014).

18. **Youseff L., Silva D. M. D., Butrico M. and Appavoo J., (2010)**, "*Understanding the Cloud Computing Landscape*", CRC Press Publishing, Boca Raton, pp. 1-14.

19. **Diversity-Limited Inc., (2011)**, "*White Paper:Understanding the Cloud Computing Stack* ", Rackspace Publisher, US, pp. 1-17.

20. **Schubert L., Jeff K. and Neidecker-Lutz B., (2010)**, "*The Future of Cloud Computing*", European Communities Publishing, Berlin, pp. 1-62.

21. **Prodan R. and Ostermann S., (2009)**, "A Survey and Taxonomy of Infrastructure as a Service and Web Hosting Cloud Providers", 10th IEEE / ACM International Conference on Grid Computing, pp. 17-25.

22. **Varia J. and Mathew S., (2014)**, "*Overview of Amazon Web Services*", Amazon Publishing, pp. 1-22.

23. **Sullivan D., (2010)**, "*The Definitive Guide to Cloud Computing*", Realtime Publishers, pp. 1-60.

24. **Baun C., Kunze M., Nimis J. and Tai S., (2011)**, "*Cloud Computing Web-Based Dynamic IT Services*", Springer Publishers, Karlsruhe, pp. 5-14.

25. **Keller A. and Ludwig H., (2003)**, "The WSLA Framework Specifying and Monitoring", Journal of Network and Systems Management, vol. 11, no. 1, pp. 57-81.

26. **Trapple T., (2010)**, "If It's in the Cloud, Get It on Paper: Cloud Computing Contract Issues", Educause Magazine, pp. 1-4.

27. **Andrieux A., Czajkowski K., Dan A., Keahey K., Ludwig H., Nakata T., Pruyne J., Rofrano J., Tuecke S. and Xu M., (2007)**, "*Web Services Agreement Specification*", Open Grid Forum, pp. 1-80.

28. **Keller A. and Ludwig H., (2002)**, "*Defining and Monitoring Service Level Agreements for Dynamic e-Business*", The Proceedings of LISA 2002 Sixteenth Systems Administration Conference, Philadelphia, pp. 189-204.

29. **Scher R., (2011)**, "*A Service Level Agreement Primer*", PC Today Magazine, vol. 9, no. 3, pp. 22-23.

30. **Shomron D., (2009)**, "*SLA Management for SaaS*", http://saasperspective.blogspot.com.tr/2009/11/sla-management-in-saas.html. (Data Download Date:15 October 2014).

31. **Verma D. C., (2004)**, "*Service Level Agreements on IP Networks*", Proceedings of The IEEE, vol. 92, no. 9, pp. 1382-1388.

32. **Badidi E., (2013)**, "A Cloud Service Broker for SLA-based SaaS Provisioning", IEEE, pp. 61-66.

33. **Sun W., Xu Y. and Liu F., (2005)**, "*The Role of XML in Service Level Agreements Management*", Network Manage. Res. Center, Beijing Jiaotong University, IEEE, China, pp. 1118-1120.

34. **Bianco P., Lewis G. A. and Merson P., (2008)**, "*Service Level Agreements in Service-Oriented Architecture*", Carnegie Mellon University, Pittsburgh, pp. 1-27.

35. **Telemanagement Forum, (2009)**, "*SLA Handbook Solution Suite Version 2.0*", http://www.tmforum.org/SLAHandbookSolution/SLAHandbookSoution/29298/article.html. (Data Download Date:12 October 2014).

36. **IT Manager's Guide, (2011)**, "*White Paper: How to Make an SLA?*", TechExcel Publishing, London, pp. 1-6.

37. **Torkashvan M. and Haghighi H., (2012)**, "*CSLAM: A Framework for Cloud Service Level Agreement Management Based on WSLA*", 6'th International Symposium on Telecommunications (IST 2012), Tehran, pp. 577-585.

38. **CSMIC Inc., (2014)**, "*Service Measurement Index Version 2.1*", Carnegie Mellon University, Silicon valley, CA, pp. 1-7.

39. **Qiu M. M., Zhou Y. and Wang C., (2013)**, "*Systematic Analysis of Public Cloud Service Level Agreements and Related Business Values*", IEEE 10th International Conference on Services Computing, pp. 726-736.

40. **Alhamad M., Dillon T. and Chang E**., (2010), "*SLA-Based Trust Model for Cloud Computing*", 13th International Conference on Network-Based Information Systems, pp. 321-324.

41. **Alhamad M., Dillon T. and Chang E., (2010)**, "*Conceptual SLA Framework for Cloud computing*", 4th IEEE International Conference on Digital Ecosystems and Technologies, pp. 607-610.

42. **Garg S. K., Versteeg S. and Buyya R., (2012)**, "*A Framework for Ranking of Cloud Computing Services*", Journal of Future Generation Computer Systems, pp. 1012-1023.

43. **Siegel J. and Perdue J., (2012)**, "*Cloud Services Measures for Global Use: The Service Measurement Index (SMI)*", Service Research and Innovation Institute Global Conference/IEEE, CA, pp. 411-415.

44. **Frey S., Luthje C. and Reich C., (2013)**, "*Key Performance Indicators for Cloud Computing SLAs*", The Fifth International Conference on Emerging Network Intelligence, ISBN:978-1-61208-292-9, pp. 60-64.

45. **Monteiro L. and Vasconcelos A., (2013)**, "*Survey on Important Cloud Service Provider Attributes Using the SMI Framework*", Centeris 2013 Conference on Enterprise Information Systems, Procedia Technology, pp. 253-259.

46. **Khanjani A., Rahman W. A., Ghani A. and Sultan A. M., (2014)**, "*Saas Quality of Service Attributes*", Journal of Applied Sciences, vol. 14, no. 24, pp. 3613-3619.

47. **Burkon L., (2013)**, "*Quality of Service Attributes for Software as a Service*" Journal of Systems Integration, vol. 4, no. 3, pp. 38-47.

48. **Kaskade J., (2011)**, "*A Chink in Amazons Armor – We Want 5 Nines*", http://jameskaskade.com/?p=1500. (Data Download Date: 11 December 2014).

49. **Hoelzle U.,(2012)**, "*Economies of Scale in the Datacenter: Gmail is 100x Cheaper to Run than Your Own Server*", http://highscalability.com/blog/2012/8/23/economies-of-scale-in-the-datacenter-gmail-is-100x-cheaper-t.html. (Data Download Date: 14 December 2014).

50. **Kaplan J., (2012)**, "*8 Things to Consider When Moving Your SaaS Model To The Cloud*", http://www.rackspace.com/blog/8-things-to-consider-when-moving-your-saas-model-to-the-cloud/. (Data Download Date: 15 December 2014).

51. **BSA The Software Alliance Inc., (2013)**, "*2013 BSA Global Cloud Computing Scorecard*", http://cloudscorecard.bsa.org/2013/countries.html. (Data Download Date: 21 December 2014).

APPENDICES A

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Almallah, Ashraf

Date and Place of Birth: 11 April 1985, Iraq

Marital Status: Married and I have two daughters

Phone: +905535066524, +9647701744991

Email: ashrafn1427@yahoo.com

EDUCATION

Degree	Institution	Year of Graduation
M.Sc.	Çankaya University, Information Technology	2015
B.Sc.	Mosul University, Computer Science Department	2007
High School	Omar Ban Abdulazeez / Scientific Section	2003

WORK EXPERIENCE

Year	Place	Enrollment
2011 December	Mosul University, College of Computer Science and Mathematics	Programmer
2011 February	Technical University of Berlin/ IT administrator's Training Course	Participant
2008 January	Mosul University, College of Computer Science and Mathematics/ Department of Computer Science	Programmer assist
2007 July	Worked in Shop for Computer and Software Maintenance	Employee

FOREIGN LANGUAGES

Native Arabic, Advanced English, Beginner Turkish.

HOBBIES

Travel, Reading, Swimming, Driving.