The Analysis of Cloud Computing Service Level Agreement (SLA) to Support Cloud Service Consumers with the SLA Creation Process

by

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Les analyses du niveau de service sur l'infonuagique (Cloud computing) pour aider les utilisateurs de services l'infonuagique au processus de création de Contrat de niveau de service

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RÉSUMÉ

Le l'infonuagique s'est développé rapidement ces dernières années. Les parties prenantes et plusieurs utilisateurs ont commencé à migrer leurs données vers le l'infonuagique pour tirer parti de son utilisation et de son stockage. La première chose que le fournisseur de services l'infonuagique(CSP) et les clients du service cloud (CSC) doivent traiter est l'accord de niveau de service (SLA). Il s'agit d'un accord conclu entre le fournisseur de service cloud et le client du service cloud, contenant les exigences du consommateur et le niveau de service fourni par le fournisseur de services cloud. Le processus de création d'un contrat de niveau de service est essentiel pour les fournisseurs de service de l'infonuagique et les consommateurs. Cependant, cela pourrait être vague et pas bien défini. Pour améliorer l'utilisation de tous les services de l'infonuagique, le contenu et la création de l'accord de niveau de service doivent être gérés de manière efficace et prudente.

Dans cette thèse, nous avons d'abord effectué une revue de littérature pour vérifier le niveau d'occurrence des paramètres SLA et l'objectif de niveau de service SLO dans le monde universitaire et générer une liste des paramètres SLA et SLO les plus et les moins étudiés. Dans le deuxième chapitre, nous avons confronté cette liste aux trois fournisseurs de services de l'infonuagique les plus populaires du marché moderne (Amazon, Microsoft et Google) afin d'enquêter sur la couverture de leur contrat de niveau de service.

Enfin, dans le dernier chapitre, nous avons proposé un outil SLA qui pourrait aider les fournisseurs de service cloud et les consommateurs dans le processus de création de SLA. Cet outil SLA aiderait les consommateurs tout au long de la phase de négociation et faciliterait le processus de selection, afin de choisir le fournisseur de service le plus adapté.

Mots-clés: L'infonuagique, Contrat de niveau de service (SLA), Objectif de niveau de service (SLO), Cycle de vie du SLA, Phase de négociation du SLA.

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ABSTRACT

Cloud computing has been developing rapidly in the past few years. Stakeholders and several users started to migrate their data to the cloud to benefit from its usage and storage. The first step cloud service provider (CSP) and cloud service consumers (CSC) deal with is the service level agreement (SLA). It is an agreement issued between the cloud service provider and the cloud service customer that contains the consumer's service requirements and the service level provided by cloud service providers. The process to create an SLA agreement is very essential for both cloud service providers and consumers. However, it could be vague and not well defined. To enhance the usage of any cloud services, the content and the creation of the SLA agreement should be handled efficiently and carefully.

In this thesis, first we conducted a literature review to check the level of occurrence of SLA and SLO parameters in the academia and generate a list of the most and least studied SLA and SLO parameters. In the second chapter, we confronted this list to the three most popular cloud service providers in the modern market (Amazon, Microsoft and Google) to investigate their SLA agreement coverage.

Finally, in the last chapter, we proposed an SLA toolkit that could assist cloud service providers and consumers in the process of SLA creation. This SLA toolkit would help the consumers through the negation phase and facilitate the selection process to choose the most applicable cloud service providers' offer.

Keywords: Cloud computing, Service level agreement (SLA), Service level objective (SLO), SLA life cycle, SLA Negotiation phase.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS AND ACRONYMS

AWS	Amazon Web Service
CC	Cloud Computing
CSC	Cloud Service Consumer
CSP	Cloud Service Provider
IaaS	Infrastructure as a service
KPIs	Key performance Indicators
PAYG	Pay As you Go Cloud computing
PaaS	Platform as a service
QoS	Quality of Service
QRs	Quality Requirements
RTO	Recovery Time Objective
SLA	Service Level Agreement
SLO	Service Level Objective
SL	Service level
SaaS	Software as a service
S3	Amazon Simple Storage Service

INTRODUCTION

Considering the several advantages cloud computing is providing for users such as reduction in cost and elastic resources, etc., it is rapidly taking over traditional IT infrastructure and many business stockholders, government and academia nowadays are transforming and uploading their work to the cloud. It is a wide field that researchers keep working on to improve the level of quality provided.

The first step cloud service consumers face when subscribing to a cloud service is Service level agreement (SLA). It is a contract issued between cloud service provider and consumer that should specify the service level requested by cloud service consumers and identifies their requirements (Terfas, Suryn, Roy & Moazzezi Eftekhar, 2018, P.2). Having a well-structured SLA could lead to a better service level and less service violations. However, "One open problem is that service level agreements (SLAs) in the cloud ecosystem are yet to mature to a state where critical applications can be reliably deployed in clouds" (Faniyi & Bahsoon, 2015, P.1). Therefore, several researches are conducted to improve the SLA structure and facilitate the creation process. Although many researchers tried to simplify the use and the initiation of an SLA, they didn't focus enough on SLA and SLO parameters, which could lead us to a poor SLA agreement that contains only useless and impractical words. According to Faniyi, most of the studied papers in their research discussed only one to three SLA parameters rather than the rest of cloud service parameters (Faniyi & Bahsoon, 2015, P.2). In this research, we deeply analysed several papers from the literature to find out the most and least studied SLA and SLO parameters that cloud service consumers would use during the SLA creation.

Another unsolved problem is that cloud service providers define SLA and SLO parameters in advance so they don't respect all users' requirements (Rady, 2012, P.9). Consequently, we deeply investigate three well-known cloud service providers (Amazon, Microsoft and Google) and confront their SLA agreements to the SLA and SLO list extracted from the academia to check the level of coverage they offer in their SLA.

SLA life cycle consists of several stages that start with the negotiation stage. At this stage, cloud service consumers have to choose the most appropriate cloud service provider that adheres to their requested requirements. However, SLA creation process and cloud provider selection could be complicated, difficult to follow and time consuming. In this research we proposed an SLA toolkit that could help both cloud service provider and consumer. This SLA toolkit could facilitate the negation process and help the consumer in the process of cloud provider's selection. In addition, it could help cloud service consumers gain more controllability over their data to increase the level of trust towards cloud computing environments.

Thesis structure

This thesis is structured as the following: the first chapter presents a literature review conducted to show the SLA and SLO parameters distributions in the academia and to identify the most and least studied SLA and SLO parameters. Chapter two illustrates the selected cloud service providers and confronted them to the extracted SLA and SLO parameters' lists to show the coverage percentage for each cloud service provider. Chapter three presents the proposed SLA toolkit and how it works to assist cloud service providers and consumers thorough the process to create an SLA agreement. Finally, we conclude our thesis and present our future research plan.

CHAPITRE 1

LITERATURE REVIEW

In this chapter, we present a list of SLA and SLO parameters that were extracted from ISO standards 19086 and the literature. We demonstrate the occurrence percentages for all the presented SLA and SLO parameters to identify the most and the least studied SLA and SLO parameters in the academia.

1.1 SLA parameters distribution

1.1.1 Extracted SLA parameters

“Service level agreement (SLA) is a contract signed between the customer and the service provider. It states the terms of the service including the non-functional requirements of the service specified as the quality of service (QoS), obligations, service pricing, and penalties in case of agreement violations” (Emeakaroha, Brandic, Maurer & Dustdar, 2010, P.1). From a quality point of view, SLA consists of several agreements, which are combined into one contract. These agreements are based on different facts such as nature, cost and objectives of the provided service. Additionally, it can contain the number of violations that are allowed during a predefined period of time. (Mirobi & Arockiam, 2015, P.3).

Nowadays, several factors are encouraging stakeholders to migrate their data to the cloud. However, there are many unsolved issues which could slow down the process. One of the issues that cloud service consumers face when they plan to move to the cloud is that cloud computing service level agreement (SLAs) are not reliable enough to support the deployment of their crucial applications (Faniyi & Bahsoon, 2015, P.1), Although, International Organization for standardization (ISO) has developed ISO/IEC19086 cloud computing Service level agreement (SLA) framework, only ISO/IEC 19086 part 1 and 3 are published while ISO/IEC19086 part 2 and 4 are still under development.

Also ISO/IEC 20000 series was developed to support IT service management. It identifies different requirements to support service management systems SMS. It consists of 11 parts. ISO/IEC 20000-9 focuses on cloud services and provides a guideline to facilitate the usage of ISO/IEC 20000-1 for cloud services by proposing some scenarios that can help both cloud service providers and consumers. However, service level agreement was only mentioned as a tool to ensure the quality of the service and did not include any SLA or SLO parameters that could be useful in the SLA creation process. Regarding service level agreement SLA, ISO/IEC 20000 defines SLA as a document that includes service requirements and service targets. According to ISO/IEC 20000, one or more service level agreements SLAs could be created for each IT service. In addition, SLAs should be updated according to any requirements change. According to Zitek, "ISO/IEC 20000 defines SLA as a mandatory requirement as one of the service delivery process" (20000Academy, 2015). ISO/IEC20000 specified some recommendations and conditions which could apply for service management systems SMS process that includes some SLA contents and conditions which could be considered in an SLA contract. However, no SLA or SLO parameters were suggested or proposed. Therefore, it was not considered in this analysis due to the shortage use and consideration of SLA and SLO parameters.

Meanwhile, information technology infrastructure library ITIL consists of best practices collection that could be used for IT service managements. It can help organizations by improving the delivery of IT services. Service level agreement SLA were discussed in ITIL, only in two core areas service design and continual service improvement to cover any service updates that can affect the SLA. Based on Zitek, ITIL defines SLA in the scope of the service level management process and specifies other types of agreements that could be used besides SLAs such as operational level agreement (OLA) and underpinning contract (UC) (20000Academy, 2015). In addition, it provides guidance that could help providers and consumers in the initiation process of an SLA. For example, the responsibilities of providers and consumers should be well defined in an SLA contract. Also a single SLA could be used by various consumers for several IT services (Morin, Aubert& Gateau, 2012, P.4). ITIL assists organizations to know the value of their IT services to help understanding the

importance of this value to define a better SLA. However, ITIL is not totally focusing on obtaining this (Wegmann, Regev, Garret &Maréchal, 2008, P.1). Therefore, ITIL do not provide any SLA or SLO parameters to help in the definition of an SLA. Even though ITIL provided several recommendations regarding the SLA creation, it did not include any SLA and SLO parameters that could be helpful to use in an SLA and in this research analysis.

Cloud computing SLA is still suffering from an obvious lack of standardization. In spite of the fact that there are a wide variety of papers on SLA in the academia, only few of them discuss SLA parameters. As shown by Faniyi & Bahsoon in their systematic survey, they demonstrated that only one to three SLA parameters were mentioned in the greater part of the analysed articles, while only a few articles considered four to five SLA parameters (Faniyi & Bahsoon, 2015, P.7).

We conducted a literature review to extract the most studied SLA parameters in the academia and create a list of the most frequently mentioned SLA parameters. This list would help analysing and verifying the applicability of SLA contracts for (Amazon, Google and Microsoft) in the modern market.

1.1.2 Literature review methodology

In this research, we used several research engines such as Compendex, IEEE Xplore and Google Scholar to look for articles concerning this topic. By using multiple related keywords and some questions, related articles were found and analysed. Some keywords that were used are cloud computing Service level agreement SLA, quality aspects, SLA parameters, SLA challenges, SLA initiation and SLA Frameworks.

The following research questions were investigated:

Q1: What are the SLA parameters that should be covered in cloud computing SLAs?

Q2: What is Service Level Agreement?

Q3: What is the state of cloud computing SLAs today?

To answer the above mentioned questions, we conducted a literature review and the most relevant articles were investigated. However, only the applicable ones were selected. At the beginning of this research, 40 articles were found in this area. By carefully scanning the abstracts, only 25 were selected and finally after reading all of these articles individually, only 19 included the required information for this research analysis. Many of the considered papers proposed SLA frameworks. SLA and SLO elements were discussed and used to prove the applicability of their frameworks, while other articles discuss only SLA definition and its importance in the industry. Due to the limited research papers on this area (SLA) a lot of the chosen papers were conference papers. Articles take longer time to be published. Furthermore, conference papers are more up to date.

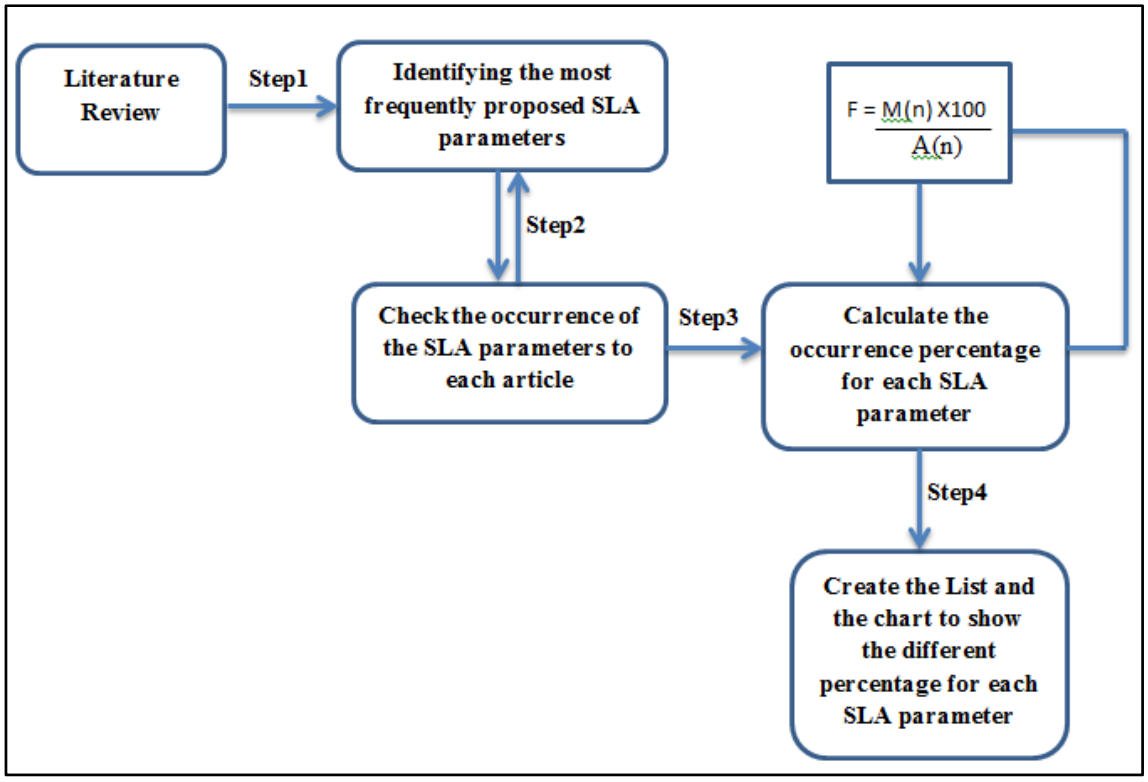

Figure 1.1 SLA Parameter Extraction Process

As shown in figure 1.1 stage 3, these are the variables definitions:

- Let **(F)** be the percentage of the frequency of SLA parameters.
- Let **M(n)** be the number of how many times each parameter was mentioned across all the articles.(when the parameter is mentioned one time or more in each article, it is considered as 1)
- Let **A(n)** be the total number of the analysed articles.
- **(n):** means the total number. For example, **A(n)** is the total number of the analysed articles

As seen in Figure 1.1 SLA parameters extraction process consists of 4 steps:

Step.1: The literature review was conducted; SLA parameters were extracted from several articles that were found in the academia.

Step.2: A table for each article was created. It includes SLA and SLO parameters that were found in each reference.

Step.3: After the duplicated parameters were eliminated, the next step was to check the occurrences for each SLA parameter in all the provided references. For further details, please refer to the tables in Appendix I and II. As shown in appendix I and II, M (Mentioned) was chosen when the SLA parameter was mentioned while NM (Not Mentioned) was chosen when the parameter was not mentioned in the reference.

Step.4: After applying the above mentioned steps to all extracted SLA parameters, the occurrence percentage was calculated using the following equation:

$$\mathbf{F} = \frac{M(n)\ X\ 100}{A(n)}$$

Where **F** is the distribution percentage of the SLA parameter in the academia, a percentage for each SLA parameter was identified. Based on this, the list of the most frequently used SLA parameters in the academia was created. In addition, a chart was drawn to show the highest and the lowest percentage of the parameters and to clarify the distribution for the rest of the SLA parameters.

NOTE: This methodology was also used to create the list of the extracted SLO parameters.

The following chart (figure 1.2) shows the most studied and least studied SLA parameters found in the academia

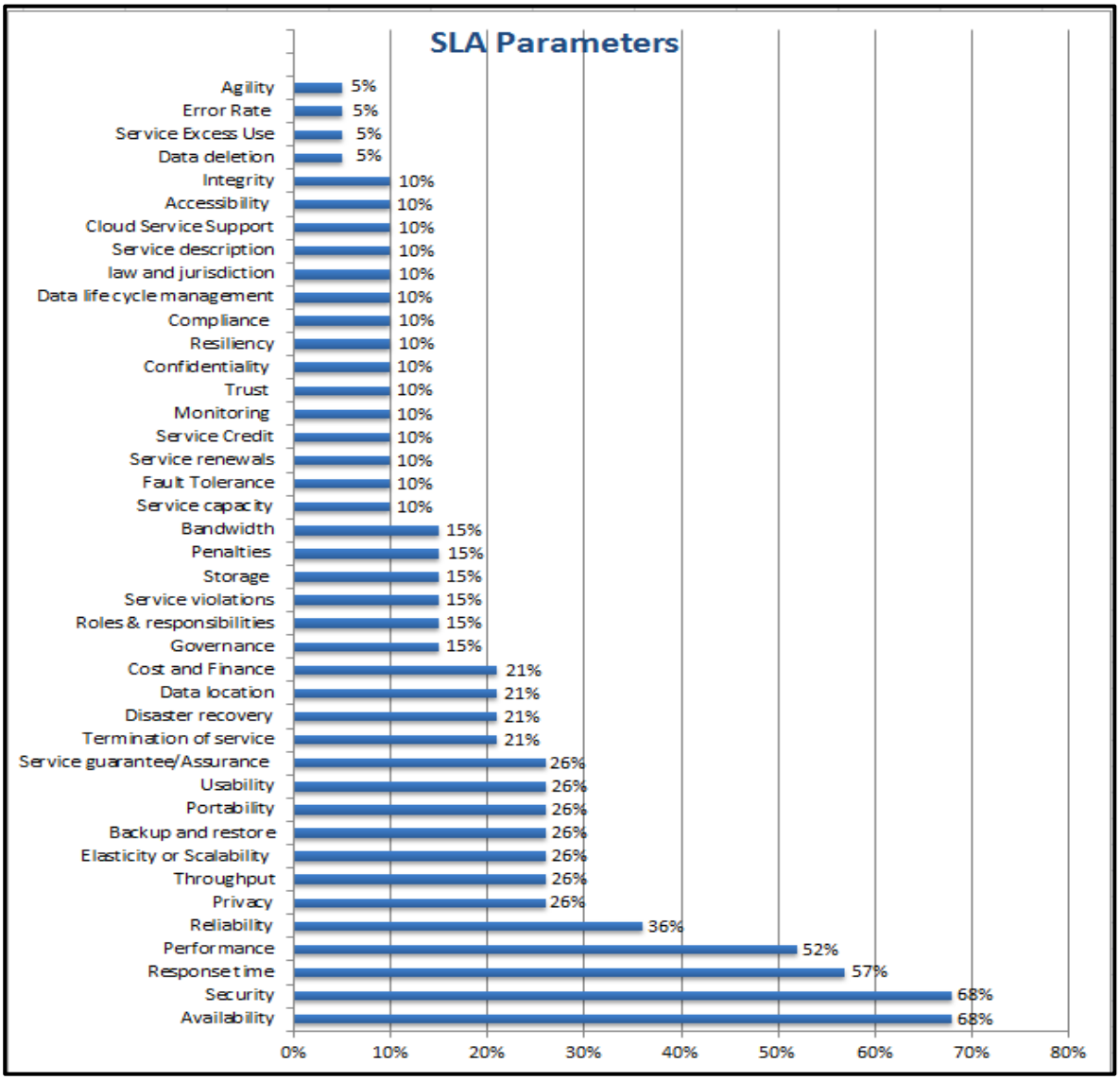

Figure 1.2 SLA Parameters Distributions Chart

After classifying the extracted SLA parameters and identifying the percentage of their distribution, we have indicated that these SLA parameters which are presented in figure 1.2 were found in the literature and used or defined by a variety of researchers. After extracting SLA parameters from the literature, we calculated their occurrence percentages as shown previously to find out the frequency percentage for each parameter and how many times it

was mentioned. Based on this, the criteria used to identify the most and least used SLA parameters was that parameters with the highest percentages were considered as the most studied SLA parameters in the literature while parameters with the lowest percentages were considered as the least studied SLA parameters. Overall, the bar graph illustrates the percentage of occurrence for the SLA parameters according to their distributions in the academia.

The chart consists of 41 SLA parameters. The highest occurrence percentage is 68% and the lowest is 5%. Looking in closer detail at the chart it can be seen that availability and security are on the top of the graph. They were the most studied SLA parameters in the academia and have the highest percentage among all other extracted parameters, while response time and performance came right after them with a percentage of 57% and 52% respectively.

On the other hand, some SLA parameters such as (Service Excess Use, Data deletion, Agility and Error rate) have the lowest occurrence percentage. Therefore, they are considered as the least studied SLA parameters.

This list of SLA parameters support cloud service consumers and providers with the most prominent SLA parameters to be analysed and discussed when creating a user-tailored SLA for cloud service consumers. In addition, in the modern market, providing cloud service consumers with longer list of parameters would help to persuade cloud service consumers and encourage them to move to the cloud (Suryn, 2013, P.152).

To simplify this analysis and explanation, we divided the chart in figure 1.2 into two charts and illustrated them individually.

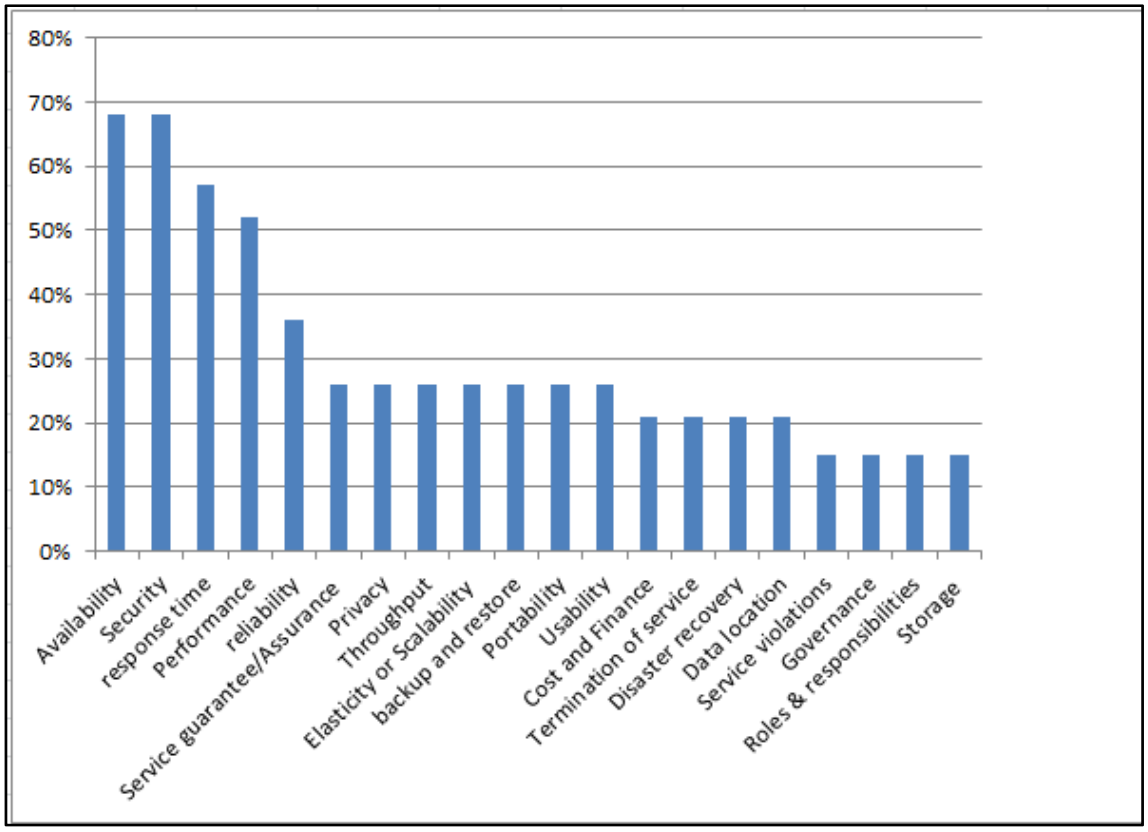

Figure 1.3 SLA Parameters' Distribution Part1

As shown in figure.1.3, the bar graph shows the SLA parameters that were derived from several articles in the academia such as (Faniyi & Bahsoon, 2015), (San & Irena, 2016) & (Ghosh & Ghosh, 2012), etc., where they were mentioned as critical SLA parameters to cloud service consumers. By closely observing the graph, it can be seen that availability and security are mentioned frequently often, when comparing them to other the SLA parameters in the reviewed papers, while service violation, storage and role and responsibility got less consideration and were at the bottom of the chart.

In following paragraphs the definitions of some extracted SLA parameters are presented, addressing the sources, where they were discussed and derived from. The upcoming SLA parameters were selected based on their order and percentage in the chart in figure 1.3. We illustrated the SLA parameters with different percentages to show the variety among these presented percentages.

SLA parameter 1 (Availability). According to ISO/IEC 17788 cloud computing standard "Availability is the property of being accessible and usable upon demand by an authorized entity". This SLA parameter clarifies to the user that the requested service is easy to access and usable in a certain period of time. A new SLA framework for E-commerce cloud service with respect to the end user perspectives was proposed by (Busalim, Hussin & Ibrahim, 2013, P.1). They provided a list of the most applicable SLA parameters and their objectives. Availability was on the top of this list. "Most of cloud service provider's focus only on small set of parameters, namely availability, request completion rate and response time". (Busalim et al., 2013, P.3). In accordance with Frey, to encourage cloud service consumers to move their data to the cloud, an individual SLA agreement should be build according to the requirements of each requested service rather than having a standard SLA for all cloud service consumers neglecting their different needs (Frey, Luthje, Teckelmann& Reich,2013, P.1). They illustrated a machine processed Adaptable Service Level Objective Agreement (A-SLO-A). They also suggested that Availability is one of the critical SLA parameters to be included when creating an SLA agreement to suit the requirements of different cloud service consumers.

SLA parameter 2 (Security). Security is another issue that cloud service consumers and providers have to deal with. It is a vital SLA parameter that is recommended to be considered when creating an SLA contract. ISO/IEC 19086 part 4 discusses security and privacy in cloud computing. As indicated by (Ghosh & Ghosh, 2012, P.3), to assure the security of data transitions from and to the cloud, SLAs should consider security as a crucial element. Considering the difficulties cloud service consumers face when choosing the appropriate cloud service provider, (San & Irena, 2016, P.12) precisely explained the most important elements to be considered in an SLA and Security parameters were mentioned.

SLA parameter 3 (Service assurance and guarantee). Based on Garg, "Assurance indicates the likelihood of a Cloud service that it will perform as expected or promised in the SLA." (Garg, Versteeg & Buyya, 2011, P.2). Therefore, stakeholders consider it as an important element when they move their data to the cloud. According to Ghosh, even though the

majority of cloud service providers are focusing on availability rather than other parameters, cloud service consumers still demand more assurance and guarantees to the provided service (Ghosh & Ghosh, 2012, P.1). Therefore, it is specified as an important parameter to discuss when creating cloud computing SLA contract.

SLA parameter 4 (SLA violation). SLA violation is one of the challenges that could affect cloud service providers and consumers. It is the possibility of job failures or not meeting the service levels required by cloud service consumer (Faniyi & Bahsoon, 2015, P.4). A survey was conducted by (Faniyi & Bahsoon, 2015, P.5) to improve the structure of cloud SLAs and their management. One of the studied SLA violation parameters is allowable violations, which defines the allowed number of violation permitted. (Chana & Singh, 2014, P.4) discussed the relationship between quality of service QoS and cloud computing SLAs. Moreover, they presented the elements each SLA should consist. Service violation was one of the components that were suggested to be included.

SLA parameter 5 (Cost and finance). Since cloud computing is considered as a cost effective service in contrast to the traditional computing, cost is one of the most crucial elements that affects cloud service consumers decision to migrate to the cloud (El-Awadi &Abu-Rizka, 2015, P.2). Therefore, it is a prominent feature that encourages stakeholders to migrate to the cloud. Based on El-Awadi, finance is one of the parameters that need to be discussed when creating and negotiating the SLA contract (El-Awadi &Abu-Rizka, 2015, P.3). Cost was identified as one of the parameters included in the top level QoS groups by (Garg et al., 2011, P.2). Thus, "Cost is clearly one of the vital attributes for IT and the business". According to the systematic analysis conducted by (Faniyi & Bahsoon, 2015, P.7), cost was one of the most studied SLA parameters and used especially in the platform as a service (PaaS).

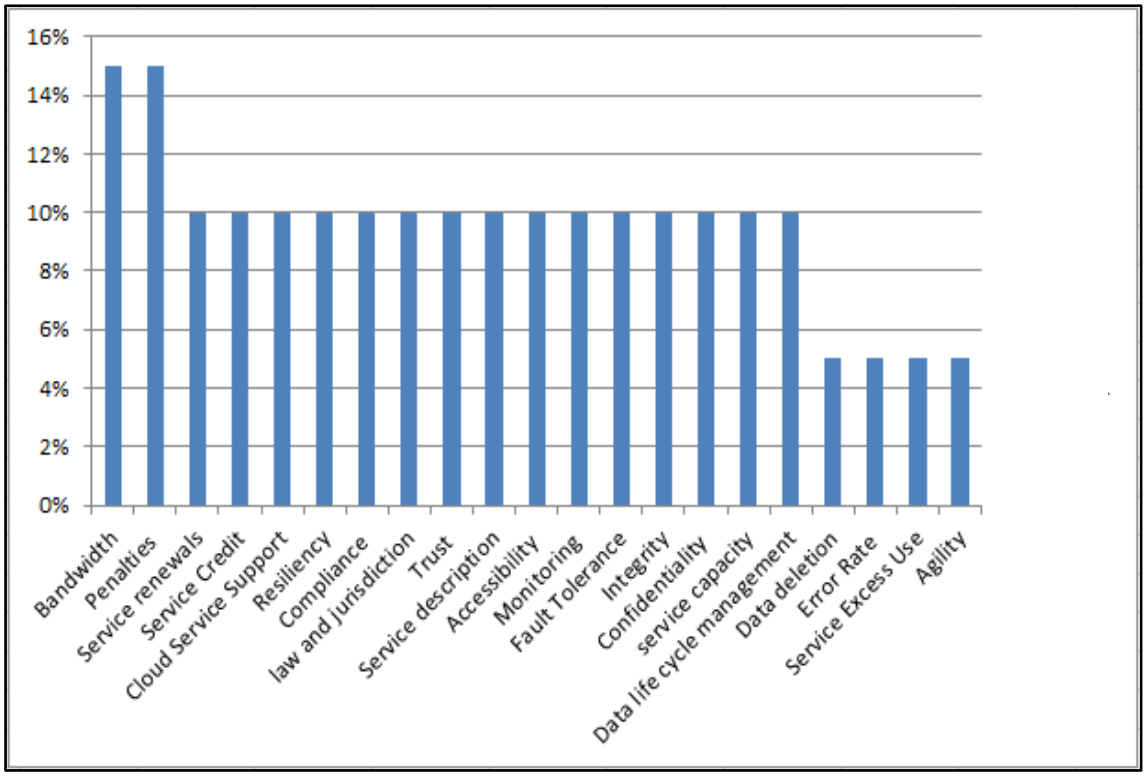

Figure 1.4 SLA Parameters' Distribution Part 2

As shown in figure.1.4, the bar chart presents the rest of the extracted SLA parameters derived from several articles in the academia such as (Faniyi & Bahsoon, 2015), (San & Irena, 2016) & (Emeakaroha et al., 2010, P.6), etc. Data deletion, agility, service excess use and error rate has the lowest occurrence percentage of 5%. Most of these SLA parameters showed in the graph were mentioned once or twice in the analysed articles. In addition, some of them such as bandwidth and error rate were mentioned as SLA parameters in some papers and as SLO parameters in others.

In following paragraphs the definitions of some extracted SLA parameters are presented, addressing the sources, where they were discussed and derived from. The approaching SLA parameters were chosen based on their percentage and position in the chart in figure 1.4. We demonstrated the SLA parameters with different percentages to show the variety among these presented percentages.

SLA parameter 1 (Bandwidth). Based on Faniyi, bandwidth was one of the most studied SLA parameters in the survey they conducted (Faniyi & Bahsoon, 2015, P.7). However, in this research, we found that bandwidth was mentioned as an SLA parameter in some papers and in a few articles as an SLO parameter. Moreover, based on Emeakaroha, bandwidth was divided into incoming bandwidth and outgoing bandwidth (Emeakaroha et al., 2010, P.6).

SLA parameter 2 (Service renewal). Cloud computing offers many features for users such as pay as you go (PAYG cloud computing), which means cloud service users can pay only when they use the service. However, some SLA contracts include a starting and an ending date (San & Irena, 2016, P.7). According to San & Irena, service renewal is one of the crucial SLA parameters, which helps to identify how consumers could renew their service, and clarifies any available renewal conditions.

SLA parameter 3 (Service credit). When any SLA violations occur or any service guarantees are not met, cloud service providers should compensate cloud service consumers with Service credit. Some companies nowadays such as Amazon and Google offer service credit as money refund or additional service applied to the user's usage in the future. Based on San & Irena, Service credit is an obvious element when discussing SLA agreements (San & Irena et al., 2016, P.6).

SLA parameter 4 (Data deletion). According to ISO/IEC19086 part-1, "Data deletion is the removal of access to cloud service customer data through the user and administrator capabilities of the cloud service". In this research, data deletion was one of the least studied SLA parameters in the literature with a 5%. When any failures occur in the cloud service an automatic action is taken and replicates the data directly to save it in multiple servers. Therefore, when terminating the service there is an issue to secure the deletion of all stored data and that is why ISO/IEC 19086-1 mentioned data deletion as an SLA parameter to consider in cloud SLAs.

SLA parameter 5 (Error rate). Error rate was also one of the least studied SLA parameters, as it was mentioned only in one article. Based on Ghosh, Error rate is one of the important SLA parameters that should be considered when creating an SLA agreement for storage as a service cloud (Ghosh & Ghosh, 2012, P.3).

SLA parameter 6 (Service excess use). While cloud computing offers pay as you use features, cloud service consumers can also initiate a contract where they can set and indicate the amount of usage with the cloud service provider. Consequently, the user needs to know the usage and check for any access use.

Overall, looking into the aforementioned information, some SLA parameters found in the academia were well defined and precisely explained, while others were defined differently from an article to another. Besides, part of the analysed papers mentioned some SLA parameters as SLO parameters, which indicated the lack of standardization. Although authors in several articles demonstrated in details the definitions of SLA agreements and their importance to cloud service providers and consumers, there was no clear method or recommendations on how to evaluate SLA agreements using these SLA parameters or how cloud service consumers could measure SLA parameters to assess the provided service.

For further information refer to appendix I and appendix II.

1.2 SLO parameters distribution

1.2.1 Extracted SLO parameters

According to Frey, "Service Level Objectives (SLOs) are a central element of every service level agreements (SLA), which include the negotiated service qualities (service level) and the corresponding Key Performance Indicators" (Frey et al,2013, P.3). They are the metrics or measures that could be used to check and evaluate all SLA parameters.

The following chart (figure 1.5) shows the Most studied and least studied SLO parameters found in the academia.

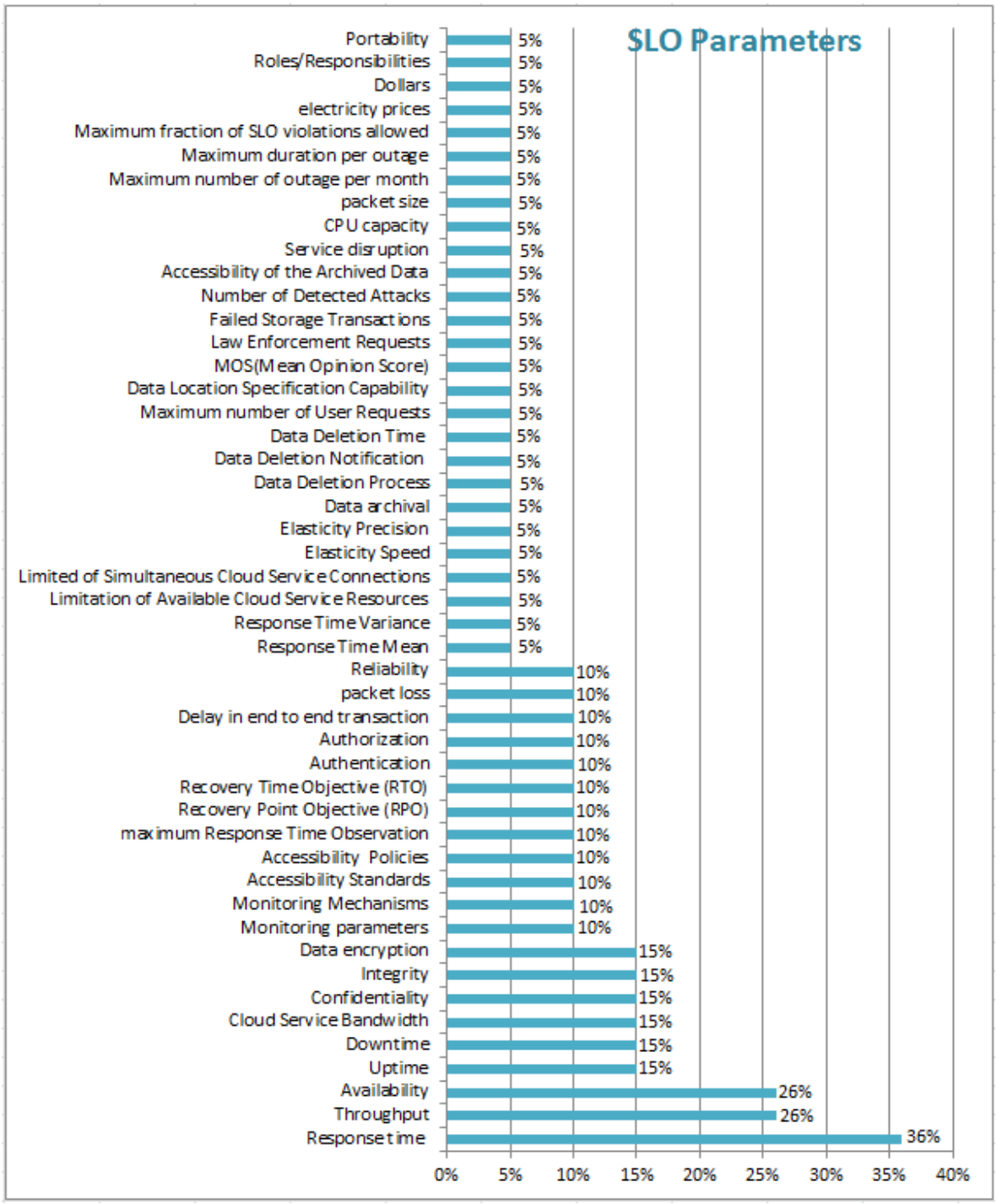

Figure 1.5 SLO Parameters Distribution Chart

The bar chart presented in figure 1.5 demonstrates the percentage of occurrences for the Service level objectives (SLO) in cloud computing based on their distribution in the academia. After extracting SLO parameters from the literature, we calculated their occurrence percentage as shown previously for SLA parameters to find out the frequency percentage for each parameter and how many times it was mentioned. Based on this, parameter with the highest percentages were considered as the most studied SLA parameters in the literature while parameters with the lowest percentages were considered as the least studied SLA parameters. Looking in closer detail at the chart, it can be observed that most of the SLO parameters calculated percentage was 5% to 10 % which shows an obvious poor occurrence for SLO parameters in the academia.

The graph consists of 48 SLO parameters. Response time was on the top of the list with 36%, while throughput and availability came second with 26% each. The rest of the SLO parameters were ranked between 15% and 5%.

On the other hand, some SLO parameters were also mentioned in the literature as SLA parameters too, such as response time, availability, portability and reliability. Consequently, in this research we faced several limitations regarding cloud computing SLO parameters.

Overall, it can be clearly seen that there is a lack of connection between SLA and SLO parameters in the academia. While SLA parameters were mentioned in some academic articles, there is a scarcity of information regarding the definitions and the usages of SLO parameters.

To clarify this analysis, we divide the chart in figure 1.5 into two charts and demonstrate them individually.

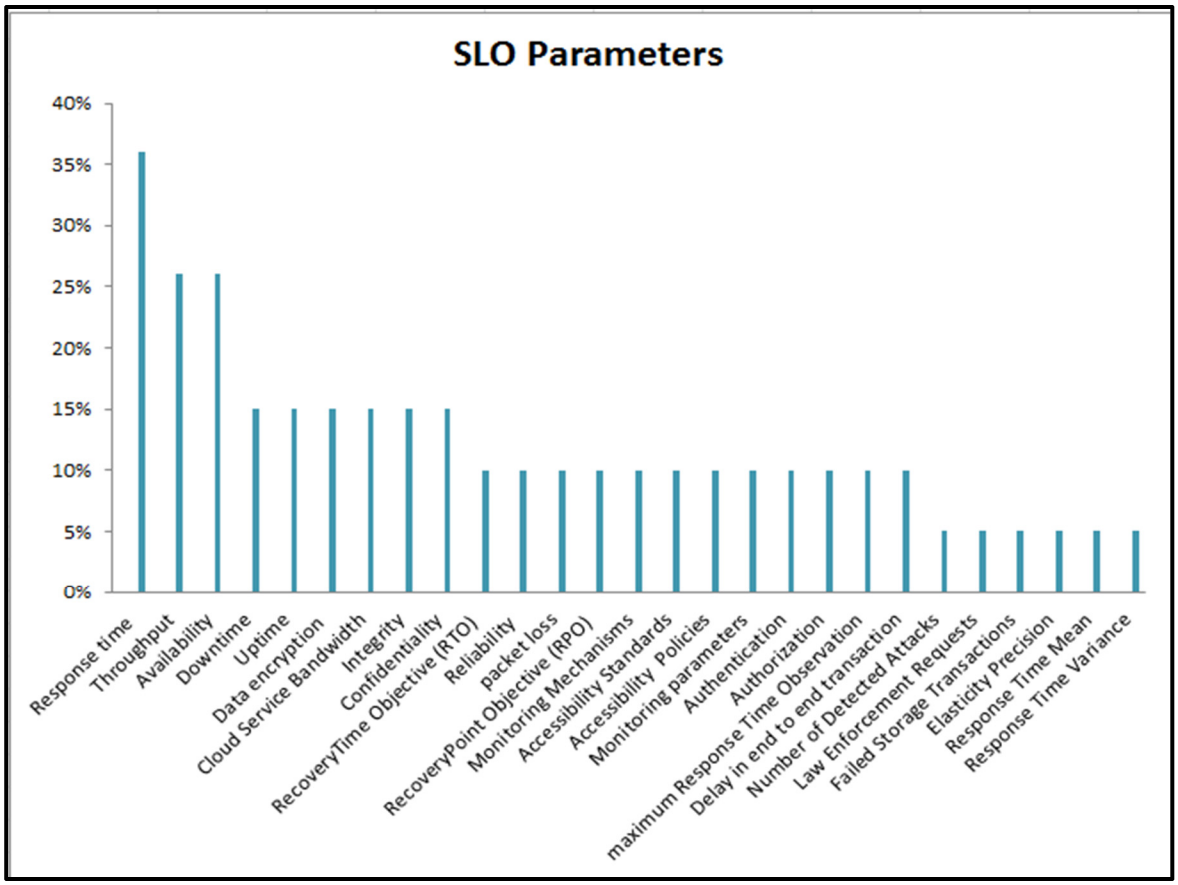

Figure 1.6 SLO Parameters' Distribution Part 1

As shown in figure 1.6, the bar chart presents the extracted SLO parameters according to the literature. Response time, availability and throughput got the highest occurrence percentage among all other SLO parameters. In addition, as seen in figure 1.5 and based on the conducted literature review, there is a tremendous gap between cloud SLO parameters and their definitions, usage and distributions. It is very obvious that SLO parameters are not well defined and poorly mentioned. Moreover, in some cases they were completely ignored.

In following paragraphs the definitions of some extracted SLO parameters are presented, addressing the sources, where they were discussed and derived from. The upcoming SLO parameters were chosen based on their percentage and order in the chart in figure 1.6. We demonstrated the SLO parameters with different percentages to show the variety among these presented percentages.

SLO parameter 1 (Response time). According to Busalim, response time was classified as an SLO parameter for cloud performance. It is a certain period of time when a service request is sent and a response is received by the user (Busalim et al., 2013, P.4). Although response time was mentioned as an SLA parameter in several articles, it was considered as an SLO parameter in others. A new SLA framework for monitoring and checking SLOs by using a third party was proposed by (Ghosh, Ghosh & Das, 2015, P.4). They considered response time as an SLO parameter example, while they mentioned it as an SLA parameter too.

SLO parameter 2 (Throughput). It is the number of inquiry that the service can deal with in a specific period of time (Busalim et al., 2013, P.4). Throughput was considered as an SLO parameter for performance in several articles such as (ISO SLA standard 19086-1) and (Busalim et al., 2013. P.4). Based on Frey, throughput was also specified as one of the SLO parameters that could be used in cloud computing (Frey et al., 2013, P.4).

SLO parameter 3 (Uptime and Downtime). According to ISO19086-1, uptime and downtime are considered as SLO parameters to check and evaluate the availability of the service. Actually they refer to the time when the service is accessible or not and it is usually calculated over a certain period of time.

SLO parameter 1 (Data encryption). It is a mechanism that helps to control and check whether the sent information or the data which is stored in the cloud storage is encrypted or not. In addition, it checks the percentage of encrypted data which is stored in cloud infrastructure (Rios, Mallouli, Rak, Casola & Ortiz, 2016, P.6).

SLO parameter 4 (Recovery Time objective RTO). Based on Ghosh, "Recovery Time objective (RTO) is the period of time allowed for recovery" (Ghosh & Ghosh, 2012, P.4). Moreover, it was also mentioned in ISO/IEC 19086-1 as a part of the cloud service provider disaster recovery plan. According to ISO/IEC 19086-1, when cloud service provider announces a disaster and a recovery process is initiated, the recovery time objective period

starts and ends when cloud service consumer can access and work on the secondary environment provided.

SLO parameter 2 (Reliability). Based on Garg, reliability means that no service failures occur in a predefined period of time (Garg et al., 2011, P.4). Choosing the best and most appropriate cloud service provider is a huge challenge all cloud consumers face when they decide to move their data to the cloud. A framework that allows cloud consumers to evaluate several cloud providers' offers was proposed by (El-Awadi &Abu-Rizka, 2015, P.3). They indicated that reliability is a key performance indicator (KPI) for assurance.

SLO parameter 3 (Packet loss). Packet loss was defined and considered as one of the SLO parameters that could be used in an SLA. It is the number of lost packets during all the transmissions (Frey et al., 2013, P.4).

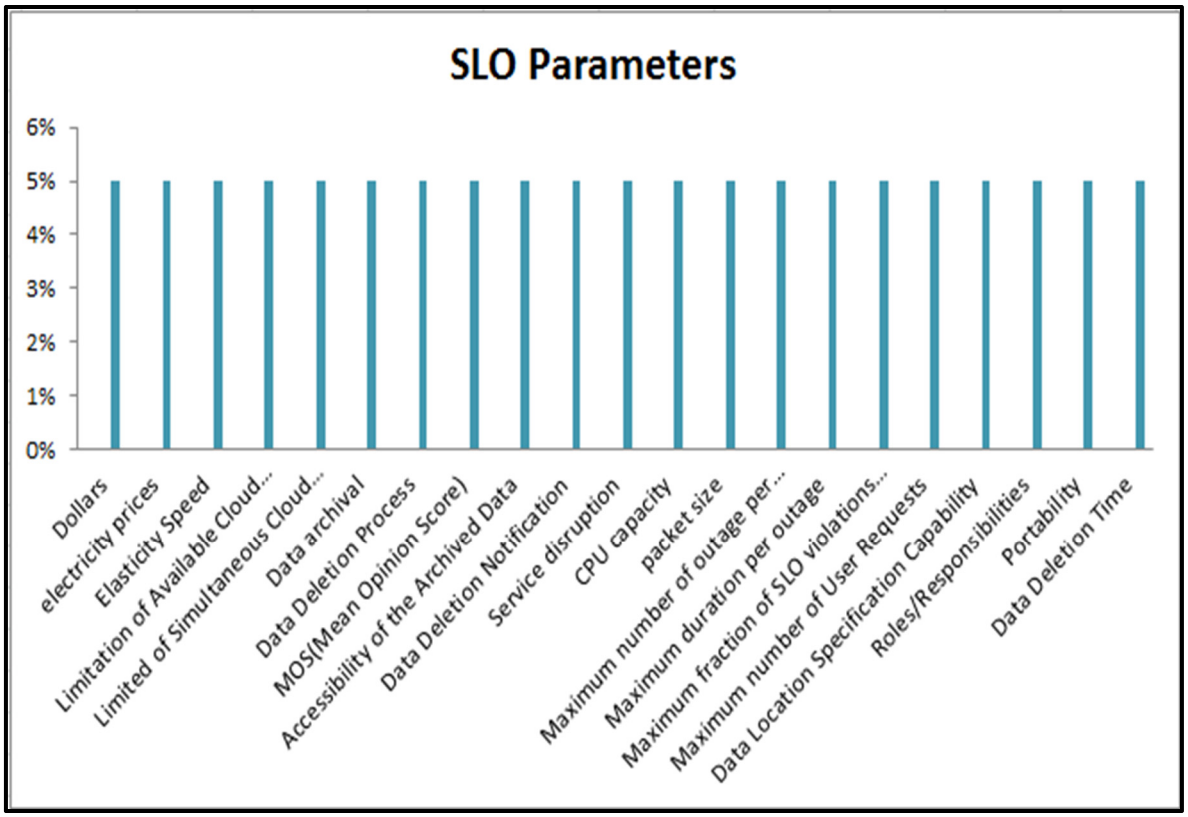

Figure 1.7 SLO Parameters' Distribution Part 2

As presented in figure 1.7, the bar graph illustrates the occurrence percentage of the rest of the SLO parameters' list. By observing the chart, it can be seen that all of the SLO parameters shown in this chart are the least studied SLO parameters in the literature. In addition, all of them have the lowest occurrence percentage, which is 5%. This means that it was mentioned only in one article from the literature. In general, the poor occurrence for the SLO in the literature showed several gaps concerning the SLOs definition and their connection to SLA parameters.

In following paragraphs the definitions of some extracted SLO parameters are presented, addressing the sources, where they were discussed and derived from. The upcoming SLO parameters were chosen based on their position and percentage in the chart in figure 1.7.

SLO parameter 1 (Dollars, electricity price). Based on Faniyi, Dollar and electricity price are some of the SLO parameters assigned to the SLA parameter 'cost' (Faniyi & Bahsoon, 2015, P.6). However, there is no way or method how these SLO parameters can be used to measure the cost of the cloud service.

SLO parameter 2 (Elasticity Speed). Based on ISO 19086-part 1, elasticity could be measured using two SLO parameters, which are elasticity speed and elasticity precision. Elasticity speed is the time that cloud service would take to react to a resource request. There are two types of elasticity which are manual and automatic. Therefore, elasticity speed is the fastest reaction the service would take under these two scenarios.

Overall, looking into the aforementioned information, there was a huge gap regarding SLA and SLO parameters and their usage and definitions. Several investigated articles showed different analyses regarding SLA and SLO parameters. Some SLA parameters were mentioned as SLO parameters and vice versa. Moreover, some SLA parameters were defined differently. Several SLO parameters were not connected to any SLA parameters. This work demonstrated many academic articles and showed cloud computing SLA and SLO parameters statues in the academia. In addition, it indicated that there is a tremendous lack of standardization concerning SLA and SLO parameters.

For more detailed information, refer to appendix I and appendix II.

NOTE: all the above extracted SLA and SLO parameters will be used in the next chapter to analyse and prove the applicability of some popular cloud service providers in the modern market such as Amazon, Google and Microsoft.

CHAPITRE 2

CONFRONTING CLOUD SLA AND SLO PARAMETERS'S LIST WITH MOST POPULAR CLOUD SERVICE PROVIDERs IN THE MODREN MARKET

In this chapter we will illustrate the selected cloud service providers SLA agreements and confront them to the SLA and SLO parameters' list from the previous chapter to find out the coverage percentage for each cloud service provider.

2.1 Introduction

Cloud computing has been developing expeditiously over the past few years and impacting our lives in so many different ways. It intends to help cloud service users to store and access an enormous amount of data and facilitates the usage of many software programs. Several companies across industries decide to move their business and their data to the cloud to perform efficiently and more economically. A service level agreement (SLA) is the first stage cloud service provider and consumer start with. " Service level agreements (SLA) is a contract signed between the customer and the service provider. It states the terms of the service including the non-functional requirements of the service specified as the quality of service (QoS), obligations, service pricing, and penalties in case of agreement violations" (Emeakaroha et al., 2010. P.1). It clarifies the cloud consumers' requirements and demonstrates cloud providers' offers to assure the level of service expected by cloud service clients.

Through the past years, cloud computing has helped and increased the productivity in our modern world and provided the users with many advantages that could enhance the usability and the development in different life aspects such as health, Information Technology and education, etc. Nevertheless, in some scenarios that was not the case. Several cloud breaches and incidents have occurred and caused the users a lot of damage, money and data loss. According to (Bradford, 2018), in April 2016 the national Elections in Mexico faced a cloud breach on the data of the voters. As a consequence of the poor database that was used, most

of the collected votes were missing or were not protected and became accessible to the public. After investigating in the incident, it was concluded that the data was stored illegally outside of Mexico in an unreliable Amazon cloud server. If the SLA agreement of this cloud service was appropriately negotiated, well reviewed and the SLA parameter data location was properly demonstrated and emphasized that the data is confidential and should be stored in a certain location, all of this would not happen and the National Electoral Institute would have avoided the scandal. Another example that can show the effect of cloud breaches is the incident that happened to Anthem, a healthcare insurance company. Based on (Latouf, 2017) Anthem experienced a huge data breach that costs the company around 80 million dollar loss. The company lost a lot of patients and employees records. After investigating the incidence, it was revealed that the breach was due to a cloud-based file sharing service they used. The above mentioned examples, show how important is the process of creating an SLA agreement and how cloud service providers and consumers should pay more attention and be well prepared when they decide to initiate an SLA agreement for a certain service.

Cloud service providers can give the users so many guarantees related to the level of the service they provide and attract them with the high availability rates or a quick response time rate. But some SLA attributes are neglected and are not discussed enough to protect the users from any service violation that might occur in the future. Therefore, SLA agreements should cover all aspects of the provided service and support the consumers with the appropriate tools or measures to help them gain more controllability on their data.

In reference to the previous chapter, the extracted SLA and SLO lists will be used to check the applicability and the coverage of these cloud service providers SLA offers and analysed, which parameters from chapter 1 applied to the parameters offered by these providers SLAs. The analysis in this research will focus mainly on public cloud offers rather than other cloud deployment models, which will be analysed in future research.

Data is considered as a crucial component in cloud service environments. Therefore, Cloud service providers claim that cloud computing could be a helpful solution to protect data especially against potential risks associated with hardware. This would persuade stakeholders to migrate their data to be stored in cloud. In addition, cloud storage service also has a vital role and it is an essential feature of cloud computing, we chose to focus mainly on cloud storage products offered by the most popular cloud service providers in the modern market such as Amazon Web Service (AWS), Microsoft Azure and Google to investigate their SLAs and confront them to the SLA and SLO parameters' list from the previous chapter.

NOTE: The terms such as parameters, attributes and characteristics are used frequently through this document. Since the term (parameter) is used in cloud SLA agreements, it will be further employed in this work to simplify the representation in this analysis.

2.2 Cloud computing providers' SLA offers

2.2.1 Amazon

Amazon Web Service (AWS) is one of the most popular cloud service providers in the modern world. It provides us with several types of cloud storage services such as Amazon Elastic Block Store (Amazon EBS), Amazon Simple Storage Service (Amazon S3) and Amazon Glacier, Etc.

Amazon simple storage service (amazon S3) is a web service provided by AWS to facilitate the storage and the retrieval of the data stored in cloud. We chose to analyse the SLA of this service due to its features and simplicity. As mentioned above, there are many storage products Amazon provides. However, Amazon S3 is a simple, flexible storage product that any user can use. Hence, it would facilitate and simplify the comparison process with other cloud providers.

We contacted Amazon customer service through the phone and asked them to provide us with their official storage SLA that they give to all customers. They sent us an email with the link to their Amazon S3 Service Level Agreement online. We analysed and reviewed the provided SLA document and extracted the SLA parameters that were discussed to show and demonstrate the coverage of Amazon S3 SLA Agreement in comparison with the list we created in the previous chapter.

In the following paragraphs, the Amazon S3 SLA agreement will be demonstrated and analysed.

2.2.1.1 Amazon S3 SLA

It was lately updated on April 4, 2018. It starts with a brief explanation of the service and the SLA terms including the payment procedures and the SLA exclusions. After analyzing and deeply reviewing the document, the used SLA parameters were identified as the following SLA contents:

- Error Rate
- Monthly Uptime Percentage
- Service Credit
- (Remedy, unavailability, non-performance)
- Termination
- SLA exclusions

In addition, we investigated other Amazon SLAs that are provided online and could be related to Amazon S3 SLA such as AWS customer agreement and AWS service terms. After analyzing and reviewing the previously mentioned SLAs, we extracted more SLA parameters that could be relevant to Amazon S3 SLA agreement and demonstrated them as the following.

2.2.1.2 AWS customer agreement

It is a contract made between Amazon provider and cloud customers. It consists of several terms and conditions that could control the usage and the access of any service offered by Amazon. Each term has several conditions and cases related to it, which explains different situations and the actions that must be taken in case of a service violation. Moreover, it shows the responsibilities and limitations for both Amazon provider and service users. This SLA was lately updated on July 1, 2018. The used SLA parameters (terms) were identified as the following:

- Use of the service
- Change of service
- Security and data privacy
- Consumer' responsibility
- Fees and payment
- Temporary suspension
- Termination
- Proprietary rights
- Identification
- Disclaimers
- Limitations of Liability
- Modification to the agreement
- Miscellaneous
- Definition

2.2.1.3 AWS service terms

This SLA agreement was lately updated on October 5, 2018. The first part of this agreement is universal and applies to all types of Amazon offered services including Amazon S3.

However, most of the terms speak about the extra fees or responsibilities every user has towards using other or additional types of services.

This document mainly contains terms and conditions rather than clear SLA parameters. As the first section of this agreement applies to Amazon S3, the rest of the document discusses conditions related to other provided services. In the first section, Amazon lists several rules to be followed in certain situations. For example, special pricing program, users are allowed to receive only one discount per service when Amazon offers multiple discount offers. Another term mentioned was about service maintenance, Amazon clarifies that they will notify the consumers with any maintenance in advance and users have to cooperate and follow any instructions requested by Amazon. Moreover, technical documentation are updated from time to time, users have to adhere to the current technical documentation that is up to date.

Overall, after reviewing all available SLA documents that could be related to Amazon S3 service, we found out that Amazon S3 SLA mainly focuses on service availability and service credit rather than other SLA parameters. There are other SLA parameters that are mentioned in these SLAs such as security, privacy and response time, etc. However, the main focus was mainly on service up time and down time (availability) and service credit and pricing.

2.2.2 Microsoft

Microsoft Azure is a cloud computing service that provides software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS). It is launched by Microsoft Company and offers several types of services such as virtual machines, Azure database for MySQL and storage, etc. It is considered one of the most well-known cloud services that are available in the current market.

Microsoft Azure Storage is a service provided by Microsoft that supports cloud users with a scalable and protected storage to upload their data to. We emailed Microsoft Azure customer service and asked them to send us their official storage SLA that they give to all customers. They called us and we discussed with them about their storage products and asked them to provide us with a simple storage product. They suggested Microsoft Azure Storage, so they sent us an email with the link to their Microsoft Azure Storage Service Level Agreement online. We started looking into the provided SLA document to analyse and extract SLA parameters. In the following paragraphs, Microsoft Azure Storage SLA will be demonstrated and analysed.

2.2.2.1 SLA for storage

It is a contract made between Microsoft provider and customers. It consists of three parts, which are introduction, general terms and SLA details. It was updated in December, 2017. At the beginning of this document, there are some guarantees Microsoft Azure illustrates to the consumers regarding the cool access tire and read/write data from and to different storages. Afterwards, it starts with a small introduction linked this SLA to another SLA, which is the Microsoft Azure Agreement. It was also mentioned that when service levels are not met as mentioned in the SLA, a service credit towards the monthly fees could be issued. Moreover, when the service subscription is renewed, the current SLA will be automatically applied to the new agreement.

The rest of the SLA document was speaking about general terms and their descriptions, SLA details and some SLA limitations.

Extracted SLA parameters:

Table 2.1 Microsoft Storage Extracted SLA Parameters

Extracted SLA parameters	
▪ Service credit	▪ Service renewal
▪ Application monthly period	▪ Application monthly service fees
▪ Downtime	▪ Error code
▪ External connectivity	▪ Incident
▪ Management Portal	▪ Service Level
▪ Service Resource	▪ Success Code
▪ Support Window	▪ Claims
▪ SLA Limitations	▪ Average Error Rate
▪ Blob Storage Account	▪ Cool Access Tier
▪ Hot Access Tier	▪ Excluded Transactions
▪ Error Rate	▪ Failed Storage Transactions
▪ Geo Replication Lag	▪ Geographically Redundant Storage (GRS) Account
▪ Locally Redundant Storage (LRS) Account	▪ Primary Region
▪ Read Access Geographically Redundant Storage (RA-GRS) Account	▪ Secondary Region
▪ Total Storage Transactions	▪ Zone Redundant Storage (ZRS) Account
▪ Monthly Uptime Percentage	

We found out that there was another related SLA that is linked to Azure storage SLA. We analysed the document and extracted the mentioned and used SLA parameters in the following paragraph.

2.2.2.2 Microsoft Azure agreement

It was updated in January, 2014. It is an agreement that applies to several provided services by Microsoft Azure. It includes some terms and conditions that should be considered when subscribing to the service. As was mentioned in the storage SLA agreement, some used terms are not defined in the storage SLA but their definitions could be found in Microsoft Azure Agreement. Therefore, we deeply analysed this agreement and extracted the following terms that could be related to storage SLA.

Extracted SLA Parameters:

- Use of Services
- Security, privacy, and data protection
- Purchasing Services
- Term, termination, and suspension
- Warranties
- Defense of claims
- Limitation of liability
- Software
- Miscellaneous
- Definitions

The aforementioned parameters are identified as the main titles and each of them consists of several conditions and terms that could be followed in certain situations.

To conclude, Microsoft Azure storage SLA was mainly concentrating on service uptime, service downtime credit and storage location. Moreover, it was specified that Consumers can identify the primary region of where their data will be stored. However, they have no control on the secondary region. At the end of the storage agreement document, they provided the

users with several service credits according to different uptime percentages. Yet, no tools or coherent way to monitor or check the provided service is clearly provided.

2.2.3 Google

Google cloud platform offers several types of services and products to help facilitate and simplify the usage of cloud service for a variety of users. In addition, it is one of the most popular cloud service providers nowadays and many well-known companies are using it. From a storage perspective, it provides us with many storage products such as cloud storage, persistent disk and cloud storage for firebase, etc.

Google cloud storage is a storage product provided by Google cloud to help cloud users store and manage their data. We decided to focus on this product since it is very similar to the storage products that we chose from the previous cloud providers. Moreover, there is a comparison between Google storage and Amazon S3 on Google cloud website which could point out the similarity between them. We contacted Google through email and asked them to provide us with their official SLA for this product. They sent us an email with the link, where we started our analysis and extraction of SLA parameters. Three SLA agreements were included when evaluating this service SLA.

2.2.3.1 Google cloud storage SLA

It is a storage SLA agreement issued between Google provider and consumers when subscribing to the service. It was lately modified in October, 2018, and it is considered as the SLA agreement for Google cloud storage. It consists of term definitions, financial credits and SLA exclusions. We deeply analysed the document and extracted the mentioned and used SLA parameters as the following:

- Monthly up time percentage
- Financial credits
- Back-off requirements

- Covered service
- Error rate
- Valid requests
- Maximum financial credits
- SLA exclusions

2.2.3.2 Google cloud platform terms of service

It is an agreement that is signed between Google and google cloud consumers. It was recently updated in October, 2018, and it covers most of the service provided by Google and contains some term definitions. We reviewed this document to extract the SLA parameters that were used and are relevant to cloud storage agreement. The followings are the SLA terms with their sub terms.

Extracted SLA parameters:

Table 2.2 Google Cloud Platform Term Extracted SLA parameters

Provision of the Services	
Services Use	Accounts
Console	New applications and service
Facilities	Modifications
Data Location	Service Specific Terms and Data Processing and Security Terms
Payment Terms	
Free Quota	
Invoice disputes and refunds	
Online billing	
Delinquent payments, suspension	
Taxes	No purchase order number required

Table 2.2 Google Cloud Platform Term Extracted SLA parameters (Continued)

Customer Obligations	
Compliance	Third Party Components
Privacy	Documentation
Restrictions	Copyright Policy
Suspension and Removals	
Suspension/Removals	Emergency Security Issues
Intellectual Property Rights; Use of Customer Data; Feedback; Benchmarking.	
Intellectual Property Rights	Customer Feedback
Use of Customer Data	Benchmarking
Technical Support Services	
By Customer	By Google
Deprecation of Services	
Discontinuance of Services	Deprecation Policy
Confidential Information	
Obligations	Required Disclosure
Term and Termination	
Agreement Term	Termination for Breach
Termination for Inactivity	Termination for Convenience
Effect of Termination	
Publicity	
Representations and Warranties	
Disclaimer	
Limitation of Liability	
Limitation on Indirect Liability	
Limitation on Amount of Liability	
Exceptions to Limitations	

Table 2.2 Google Cloud Platform Term Extracted SLA parameters (Continued)

Indemnification	
By consumer	By Google
Exclusions	Conditions
Remedies	Sole rights and obligations
U.S. Federal Agency Users	
Miscellaneous	
Notices	Assignment
Change of Control	Force Majeure
No Agency	No Waiver
Severability	No Third-Party Beneficiaries
Equitable Relief	U.S. Governing Law
Amendments	Survival
Entire Agreement	Conflicting Terms
Definitions	

2.2.3.3 Google service specific terms

This SLA refers to all types of Google products. In addition, any terms that are not defined in the previous SLAs could be found in this document. We analysed the document and extracted the terms that are related to Google cloud storage.

Extracted SLA parameters:

- Data storage
- Data location
- Transient storage
- Data location limitations
- Bucket lock

To conclude, Google cloud storage is one of the storage products that supplies cloud users with several services such as storing, managing and moving their data among different storage classes. However, their SLA does not cover the various features they provide. It guarantees the user with different service levels and provides the consumer with expected monthly uptime in different storage classes. However, it does not provide any measuring tools to monitor or check the applicability of these guarantees services. Additionally, it primarily speaks about the financial credits and how consumers should apply to get them. Yet, it is only towards their future payments not direct refunds.

2.3 The comparison between the extracted SLA and SLO lists and modern cloud providers SLA offers

2.3.1 Modern cloud providers SLA offers and the extracted SLA parameters' list

Concerning the above mentioned SLA parameters that were extracted from the chosen cloud providers' storage SLAs, we investigated these parameters and confronted them to the list of SLA parameters from the previous chapter. The following table contains the first 20 SLA parameters that have the highest occurrence percentage in the academia.

2.3.1.1 The criteria used in the comparison between cloud service providers' SLA offers and the extracted SLA parameters:

SLA parameters considered mentioned M when:

- The parameter is mentioned as an SLA parameter and discussed in the document.
- The parameter is connected or followed by any SLOs, equations or measures.
- The parameter is illustrated by one or more terms or conditions.

Otherwise, the SLA parameter is considered not mentioned NM. In addition, any SLA parameter that was only mentioned as an explanation to another SLA parameter is not considered mentioned M.

Table 2. 3 The Comparison of Most Studied SLA Parameters and Cloud Providers

Most studied SLA parameters	%	Amazon	Microsoft	Google
Availability	68%	M	M	M
Security	68%	M	M	M
Response time	57%	NM	M	NM

Table2. 3 The Comparison of Most Studied SLA Parameters and Cloud Providers (Continued)

Most studied SLA parameters	**%**	**Amazon**	**Microsoft**	**Google**
Performance	52%	NM	NM	NM
Reliability	36%	NM	NM	NM
Privacy	26%	M	M	M
Throughput	26%	NM	NM	NM
Elasticity or Scalability	26%	NM	NM	NM
Backup and restore	26%	M	M	M
Portability	26%	NM	NM	NM
Usability	26%	M	M	M
Service guarantee/Assurance	26%	NM	M	M
Termination of service	21%	M	M	M
Disaster recovery	21%	NM	NM	NM
Data location	21%	NM	M	M
Cost and Finance	21%	M	M	M

Table2. 3 The Comparison of Most Studied SLA Parameters and Cloud Providers (Continued)

Most studied SLA parameters	**%**	**Amazon**	**Microsoft**	**Google**
Governance	15%	NM	NM	M
Roles & responsibilities	15%	M	M	M
Service violations	15%	M	M	M
Storage	15%	M	M	M
Final percentage for each cloud provider SLA offer		**50%**	**65%**	**65%**

M: Mentioned

NM: Not Mentioned

As illustrated at the end of the table, the calculated percentages present the average coverage for each cloud provider's SLA agreement confronted to the SLA parameters' list from the previous chapter. The percentage was calculated as the following:

- Let **(P)** be the percentage for the coverage of each cloud Service provider's SLA offer
- Let **M(n)** be the number of how many SLA parameters were covered.
- Let **A(n)** be the total number of the used SLA parameters, which is 20 parameters .

$$P = \frac{M(n) \text{ X } 100}{A(n)}$$

Overall, it can be clearly seen that there is a huge gap between the literature, the ISO standards, and the industry when it comes to the SLA agreement and what should be included. What's more, Amazon has the lowest percentage among the other cloud service

providers although it is considered one of the most popular and most used cloud services. Since the coverage percentage of these cloud providers' SLA was only 65% and less, cloud service consumers should think cautiously when they subscribe to these services.

2.3.2 Modern cloud providers' SLA offers and the extracted SLO parameters' list

We intensely reviewed and analysed Amazon, Google and Microsoft SLA agreement and the attached documents to extract any SLO parameters that could be helpful to evaluate and monitor the provided service to confront them to the SLO parameters' list from the previous chapter. The following table contains the first 15 SLO parameters that were listed in the first SLO parameters bar chart number (figure 1.6) from the previous chapter.

2.3.2.1 The criteria used in the comparison between cloud service providers' SLA offers and the extracted SLO parameters:

SLO parameters considered mentioned M when:

- The parameter is mentioned as an SLO parameter or as a measuring tool that could be used to measure the service.

- The parameter contains any occasions or measures to monitor or check the provided service.

Otherwise, the SLO parameter is considered not mentioned NM.

Table 2. 4 The Comparison of Most Studied SLO Parameters and Cloud Providers

Most studied SLO parameters	**%**	**Amazon**	**Microsoft**	**Google**
Response time	36%	NM	M	NM
Throughput	26%	NM	NM	NM
Uptime	15%	M	M	M
Downtime	15%	NM	NM	NM
Monitoring Parameters	10%	NM	NM	NM
Monitoring Mechanisms	10%	NM	NM	NM
Accessibility Policies	10%	NM	NM	NM
Maximum Response Time Observation	10%	NM	M	NM
Response Time Mean	5%	NM	NM	NM
Response Time Variance	5%	NM	NM	NM
Cloud Service Bandwidth	15%	NM	NM	NM
Limit of Available Cloud service	5%	NM	NM	NM
Limit of Simultaneous Cloud Service	5%	NM	NM	NM
Elasticity Speed	5%	NM	NM	NM
Elasticity Precision	5%	NM	NM	NM
Final percentage for each cloud provider SLA offer		**6.6%**	**20%**	**6.6%**

M: Mentioned

NM: Not Mentioned

As showed at the end of the table, the percentage of the coverage for each cloud service provider's SLA offer to the provided SLO parameters are calculated. It presents the average coverage for each SLA agreement when we confront it to the SLO parameters' list from the previous chapter. The percentage was calculated as the following:

- Let **(P)** be the percentage for the coverage of each cloud Service provider's SLA offer
- Let **M(n)** be the number of how many SLO parameters were covered
- Let **A(n**) be the total number of the used SLO parameters, which is 15 parameters

$$P = \frac{M(n)\ X\ 100}{A(n)}$$

The final percentages for the covered SLO parameters show how poor and incomplete these agreements are. All the documents we investigated and studied have not mentioned any measures or SLOs only in a few points. For example, In Microsoft Azure, there was a formula to help users calculate the amount of monthly uptime percentage. The formula is 100% (uptime) - the average error rate, which was also indicated in the SLA details section, how to calculate the average error rate for each month. Nevertheless, there were many SLA parameters mentioned with no connected SLOs or any methods to check or monitor them. Consequently, the percentages show that the agreements are void and these cloud service providers should not be trusted, considering that the provided SLA parameters are not supported by enough measures and users have no control over their data.

2.4 Observations and conclusion

In following paragraphs the observations on the previously mentioned cloud service providers is presented, addressing the reviewed SLA agreements and their coverage.

- After reviewing all the above mentioned documents, these cloud service provider's focus mostly on the finance. Money is an important subject when consumers decide to subscribe to a service. However, it is not as vital as the rest of the parameters. A huge part of these cloud provider's SLAs speaks about how cloud service consumers could get service credits and when they are not applicable for it. For Amazon, Microsoft and Google, service credits are paid towards your future monthly bills, so no cash or refund is given, but what if the cloud service consumer was deeply damaged due to the service failure and decided to terminate the service. How could he/she get their service credits?

- Concerning the data location. Microsoft uses two regions to store and replicate the data, which are the primary region and the secondary region. They allow cloud service consumers to specify the primary region and where their data could be stored. However, they don't have such control on the secondary region. While at Google, consumers can choose the location where they want their data to be stored through data location selection. However, if the location they choose is not covered in the service specific terms, Google have the control to store the data at any of their facilities. In Google's SLA, they mentioned that when Google controls the data location based on the scenario mentioned above, Google is just a data processor. Yet, they don't provide any methods or measures cloud service consumers can use to check and insure the credibility and the applicability of their claim.

- Another issue that concerns the data location is Geo replication lag. Microsoft does not give any guarantees regarding the time that will take data to be replicate in the secondary region. Microsoft did not indicate what will happen if any service violations related to data occur and the data is not replicated yet in the secondary region. This could cause the users a lot of trouble.

- Based on this research, there is a huge gap between the literature, the ISO standards and the industry regarding the definition, the use and the connections between the SLA and SLO parameters. SLA and SLO parameters have different definitions from an article to another. Some consider parameters as SLA parameters while others consider them as an SLO parameter, so there is a huge confusion between both parameters. This issue should be solved so that cloud service providers and consumers can use the same reference when defining or using cloud service SLA and SLO parameters.

- There are no tools, methods or measures provided for the cloud service users to check the provided service. On each SLA, you can find several SLA parameters that are defined but are not supported or connected to any SLOs or measurements. How the service could be monitored if there are no provided methods to do that? Since consumers have no control over their data and cloud service providers could not be trusted, and due to the lack of measures and the insufficient connections between the SLA parameters and the SLO parameters, these agreements could be considered void.

- Some SLA parameters such as performance, reliability, disaster recovery, etc., were only illustrated as features for Amazon, Microsoft and Google's provided services. However, these parameters were only mentioned in other SLA parameters definitions. They just indicated them in their SLAs and do not provide the connected SLOs to check them. For example, in Amazon, disaster recovery could be found as a feature of Amazon service but in their SLA they do not include it as an SLA parameter or provide the user with measures such as Recovery Time Objective (RTO), which is the maximum time required to recover the data in case of disaster.

- Azure storage gives guarantees regarding the read and write of data in different storage in cool accesses tire at the very beginning of its SLA document. However, there is no mention of any provided tools or measures to check or assure theses guarantees.

- During the period when this research was conducted, the studied cloud service providers updated and modified their SLA repeatedly. For example, Google updated their SLA twice or three times a month. Amazon had the same issue too but less frequent. This can show how these clouds service providers are in doubt and not sure of what to put in their SLAs.

- Google specified in their agreements that they have the right to modify their SLA agreements and their prices from time to time. What's more, if cloud service consumers do not accept these modifications, the only option they have is to stop using the service. How could cloud service consumers trust this cloud provider, when their SLAs or the service prices could be changed any time and they should accept these modifications?

- Another issue that we faced when we were reviewing these cloud providers' portals and their SLAs is the low usability of these SLA documents. There are too many attached documents to review that users should find. In addition, in some cases, there are no links to these documents. It was very confusing and distracting to study these SLAs and find all their related documents. It would be extremely helpful if all the information users need to review was in the same document, so that cloud service consumers will not get confused going from a document to another.

- Microsoft indicates in their SLA that there is a possibility that other companies could be hired to provide some services on behalf of them. They demonstrate that these companies are not allowed to use the consumers' data. However, there is no way cloud service consumers could assure their credibility and guarantee that their data is not going to be used by a third party.

In the following chapter, we will introduce a new toolkit that can assist Cloud service users in the process of creating an SLA and allow them to achieve more controllability over their data.

CHAPTER 3

PROPOSED SLA TOOLKIT

In this chapter, we will propose an SLA toolkit to enhance the creation process of SLA agreement and help cloud service providers and consumers through the SLA lifecycle negotiation stage.

3.1 Cloud computing SLA life cycle

There are many proposals in the academia for SLA life cycle, However there is no widely accepted SLA life cycle in the literature (Maarouf, Marzouk & Haqiq, 2015, P.2). Cloud computing SLA life cycle consists of several stages that demonstrate the process of creating an SLA agreement.

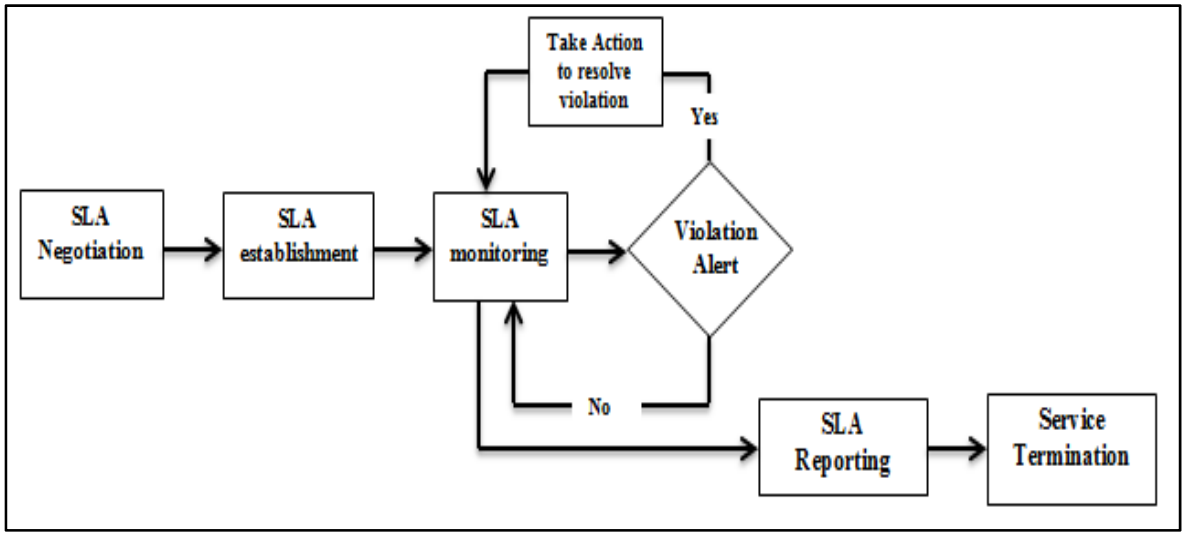

Figure 3.1 Classic SLA management Life Cycle
Taken from Faniyi & Bahsoon (2015, P.3)

According to Faniyi (Figure.3.1), Service level agreement (SLA) life cycle consists of five phases, which are Negotiation, Establishment, Monitoring, Violation Management and Reporting and Termination (Faniyi & Bahsoon, 2015, P.3). One of the most crucial phases

is the negotiation phase. Negotiation is the first stage where cloud service providers and consumers discuss and negotiate the service level required and the SLA contents. “In this phase, cloud service consumers decide which cloud service provider has the best offer that can meet their requirements and discuss the required service level. However, SLA negotiation is usually more complicated than other SLA lifecycle phases” (Terfas et al., 2018). This phase could be very ambiguous and confusing for both cloud service provider and consumer.

According to Venticinque, unsupported dynamic negotiation process could result in a poorly constructed SLA, which can also lead to many other issues that cloud service consumers could face, such as SLA violations (Venticinque, Aversa & Martino, 2010, P.1). SLA violation is one of the challenges cloud computing is facing. However, predefined SLA parameters could be the solution to help in the early detection of these violations (Terfas et al., 2018, P.11). The definition of SLA parameters is very important for both cloud service providers and consumers. Therefore, based on Terfas, “the predefined SLA parameters in early stage of SLA lifecycle can affect the whole SLA lifecycle and influence the level of service required” (Terfas et al., 2018, P.11). This step could be done during the SLA negotiation stage to insure that the service level will be provided as expected. Cloud service consumers should be given the opportunity to prepare the list of SLA parameters required for their service and follow cloud service providers during the negation process to create a well-constructed SLA agreement that covers all the requirements and assist them to choose the best cloud service provider among all the provided offers (Terfas et al., 2018, P.11). In accordance with the previously discussed issues, a toolkit to help cloud service consumers choose the most appropriate cloud service provider and be more prepared and confident during the negotiation and the establishment phases is introduced.

3.2 SLA toolkit

Cloud service provider selection process could be complicated and difficult to achieve for some cloud service consumers. Moreover, the negotiation stage is also known as a bottleneck

(Dastjerdi & Buyya, 2012, P.1). Based on all these indicated issues, an SLA toolkit to facilitate the negotiation phase process and help in the selection of cloud service provider is proposed.

There are many SLA toolkits available in the modern market that consumers have to purchase in order to use. They provide a pre-defined check list of SLA parameters to be considered in their SLA creation process (Terfas et al., 2018, P.11). The proposed SLA toolkit was developed as the result of the analysis that was conducted on these toolkits and the SLA parameters list from the previous chapter.

The Toolkit is built of three components:

- The SLA parameters list from chapter 1, which contain the most Studied SLA parameters in the academia.
- An SLA parameter identification form (Figure 3.2), and
- An SLA Toolkit Work Process (Figure 3.3).

3.2.1 How does it work

As illustrated in the previous section, Figure 3.2 and Figure 3.3, the SLA toolkit could address all the SLA parameters included in the most studied SLA parameters list which was discussed in the chapter 1. This toolkit could be a good start to help end users control their data and assess them in the process of creating SLA agreements.

Cloud Service Provider name: ……..

CCR: Cloud Customer Requirements		Provided		
SLA Parameters	Required	Compliance Yes	Compliance No	Notes
▪ Parameter 1	☐	☐	☐	
▪ Parameter 2	☐	☐	☐	
▪ ⋮				
▪ Parameter N ▪	☐	☐	☐	

Figure 3.2 SLA Parameters Identification Form

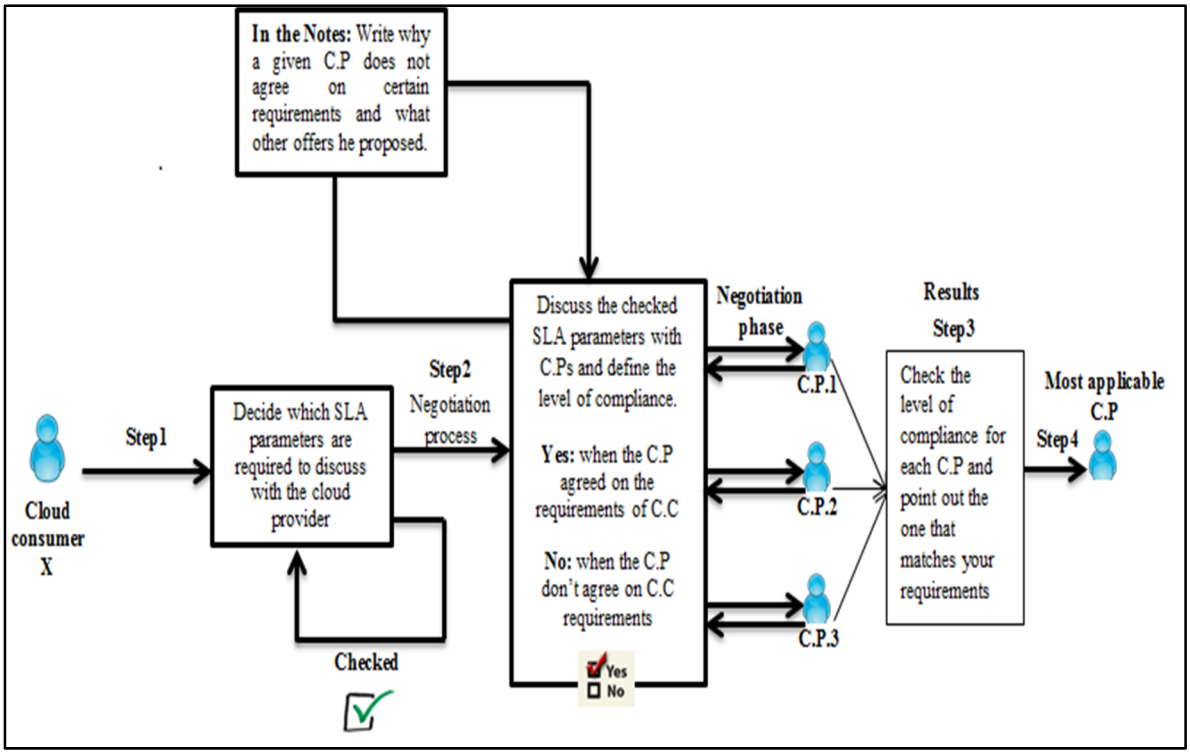

Figure 3.3 SLA Toolkit Work Process

As shown in Figure 3.3, the SLA Toolkit Work Process consists of 4 steps:

Step.1: Using the proposed SLA parameter identification form, cloud service consumer should identify and choose all the required SLA parameters. Step1 should be done before the beginning of the negotiation phase.

Step.2: Once the negotiation process begin, the cloud service consumer has to discuss and review all the chosen SLA parameters with cloud service provider to specify the service level required and the degree of compliance for each cloud service provider. When cloud service provider agrees to a certain requirement of the consumer, the corresponding SLA parameter should be checked as "Yes", otherwise "No" checkbox is chosen. Moreover, the possible alternative in case of "No" should be discussed and illustrated in Notes section.

Example: The cloud service consumer X identifies the SLA parameter of Data Location as required. Therefore, cloud service provider will note that it is vital for cloud consumer to

know where the data is stored. If cloud service provider agrees to provide such information, “Yes” is chosen. On the other hand, if cloud service provider declines to specify the location, then “No” is chosen and the cloud service consumer should write in the Notes section whether the cloud provider proposes any other alternatives, like specifying several locations data could be stored in but not the exact location. These notes will be used in the next step.

Step.3: In this step, cloud service consumers have to evaluate the level of compliance for each cloud service provider by checking which cloud service provider’s offer adheres more to the requested requirements.

NOTE: This evaluation can be easily performed in a rudimentary form by assigning numeric value of “1” to “Yes”, a value of “0” to “No”, a weight scale reflecting the importance of the given parameter (for example 0-5) and calculating the weighted average for all parameters in the form.

The note section will be used in case there are cloud service providers with the same level of compliance. Consumers have to review the note section for any additional information that could help to distinguish between them.

Step.4: Finally, using the aforementioned information, cloud service consumer will be able to choose the most suitable cloud service provider that can cover all the required SLA parameters or provide appropriate alternatives.

3.3 Conclusion

Service Level Agreement is a contract signed between two parties, which are cloud service consumer and provider. It intends to help cloud service consumers to identify the service level (SL) requested and present their quality requirements (QRs) to cloud service provider. Therefore, it assists cloud service provider to recognize all consumers' needs. The process of creating an SLA agreement is ambiguous and difficult to follow. In addition, in chapter 2, we found out that cloud service consumers privileges with existing cloud service providers are limited, they cannot find all their required SLA parameters in the offered agreements and the level of controllability on their data is low. Therefore, the proposed SLA toolkit would assist cloud service consumers during this process especially in the negotiation phase. It will help cloud service consumers clearly discuss their requirements and SLA parameters with their cloud providers to achieve a better service level. Moreover, it can help cloud consumers evaluate the pre- defined SLAs of cloud service providers. It intends to facilitate the Cloud service providers' selection process and help the consumer to choose the most applicable cloud service provider. This presented SLA toolkit will also insure cloud service consumer gain more controllability on their data to increase the level of trust between these two parties.

The next section concludes this thesis document

CONCLUSION

In this thesis, we conducted a literature review to identify the most studied and the least studied SLA and SLO parameters in the academia. To do so, we analysed several articles and extracted the mentioned SLA and SLO parameters. Then, we calculated the percentages of occurrence for each parameter to find out which SLA and SLO parameters have the highest and the lowest occurrence percentages. Finally, we generated a list of the most and least studied SLA and SLO parameters in the literature based on their occurrence percentage.

After that, we used this list to investigate the coverage of three well known cloud service providers in the modern market. We confronted their SLA agreements to this list and calculated the coverage percentage for each one. Finally, we provided our observations on each cloud service provider's SLA agreement.

At the end of this thesis, we proposed an SLA toolkit that would help cloud service consumers gain more controllability over their data. It enhances the process of SLA creation for both cloud service provider and consumer. Moreover, it assists them through the stages of an SLA lifecycle and helps cloud service consumers in the selection of the most appropriate cloud service provider that best adheres to their requirements.

Conference Papers

Published

- Terfas, H., Suryn, W., Roy, J., & Eftekhar, S. M. (2018). Extending ISO/IEC 19086 Cloud Computing SLA standards to support cloud service users with the SLA negotiation process. SQM XXVI, 127.

RECOMMENDATIONS

Cloud computing is a large field that is developing every day to suit the needs and requirements of various types of users. Several researches are intended to enhance the use of cloud computing services and decrease the incidents that could occur and violate the service level requested. As aforementioned in the previous chapters, in academia and industry SLA and SLO parameters are not well defined and are used differently. Therefore, as a future work, we are planning to develop an extensive list that would cover as many as possible in given market and industry circumstances cloud computing SLA and SLO parameters. This list should involve definitions for all the included SLA and SLO parameters. After that we will propose a model that should contain all these SLA parameters connected to their SLO parameters and measures to give the end users more controllability over their data and allow them to trust their cloud service providers.

ANNEX I

SLA AND SLO PARAMETERS EXTRACTION

In this annex I, we will present the tables that contain all the extracted SLA and SLO parameters addressing the sources, where they were discussed and derived from.

Table-A I- 1: ISO Standard 19086

Cloud computing ─ Service Level Agreement(SLA) framework and terminology 19086-1— Part 1	
SLAs	**SLOs**
• Covered Service	•
• Cloud SLA Definitions	•
• Service Monitoring	• Monitoring Parameters • Monitoring Mechanisms
• Roles and Responsibilities	•
• Accessibility	• Accessibility Standards • Accessibility Policies
• Availability	• Availability(uptime and downtime)
• **Cloud service performance** • Cloud service response time	• Cloud Service maximum Response Time Observation • Cloud Service Response Time Mean • Cloud Service Response Time Variance
• **Cloud service performance** • Cloud service capacity	• Limited of Simultaneous Cloud Service Connections • Limitation of Available Cloud Service Resources • Cloud Service Throughput • Cloud Service Bandwidth
• **Cloud service performance** • Elasticity	• Elasticity Speed • Elasticity Precision
• Protection of Personally Identifiable Information (PII)	Erasure period for temporary files Log information deletion period (where logs contain PII) Notification period for a data breach Geographical location(s) for PII storage and processing • Check ISO 19086-4

Table-A I- 1: ISO Standard 19086(Continued)

Cloud computing ─ Service Level Agreement(SLA) framework and terminology 19086-1— Part 1	
SLAs	**SLOs**
Information Security	Still under study
Termination of service	Data retention period Log retention period Notification of Service Termination Return of Assets
Cloud Service Support	Support Hours Service Incident Support Hours Service Incident Notification Time Maximum First Support Response Time Maximum Incident Resolution Time Support Plans Support Methods Support Contracts Service Incident Reporting Service Incident Notification
Governance component	Regulation Adherence Standards Adherence Policy Adherence Audit Schedule
Changes to the cloud service features and functionality	Minimum Service Change Notification Period Minimum Time Before Feature/Function Deprecation Service Change Notification Method
Service reliability Service resilience/fault tolerance component	Time to Service Recovery (TTSR) Mean Time to Service Recovery Maximum Time to Service Recovery (MTTSR) Number of Service Failures Service resilience/fault tolerance method
Service reliability Customer data backup and restore	Backup Interval Retention Period for Backup Data Number of Backup Generations Backup Restoration Testing Backup Method Backup Verification Backup Restoration Test Reporting Alternative Methods for data recovery Data Backup Storage Location
Service reliability Disaster recovery	Recovery Time Objective (RTO) Recovery Point Objective (RPO) Cloud Service Provider Disaster Recovery Plan

Table-A I- 1: ISO Standard 19086(Continued)

Cloud computing ─ Service Level Agreement(SLA) framework and terminology 19086-1— Part 1	
SLAs	**SLOs**
Data management Intellectual Property Rights (IPR) component	Intellectual Property Rights
Data management Cloud Service Customer Data	Cloud Service Customer Data Cloud Service Customer Data Usage
Data management Cloud Service provider Data	Provider Data
Data management Account Data Component	Account Data
Data management Derived Data	Derived Data Derived Data Usage Derived Data Access
Data management Data Portability	Data Portability Capabilities
Data management Data deletion	Data Deletion Time Data Deletion Process Data Deletion Notification
Data management Data location	Data Location Data Location Specification Capability Data Location Policy
Data management Data examination	Data Examination
Data management Law enforcement access	Law Enforcement Requests
Attestations, certifications and audits	Cloud Service Attestations Cloud Service Certifications Cloud Service Audits
A brief preview of the paper: ISO/IEC 19086 cloud computing Service level agreement (SLA) framework was recently published to clarify the definition of cloud computing (SLA) between cloud service providers and cloud service consumers. It consists of four parts. ISO/IEC 19086-1 part one is an overview and term definitions of cloud computing SLA.	

Table-A I- 2: Extracted SLA and SLO

Service level agreement framework for e-commerce cloud end-user perspective	
SLAs	**SLOs**
• Availability	•
• Scalability	•
• Portability	•
• Performance	• Response time • Throughput
• Security	• Authenticity • Data Integrity • Data Confidentiality • Privacy
• Reliability	• Service Reliability • Message Reliability
• Usability	•
• Backup&Recovery	•
• Data location	•
A brief preview of the paper: (Busalim, Hussin, & Ibrahim, 2013) In this paper, the authors proposed a new SLA framework for E-commerce cloud service with respect to the end user perspectives. They provided a list of the most applicable SLA parameters and their objectives, which should be considered when initiating an SLA framework for E-commerce cloud. These parameters will help reducing the risks and challenges that face E-commerce cloud end users.	

Table-A I- 3: Extracted SLA and SLO

Monitoring and Management of Service Level Agreements in Cloud Computing	
SLAs	**SLOs**
• Response time	• Time to order. • Time to delivery. • Delay in end to end transaction. • Failed service re-quest rate • Availability of service rate
A brief preview of the paper: (Anithakumari & K, 2015) In this paper, a framework to detect SLA violations by monitoring its parameters has been proposed. Using the results of the predicted SLA violations, helped initiating an adaptive resource allocation system, which tries to reduce any SLA violations may occur. In this experiment, an online shopping service SLA was used as an example, and only one SLA parameter was monitored and analysed including its Service level objectives at runtime.	

Table-A I- 4: Extracted SLA and SLO

Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Service	
SLAs	**SLOs**
• availability	•
• Accounting of services,	•
• IT continuity plans	•
• service development plans	•
• Terminologies	•
• Escalation plan	•

Table-A I- 4: Extracted SLA and SLO (Continued)

Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	
SLAs	**SLOs**
• Guidelines for priorities	•
• Responsibilities of both customer and company	•
• Data of both parties	•
• Service of both times	•
• Accomplishment penalties	•
• Signing an ID	•
• Termination reason	•
A brief preview of the paper:(Frey, Luthje, Teckelmann, & Reich, 2013) Most cloud providers offer a standard SLA for their customers. However, customers' needs and requirements are distinct from each other most of the time. This issue is usually facing companies and individuals when trying to move their work or data to the cloud. In this paper, the authors are suggesting to create a special SLA for each customer respecting all related SLOs that are needed to evaluate and measure the service. They only mentioned the parts that each SLA should contain and present an USECASE about Availability.	

Table-A I- 5: Extracted SLA and SLO

Cloud Service Level Agreement. Encyclopedia of Cloud Computing	
SLAs	**SLOs**
• Availability	•
• Response time	•
• Disaster recovery	•
• Ticket resolution	•
• Data backups	•
• Throughput	•
• Data storage location	•
• Data-redundancy	•
• Data privacy policies	•
• Service renewals	•
• Service Restoration	•
• Service Acceptable Usage Policy	•
• Service Guarantee Granularity	•
• Service guarantee exclusions	•
• Service Credit	•
• Service Violation Detection and Measurement	•
• Service Activation and Deactivation(Service termination)	•
• Service Excess Use	•
• Service Transferability (portability)	•
• Security	•
• Performance	•

Table-A I- 5: Extracted SLA and SLO (Continued)

Cloud Service Level Agreement. Encyclopedia of Cloud Computing
A brief preview of the paper: (San & Irena, 2016) Considering the lack of standardization cloud computing is suffering from, most cloud consumers face several challenges in term of choosing the appropriate cloud provider. In this chapter, the author precisely explains the most important elements to consider in an SLA, and then provides two real-life examples of the most popular cloud providers in the market (Amazon and Rackspace). At the end, the author discusses how SLA could be defined by the cloud provider in the future to help cloud consumer compare and choose the best cloud provider that matches their requirements.

Table-A I- 6: Extracted SLA and SLO

On Service Level Agreement Assurance in Cloud Computing Data Centers	
SLAs	**SLOs**
Cloud service performance	Response time User to user time Delay time End to end delay MOS(Mean Opinion Score) Jitter packet loss
A brief preview of the paper: (Zainelabden, Ibrahim, Kliazovich, & Bouvry, 2016) Service level agreement is a contract that is made between cloud provider and cloud consumer to identify the level of service required by the consumer and delivered by the provider. However, there are no guidelines or methods to validate and confirm that the quality of service will be delivered as mention in the SLA. In this paper, the authors proposed a framework to assure the SLA and guarantee the service. This framework could be useful for both cloud providers and consumers. In contrast to all previous frameworks, this framework concentrates mostly on evaluating the performance of the cloud and help providing a better service quality which concerns both cloud providers and consumers.	

Table-A I- 7: Extracted SLA and SLO

A comprehensive review on QoS measures for resource allocation in cloud environment	
SLAs	**SLOs**
• Reliability in Storage	•
• High network Bandwidth	•
• Resource Availability	•

Table-A I- 7: Extracted SLA and SLO(Continued)

A comprehensive review on QoS measures for resource allocation in cloud environment	
• Security	•
• Confidentiality	•
• Integrity	•
• Reliability and Fast Access	•
• Flexibility and Creative User group Infrastructure Service	•
• Testing time.	•
• Latency	•
• Data Backup	•
• Visibility	•
• Good Response	•
• Usability	•
• Portability	•
• Reliability	•
A brief preview of the paper: (Shiny & Vignesh, 2017) In this paper, the authors focused on resource allocation in cloud computing service and discussed the most common issues that might face cloud providers and consumers. According to the QoS metrics, SLA violation is one of the challenges that might affect cloud provider in resource allocation. They present several resource allocation methods and point out the QoS requirements that an end user expected in different applications when it comes to resource allocation. These requirements could be considered as SLA elements that have to be met when offering a certain service.	

Table-A I- 8: Extracted SLA and SLO

Quality of service and service level agreements for cloud environments: Issues and challenges	
SLAs	**SLOs**
Availability	
Reliability	
Scalability	
Security	
Trust	
performance supervision	
Service description	
Problem administration	
Consumer responsibilities and accountabilities	
Licenses and cures	
Reservation	
Recovery(catastrophe recovery)	
Service Termination	
Service Assurance(Provider side)	
fault perseverance time(P)	
Service Assurance Time Period(P)	
Response time(P)	
Service assurance granularity(P)	
Service guarantee(P)	
Service recognition(P)	
Service Violation Measurement and Reporting(P)	
A brief preview of the paper: (Chana & Singh, 2014) In this paper, the relation between quality of service QoS and cloud computing is discussed. The authors focused more on the relation between QoS and the SLA agreement. How cloud service providers can assure the level of QoS provided to the consumers. They also discussed the elements that should be considered in an SLA and the challenges that an SLA could face.	

Table-A I- 9: Extracted SLA and SLO

A Framework for Negotiating Service Level Agreement of Cloud-based Services	
SLAs	**SLOs (KPI metrics)**
• Usability	• Accessibility • Client personal requirements • Installability • Learnability • Operability • Transparency • understandability
• Accountability	• Auditability • Compliance • Contacting experience • Data ownership • Ease of doing business • Governance • Provider SLA Verification • sustainability
• Agility	• Adaptability • Capacity • Elasticity • Extensibility • Flexibility • Portability • Scalability
• Assurance	• Availability • Maintainability • Recoverability • Reliability • Fault-Tolerance • Service stability • Service-ability
• Financial	• Acquisition cost • On-going cost • Profit or cost sharing
• Performance	• Accuracy • Functionality • Suitability • Interoperability • Response time • Throughput

Table-A I- 9: Extracted SLA and SLO (Continued)

A Framework for Negotiating Service Level Agreement of Cloud-based Services	
SLAs	**SLOs (KPI metrics)**
• Security and Privacy	• Access control • Data geographic • Data integrity • confidentiality • Data privacy and data loss • Physical, environmental • Threat and vulnerability • Retention, Disposition
A brief preview of the paper:(El-Awadi & Abu-Rizka, 2015) The market of cloud computing is getting more and more competitive every day. Therefore, choosing the best and most appropriate cloud provider would be a huge issue that faces all cloud consumers. In this paper, the authors present a new framework that would solve this matter by helping cloud consumers making the right decision and choose the most relevant cloud provider that matches their requirements. This framework will allow cloud consumers to evaluate several cloud providers' offers and select among them. The authors also support their framework by a case study to show.	

Table-A I- 10: Extracted SLA and SLO

SMICloud: A Framework for Comparing and Ranking Cloud Services	
SLAs(high/top level attributes**)**	**SLOs (KPIs)**
• **Accountability**(This service attribute depends on multiple factors such as) • Auditability • Compliance • data ownership, • provider ethicality • sustainability	•

Table-A I- 10: Extracted SLA and SLO (Continued)

SMICloud: A Framework for Comparing and Ranking Cloud Services	
SLAs(high/top level attributes**)**	**SLOs (KPIs)**
• **Agility**(This service attribute depends on multiple factors such as) • Elasticity • Portable • Adaptable • flexible	•
• **Assurance of Service**(This service attribute depends on multiple factors such as) • Reliability • resiliency • service stability	•
• **Cost**	•
• **Performance**(This service attribute depends on multiple factors such as) • Functionality • service response time • Accuracy.	•
• **Security and Privacy**(This service attribute depends on multiple factors such as) • Privacy • Data loss • Integrity	•
• **Usability**(This service attribute depends on multiple factors such as) • Accessibility • Installability • Learnability • Operatibility	•
•	• **Service Response Time** • Average response time • Maximum Response Time • Response Time Failure

Table-A I- 10: Extracted SLA and SLO (Continued)

SMICloud: A Framework for Comparing and Ranking Cloud Services	
SLAs(high/top level attributes**)**	**SLOs (KPIs)**
•	• **Sustainability** • Service sustainability • Environmental Sustainability
•	• **Suitability** • number of non-essential features provided by service • number of non-essential features required by the customer
•	• **Accuracy** • frequency of failure
•	• **Transparency**
•	• **Interoperability**
•	• **Availability** • Total time for which the service was not available
•	• **Reliability** • Mean time to failure • Number of failure
•	• **Stability**
•	• **Cost** • acquisition • on-going
•	• **Adaptability**
•	• **Elasticity** • mean time taken to expand • maximum capacity
•	• **Usability**
A brief preview of the paper: (Garg, Versteeg, & Buyya, 2011) Cloud computing is growing rapidly and a lot of companies and individuals are transferring their business into the cloud. Yet the only challenge that concerns the consumers is how to choose the best and most convenient cloud provider that matches their requirements. In this paper, the authors proposed a framework and a mechanism that could help in solving this problem. According to the user requirements, The suggested platform can compare several cloud providers and assist the user to decide the best offers that can match his needs.	

Table-A I- 11: Extracted SLA and SLO

Conceptual SLA framework for cloud computing	
SLAs	**SLOs**
• Availability	•
• Scalability	•
• Response time.	•
• Security and privacy	•
• Performance	• response time CPU capacity
• **SLA metrics for IAAS**(consumer) • CPU capacity • Memory size • Boot time • Storage • Scale • Scale down • Scale up time • Scale down time • Auto scaling • Max number can be configured on physical server • Availability • Response time	•
• **SLA metrics for PAAS**(consumer) • Integration • Scalability • Pay as you go billing • Environments of deployment • Servers • Browsers • Number of developers	•
• **SLA metrics for SAAS**(consumer) • Reliability • Usability • Scalability • Availability • Customizability	•

Table-A I- 11: Extracted SLA and SLO (Continued)

Conceptual SLA framework for cloud computing	
SLAs	**SLOs**
• **SLA Metrics for storage as a service** • Geographic location • Scalability • Storage space • Storage billing • Security • Backup • Recovery • System throughput • Transferring bandwidth • Data life cycle management	•
• Monitoring	•
• Billing	•
• Security	•
• Networking	
• Privacy	
• Local and international policies	
• Support service	
A brief preview of the paper: (Alhamad, Dillon, & Chang, 2010) In this paper, the authors discussed the negotiation process and some strategies that are used. Moreover, they presented the essential criteria that should be used in the stage of an SLA design. They also proposed a method to retain the trust level between cloud service provider and consumer.	

Table-A I- 12: Extracted SLA and SLO

Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	
SLAs	**SLOs**
• Availability	• Downtime (mean time to repair (MTTR)) • Uptime (mean time between failure (MTBF))
• Response time	• In bytes, • out bytes, • packet size, • avail .bandwidth in, • avail .bandwidth out
• Storage	• disk space
• Memory	•
• Incoming Bandwidth	•
• Outgoing Bandwidth	•
A brief preview of the paper: (Emeakaroha, Brandic, Maurer, & Dustdar, 2010). In this paper, a new framework to detect SLA violation is proposed. This framework could help in the detection of SLA threats and inform the enactor component. They also present an experimental to prove their work.	

Table-A I- 13: Extracted SLA and SLO

Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC	
SLAs	**SLOs**
• Availability	• Availability percentage • Maximum number of outage per month • Maximum duration per outage
• Response time	•
• Throughput	•
A brief preview of the paper: (Ghumman & Schill, 2017) In this paper, the authors discussed the SLA lifecycle and presented a method that minimize the amount of communications of SLA violations. This proposed work is applicable for service that is used at one location or more.	

Table-A I- 14: Extracted SLA and SLO

A Systematic Review of Service Level Management in the Cloud	
SLAs	**SLOs**
• Allowable violation	• Maximum fraction of SLO violations allowed
• Availability	• Percentage uptime or downtime
• Bandwidth	• Throughput (KB/s or MBit/s), data transfer time, round trip time
• Cost	• Dollars, electricity prices, VM cost per time unit, revenue per request
• CPU cycle	• MIPS, MHz, number of cores/CPU/vCPU/cycles, CPU utilization/ consumption/speed
• Duration of service	• Length of SLA time window, service time, execution time
• Energy	• Cost per kWh, power (watts)
• Memory	• MB, GB
• Penalty rate	• SaaS VM parameter, average penalty ($)

Table-A I- 14: Extracted SLA and SLO (Continued)

A Systematic Review of Service Level Management in the Cloud	
SLAs	**SLOs**
• Performance	• Throughput (MB/sec), response time, MIPS, latency, execution time, deadline, job processing time
• Request arrival rate	• Customer QoS parameter, request/sec, arrival rate factor (user side)
• Security	•
• Space/Storage	• GB, I/O access (read size in MB)
• Upgrade request frequency	• Customer QoS parameter
• Others	• Intensity rate generator, VM initiation time, client classification (gold/silver/bronze), priority of job, number of VMs
• **Cloud federation SLA parameters:** Availability	•
• bandwidth	•
• Cost	•
• CPU cycle	•
• Duration of service	•
• Penalty rate	•
• Performance	•
• Request arrival rate	•
• Security	•
• Space/ storage	•
• **SaaS SLA parameters:** Allowable violation	•
• CPU cycle	•
• duration of service	•
• Memory	•

Table-A I- 14: Extracted SLA and SLO (Continued)

A Systematic Review of Service Level Management in the Cloud	
SLAs	**SLOs**
• penalty rate	•
• performance	•
• request arrival rate	•
• service initiation time	•
• space/storage	•
• upgrade request frequency	•
• **PaaS SLA parameters:** cost	•
• performance	•
• **IaaS SLA parameters:** availability	•
• bandwidth	•
• cost	•
• CPU cycle	•
• energy	•
• memory	•
• penalty rate	•
• performance	•
• request arrival rate	•
• space/storage	•
• **StaaS SLA parameters:** performance	•
• storage/space	•
• **NaaS SLA parameters:** Bandwidth	•
• **DaaS SLA parameters:** performance	•
• **Other SLA parameters:** CPU cycle, memory	•
A brief preview of the paper:(Faniyi & Bahsoon, 2015) In this paper, a survey on cloud computing SLA was conducted to help improving the structure of cloud SLAs and their management. & we consider the presented unit of measure as an SLO to the proposed SLA parameters. The presented parameters where ordered based on different cloud level of abstractions	

Table-A I- 15: Extracted SLA and SLO

Real-Time and Proactive SLA Renegotiation for a Cloud-Based System	
SLAs	**SLOs**
• Throughput	•
• Availability	•
• Response time	•
•	•
•	•
•	•
A brief preview of the paper: (Paputungan, Hani, Hassan, & Asirvadam, 2018) In this article, the authors introduced a real time negotiation model to support the negation process in the cloud. They presented a new method to detect service violation to guarantee better negotiation.	

Table-A I- 16: Extracted SLA and SLO

SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	
SLAs	**SLOs**
• Security	Controls: User access authorization/restriction, User access revocation, Roles/Responsibilities, Segregation of duties, Encryption, Encryption key management, Vulnerability/ Patch management, Anti-virus/malicious software, Audit tool access, Incident reporting, Network security, Remote user multi-factor authentication
• Availability	•
• Response time	•
• Throughput	•
• Reliability trust	•
• Decision trust	•
• Reputation	•
• Compliance	•
• Data Governance	•
• Resiliency	•
• Operations Management which control Capacity/resource planning, Equipment maintenance	•
A brief preview of the paper: (Ghosh, Ghosh, & Das, 2015) A framework to assist cloud service consumers while choosing and identifying the most applicable cloud provider which could assure the quality of the service provided, is proposed in this paper. The authors The authors consider these SLA parameters as the standard ones that are used with several cloud service SLAs: Availability, Response time and Throughput	

Table-A I- 17: Extracted SLA and SLO

Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	
SLAs	**SLOs**
• availability	•
• Accounting of services,	•
• IT continuity plans	•
• service development plans	•
• Terminologies	•
• Escalation plan	•
• Guidelines for priorities	•
• Responsibilities of both customer and company	•
• Data of both parties	•
• Service of both times	•
• Accomplishment penalties	•
• Signing an ID	•
• Termination reason	•
A brief preview of the paper:(Frey et al., 2013) Most cloud providers offer a standard SLA for their customers. However, customers' needs and requirements are distinct from each other most of the time. This issue is usually facing companies and individuals when trying to move their work or data to the cloud. In this paper, the authors are suggesting to create a special SLA for each customer respecting all related SLOs that are needed to evaluate and measure the service. They only mentioned the parts that each SLA should contain and present an USECASE about Availability.	

Table-A I- 18: Extracted SLA and SLO

<table>
<tr><td colspan="2">An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model.</td></tr>
<tr><td>SLAs</td><td>SLOs, (KPIs) Key Performance Indicators</td></tr>
<tr><td>• Fault Tolerance</td><td>• Data Replication
• Data Mirroring
• Multipath Input and output IO</td></tr>
<tr><td>• Performance</td><td>• Type of Application
• Maximum number of User Requests
• Response Time
• Transferring Bandwidth</td></tr>
<tr><td>• Disaster Recovery</td><td>• Recovery Point Objective (RPO)
• Recovery Time Objective (RTO)</td></tr>
<tr><td>• Security</td><td>• Confidentiality
• Integrity
• Availability
• Authentication
• Authorization</td></tr>
<tr><td>• Data Life Cycle Management (DLM)</td><td>• Data Archival
• Accessibility of the Archived Data
• Access Time</td></tr>
<tr><td>• Governance</td><td>• Geographic Location
• Regulations
• Availability</td></tr>
<tr><td colspan="2">A brief preview of the paper:(Ghosh & Ghosh, 2012)
Although consumers demand more assurance and guarantees to the provided service, most cloud providers nowadays are focusing on availability rather than other performance and management assurance.
In this paper, the authors indicate the non-Trivial SLA parameters that are related to Storage-as-a-Service cloud, in addition to proposing a new SLA framework for monitoring and checking SLOs by using a third party. They also point out the limitations that most current SLAs in the market suffer from.</td></tr>
</table>

ANNEX II

SLA AND SLO PARAMETERS OCCURANCE PERCENTAGES

In this annex II, we will present the tables that contain all the extracted SLA and SLO parameters that were used to identify the occurrence percentage for each SLA and SLO parameters.

- **SLA Parameters**

Table-A II- 1:SLA occurrence percentages

Reference Titles	Availability	response time	Governance	Security	Termination of service	Privacy	Performance	Throughput	Roles & responsibilit	service capacity	Elasticity or Scalability	Disaster recovery
1. ISO/IEC 19086-1 SLA Standard	M	M	M	M	M	NM	M	NM	M	M	M	M
2. An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	NM	M	M	NM	NM	M	NM	NM	NM	NM	M
3. Service level agreement framework for e-commerce cloud end-user perspective	M	NM	NM	M	NM	NM	M	NM	NM	NM	M	NM
4. Monitoring and Management of Service Level Agreements in Cloud Computing	NM	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
5. Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	M	NM	NM	NM	M	NM	NM	NM	M	NM	NM	NM
6. Cloud Service Level Agreement. Encyclopedia of Cloud Computing	M	M	NM	M	M	M	M	M	NM	NM	NM	M
7. On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	NM	NM	M	NM	NM	NM	NM	NM
8. A comprehensive review on QoS measures for resource allocation in cloud environment	M	M	NM	M	NM	NM	NM	NM	NM	NM	NM	NM
9. Quality of service and service level agreements for cloud environments: Issues and challenges	M	M	NM	M	M	NM	M	NM	M	NM	M	M

Table-A II- 1:SLA occurrence percentages (Continued)

Reference Titles	Availability	response time	Governance	Security	Termination of service	Privacy	Performance	Throughput	Roles & responsibilit	service capacity	Elasticity or Scalability	Disaster recovery
10. A Framework for Negotiating Service Level Agreement of Cloud-based Services	NM	NM	NM	M	NM	M	M	NM	NM	NM	NM	NM
11. Key performance indicators for cloud computing SLAs	M	NM	NM	M	NM	M	NM	NM	NM	NM	NM	NM
12. SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	NM	NM	NM	M	NM	NM	NM	NM	NM	NM	NM	NM
13. SMICloud: A Framework for Comparing and Ranking Cloud Services	NM	M	NM	M	NM	M	M	NM	NM	NM	M	NM
14. Conceptual SLA framework for cloud computing	M	M	NM	M	NM	M	M	M	NM	NM	M	NM
15. Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	M	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
16. Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	M	M	NM	NM	NM	NM	NM	M	NM	NM	NM	NM
17. A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	M	NM	NM	M	NM	NM	M	NM	NM	NM	NM	NM
18. Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	M	M	NM	NM	NM	NM	NM	M	NM	NM	NM	NM
19. SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	M	M	M	M	NM	NM	NM	M	NM	M	NM	NM
Mentioning Percentage %	68%	57%	15%	68%	21%	26%	52%	26%	15%	10%	26%	21%

Table-A II- 2:SLA occurrence percentages

Reference Titles	backup and restore	reliability	Data location	Portability	Data deletion	Fault Tolerance	Usability	Service renewals	Service Credit	Service violations	Monitoring	Service Excess Use
1. ISO/IEC 19086-1 SLA Standard	M	M	M	M	M	M	NM	NM	NM	NM	M	NM
2. An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	NM	NM	NM	NM	M	NM	NM	NM	NM	NM	NM
3. Service level agreement framework for e-commerce cloud end-user perspective	M	M	M	M	NM	NM	M	NM	NM	NM	NM	NM
4. Monitoring and Management of Service Level Agreements in Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
5. Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM	NM	NM	M*	NM	NM	NM	NM
6. Cloud Service Level Agreement. Encyclopedia of Cloud Computing	M	NM	M	M	NM	NM	NM	M	M	M	NM	M
7. On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
8. A comprehensive review on QoS measures for resource allocation in cloud environment	M	M	NM	M	NM	NM	M	NM	NM	NM	NM	NM
9. Quality of service and service level agreements for cloud environments: Issues and challenges	NM	M	NM	NM	NM	NM	NM	NM	NM	M	NM	NM
10. A Framework for Negotiating Service Level Agreement of Cloud-based Services	NM	NM	NM	NM	NM	NM	M	NM	NM	NM	NM	NM
11. Key performance indicators for cloud computing SLAs	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM	NM
12. SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

Table-A II- 2:SLA occurrence percentages (Continued)

Reference Titles	backup and restore	reliability	Data location	Portability	Data deletion	Fault Tolerance	Usability	Service renewals	Service Credit	Service violations	Monitoring	Service Excess Use
13. SMICloud: A Framework for Comparing and Ranking Cloud Services	NM	M	NM	M	NM	NM	M	NM	NM	NM	NM	NM
14. Conceptual SLA framework for cloud computing	M	M	M	NM	NM	NM	M	NM	NM	NM	M	NM
15. Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
16. Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
17. A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	NM	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM
18. Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
19. SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	NM	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mentioning Percentage %	26 %	36 %	21 %	26 %	5%	10 %	26 %	10 %	10 %	15 %	10 %	5%

Table-A II- 3:SLA occurrence percentages

Reference Titles	Cost and Finance	Trust	Confidentiality	Storage	Resiliency	Compliance	Data life cycle management	law and jurisdiction	Penalties	Service guarantee/Assurance	Service description	Cloud Service Support
ISO/IEC 19086-1 SLA Standard	NM	NM	NM	NM	NM	NM	NM	M	NM	NM	M	M
An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	NM	NM	NM	NM	NM	M	NM	NM	NM	NM	NM
Service level agreement framework for e-commerce cloud end-user perspective	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Monitoring and Management of Service Level Agreements in Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM	NM
Cloud Service Level Agreement. Encyclopedia of Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM
On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A comprehensive review on QoS measures for resource allocation in cloud environment	NM	NM	M	NM	NM	NM	NM	NM	NM	NM	NM	NM
Quality of service and service level agreements for cloud environments: Issues and challenges	NM	M	NM	NM	NM	NM	NM	NM	NM	M	M	NM
A Framework for Negotiating Service Level Agreement of Cloud-based Services	M	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM
Key performance indicators for cloud computing SLAs	NM	NM	M	NM	NM	NM	NM	NM	M	M	NM	NM
SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SMICloud: A Framework for Comparing and Ranking Cloud Services	M	NM	NM	NM	M	M	NM	NM	NM	M	NM	NM
Conceptual SLA framework for cloud computing	M	NM	NM	M	NM	NM	M	M	NM	NM	NM	M
Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	NM	NM	NM	M	NM	NM	NM	NM	NM	NM	NM	NM

Table-A II- 3:SLA occurrence percentages (Continued)

Reference Titles	Cost and Finance	Trust	Confidentiality	Storage	Resiliency	Compliance	Data life cycle management	law and jurisdiction	Penalties	Service guarantee/Assurance	Service description	Cloud Service Support
Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	M	NM	NM	M	NM	NM	NM	NM	M	NM	NM	NM
Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	NM	M	NM	NM	M	M	NM	NM	NM	NM	NM	NM
Mentioning Percentage %	21 %	10 %	10 %	15 %	10 %	10 %	10 %	10 %	15 %	26 %	10 %	10 %

Table-A II- 4:SLA occurrence percentages

Reference Titles	Accessibility	Error Rate	Integrity	Agility	Bandwidth
1. ISO/IEC 19086-1 SLA Standard	M	NM	NM	NM	NM
2. An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	M	NM	NM	NM
3. Service level agreement framework for e-commerce cloud end-user perspective	NM	NM	NM	NM	NM
4. Monitoring and Management of Service Level Agreements in Cloud Computing	NM	NM	NM	NM	NM
5. Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM
6. Cloud Service Level Agreement. Encyclopedia of Cloud Computing	NM	NM	NM	NM	NM
7. On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	NM
8. A comprehensive review on QoS measures for resource allocation in cloud environment	NM	NM	M	NM	M
9. Quality of service and service level agreements for cloud environments: Issues and challenges	NM	NM	NM	NM	NM
10. A Framework for Negotiating Service Level Agreement of Cloud-based Services	NM	NM	NM	M	NM
11. Key performance indicators for cloud computing SLAs	NM	NM	NM	NM	NM
12. SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	NM	NM	NM	NM	NM
13. SMICloud: A Framework for Comparing and Ranking Cloud Services	M	NM	M	NM	NM
14. Conceptual SLA framework for cloud computing	NM	NM	NM	NM	NM
15. Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	NM	NM	NM	NM	M
16. Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	NM	NM	NM	NM	NM
17. A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	NM	NM	NM	NM	M

Table-A II- 4:SLA occurrence percentages (Continued)

Reference Titles	Accessibility	Error Rate	Integrity	Agility	Bandwidth
18. Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM
19. SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	NM	NM	NM	NM	NM
Mentioning Percentage %	10%	5%	10%	5%	15%

M: Mentioned

NM: Not Mentioned

MSLA: Mentioned as SLA Parameter

MSLO: Mentioned as SLO Parameter

- Let **(F)** be then percentage of the frequency of SLA parameters.
- Let **M(n)** be the number of how many times the parameter was mentioned.
- Let **A(n**) be the total number of the analysed articles.

$$\frac{F = M(n)\ X\ 100}{A(n)}$$

- **SLO parameters**

Table-A II- 5: SLO occurrence percentages

Reference Titles	Response time	Throughput	Uptime	Downtime	Monitoring parameters	Monitoring Mechanisms	Accessibility Standards	Accessibility Policies	maximum Response Time Observation	Response Time Mean	Response Time Variance	Cloud Service Bandwidth
ISO/IEC 19086-1 SLA Standard	MSLA	M	M	M	M	M	M	M	M	M	M	M
An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Service level agreement framework for e-commerce cloud end-user perspective	M	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Monitoring and Management of Service Level Agreements in Cloud Computing	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cloud Service Level Agreement. Encyclopedia of Cloud Computing	MSLA	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
On Service Level Agreement Assurance in Cloud Computing Data Centers	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A comprehensive review on QoS measures for resource allocation in cloud environment	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Quality of service and service level agreements for cloud environments: Issues and challenges	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A Framework for Negotiating Service Level Agreement of Cloud-based Services	M	M	NM	NM	NM	NM	M	M	NM	NM	NM	NM
Key performance indicators for cloud computing SLAs	M	M	NM	NM	M	M	NM	NM	NM	NM	NM	M
SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SMICloud: A Framework for Comparing and Ranking Cloud Services	MSLOMSLA	NM	NM	NM	NM	NM	NM	NM	M	NM	NM	NM

Table-A II- 5: SLO occurrence percentages (Continued)

Reference Titles	Response time	Throughput	Uptime	Downtime	Monitoring parameters	Monitoring Mechanisms	Accessibility Standards	Accessibility Policies	maximum Response Time Observation	Response Time Mean	Response Time Variance	Cloud Service Bandwidth
Conceptual SLA framework for cloud computing	MSLO MSLA	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	MSLA	NM	M	M	NM	NM	NM	NM	NM	NM	NM	MSLO MSLA
Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	MSLA	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	M	M	M	M	NM	NM	NM	NM	NM	NM	NM	MSLA
Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	MSLA	MSLA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mentioning Percentage %	36%	26%	15%	15%	10%	10%	10%	10%	10%	5%	5%	15 %

Table-A II- 6:SLO occurrence percentages

Reference Titles	Limit of Available Cloud Service Resources	Limit of Simultaneous Cloud Service	Elasticity Speed	Elasticity Precision	Recovery Point Objective (RPO)	Recovery Time Objective (RTO)	Confidentiality	Integrity	Availability	Authentication	Authorization	Data archival
ISO/IEC 19086-1 SLA Standard	M	M	M	M	M	M	NM	NM	MSLA	NM	NM	NM
An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	NM	NM	NM	M	M	M	M	M	M	M	M
Service level agreement framework for e-commerce cloud end-user perspective	NM	NM	NM	NM	NM	NM	M	M	MSLA	NM	NM	NM
Monitoring and Management of Service Level Agreements in Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM	NM
Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM
Cloud Service Level Agreement. Encyclopedia of Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM
On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A comprehensive review on QoS measures for resource allocation in cloud environment	NM	NM	NM	NM	NM	NM	MSLA	MSLA	MSLA	NM	NM	NM
Quality of service and service level agreements for cloud environments: Issues and challenges	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM
A Framework for Negotiating Service Level Agreement of Cloud-based Services	NM	NM	NM	NM	NM	NM	M	M	M	NM	NM	NM
Key performance indicators for cloud computing SLAs	NM	NM	NM	NM	NM	NM	MSLA	NM	MSLA	NM	NM	NM
SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM	NM
SMICloud: A Framework for Comparing and Ranking Cloud Services	NM	NM	NM	NM	NM	NM	NM	MSLA	M	NM	NM	NM
Conceptual SLA framework for cloud computing	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM

Table-A II- 6: SLO occurrence percentages (Continued)

Reference Titles	Limit of Available Cloud Service Resources	Limit of Simultaneous Cloud Service	Elasticity Speed	Elasticity Precision	Recovery Point Objective (RPO)	Recovery Time Objective (RTO)	Confidentiality	Integrity	Availability	Authentication	Authorization	Data archival
Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM
Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM
A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	NM	NM	NM
Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	NM	NM	NM	NM	NM	NM	NM	NM	MSLA	M	M	NM
Mentioning Percentage %	5%	5%	5%	5%	10%	10%	15%	15%	26%	10%	10%	5%

Table-A II- 7:SLO occurrence percentages

Reference Titles	Data Deletion Process	Data Deletion Notification	Data Deletion Time	Maximum number of User Requests	Delay in end to end transaction	Data Location Specification Capability	packet loss	MOS(Mean Opinion Score)	Law Enforcement Requests	Failed Storage Transactions	Number of Detected Attacks	Accessibility of the Archived
ISO/IEC 19086-1 SLA Standard	M	M	M	NM	NM	M	NM	NM	M	NM	NM	NM
An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	NM	NM	M	NM	NM	NM	NM	NM	M	NM	M
Service level agreement framework for e-commerce cloud end-user perspective	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Monitoring and Management of Service Level Agreements in Cloud Computing	NM	NM	NM	NM	M	NM	NM	NM	NM	NM	NM	NM
Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cloud Service Level Agreement. Encyclopedia of Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	M	NM	M	M	NM	NM	NM	NM
A comprehensive review on QoS measures for resource allocation in cloud environment	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Quality of service and service level agreements for cloud environments: Issues and challenges	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A Framework for Negotiating Service Level Agreement of Cloud-based Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Key performance indicators for cloud computing SLAs	NM	NM	NM	NM	NM	NM	M	NM	NM	NM	NM	NM
SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	M	NM
SMICloud: A Framework for Comparing and Ranking Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Conceptual SLA framework for cloud computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

Table-A II- 7: SLO occurrence percentages (Continued)

Reference Titles	Data Deletion Process	Data Deletion Notification	Data Deletion Time	Maximum number of User Requests	Delay in end to end transaction	Data Location Specification Capability	packet loss	MOS(Mean Opinion Score)	Law Enforcement Requests	Failed Storage Transactions	Number of Detected Attacks	Accessibility of the Archived
Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Mentioning Percentage %	5%	5%	5%	5%	10%	5%	10%	5%	5%	5%	5%	5 %

Table-A II- 8:SLO occurrence percentages

Reference Titles	Data encryption	Service disruption	CPU capacity	packet size	Maximum number of outage per month	Maximum duration per outage	Maximum fraction of SLO violations allowed	electricity prices	Dollars	Roles/Responsibilities	Portability	Reliability
ISO/IEC 19086-1 SLA Standard	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
An approach to identify and monitor SLA parameters for storage-as-a-service cloud delivery model	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Service level agreement framework for e-commerce cloud end-user perspective	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Monitoring and Management of Service Level Agreements in Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Adaptable Service Level Objective Agreement (A-SLO-A) for Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Cloud Service Level Agreement. Encyclopedia of Cloud Computing	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
On Service Level Agreement Assurance in Cloud Computing Data Centers	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A comprehensive review on QoS measures for resource allocation in cloud environment	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Quality of service and service level agreements for cloud environments: Issues and challenges	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A Framework for Negotiating Service Level Agreement of Cloud-based Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	M	M
Key performance indicators for cloud computing SLAs	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SLA-Driven Monitoring of Multi-cloud Application Components Using the MUSA Framework	M	M	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SMICloud: A Framework for Comparing and Ranking Cloud Services	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	M

Table-A II- 8: SLO occurrence percentages (Continued)

Reference Titles	Data encryption	Service disruption	CPU capacity	packet size	Maximum number of outage per month	Maximum duration per outage	Maximum fraction of SLO violations allowed	electricity prices	Dollars	Roles/Responsibilities	Portability	Reliability
Conceptual SLA framework for cloud computing	NM	NM	M	NM	NM	NM	NM	NM	NM	NM	NM	NM
Low level Metrics to High level SLAs - LoM2HiS framework: Bridging the gap between monitored metrics and SLA parameters in cloud environments	NM	NM	NM	M	NM	NM	NM	NM	NM	NM	NM	NM
Continuous and Distributed Monitoring of Cloud SLAs Using S3LACC. 2017 IEEE Symposium on Service-Oriented System Engineering (SOSE)	NM	NM	NM	NM	M	M	NM	NM	NM	NM	NM	NM
A Systematic Review of Service Level Management in the Cloud." ACM Computing Surveys	NM	NM	NM	NM	NM	NM	M	M	M	NM	NM	NM
Paputungan, I. V., A. F. M. Hani, M. F. Hassan and V. S. Asirvadam (2018). "Real-Time and Proactive SLA Renegotiation for a Cloud-Based System." IEEE Systems Journal: 1-13.	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SelCSP: A Framework to Facilitate Selection of Cloud Service Providers	M	NM	NM	NM	NM	NM	NM	NM	NM	M	NM	NM
Mentioning Percentage %	15%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	10 %

M: Mentioned

NM: Not Mentioned

MSLA: Mentioned as SLA Parameter

MSLO: Mentioned as SLO Parameter

- Let **(F)** be the percentage of the frequency of SLO parameters.
- Let **M(n)** be the number of how many times the parameter was mentioned.
- Let **A(n)** be the total number of the analysed articles.

$$\frac{F = M(n)\ X\ 100}{A(n)}$$

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