ISBN 978-83-60810-51-4

Standardization Approaches within Cloud Computing: Evaluation of Infrastructure as a Service Architecture

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Abstract— Cloud Computing is becoming increasingly established and offers several opportunities to obtain IT services in an on-demand manner. Especially infrastructure services, like storage and scalable computing resources, are gaining relevance and provide alternatives to conventional sourcing models. Despite the Cloud paradigm of flexible and limitless scalability the lack of standardization presents a big challenge in this context. Due to many providers, which are using different Cloud software including proprietary interfaces, the interoperability in the Cloud remains a theoretical construct. In this paper we examine standardization approaches within Cloud Computing and provide a comparison to practical implementations of interfaces of relevant Cloud software on the market. Finally, characteristics for a potential Cloud standard on the infrastructure level will be postulated.

I. Introduction

Usually the operation of large data centers or computer clusters involves high costs, not only capital expenditures for hardware and software but also operational costs regarding energy, staff, facilities and maintenance efforts emerge. Along with Cloud Computing virtual IT infrastructures have become increasingly established and make it possible to rent IT resources in a fast and flexible manner. Here costs only occur for the duration of use, known as the pay-per-use concept. Following the Cloud Computing concept, resources (e.g. networks, servers, storage, applications and services) can be rented in a scalable way via the Internet without the need for any long-term capital expenditures and specific IT knowledge on the customer side [1]. It is possible to obtain complete software applications or the underlying IT infrastructure in the form of virtual machine images. Basically, Cloud Computing is composed of the above described characteristics and consists of three levels, which are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [2] [3].

Recently, companies from several industries try to utilize the concept of Cloud Computing and pursuit to enhance their IT infrastructures. Due to the lack of a universal definition and various perceptions of Cloud Computing including the related benefits and challenges many companies struggle to make use of the Cloud. To respond to this demand, several independent providers are offering Cloud service comparisons (e.g. Techtarget.com, CIO.de), where rankings are published. Unfortunately these rankings are based on heterogeneous values and comparing “apples” with “oranges”. Especially on the software and platform level, these comparisons are superficial and do not cover either measurable characteristics (e.g. availability, performance and prices) or soft characteristics (e.g. guarantee, reliability or security) in a sufficient way. Better possibilities exist on the infrastructure level, where benchmarks already have been made available (e.g. Cloudharmony.com). For an useful comparison, the standardization of Cloud Computing is essential and necessary to provide a benchmarking foundation. Through the compliance of standards products can be combined and become more transparent. The customer can avoid to be locked in to one provider and is not limited to use only Cloud services from the same provider. Whereas the competition between providers increases while they are getting the opportunity to establish standardized software solutions independent from the underlying infrastructure at the customers side. A standardized product enables higher quality standards due to the comparison of service levels and a higher transparency of services and can lead to an increasing trust of the customer in the provider [4].

We want to summarize in this paper the currently most recognized facts and propose a structure for a standard. Moreover, we show gaps in current implementations and justify them with customer oriented needs. For this purpose we explain our research approach in section 2 followed by an introduction into the subject which is divided into an analysis of the related work and current standardization efforts. In section 4 we clarify our evaluation in the “Infrastructure as a Service” layer. This starts with a market research for the established Cloud concepts in section 4.1. Afterwards, in section 4.2, we derive a basically set of requirements on the basis of the considered provider on the market. For applicability reasons a survey is conducted to capture the requirements in the given interface functions on the market. Section 5 completes the paper with a discussion and conclusion of the topic.

II. Research Approach

Our research is a combination of deductive and inductive elements and draws on a systematic literature review and an extensive market analysis of Cloud providers.

The deductive part of our research is based on a concept-centric systematic literature review [5] [6]. First we defined our review scope and focused on standardization in Cloud Computing. We used the following key words: standardization*, standard*, interface*, interoperability*, compatibility*, uniform*, lock-in*, provider* combined with "Cloud Computing", "Cloud service", "IaaS" and "as a Service". By means of wildcards as common terms used in system identification we assure the identification of related, conjugated terms. Then we applied these key words to scientific databases like AISeL, Science Direct, EBSCO (Business Source Complete) and IEEE Xplore to get scientific, peer-reviewed papers. We extended our literature review based on a forward (author-based) and backward (reference-list-based) centric search.

The inductive approach of this article comprises a market analysis of software vendors and providers of IaaS and web hosting. We identified 74 relevant providers worldwide, most of them, especially the larger ones, located in the US and UK. The providers on the IaaS level are fewer, compared to the large SaaS market with over 1100 providers (www.saasdir.com). This manageable size of IaaS providers is related to the large IT infrastructures (data centers, global distribution and quality of service) necessary to offer scalable virtual IT resources. We examined each provider by gathering information from its website. If necessary we initiated direct contact and requested missing data via email or registered an account for a free test period. In some cases we could not get data on a free basis and were therefore limited with our analysis of some providers. In the table in section 4.3 each provider with limited information access is marked. If the information access was given, we looked at the basic data of a provider and concentrated our investigation on the interfaces (API) and provided functionalities.

III. Related work – Cloud Computing standardization

The problem of Cloud Computing standardization has been discussed by many [7]. Likewise, many have tried to find a definition [8] [9] and finally there is determined a lack of definition and standardization as well as insufficient expertise and policies in Service Level Agreements (SLAs) [10]. The lack of standards and interoperability between providers makes a provider selection often irreversible [11] [12] and can act as a barrier to adoption of Cloud Computing. Some organizations perceive conceptual factors in relation to the current immature state of the Cloud Computing concept [13].

As we can see, the subject of standardization gets a new relevance in the Cloud. The necessity of migration and integration of applications and data requires full interoperability between systems from different vendors. Five maturity levels of interoperability can be distinguished. The lowest level is characterized by an isolated interoperability, in which the extraction and integration of data and applications across multiple stand-alone systems is performed manually. The top level is marked by cross-enterprise interoperability, which provides an universal environment of wide-area networks, shared data and applications, cross-domain information exchange and enhanced cooperation [14]. The main indicator to determine this level is the portability and mobility of applications and data. Portability is known as the ability to move a down-status image between providers and boot it at its destination. Mobility describes the ability to migrate a running virtual machine under work load between vendors without any interruption [15].

By the increasing number of vendors in the Cloud Computing market, the need for interoperability between Cloud platforms is growing [14] [16]. Standardization efforts of many groups try to fulfill this requirement. Independent institutions as well as providers of Cloud services develop their own standards. This variety of activities result in opposing standards and main principles and benefits of Cloud Computing may be inaccessible [7]. The practitioners go along with the researchers that standards are necessary letting the user compare different offers, reaching independency from suppliers and maximizing their own benefits [7] [17]. Without an agreement, in form of a standard, providers as well as users are facing a much more complicated situation by adopting or offering Cloud Computing solutions. Especially vendors are interested in binding users to their own product in order to gain competitive advantages [7]. It should be considered that many concepts have already gained recognition and have no compulsion of a new Cloud specific standardization [18].

A special deficiency of standardization is apparent in applying data security and encryption of sensitive data outside the company [19]. So far, there is no standardized way to consistently reflect security requirements on Cloud services [7], but currently there are many initiatives that deal with this issue (e.g. OASIS - Organization for the Advancement of Structured Information Standards).

Cloud standardization has to start with the basic concept of Cloud Computing - virtualization. So far, no uniform virtualization standard is used. Various Cloud platforms use different formats [7], which again is contrary to the interoperability and portability. A first step in the direction of a standard was taken by the Distributed Management Task Force (DMTF) with the creation of the Open Virtualization Format (OVF). This standard makes the migration of virtual machines between individual Clouds possible. The control of the outsourced infrastructure occurs via interfaces, such as the Open Cloud Computing Interface (OCCI) [20]. Other initiatives that deal with standardization in the Cloud are listed in Table 1 [21] [7].

The column "Standardization Approaches" shows that most initiatives dealing with standardization in the Cloud. They mainly focus on guidelines and not on technical to support the generation of a technical standard.

In relation to the cloud stack, the standardization at the infrastructure level is the precondition of constructive service standards at the platform and application level. For this reason, we focus in the following section on the infrastructure level (IaaS).

IV. EVALUATION OF THE INFRASTRUCTURE AS A SERVICE ARCHITECTURE

Based on an extensive market analysis of 74 infrastructure providers, where the interface descriptions from the provider's websites were examined, we will give an overview of which interface methods are available and draw conclusions for building an interface standard. The data analysis was complicated due to denied or limited access to the interfaces or the descriptions by the software manufacturer. In some cases, the information of the interface functionalities offered by the provider is only accessible after the service/product is purchased.

A. Cloud computing concepts

The information, relevant for Cloud services, can be exchanged via interfaces which are in principle based on a Cloud Software. Any Cloud provider offers different types of interfaces that can be accessed either directly or indirectly. The indirect approach requires human interaction via a Human Interface Device (HID). These include for example the website of a provider as well as a Web portal or

TABLE 1: STANDARDIZATION APPROACHES WITHIN CLOUD COMPUTING

Name	Description	Standardization Approaches
ARTS	Association for Retail Technology Standards	• Cloud Computing for Retail (Whitepaper)
BITKOM	Industry association for the ICT industry, represents about 90% of the German ICT companies	• Cloud Computing – "Was Entscheider wissen müssen" (A holistic view of the Cloud technique, positioning, contract law, privacy, information security, and compliance) • „Cloud Computing – Evolution in der Technik, Revolution im Business", "Desktop-Virtualisierung", "Server-Virtualisierung", „Leitfaden für SaaS-Anbieter" (Guidelines)
BSI	Deutsches Bundesamt für Sicherheit in der Informationstechnik (German Federal Agency for Security in Information Technology)	• Key Issues Paper: Safety recommendations for Cloud Computing providers (minimum security requirements in information security)
CSA	Cloud Security Alliance, International Organization for Security in Cloud Computing	• Security Guidance for Critical Areas of Focus in Cloud Computing • Top Threats to Cloud Computing • CloudAudit and the Automated Audit, Assertion, Assessment, and Assurance API
DMTF	Distributed Management Task Force, Association of companies in the IT industry, includes 160 companies and organizations from 43 countries	• OVF – Open Virtualization Format • VMAN – Virtualization Management • CLOUD – Cloud Management
NIST	National Institute of Standards & Technology, U.S. federal agency	• Special Publication: The NIST Definition of Cloud Computing (Draft) • Standards Acceleration to Jumpstart Adoption of Cloud Computing (SAJACC)
OASIS	Advancing open standards for the information society, International organization, partnering with ETSI	• OASIS Identity in the Cloud (IDCloud) TC • OASIS Symptoms Automation Framework (SAF)
OGF	Open Grid Forum, Community for distributed Computing with over 400 organizations in more than 50 countries	• Open Cloud Computing Interface
Open Cloud Manifesto	Initiative for open standards in Cloud Computing, 40 IT companies	• Cloud Computing Use Cases
SNIA	Storage Networking Industry Association, European trade association for the development of storage standards	• CDMI – Cloud Data Management Interface • CDMI Reference Implementation
The Open Group	Vendor- and technology-neutral commission to develop standards	• Building Return on Investment from Cloud Computing • Strengthening your Business Case for Using Cloud • Cloud Buyers' Decision Tree • Cloud Buyers' Requirements Questionnaire
TM Forum	Global, non-profit industry association for application integration for service providers in the ICT sector, over 700 members from more than 195 countries	• Cloud & New Services Initiative

other console programs, which again have direct access to the interfaces of the Cloud. In the direct way, interfaces can be automatically accessed by an application and require no user interaction. In the scope of Cloud standardization, only the direct access via interfaces (e.g. web services, REST or API) is relevant.

Based on the provider market analysis, different implementation approaches were detected for IaaS Cloud services. Fig. 1 depicts an exemplary structure, which has found implementation in practice and allows the user to access the Cloud. The Organization Z represents a customer who uses scalable products for their daily business. The customer has two opportunities to obtain necessary resources to keep his business running and to realize scalable services.

The first concept (see Organization X) contains of a Cloud Computing software which has been developed on a proprietary architecture. To control the Cloud resources, proprietary interfaces in the form of web services are available to support communication via Internet-based protocols [22] but the concrete design remains unknown for a customer, like a black box. The Amazon Web Services (we have selected Amazon because of its pioneering role) are used in the Cloud Computing sector by many companies as a mature standard for a comprehensive cloud interface.

The second concept is based on third-party software and hardware (see Organization Y). The use of already existing and fully developed software has the advantage to base on a certain degree of quality and know-how. Furthermore, the transparent structure makes it possible to implement specific enhancements in addition to the available interfaces in order to increase the quality or scope of information [23].

B. Deduction of interface functionalities

In reflection of the provider market, we conglomerate the interface functionalities. To put them in a general context and to obtain a corresponding structure, we divided use cases of the main interface into four modules. Each module consists of at least one functionality component that combines a range of interfaces. Fig. 2 shows the hierarchical structure of all identified cloud functionalities, that well-engineered software should support.

The Access Module is the foundation of all other modules, since its components provide access to the Cloud. The Resource Module encapsulates components of the core tasks. All functionalities have a direct impact on the infrastructure and the resources usage. The Support Module covers the customer advice and the sustainability of performance on the software layer. The Configuration Module contains the functions that already need resources but do not cost money yet. These components are preparing a smooth and user-defined operation.

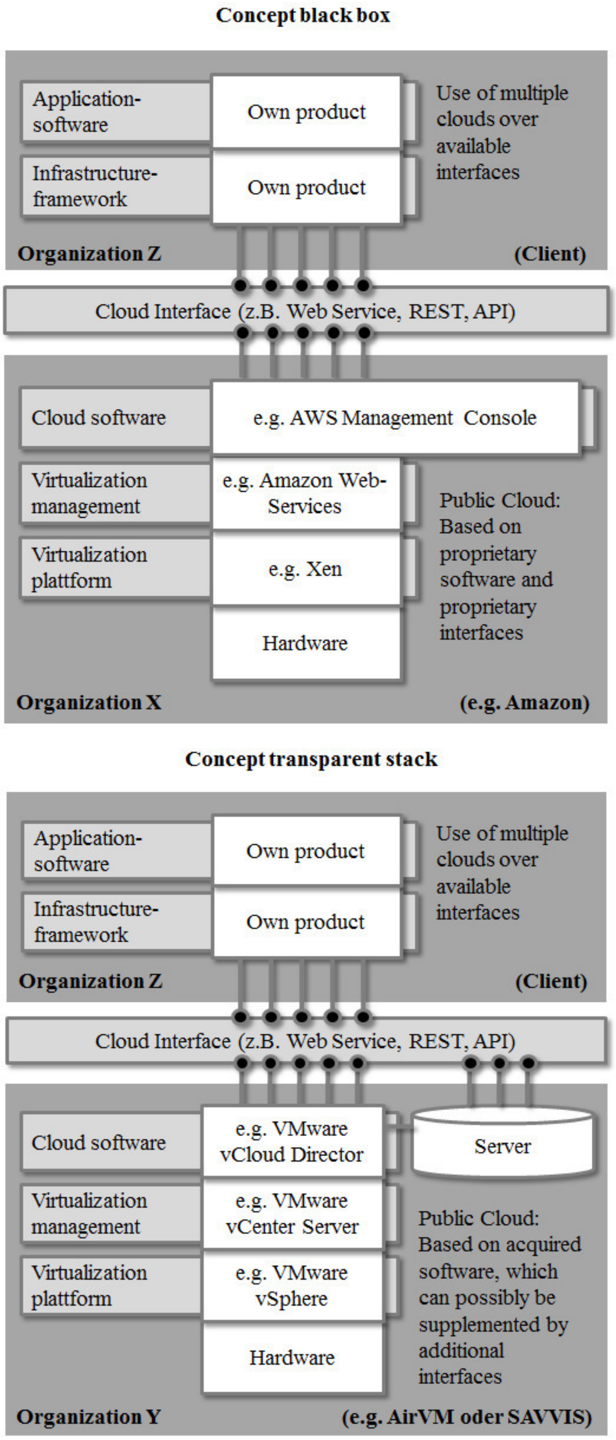

Fig. 1: Cloud Software concept

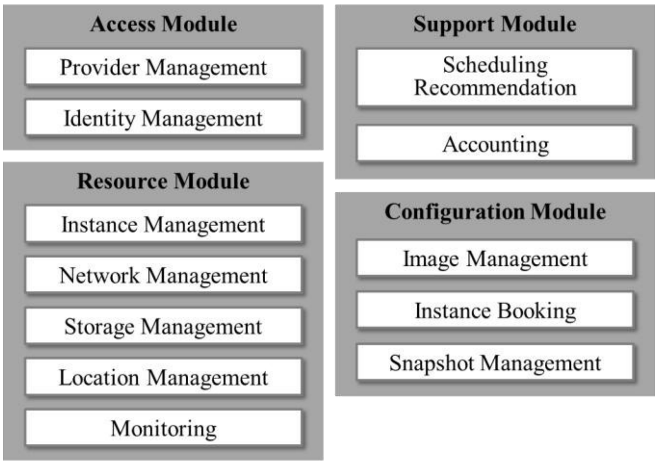

Fig. 2: Functionality components and modules

The functionality components related to interfaces found in the market analysis will be described below, in the order of the four modules:

- **Provider Management**: The Provider Management allows the user to retrieve information about the provider and its data centers. The types of information include a list of available datacenters with their locations and properties and its availability, the current bandwidth and the current utilization.
- **Identity management**: Especially in companies with many employees, who need to have access to the Cloud infrastructure, identity management provides the possibility to assign a person to a company or a department and define business roles. The employees can use their roles to access the Cloud, book resources, or use services. The role of an employee is a collection of permissions that will be created and managed by an administrator. In addition to the role, a budget for the maximum expenses can be determined to control the usage of Cloud services. Thus, a cost control is achieved and the ability is acquired to track actions of individuals or departments.
- **Image Management**: The Image Management offers its customers the opportunity to configure, to manage, to create, and to use images which are provided by the provider. These images can be categorized and classified into different availabilities (e.g. private or public). In addition, image properties and rights according to roles can be defined.
- **Booking Instance**: This functionality enables the assignment of instances to an accounting model, to allocate and to reserve resources for future events. The resource reservation allows a predictive planning and is also reflected in the resulting costs. The characteristics of an instance such as the number of CPUs or the size of memory can be explicitly selected or adjusted during the operation.
- **Snapshot Management**: When an instance is crashed, then all the data, which was locally stored on the instance, will be lost. By means of the Snapshot Management a backup copy of the current state of an instance can be made and resumed at a later date prior to the shut down or during the operation. This feature allows, through small changes in the instance parameters, a duplicate or a clone of the instance in a particular state. Thus, with little effort a specific configuration can be copied and a more flexible scaling is provided.
- **Instance Management**: The Instance Management is the core component of the infrastructure as a service layer. This component allows managing current resources and to create or shut down instances of different images. Based on the Identity Management, the running instances can be categorized, migrated, stopped, rebooted or destroyed. In addition, this component has the ability to assign attributes of an instance or to pass parameters between instances.
- **Network Management**: Via the Network Management virtual machines can be grouped into networks. The network component includes a DHCP services, a firewall and a VPN service. These and other services can be configured and customized using routing tables and VLAN structures. Through the virtual network structure, subnets can be established quickly and demand-oriented or divided and split flexible.
- **Storage Management**: To achieve a permanent availability of the dynamic data of an instance, the storage management provides a variety of ways. The data may be distributed and provided in the network using a database, a remote drive, a local device or a service-oriented storage. The storage component is not only for storing data, but also realizes an increasing of the distributed system performance. By distributing the data a scalable infrastructure is achieved where the information from multiple locations can be retrieved and transferred at high performance.
- **Location Management**: Location Management allows instances to be placed within a data center or to be grouped within a rack. The location of an instance can play an important role for massively parallel and other certain applications, because the performance depends crucially on the latency between virtual machines due to the compute intensive processes that are mostly based on distributed communications. For this reason, it makes sense to join such virtual compute nodes within a rack or a physical network.
- **Monitoring**: Monitoring is used to observe instances. It provides the administrator with a suitable tool to monitor the infrastructure. Here, the state and the utilization of an instance can be requested. In case of a deviation from normal IT operations escalation procedures can be defined using the monitoring data. For example, an e-mail notification will be sent if a deadlock of an instance has been detected. The security of the infrastructure will increase due to early detections of unusual system behavior and changes in the

TABLE 2
FUNCTIONALITY COMPONENTS OF CLOUD SOFTWARE

	Functionality components											
Cloud Software	Provider Management	Identity Management	Image Management	Instance Booking	Snapshot Management	Instance Management	Network Management	Storage Management	Location Management	Monitoring	Scheduling Recommendation	Accounting
Abiquo	Not publicly available											
Amazon Elastic Compute Cloud (EC2), Simple Storage Service (S3), Elastic Block Store (EBS), Auto Scaling, CloudWatch	O	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	O
Cloud.com CloudStack	Not publicly available											
Convirture ConVirt	O	O	O	O	O	O	O	O	O	O	O	O
ElasticStack	O	O	O	✓	O	✓	✓	✓	✓	✓	O	O
Eucalyptus	O	O	✓	O	O	✓	O	O	O	✓	O	O
Flexiant Extility	O	✓	✓	✓	✓	✓	✓	✓	O	O	O	O
HP CloudSystem	Not publicly available											
IBM CloudBurst	O	O	✓	✓	✓	✓	✓	✓	✓	O	O	O
Incontinuum CloudController	Not publicly available											
GoGrid	O	O	✓	O	✓	✓	✓	O	✓	O	O	✓
Nimbula Director	Not publicly available											
Novell Cloud Manager	O	O	O	O	O	O	O	O	O	O	O	O
OnApp	O	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OpenNebula	O	O	✓	O	✓	✓	✓	✓	O	✓	O	O
OpenStack (Rackspace)	O	O	✓	O	✓	✓	✓	✓	O	✓	O	O
Parallels Automation for Cloud Infrastructure (CI)	Not publicly available											
Red Hat CloudForms	Not publicly available											
SpotCloud	✓	O	✓	O	O	✓	O	O	✓	O	✓	✓
VMware vCloud	O	✓	✓	O	O	✓	✓	O	✓	✓	O	O
Xen Cloud Platform (XCP)	Not publicly available											

infrastructure based on possible attacks from outside world or inside the company.

- **Scheduling Recommendation**: The scheduling recommendation replaces the direct customer service and enables recommendations on proposed transactions. The scheduling recommendation can help the user in different ways. On one hand specific user requirements can trigger automatic system recommendations for convenient bookable resources. On the other hand resources can be scaled automatically up or down based on a defined budget. This peak loads can be intercepted and a smooth operation is ensured.
- **Accounting**: The accounting will not only increase the confidence of the customer, but also provide the ability to use cost-based control for Cloud services. Through the permanent availability and overview of the accrued costs, companies can strategically respond to needs and prevent to become insolvent or getting problems with outstanding debts. The availability of pricing information for services and configurations allows a strategic planning of resources and provide transparent accountability on the occurrence of certain costs.

C. Provided range of interface functionalities

To give an overview of which interface functionalities are provided on the market, we focus on the Cloud software used by the provider. Most providers are using the Cloud concept like "Organization Y" shown in Fig. 1, and offer their services based on a given virtualization platform and Cloud software of a foreign provider. Therefore the interface functionalities from different providers are often identical. The examined 74 infrastructure providers on the market use 21 different implementations of Cloud software. Table 2 shows how the used Cloud software fulfills the set of interface requirements. Here Cloud software is allocated to a functional component as long as only one interface method of the functional component is available. A "✓" stands for "supported" and an "o" for "not supported". Due to this top level score it is not possible to recognize how extensive a functionality of a component is realized or implemented.

Cloud providers and Cloud software manufacturer are implementing the described components of their interfaces in varying degrees. Based on this fact the necessity arose to unify and standardize the interfaces and functionalities so that the main Cloud principle of standardized services can be realized. If a standard would exist the interfaces are comparable by means of percentage coverage of functionality to the relevant standard.

V. Discussion and Conclusion

The economic impact and potential of standardization of the Cloud infrastructure constitutes to all participants of the market, the vendors, users, competitors and the state. First, standardized Cloud infrastructure helps the provider to deliver an offer which fulfills the principle of Cloud. Virtual infrastructure can be easily scaled and migrated freely between providers. In addition, the understanding of Cloud services and their properties between providers and users is raised to a common level. With full ensured interoperability, the user is able to exchange and combine the services and products from different vendors. Its own applications or data can be moved freely between different providers, which promote portability and mobility of applications and data. As a result, users gain a certain independence from the suppliers and have free choice of their Cloud services. The offers are more transparent and significantly facilitate a comparison between the levels of service providers. This allows users to optimize their investment in Cloud services and fully exploit their benefits. In consideration of the competitors, standardized Cloud Computing is opening new markets for vendors whose offerings consist of expertise or mediation, aggregation and integration of existing services. At last standardization brings significant benefits for the duty of government controls. Legal regulations relating to compliance are easier to express with the help of standards and monitoring.

As already mentioned, several application areas for Cloud software exist, therefore the functionality needs to be adjusted accordingly. A standard should describe all the components, their functionality and then assign the components of the corresponding areas. In this paper an abstract overview of the variety of functions and specific implementations of relevant interfaces of an IaaS Cloud is given. According to the authors, these components can be seen as a basic framework for a Cloud structure in the infrastructure level.

This paper shows clearly, that the standardization in the Cloud Computing is still in its infancy. Due to considerable expenses of standardization efforts the desire arises for a proper comparison basis (benchmarking) of Cloud providers and services. Actually these efforts will be implemented at both the organizational and technical level. However, no standard has uniquely been generally accepted so far. Given the fact, that the topic of Cloud is currently in its early stages, the standardization of interfaces and Cloud services is still changing and developing. Currently the most promising approach is the Open Cloud Computing Interface (OCCI). Even some Cloud software vendors have recognized the trend and have expanded their products to this interface. These include OpenNebula, Eucalyptus and OpenStack.

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