Systematic Analysis of Public Cloud Service Level Agreements and Related Business Values

Meng Maggie Qiu
School of Information Technologies
The University of Sydney
Sydney, Australia
mqiu1019@uni.sydney.edu.au

Ying Zhou
School of Information Technologies
The University of Sydney
Sydney, Australia
ying.zhou@sydney.edu.au

Chen Wang
CSIRO ICT Center
PO Box 76, Epping
NSW 1710, Australia
chen.wang@csiro.au

***Abstract*—Cloud computing offers lots of attractive benefits to individuals and organizations. However, the adoption rate is a far cry from what it really deserves. Lack of well defined Service Level Agreement (SLA) is one of the key factors. This research aims to provide better understanding of the status quo of the current public cloud service level agreements and to recommend best practices. We conducted a content analysis on around thirty SLAs to identify commonly stated attributes and commonly missing attributes. A follow up case study interviewed a selection of cloud customers further investigates the importance of SLA attributes and its relationship with potential business. The result reveals that some of the commonly missed attributes such as customer support, data protection plan are considered as very important attributes and most SLA attributes are directly related with business values.**

***Keywords*-Cloud Computing, Service Level Agreement, Business Value**

I. Introduction

The economic environment businesses operates has changed dramatically over the last century, especially since the start of the digital era. Businesses still running on traditional business models with fixed cost operations are experiencing great difficulties in competing in the today's market [23]. As the current economics markets are more globalized, open, agile, uncertain and unpredictable, assets are becoming more like a burden similar to liabilities to businesses rather than real values. This makes cloud computing, which has minimal to zero upfront cost, very attractive in the current business environment. As cloud computing continues to enjoy and leverage the rapid advancement in network infrastructures and significant increase in computing powers, Gartner has listed it as one of the "top 10 strategic technology trend" that will greatly impact the IT experiences of individuals and organizations in 2012 and in the coming years [10].

There are numerous surveys about actual adoption rate and possible consumer concerns on cloud computing. An annual survey conducted by InformationWeek since 2008 has shown steady growth in cloud adoption among survey respondents. The most recent one shows that around one third of the respondents are using services from a cloud provider[45]. Yet the message among those skeptical respondents is quite consistent. Those organizations find it is hard to measure the business value of cloud computing and service level agreements (SLAs) "*rarely help buyers sort out exactly what sort of service they'll get for the price they'll pay.*" Another survey done by Cisco in 2012 also put service level agreement as one of the top three "most critical infrastructure for cloud deployments"[11]. Furthermore, [21] points out that a lack of well-defined SLAs in the cloud-related services has hold back the wider adoption of cloud computing.

In this work, we run a systematic analysis on around thirty public SLAs from various cloud providers to get an in depth understanding of the current status quo of the SLAs and to provide some guidelines to fill the gaps of the consumer expectation and SLA. We try to make the following contributions:

- We conducted a systematic analysis on a number of public cloud SLAs in various services model to identify common gaps
- We run a case study with selected clould customers or potential customers to reveal the importance of having a comprehensive list of attributes in SLA and their relationship with potential business values.

The rest of the paper is organized as below. Section II briefly reviews some important concepts on cloud computing. Section III reports the content analysis carried out on a sample of public cloud SLAs. In section IV we describe the case study and result. Section V concludes the paper.

II. Background

The cloud computing paradigm has many unique features, which makes it hard for people to agree on a single definition and classification. The U.S. National Institute of Standards and Technology (NIST) describes it as "*A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models*" [30]. This definition is broad enough to cover many aspects of cloud computing. We will follow the definition and especially its classification on service models and deployment models.

The three service models in NIST definition are: Software as a Service (SaaS), Platform as a Service (PaaS) and In-

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frastructure as a Service (PaaS). Even though a few services might not be easily categorized [5], majority of the existing cloud services can be clearly classified as one of the *XaaS* models. Moreover, such classification also helps to clarify the responsibilities of cloud providers and customers. For instance, the IaaS providers only provision and control fundamental computing resources hence their responsibilities are limited to those resources. The IaaS customers are able to deploy and run arbitrary software on provider's infrastructure and those software are customers' sole responsibility. On the other hand, SaaS providers manage the whole application stack for the customer and they are responsible for everything in the stack.

NIST also describes four deployment models: public, private, community and hybrid. Public cloud services are open to general public, which is by far the most popular deployment model and is our focus of study.

III. Content Analysis on Public Cloud SLAs

A. Data Collection

We adopt content analysis method to compare and analyze a sample of SLAs from existing cloud providers. A sample of 29 SLAs are collected. We use purposive sampling method to ensure that the services described by the SLAs are public cloud services offered to multiple entities including individuals and organizations, and the SLA documents are readily available online and can be accessed with no restriction. We also ensure that the sample covers all popular services models. Table I shows a summary of the services and the SLA versions included in our sample. In total, there are 17 SLAs for IaaS, 5 for PaaS and 7 for SaaS. To make the results representative, we have a a mixture of well known services offered by large companies and services offered by relatively small companies.

Table I shows three sub categories of IaaS, depending on the SLA coverage. Most IaaS service providers offer separate computing and storage services. Many have separate SLAs for their computing and storage service. Hence we have sub categories for "IaaS/Compute" and "IaaS/Storage". Some providers use a single SLA to cover all services they provide. They are put in the sub category "IaaS/Infrastructure".

It is worth noting that the proportion of SLAs in different services models in the sample do not reflect the proportion of providers in those services models. There are more SLAs for IaaS than for PaaS and SaaS simply because most IaaS SLAs follow the one-for-all principle and are publicly available. It is not easy to find publicly available PaaS and SaaS SLAs. We suspect that because many PaaS and SaaS providers use subscription model and there are various levels of subscription, it is possible that each level have its own SLA and these are only available to subscribers.

B. Data Analysis

Service level agreement for any services is a binding contract between the service provider and the service customer, which outlines the responsibilities, describes the service to be provisioned, defines the service commitment guarantees, penalties for non-compliance, and emergence contacts. [2] argues that the main idea of having a service level agreement is so that the service provider and service customer can have a formal agreement which clearly defines the service attributes such as obligations, availability, performance and etc. Certain agreement terms are usually expressed as one or many measurable or observable metrics. For instance, most surveyed SLAs have availability defined as a percentage of uptime over a certain period of time. Such terms are referred to as Service Level Objective (SLO)[1], SLA attributes or SLA parameters [42].

We start the analysis by identifying a general list of attributes that should appear in an SLA document and use that as a template to examine our SLA sample and to highlight common omission and common practice in cloud computing paradigm. Around 20 SLA attributes are identified from literature (c.f.[7], [37],) and real cloud SLA documents. Figure 1 shows a summary of the presence of each attribute in our SLA sample set.

It is clear that there are certain set of attributes that are commonly stated in nearly all SLAs in our sample, regardless of the services they cover. There are also set of attributes that are absent in majority of the SLAs in our study. Next we will

TABLE I
Cloud Services in the SLA sample

IaaS/Compute	
Service	SLA version
Amazon EC2	2008 [4]
Microsoft Azure Compute	2010 [31]
Google compute engine	n.a. [20]
Rackspace cloud server	n.a. [38]
Terremark vCloud Express	2009 [44]
BlueLock	n.a. [9]
OpSource	n.a. [36]
Layered Tech	n.a. [28]
IaaS/Storage	
Service	SLA version
Amazon S3	2007 [3]
Google Cloud storage	n.a.[19]
Rackspace cloud files	n.a. [38]
Windows Azure Storage	2010 [32]
HP Cloud Object Storage	n.a. [22]
IaaS/Infrastructure	
Service	SLA version
GoGrid	2012 [16]
The Joyent Cloud	n.d. [24]
AT&T Cloud Architect	2012 [6]
Ninefold	n.a. [35]
PaaS	
Service	SLA version
Google App Engine	2012 [17]
Rollbase	2010 [40]
Engine Yard	n.a. [14]
Cloudforge	2012 [12]
WSO2	2011 [46]
SaaS	
Service	SLA Version
Google Apps	n.a. [18]
Microsoft Office 365	2012 [33]
Kaseya SaaS	2012 [25]
EnterpriseWizard	n.a. [15]
SaaShost.net	n.a. [41]
Rally Software	n.a. [39]
TALENTGuard OnDemand SaaS	n.a. [43]

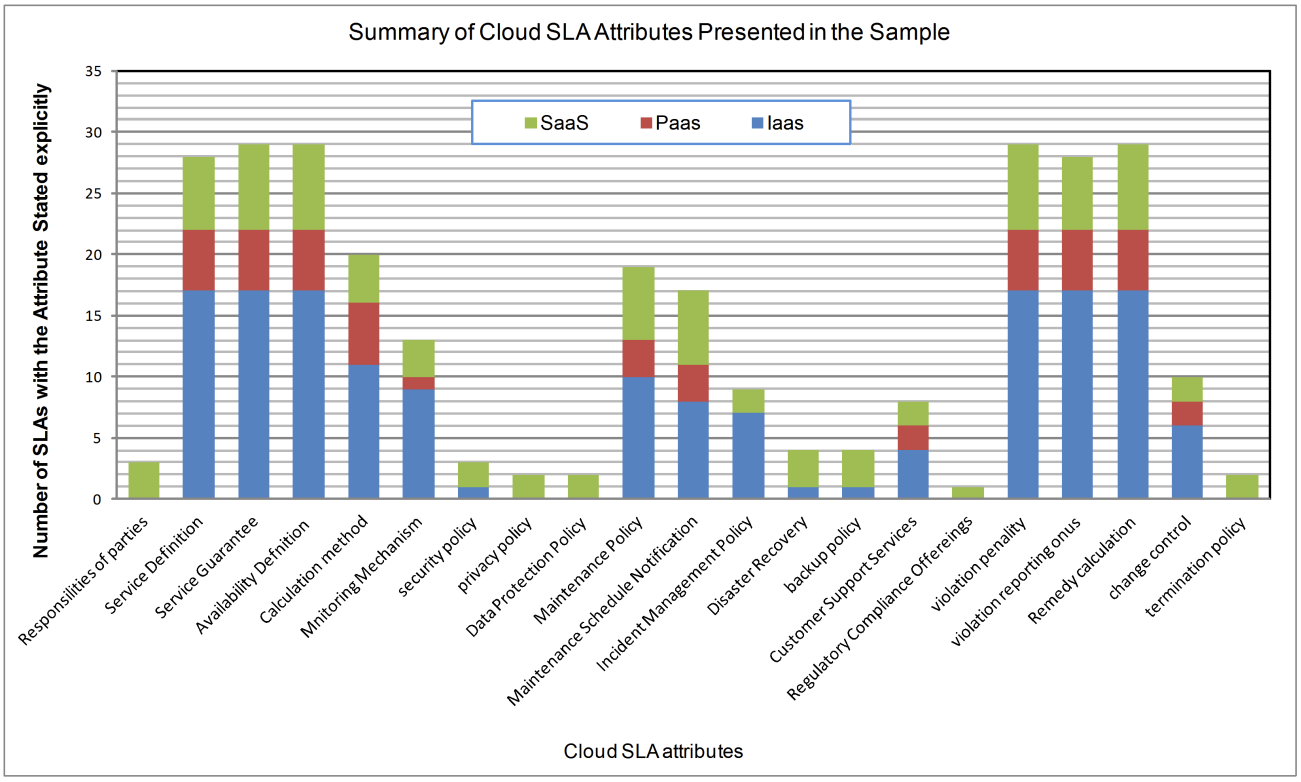

Fig. 1. Cloud SLA Attributes Summary

give a detailed description of the attributes.

C. Commonly Stated SLA Attributes

Nearly all SLAs we examined explicitly describe/name the services they cover. Such information usually appears at the beginning of an SLA document. Some may contain the scope and a brief description of the services. Services capacities are not usually given since most SLAs we examined are off-the-shelf agreements that covers a type of services with various capacity configurations. For instance, the Amazon EC2 SLA covers all EC2 instance types.

All SLAs we examined guarantee at least one service feature: *availability*. A few SLAs claim to guarantee additional features. For instance, some SLAs state that "Covered Service will be *operational* and *available* to Customer at least 99.9% of the time"[20]. One SaaS SLA also guarantees *secure network* in addition to availability[41]. Even though certain SLAs claim to guarantee additional features, none of them has provided any definition or ways of measuring those additional features. The only measurable guarantee in all SLA is *availability*.

availability is a heavily overloaded term in cloud SLA. The definition and calculation vary a lot across different types of services and even within the same service type. Nearly all SLAs we examined provide some definition of *availability*; Around two thirds of the SLAs also give calculation methods.

The most common definition of *availability* is "uptime", which can be measured annually, monthly or quarterly. This simple up/down time measurement is reasonably adequate for IaaS compute services which offer virtual computer instances to customers. The uptime is usually calculated as the percentage of the time the instance is up and running in a predefined observation period. Majority of the cloud compute services use this definition and calculation(c.f. [4], [20]). The standard "uptime" definition can be applied to IaaS SLAs that do not explicitly give a definition. However it may not be applicable to other types of services where the service itself can not be expressed by units of up/down pieces. In those cases, the definition and calculation of *availability* would incorporate related performance metrics. For instance, many SLAs use an "error rate" based *availability* calculation. Microsoft Windows Azure Storage SLA [32] defines "error rate" as the ratio of failed transaction count to the total transaction count in an observation interval. It also gave the maximum tolerable processing time for each type of transactions. Any transaction processed beyond the maximum time is considered as failed. Amazon S3 SLA[3] defines "error rate" as total number of internal server errors returned divided by the total number of request issued during any five minute time period. Google App Engine[17] also defines "error rate" as the number of requests with error code divide by the total number of requests issued during that period. There are also other service specific

definition of *availability*. For instance, GoGrid[16] use a combination of maximum packet loss rate, latency and jitter to measure its network service availability. Not all SLAs provide appropriate measurement of *availability*. Quite a few SaaS providers use simple up/down time calculation.

Even in SLAs with detailed description of *availability* computation, not all provide effective ways of monitoring the services for possible violations. A number of SLAs use server log as proof of violation for refund, but no proactive mechanism is stated ([3], [4],[20]). None the less, logs are counted as a way of "offline" monitoring mechanism. Some SLAs do state explicitly about online availability monitoring mechanism. For instance, GoGrid provides automatic monitoring services for server uptime[16]; Engine Yard describes how a customer can activate external monitoring services for availability[14]; SaaSHost.net " uses a proprietary system to measure whether the Services are Available by sending `pings` to servers in the data center at regular intervals and by monitoring the running services on the system. The USER agrees that this system will be the sole basis for resolution of any dispute that may arise between the USER and SAASHOST.NET regarding this Service Level Agreement"[41].

All SLAs give detailed description of penalties for service violation. Majority of the SLAs use service credit as the sole remedy. A few also provides monetary refund or termination option. All SLAs states ways of calculating the amount of credits entitled for customer, which is usually a constant function or step function. For instance, Amazon gives customer a service credit equal to 10% of the bill, if the annual uptime percentage for EC2 services drops below 99.95% [4]. Google gives customer service credit equals to 10% of monthly bill if the monthly uptime percentage is between 99.00% and 99.50%; If the monthly uptime percentage is dropped below 99.00% but above 95%, the customer is entitled to receive 25% of their monthly bill; or if the monthly uptime percentage is dropped below 95%, the service credit would equal 50% of the monthly bill (c.f.[20], [17]). The step function as used by Google is the more popular one among SLAs we examine.

All SLAs, regardless of monitoring mechanisms used, require customers to file credit claim for any service violation. In certain cases, especially IaaS services, customers are also required to furnish evidence of the violation, which is usually in the form of anatomized server log (c.f. [4], [20]). Alternatively, the provider will use their system log or monitoring system to verify the violation claim(c.f. [14], [39], [41]). This is more common in PaaS and SaaS where customers have less control and access to system level data. A number of SLAs only mention that the provider will verify customer claim without stating how. The claim window ranges from 48 hours following the event (c.f. [9], [16]) to 30 days following the event(c.f. [4], [20], etc.). Some set the claim window based on billing cycle (c.f. [3], [32], etc.).

All service providers routinely run maintenance to ensure proper functioning of their services. Nearly all SLAs make it clear that service disruption caused by maintenance is not counted as downtime for availability calculation. It is important for customer to know the maintenance frequency, duration and to get advanced notice about possible effect to their services. However, not all SLAs include these information. Around 60% of the SLAs we examine include a paragraph describing the maintenance policy and how customers are notified. There are various maintenance notification media ranging from ticketing system, email, pre-scheduled timetables outlined within the SLAs and so one.

Customer support services might be available but they are not commonly stated in public cloud SLAs we examined. Only around 30% of the SLAs outline customer service available time and/or response time.

D. Commonly Missed SLA Attributes

A number of important SLA attributes are missed in most SLAs we examine. For instance, only a few SLAs clearly outlined the responsibilities of parties involved, especially the responsibility of customers ([43]). Important Attributes related with customer data on the cloud such as *security*, *privacy*, *protection* and *backup* policies are generally missing in most SLAs. As a legal binding between parties, SLA is expected to include information on whether the service providers are structuring their business, management procedure or drafting their SLA according to any standards. However, only one SaaS SLA has such information which described that the terms and clauses within SLA are constructed in compliance with the state law of which the provider is physically located [43]. Possible change of terms to the SLA and termination policy are not stated in most of the SLAs we examine, except two SaaS SLAs.

E. Summary and Observation

In average, SaaS SLAs tend to include more attributes, especially those attributes on maintenance, disaster recovery, data policy, change and termination policy. Figure 2 shows the average number of attributes presented in SLAs in our sample. We believe this reflects different natures of the service models. SaaS providers has a lot more controls on the hardware, running environment, the application and even the data. SaaS customers are just users of the application. They are able to customize the application to some extent. But they have no control over the execution environment of the application execution and how data are stored. It is natural that SaaS customers would seek more guarantee from the providers. On the other hand, IaaS customers manage their own applications and data on the provider's infrastructure. Providers have no control or even knowledge on how their customers use the infrastructure. Even though not explicitly stated in SLA, the nature of IaaS implies that customers are expected to take more responsibilities of their own applications and data.

We also observe that there is a lack of consistent way of drafting cloud SLA. Even though SLAs we examine share quite a number of common attributes, the way those attributes are expressed are quite different and similar attributes might appear in different places in different SLAs. This makes

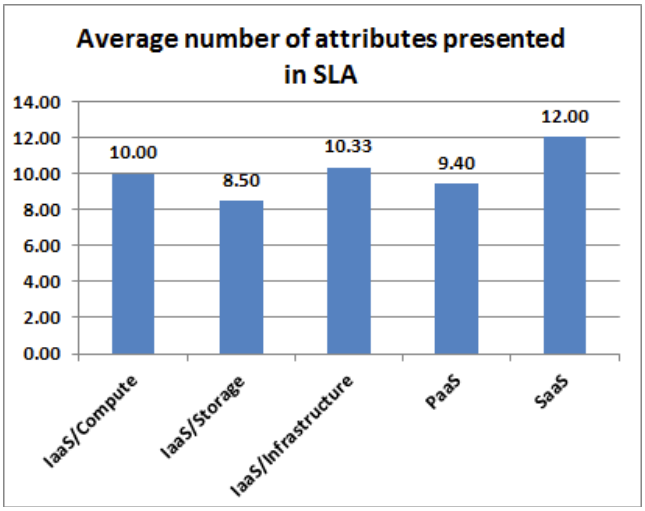

Fig. 2. Average Number of Attributes Presented in SLA

it hard for customers to compare SLAs offered by different providers offering similar services. One typical example of such inconsistency can be seen from the description of availability/uptime/downtime calculation. Table II compares the availability calculation methods in the five cloud storage SLAs we examine. We can see large variations of calculation methods across the SLAs. For instance, four of them use "error rate" based monthly availability calculation; Three of them use fixed and predefined measuring intervals for availability calculation; Some calculates availability using average availability or error rate for each interval; some calculations are based on absolute downtime minutes.

IV. Case Study on Related Business Values

A. Methodology

Business values are values defined by the business to ensure the smooth running and operation of business in the long term [13]. These values include more than just financial or economic value, it also include strategic values, shareholder values, organizational values and etc. They are often intangible values that the businesses try to gain or aim to achieve in the long run. Cloud services can potentially brings many such values to businesses, such as cost effectiveness, operational effectiveness, increased scalability and so on(c.f. [5]). But simply switching to cloud does not guarantee 100% value realization. Business or organization needs to align carefully the offered services to the actual business environment and processes.

Service Level Agreement serve as an important document for customers to understand what services are offered and guaranteed, and to estimate what business values they can achieve by using the services. However, not much has been studied on the relationship between business values and service level attributes. To understand this, we design a case study to obtain some insight from real customers and potential customers of cloud computing.

Case study has been argued to be useful when focusing on contemporary issues or event with little or poor knowledge pre-existed [8]. In particular, we adopt the multiple case study method since cloud computing has multiple delivering models and different industries would have very different ways of using cloud computing. Our units of study are individuals that are either IT managers or key personnel for decision making in different organizations or researchers in the field. We try to include individuals that are able to present different points of view, and have different expertise and knowledge for the area in our sample. The recruitment of interviewees is through emails. An invitation email is initially sent to potential interviewees with details of the research goal and a brief on the interview. All interviewees participate in the study voluntarily and they have been informed about their rights to withdraw from the research. The final sample consists of five individuals. A managing director representing an SaaS customer and a Chief Executive Officer representing both SaaS and IaaS customer are in our sample. and We expect them to share some executive/business views of cloud computing, especially on cost benefit and risk involved. There is an IT manager representing potential customer of IaaS and SaaS. We expect the IT manager to share managerial views on operational and management of cloud services. There are also two researchers, who would share their view on the technical and functionality of cloud services.

B. Business Values of Cloud Computing

A large number of potential business values have been identified by practitioners and academic researchers. Below is a list of general and well recognized values applicable to most cloud delivering models. Various providers, especially those SaaS providers may promise unique values for their customers. These are not included.

- **Cost effectiveness**: cloud computing may lower IT cost for business. There is no upfront capital expenditure for infrastructure purchasing. It also makes it unnecessary for business to provision for the peak usage. Most cloud providers use the pay-as-you-go pricing model, in which customers are charged based on the actual amount of services they use[5]. This makes the allocation of costs easier and more precise for business, it also makes coast management easier[26].
- **Operational effectiveness**: cloud computing improves operational efficiency by allowing business to only concentrate on their mission critical operations[34]. In addition, majority of the cost on IT management, maintenance and support are shifted from the customer to the providers.
- **Strategic value for application development**: Adopting cloud computing platform for application speeds up the purchase time, deployment process, time to market and time in provision, as well as enable business to better tailor the fast change in needs and demands from their end customers for service applications[29].

TABLE II
CLOUD STORAGE SERVICE AVAILABILITY CALCULATION

	Amazon S3 [3]	Google Cloud Storage [19]	Rackspace Cloud Files [38]	Windows Azure Storage [32]	HP Cloud Object Storage [22]
"error rate" based	yes	yes	no	yes	yes (only implied)
measurement interval	5 minutes	not predefined	not predefined	1 hour	6 minutes
error rate calculation	the total number of Internal server errors returned **divided** by the total number of requests during that five minute period	the number of Valid Requests that result in a error code **divided** by the total number of Valid Requests during that period	n.a.	"total number of Failed Storage Transactions **divided** by the Total Storage Transactions during a set time interval (currently set at one hour)".	total number of requests that result in internal server errors or service unavailable errors **divided** by total number of requests during that 6 minute interval
Downtime period	n.a.	a period of ten consecutive minutes of **Downtime**, which means more than a five percent Error Rate	"the Cloud Files service returns a server error response to a valid user request during two or more consecutive 90 second intervals", etc.	n.a.	n.a.
Availability calculation	monthly; calculated as 100% - average error rate from each 5 minutes period in the monthly billing cycle	monthly; "total number of minutes in a month, minus the number of minutes of Downtime suffered from all Downtime Periods in a month, divided by the total number of minutes in a month"	variable; total number of minutes in a billing cycle, minus the number of minutes of downtime during that billing cycle, divided by the total number of minutes in a billing cycle	monthly; calculated as 100% - average error rate from each 1 hour period for the billing month	monthly; calculated as the average of the Interval Availability of each 6-minute interval; the Interval Availability is calculated as 100% - the error rate of that 6-minute interval

- **Increased scalability**: cloud computing is designed to be highly scalable. Resources running customer applications can quickly scale out when end use demand is high and scale down when demand drops. This also contributes to the cost effectiveness business value.
- **Non-stop operation**: High availability is one of the key characteristic of cloud computing. Cloud providers always place a guarantee at 99.0% or higher availability which also guarantee to some extent non-stop operations[27].
- **Accessibility**: customers are supposed to access cloud services anytime and anywhere over the Internet. This accessibility is easily transferred to applications and systems running on the cloud infrastructure.

C. Case study and result analysis

For each individual in our sample, a semi-structured interview is conducted. A set of leading questions is prepared to gather knowledge on reasons of adopting cloud computing, importance of SLA and alignment of SLA attributes and business values.

1) Reasons for using cloud computing: All interviewees commented *cost effectiveness* is one of the main reasons for a switch or considering switching to cloud computing. Other factors mentioned include *scalability* and *accessibility*. For instance, one interviewee mentioned that "All on a sudden there might be a need to have more numbers of hardware to support the applications, so scalability is good thing about the cloud that gives us kind of competitive edge as well".

2) Importance of SLA in Cloud Services: On one hand, SLAs are recognized by all to be very important part of cloud computing. On the other hand, the current practice of public cloud SLAs makes a few interviewee think SLA does not play a critical role in decision making because of the way it is currently drafted. Below are some excerpts from the responses.

"I think it is definitely very critical. Because first of all when I am putting my infrastructure on IaaS ..., the first concept [I will come to think of] is that losing the control ... So if anything kind of wrong happening, then actually I am depending on the cloud service provider.... So, if things are not very clearly mentioned in my SLA, that what would happen if some certain instances are not working [and/or] if some certain services are not working, then I will be doomed as per my understanding."

"SLAs are [by nature] very critical but [in the cloud computing context] does not help the customers a lot. They are tended to be written from the provider's point of view."

"Till now, well my experience shows that service level agreement just lie in the cabinet or in your files, unless or until some problem is there, so at bad times it's only remembered."

3) Service attributes cloud customers seek: Most interviewees have commented that the service level attributed in figure 1 outlines basically all attributes their business are seeking from SLAs. Unfortunately, a large number of the attributes are not commonly stated in most SLAs we examine. Most interviewees highlighted *security* as one of the most critical attributes.

In addition, many interviewees are also concerned about the *termination policy* especially policy regarding termination

from the provider side.

"Another part of SLA [is to outline] that, in the event you leave or in the event that the company goes broke, there is potentially the question of how your documents will be given to you, whether they will be, whether they wouldn't be, whatever the case maybe"

Interviewees also commented on the wording and the phrasing of the terms and clauses. Some commented that the SLAs are hard to comprehend as they tend to target readers with technique background, and the SLA clauses are structured in a vague and complex way.

"To me a service level agreement of 99.9% is meaningless. In fact what does that actually mean? Where 43 minutes made total sense to me, I understand that. [99.9% of the time, is that critical or not critical? "

4) Relations between SLA attributes and business values: All interviewees agree that there is a connection between SLA attributes and business values. For instance, they comment that *availability* guarantee should help them to measure the possible values on *cost effectiveness*, and *customer satisfaction*, while *incident management*, *customer support* are good indicators of *operational effectiveness*.

At the same time all interviewees has emphasised that the realistic level of business values cloud customers can achieve dependens a lot on the level of confidence and trust the customers has on the provider and the cloud service. Some interviewees commented that If the company does not trust the cloud provider, they may have their own mechanism to protect their own data which might decrease the cost effectiveness.

V. Conclusion

In this research, detailed findings on the current practices in public cloud service level agreements (SLAs) are presented and analyzed. It shows the overall maturity level of public cloud SLAs and current practices. The result presented numerous missing SLA attributes, such as security, data protection and so on. These are consistent with what have been defined by previous studies as the shortcomings of public clouds. It is also validated from the case study.

Furthermore, from the case study many relations are identified between the service level agreement and the business values of cloud computing. However, the level of confidence and trust currently expressed by cloud customers are worrisome, especially on public cloud service level agreements.

Our content analysis uses a sample of twenty nine service level agreements from different public cloud services. Even though most large and well-known cloud providers, as well as some small to medium ones are included, there is a possibility that this sample may not represent the whole population. There might be a limitation on the generalizability of the findings, results and recommendation from this study. For a more complete depiction of the current state of public cloud service level agreement, a larger amount of service level agreements for more different public cloud services could be collected and analyzed in future studies. In this research, the comparisons between the current public cloud service level agreements are presented solely depending on their cloud service models. It would be interesting to investigate the trend of public cloud service level agreement offerings depending on the size of cloud service providers organization.

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