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Ivo Stankov

*Chair of Business Informatics, European University Viadrina, Frankfurt (Oder), Germany., [stankov@euv-frankfurt-o.de](mailto:stankov@euv-frankfurt-o.de)*

Rastsislau Datsenka

*Chair of Business Informatics, European University Viadrina, Frankfurt (Oder), Germany., [Datsenka@europa-uni.de](mailto:Datsenka@europa-uni.de)*

Karl Kurbel

*Chair of Business Informatics, European University Viadrina, Frankfurt (Oder), Germany., [kurbel.bi@euv-frankfurt-o.de](mailto:kurbel.bi@euv-frankfurt-o.de)*

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# Service Level Agreement as an Instrument to Enhance Trust in Cloud Computing – An Analysis of Infrastructure-as-a-Service Providers

**Ivo Stankov**  
European University Viadrina  
stankov@europa-uni.de

**Rastsislau Datsenka**  
European University Viadrina  
datsenka@europa-uni.de

**Karl Kurbel**  
European University Viadrina  
kurbel.bi@europa-uni.de

## ABSTRACT

We analyze service level agreements (SLAs) for cloud computing services, in particular SLAs published by infrastructure-as-a-service (IaaS) providers on their websites. The rationale is to investigate the potential and actual roles of SLAs as trust-enhancing instruments. Cloud computing is still not as widespread as it could be, because many decision makers do not sufficiently trust the technology or the providers, and hence are skeptical about adopting it. Enhancing trust could significantly advance cloud computing. We discuss the main aspects of trust as well as typical characteristics described in SLAs. Following this, a study of actual service level agreements offered by IaaS providers and published on their websites is presented. One of the findings is that at present only a few providers exploit the full potential of SLAs as trust-enhancing instruments.

## Keywords

Cloud computing, trust, service level agreement (SLA), infrastructure-as-a-service (IaaS)

## INTRODUCTION

Internet on-demand services in the form of cloud computing are developing rapidly and reshaping the IT market, but cloud computing is still in its infancy. Many decision makers are not fully aware of it, or, because of its novelty, are cautious about adopting it.

Because trust is a crucial enabling factor in relationships characterized by uncertainty and the risk of opportunistic behavior (Gefen, 2002; Hoffman et al, 1999; McKnight and Chervany, 2001; Williamson, 1985), one potential option for IaaS providers is to provide upfront guarantees for their services in order to show good will, expertise and differentiation (Bouchenak, 2010) from the competition. All this mitigates this level of uncertainty. This is most commonly done in the form of service level agreements (SLAs).

We investigate the role of the content of service level agreements as trust building instruments, especially at the initial stage of interaction between the companies, before a relationship has been formed. First, we specify a set of proposed SLA characteristics that can be beneficial for forming trust. Then we analyze SLAs of infrastructure-as-a-service (IaaS) providers that are explicitly published on the providers' websites and available for viewing by potential customers.

The target audience of this article is software practitioners interested in adoption or efficient implementation of IaaS solutions including both providers and users of cloud services. Providers may benefit from the discussion of cloud-specific characteristics of SLAs and how these characteristics can be used to improve the customers' trust in their service offerings. At the same time, end users of IaaS platforms may gain a clearer understanding of the trust building elements within an SLA, which need to be carefully verified when selecting a trustworthy IaaS provider.

## INFRASTRUCTURE-AS-A-SERVICE

According to Armbrust et al. (Armbrust, Fox, Griffith, Joseph, Katz, Konwinski, Lee, Patterson, Rabkin, Stoica, Zaharia, 2009) from an infrastructure perspective, the cloud computing paradigm provides three distinctive new aspects that set it apart from previous computing architectures: (1) The "illusion" of a seemingly unlimited resource pool eliminates the need to plan ahead for a possible increase or decrease in demand. (2) There is no need for an up-front commitment to a particular

level of service, which allows companies to adjust the hardware resources according to their actual needs, leading to the third point, (3) the granulation of services – the user pays only for the actual amount of resources used.

Many authors use the term "cloud computing" to describe a specific type of virtual, elastic infrastructure which is also named "infrastructure-as-a-service" (IaaS). This term describes the offering of a scalable, on-demand, elastic computer infrastructure – such as virtual machines, storage or processor time – normally based on a pay-as-you-go pricing scheme.

Cloud computing has many advantages, such as flexibility, no need for an up-front commitment and lower cost. On the other hand, a number of problems exist at its current level of maturity, hindering its widespread adoption. These include uncertainty about the actual level of service, security, reliability and privacy protection that the customer will receive from the cloud service vendor.

Since it is hardly possible for a potential customer to systematically check and audit all relevant aspects of a cloud service offering, a certain level of trust towards the technology and the particular vendor must be present in order for a fruitful partnership to develop.

### RELEVANT CONCEPTS OF TRUST

Trust is described by some researchers as a belief or expectation implying a notion of confidence and trustworthiness stemming from the potential business partner's expertise, reliability or intentions (Blau, 1964). The existence of trust between two parties is a prerequisite for interpersonal and inter-business relationships. Trust is crucial wherever risk, uncertainty or interdependence of partners exist (Morgan and Hunt, 1994).

A particularly important aspect is how trust can be established without the benefit of prior experience from a preexisting business relationship. Among the numerous different views of trust, we examine the concepts of initial trust facilitated by institution-based and calculative trust, which are briefly introduced in the following sections.

Propensity to trust is described as a trait that leads to a generalized expectation about the trustworthiness of others, especially without data about the party to be trusted (Mayer, Davis, Schoorman, 1995). *Initial trust* is considered to form under the influence of the party's general disposition to trust, institution-based trust, and cognitive processes (McKnight, Cummings, Chervany, 1998) that lead to a calculation-based decision to trust or not to trust.

*Institution-based trust* does not depend on a particular partner, but rather comes from sources such as traditions, certifications, brand names, technological maturity etc. It has been suggested that institutional trust is seminal in the creation of trust between two parties that are relatively unknown or not similar to each other (Zucker, 1986). In the case of cloud computing and relevant SLAs, this type of trust is both being put into question by the relative and perceived lack of maturity of the offered technology solutions, and strengthened by institutional structures (Pavlou, 2002) such as well-devised formal contracts (i.e. Service Level Agreements).

*Calculative trust* is a form of economic exchange (Lane and Bachmann, 1998). It is an ongoing, market-oriented, economic calculation, where the participants weigh the assets and liabilities that are incurred by the creation and maintenance of a mutual relationship (Lewicki and Bunker, 1996). Calculative trust between two parties that are not well acquainted with one another is considered to be more essential than trust that arises from repeated interactions (Ho and Weigelt, 2005). To put it more directly, potential customers with limited or no experience with a particular service provider depend almost completely on the protection provided by terms and conditions provided in the (potential) formal contract between the two parties. These assurances can mitigate opportunistic behavior and support potential relational governance (Goo et al. 2009).

Trust is especially important in virtual environments (Bailey and Bakos, 1997), because it reduces the probability or fear of opportunistic behavior (Pavlou and Gefen 2004), which would hinder the establishment of a business relationship.

As previously mentioned, the cloud computing paradigm is relatively young and there is still a certain level of uncertainty and uneasiness among CIOs and decision makers who are deciding whether or not to rely on the new technology (NTT, 2009). This speaks for apparently low levels of trust.

Based on these concepts, it can be assumed that the decision to adopt cloud technology and the process of IaaS vendor selection are influenced mainly by the formation of initial trust, but also, to an extent, facilitated by institution-based and calculative trust.

### SLA AS A TRUST-ENHANCING INSTRUMENT

The influence of SLAs on trust formation in IT-based relationships has been demonstrated by a number of studies. Common SLA characteristics have been shown to be significant direct predictors of attributes of relational governance, such as relational norms, harmonious conflict resolution, and mutual dependence. This, in turn, increases the level of trust between

the parties of a relationship (Goo, Kishore, Rao, Nam, 2009). Previous research has also shown that relational governance leading to trust relationships and formal contracts such as SLAs are positively related (Poppo and Zenger, 2002). Moreover, SLAs are particularly beneficial in the early stages of a developing relationship (Singleton, McLean, Altman, 1988).

*Published SLAs can assure potential customers of the trustworthiness of the vendor before a relationship between the two has developed.*

All these concerns, which can be only partially mitigated by actual technological means and improvements, can be made more bearable if the IaaS provider is ready to show its trustworthiness by offering transparency and understanding of the concerns of the customers, as well as setting up formal propositions such as Service Level Agreement texts published publicly on its web site. The next section considers this concept in further detail.

A well-written SLA does not leave room for opportunistic behavior. It provides potential customers with the information they need and gives them an impression of the trustworthiness of their future partner. It communicates to the customer that the provider is (1) confident about the service level they can offer, (2) aware of the Quality of Service (QoS) level the customer wishes to reach, (3) able to express SLA conditions in a simple and easily understood manner, and (4) willing to disclose information about the actual performance of the offered services.

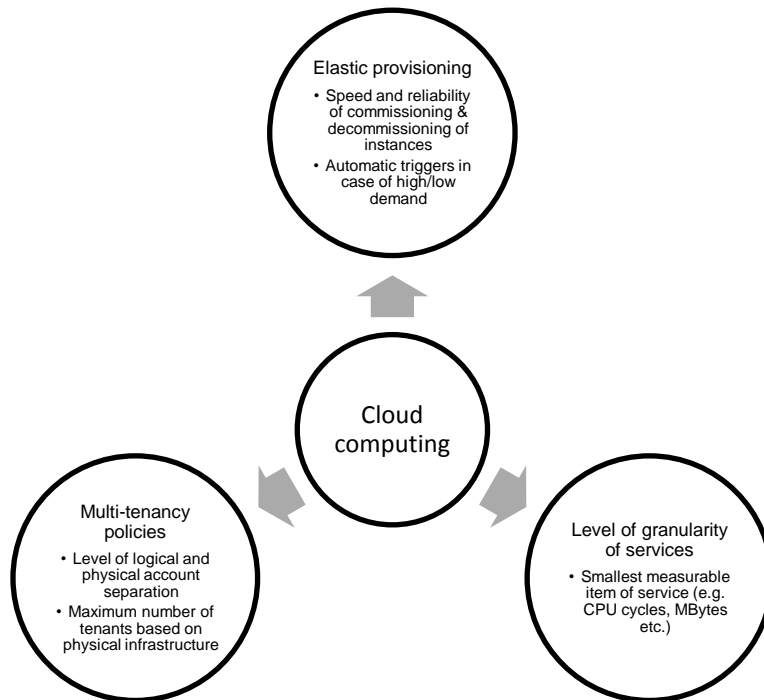
**FORMAL CONTRACTS AND SLAS**

A *service level agreement* is a formal contract between a service provider and a customer, stating the nature of the underlying service, target performance levels and obligations of the parties involved in the contract. The complexity and the scope of an SLA are closely related with the type and complexity of the service provided.

Our aim in this paper is to evaluate the potential of contractual elements in SLAs for the development of trust in cloud computing.

**Service Level Agreement Specifics for Infrastructure-as-a-Service**

Since infrastructure-as-a-service is in many ways similar to traditional hosting services, SLAs offered by IaaS providers include the same features as those offered by hosting providers. However, there are specifics of cloud computing that ought to be addressed as well. For example, in addition to typical QoS features such as service uptime, features relevant for cloud computing such as scalability need to be included.



**Figure 1. Cloud-specific SLA characteristics**

Figure 1 summarizes some of the additional characteristics of cloud computing that should be addressed in an SLA for infrastructure-as-a-service. These characteristics are:

- *Elastic provisioning* of new computing instances, allowing the service to function seamlessly
- Policies for *multi-tenancy*, supporting better resource utilization and cost savings, but also increasing the risk of service interruptions and unavailability (Vykoukal, Wolf, Beck, 2009)
- The *level of granularity*, informing the customer about the smallest measurable item of service

### Structure of an IaaS SLA

In order to be able to compare and evaluate real IaaS SLAs, we established a set of trust-related characteristics. These characteristics were derived from the ITIL Service Design book (OGC, 2007), from actual SLAs of IaaS providers, and from the literature on cloud computing.

We then identified a range of trust issues that can be theoretically attributed to these SLA elements. Next, we combined the SLA structure and the trust types in a single table. This table represents different dimensions of trust and their formal contractual representations in SLA terms.

At the final stage, we specified 20 core SLA characteristics. A short description of these characteristics is given in table 1. The final set combines three different perspectives:

- *Practical* – this subset of characteristics is partly derived from ITIL and from the actual SLA of the IaaS vendors.
- *Theoretical* – the final set also includes a number of elements that were selected based on a careful investigation of relevant literature sources. Furthermore, we attempted to connect each particular SLA characteristic with the corresponding trust-related aspect.
- *IaaS specific* – finally, our collection of SLA characteristics spans aspects that are specifically attributed to IaaS technology: multi-tenancy and elasticity.

We also filtered out all the elements that are unlikely to have any influence on the development of initial trust or are not related to IaaS.

## FINDINGS FROM EMPIRICAL STUDY

### Data collection

Our study follows an exploratory approach, seeking to analyze IaaS SLA contracts through the lens of the relevant dimensions of trust. We performed a frequency analysis regarding the occurrence of certain elements in previously collected SLA documents and coded them into categories in a binary manner. The purpose is to compute term frequencies, analyze them and derive conclusions.

Text sources for the frequency analysis were documents available from IaaS providers. We examined the websites of 70 IaaS providers and downloaded copies of 23 explicitly published SLAs. The choice of providers was based on Cloudbook, a well-established and constantly updated directory of cloud providers (<http://www.cloudbook.net>).

In order to improve the quality of the input data, we performed a pre-selection, sorting out companies which were not relevant for the IaaS cloud category or obviously used cloud terminology only as a marketing slogan without any real implementation. Thus the final dataset included 51 companies with evidentiary signs of IaaS business activities.

We examined the homepages of the IaaS providers to locate their SLAs. Additional information was gathered through detailed on-site search (if available). The relevant information available on the websites, i.e. an SLA or sometimes Terms of Services (ToS) including an SLA as an integral part, were arranged in SLA profiles and stored as text files for further examination. Profiles were extended by additional information describing the specializations of the IaaS providers (e.g. data storage, computing power). This additional information was also included in the coding template.

The SLA profiles were coded separately and independently by several individuals (two per SLA profile) with an academic background in Information Systems. A category was deemed to be met if at least one statement related to the category was found in the profile. The coded data were subsequently merged, with interpretation conflicts being resolved with the aid of a mediator. The mediation process was detached from the original encoding of the data in such a way that the mediator and the original coders re-assessed the SLA profiles. Subsequently, the relative frequencies were calculated and the data were statistically analyzed. A random sample of the considered SLAs was revisited in order to validate the statistical conclusions.

Characteristic	Description	Trust-related Aspects
<b>Purpose</b>	Explains how the deal came about and which goals the SLA was designed to accomplish.	A clear and understandable proposal of common goals and values leading to improved transparency and trust.
<b>Parties</b>	Clearly describes parties involved in the SLA and their respective roles.	Well defined roles and responsibilities, leaving no room for opportunistic behavior.
<b>Service description</b>	The SLA's key deliverables.	Short and clear statement of what is to be expected, making sure that there is no misunderstanding about what service is being offered.
<b>Customer support</b>	Description of how, when and in which situations customer support should be contacted (including metrics such as response time).	Readiness to be available for help and support when needed. Offering achievable and realistic support levels, increasing trustworthiness.
<b>Contact points and escalation</b>	Contact details of the parties and description of the escalation procedure.	Transparent description of conflict resolution steps. In case a conflict arises, the customer will be more comfortable if they know what to expect, leaving less room for opportunistic behavior.
<b>Service level objectives</b>	Target level of service measured by means of certain key performance indicators (KPIs).	Statement of measurable service levels which can be monitored and controlled.
<b>Service availability</b>	Target availability level (e.g. 99.5%).	Basic yet important indicator of capability to offer adequate service. A precisely set number (e.g. 99.95%) might be more trustworthy than "unachievable" 100%.
<b>Functionality</b>	Description of the minimal functionality provided.	Clear definitions of the offered service help the potential customer to know what to expect.
<b>Change management</b>	Handling and implementation of RFCs and mention of any known changes that may impact the contract.	Up-front transparency about possible changes and steps that will be undertaken. Possibility for opportunistic behavior in future is minimized.
<b>Service continuity</b>	Disaster back-up and recovery plans including responsibilities of various parties involved.	Assuring the customer that responsible actions will be taken in the case of a disaster, increasing trust in the provider.
<b>Security</b>	Explanation of the organization's security policy (violations, password control, etc).	Guaranteeing that the data transferred to the infrastructure provider is secure, alleviating users' concerns
<b>Privacy</b>	Explanation of the organization's privacy policy (violations, data retention, third parties access etc).	A statement that privacy breaches will have consequences for the provider. Covering privacy in the SLA will set the offer apart from the rest, which don't approach this issue.
<b>Multi-tenancy rules</b>	Level of data abstraction and separation between the different tenants. Number of tenants.	Assurance of data separation and protection. A clear understanding and transparency about the number of tenants and the data abstraction in a cloud.
<b>Elastic provisioning</b>	The speed, reliability and level of adding and removing instances.	Certainty about the exact conditions and functionality regarding elasticity, showing that cloud-specific functionalities are covered by the SLA.
<b>Responsibilities</b>	Description of the responsibilities of all parties involved in the contract.	A clear understanding of responsibilities between the parties, decreasing the possibility of opportunistic behavior.
<b>Charging</b>	Reference to the charging methods, periods, formulas and payment procedures (including invoicing).	Transparency of financial relationship may positively affect trust.
<b>Penalties</b>	Consequences in case the service provider fails to meet contractual metrics.	Declaration that the service provider is ready to carry a financial burden if the service level has not been met. The level of the accepted penalty might be an indication of the provider's self-assessment and trustworthiness.
<b>Glossary</b>	Extension of SLA by a glossary containing brief explanations of terms that an average customer may not be familiar with (technical metrics, cloud computing terminology etc).	Avoiding misunderstandings regarding the relevant terms, reducing the fear of opportunistic behavior.
<b>Restrictions and exclusions</b>	Statement concerning certain elements that are excluded from the SLA's scope, when applicable.	Clear information of what cannot be expected from the provider, delimiting the service scope and increasing transparency.
<b>Optional services</b>	Additional services extending beyond the original subject of the SLA.	Displaying additional capabilities in addition to standard services, indicating a well-established service offer and increasing trust.

**Table 1. Relevant service level agreement characteristics**

## General Observations

We examined the websites of 70 IaaS providers listed on Cloudbook. Companies without evident signs of cloud-based services were excluded from the initial population. The final dataset included 51 companies with evident signs of IaaS business activities. Out of these, we were able to extract 23 explicitly published SLAs. 28 firms (54.9%) do not have their SLAs in open public access. This does not imply, of course, that a service level agreement is not entered into when an actual contract is signed.

Locating the SLAs was not always an easy task. Often, they were well hidden on the website, and site search functions were either not available or performed poorly. From the customer's point of view, an "ideal" solution would be to have a link to the SLA directly on the homepage. However, this is rarely the case. The fact that most SLAs are not featured prominently on the providers' promotional websites suggests that an SLA is not perceived as a trust-enhancing instrument and does not play an essential role in the providers' marketing strategies.

Nearly half (43.4%, n=23) of the IaaS providers in our study rely on one-page SLAs (up to 700 words). The rest makes use of more detailed SLAs. This observation shows that vendors not necessarily tend to deliver service description in a simple and short form. A one-page SLA provides a good overview of all contractual terms, obligations and performance metrics. At the same time longer and more detailed SLAs may make a more reliable and serious impression on the potential customer than one-page SLAs. Results of the investigation show that both approaches are almost equally popular among service providers. It is also worth mentioning that certain providers integrate their SLAs into the Terms of Service (ToS). Examples of such practices are Enki (<http://www.enki.co>) and ElasticHosts (<http://www.elastichosts.com>). "Hiding" SLA text within a much longer and more detailed ToS does not improve the readability and transparency of the SLA, thus wasting a potentially positive effect on trust building.

## Provider Profiles

From the entire batch of 51 companies, 26 (51%) were identified as cloud-service providers only (offering exclusively IaaS) and 25 (49%) as general providers, offering a palette of "traditional" services along with IaaS.

As for the providers' profiles, most of the companies were identified as general hosting providers. By general hosting providers, we mean companies providing a general infrastructure without binding it to a particular set of tasks. The customer may use the hosting to deploy a database, store data, perform computations, or for any other purpose. This type of provisioning was attributed to 39 companies (76.5%).

Specialized providers of computing, database or storage facilities are much fewer in numbers, making up 25.5%, 37.3% and 33.3% respectively (a company can be attributed to more than one type).

## Typical SLA Contents

Not all characteristics listed in table 1 appear in all of the SLA texts in question. The most frequent ones (i.e. those occurring in more than 75% of the n=23 SLAs) are:

- Service availability (95.7 %)
- Penalties (95.7 %)
- Responsibilities (78.3 %)
- Restrictions and exclusions (78.3 %)

This finding underscores the observation that the main characteristics of an SLA are the level of service availability and the actual penalties the provider would incur in case this level is not met. These metrics are essential for any informed decision to choose or not to choose a particular provider, so they can be considered to have an influence on calculative trust.

On the other side of the spectrum are the characteristics that are rarely (in less than 25% of the cases) included in an SLA, as shown in figure 2: change management (8.7 %), security (13 %), functionality (17.4 %), customer support (21.7 %) and escalation procedure (21.7 %). Since several of those are closely related to uncertainty (i.e. change management, security) or relationship issues (i.e. customer support, escalation procedure), we conclude that the examined SLAs do not provide substantial transparency and assurance for the potential customer. In other words, the SLAs that we studied exhibit a substantial lack of trust-enhancing characteristics.

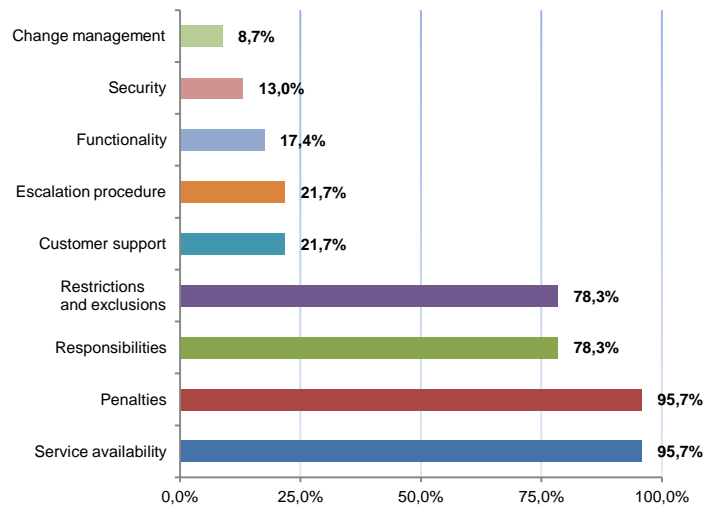


Figure 2. Most and least frequent SLA characteristics

### IaaS-specific SLA Characteristics

A number of the SLA characteristics listed in table 1 were not found in any of the examined SLA documents. In particular, privacy is completely ignored, hence penalties in case of a breach are not specified. Providers apparently omit to employ these features which could help to create initial trust in their offerings.

What is more remarkable is that none of the cloud-specific characteristics listed in figure 1 are explicitly mentioned in any of the SLAs. Multi-tenancy, elastic provisioning and the level of granularity are not addressed by the providers. This observation supports earlier findings by other authors (Prodan and Ostermann, 2009).

This disregard of the specific nature of cloud computing offerings does not give potential customers the needed assurance that appropriate measures are in place to address the issue of uncertainty.

### Dedicated IaaS SLAs vs. General Hosting SLAs

Some (30.4%) of the hosting providers that were examined in this research offer only one type of SLA for all their services, no matter whether they are standard hosting providers or IaaS providers. Obviously SLAs for general hosting will not automatically contain IaaS-specific quality-of-service features such as elastic service provisioning.

Exploring the differences between IaaS-specific SLAs and general-hosting SLAs applied to IaaS, it became evident that most characteristics were not significantly different between the two groups. Two exceptions are the characteristics "glossary" and "restrictions & exclusions". Both of them were significantly present more often in IaaS-specific SLAs than in general-hosting SLAs ( $p = 0.013$ ,  $\chi^2 = 6.188$  and  $p = 0.008$ ,  $\chi^2 = 7.09$ , respectively).

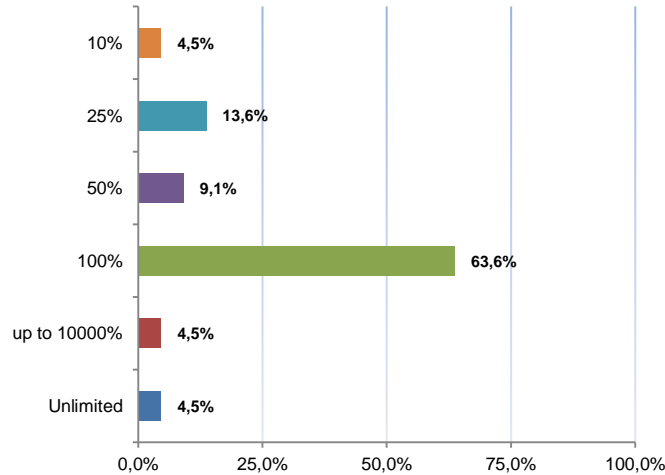
The reason why "glossary" is found more often might be that IaaS and cloud computing concepts are relatively new to many users. Providers try to reduce the users' uncertainty and increase trust in the concepts by defining specific cloud computing terms.

The fact that "restrictions & exclusions" appear significantly more often helps to make IaaS-specific SLAs more transparent. Providing up-front information about the actual offer can be considered an implicit trust-building instrument, because it is easier to create calculative trust if more relevant information is available to the customer.

### Penalties

We analyzed up to what percentage IaaS providers guarantee customer reimbursement in case they fail to meet the promised service levels. This metric is particularly interesting with respect to calculative and initial trust, because a potential customer can interpret it as the level of the provider's self-assurance regarding QoS. If the provider is sufficiently confident of being capable of maintaining the promised service level, then they could also offer more generous reimbursements in case those levels are not met.





**Figure 3. Frequencies of monthly credit reimbursement rates**

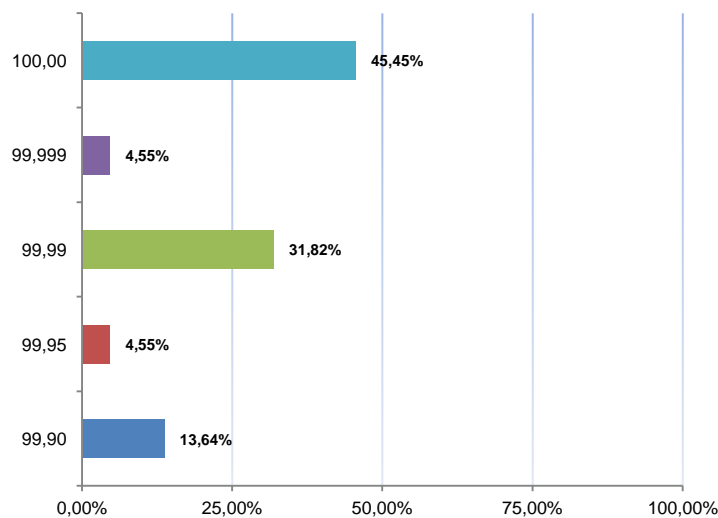
63.6% (n=22, only providers with penalties included) of all providers addressing penalties promise that the customer will get back 100% of the monthly payment in case such a failure occurs (see figure 3). The rest of the providers’ self-imposed penalties vary from 10% to 50%.

On the other hand, there are companies promising to reimburse very high percentages such as 10,000% or even unlimited. Service providers offering such high reimbursements probably intend to signal to the customer that they are completely convinced of their ability to deliver the service at a high availability level. These contents are indicative that at least some providers aim to appeal to the emotional rather than the calculative elements of initial trust formation in their potential customers.

As a whole, the aspect of using a pre-published SLA as a marketing tool that appeals to potential clients seems to be neglected by most and employed only by a handful of providers.

**Service Availability**

As to service availability, almost all service providers (95.7 %, n=23) in our final dataset addressed this SLA characteristic. High availability figures indicate the provider's self-confidence and technical ability to guarantee the declared level of service availability (see figure 4).



**Figure 4. Frequencies of service availability**

45.45% (n=22, only providers with service availability metrics included) of providers promise that their services will be available 100% of time which means that they virtually exclude the mere possibility of a technical failure. The rest of the providers declare service availability levels ranging from 99.90 % to 99.999%.

However, this characteristic does not necessarily contribute to an increased level of trust. A reimbursement rate (penalty) of 10,000% along with 99.99% service availability is a much more attractive proposal than 10% reimbursement with 100% availability. An experienced customer will most probably select the highest possible refund rather than differentiate between 99.90 % and 100% service availability levels. Thus, the role of this SLA element for trust building is questionable.

## OUTLOOK

Pre-published SLAs are still not very popular amongst IaaS providers, and the ones that are actually available are rather standard, not exhibiting any cloud-specific characteristics (e.g. multi-tenancy or elastic provisioning).

Furthermore, apart from a few exceptions, the examined SLAs do not look like they have been written and posted with the intent to assure potential customers of the provider's reliability and trustworthiness.

These observations lead us to the conclusion that, currently, IaaS providers do not fully recognize and utilize the value of SLAs as initial trust-enhancing instruments in cloud computing.

In future research, it would be especially interesting to investigate which of the characteristics mentioned in this paper do actual IaaS customers view as potentially important and how this list could be expanded. Additionally, such an investigation should reveal to what extent a trustworthy SLA could help the customer to differentiate between offers when choosing a new provider.

Having this in mind, software practitioners involved in preparing SLAs should critically reflect if they exploit the full potential of these pre-written contracts for customer acquisition and perhaps further improve them. This is true not only for IaaS offerings, but for other SLAs as well.

We have not dealt with technical options and challenges to control and enforce SLAs. While these are also important aspects, the focus of this paper was on the presentation of SLA characteristics that are technically feasible today. They could be included in SLAs to increase trust, but most providers seem to be unaware of their potential.

The customers, i.e. potential users of IaaS services, should pay attention to whether and if so, in what detail a particular SLA mentions the characteristics from table 1. This will enable them to make a more informed decision when selecting a provider.

In this paper, we offer a rough framework of SLA characteristics which can be used to enhance trust in cloud services. However, we are not aiming to fully define trust; neither can we suggest a generally accepted trust-oriented methodology for constructing cloud SLAs. These issues are likely to be topics for specific long-term research efforts.

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