

# The Cloud: Requirements for a Better Service

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**Abstract**—Cloud computing has rapidly made it to the top of the list of considerations for IT strategies in various organizations. However, there are many unanswered requirements delaying the complete adoption of this paradigm. As a result, it is essential to identify the organizations' wish-list for Cloud services. In this paper, we define a set of requirements for Cloud computing. Then we highlight the level of importance of each one for government organizations' applications, large-scale computations, financial services, healthcare applications, and the online entertainment.

**Keywords**—Cloud Computing; Governmental Applications; Large-Scale Computations; Financial Services; Healthcare Applications; Online Entertainment

## I. INTRODUCTION

Cloud computing, in spite of being an evolving paradigm, was ranked among the top technologies of the decade [7][24]. The characteristics of this paradigm assert its convenience from an enterprise perspective. Users can benefit from shared computing resources in any quantity at any time through broad network access. That could be done automatically without the need to communicate with the service provider knowing that the associated cost is relative to the quantity and duration of the resources utilization [3]. In a recent survey involving 155 companies that have already exploited the Cloud computing technology, only 4% had fully incorporated their Cloud applications and 65% described the need to improve current Cloud services as a high priority [14]. The aim of this paper is to identify the factors that are restraining the Cloud from being totally accepted and incorporated in organizations.

While the number of organizations realizing the benefits of Cloud computing is increasing, the number of Cloud service providers is also increasing. Consequently, the task of choosing between service providers is becoming complicated [16]. In fact, the choice is not only limited to the service with the best performance at the minimum cost. It is also influenced by other considerations such as security, privacy and trust issues. A suitable Cloud service typically corresponds to the minimum trade-offs among these issues while satisfying some other requirements. However, trade-off decisions depend on the organization type, goals and scope of work. Accordingly, we will discuss the issues and requirements from the enterprise point of view and then discuss their level of importance in governmental institutions, research labs, the financial service industry, healthcare providers and the entertainment industry. Our

approach emphasizes Cloud computing issues from various organizations' perspectives and thus complements other technical research efforts towards better and more satisfactory Cloud services.

The rest of this paper is organized as follows. In Section II, we present an overview of Cloud computing and Cloud services and Section III provides a list of Cloud services requirements. A number of application requirements and case studies are discussed in Section IV. Section V summarizes and compares different applications requirements. Finally, concluding remarks and future work notes are presented in Section VI.

## II. CLOUD COMPUTING CONCEPTS

Cloud computing is an emerging commercial infrastructure model that offers to eliminate the need for companies to maintain in-house high-cost hardware, software, and network infrastructures. It also reduces or even eliminates the high-cost of recruiting technical professionals to support these infrastructures and operate the in-house IT solutions. From a widely discussed idea carrying many confusing concepts and ambiguities, Cloud computing has rapidly become an emerging computing paradigm enabling various services to be provided to interested consumers at lower costs and higher profits [1]. Consequently, establishing a formal definition and description of Cloud Computing and its requirements is a pressing necessity.

The recent NIST definition of Cloud Computing [3] describes it as a paradigm allowing users to access shared configurable computing resources. The NIST definition is based on five main characteristics:

- Users can automatically benefit from the Cloud services without communicating with the service providers.
- Standard protocols are used to access the computing resources over the network.
- Cloud services follow a multi-tenant model allowing resources to be pooled and shared among users.
- Computing capabilities can be quickly scaled in or out based on the users' varying demands.
- Users pay for utilized computing capabilities based on a pay-per-use model.

Cloud services follow three service models: the Cloud Software-as-a-Service (SaaS) where a user can benefit from the Cloud provider's applications that run on the Cloud infrastructure; the Cloud Platform-as-a-Service (PaaS) where a user can deploy applications onto compatible Cloud infrastructures; and the Cloud Infrastructure as a Service

(IaaS) where a user can benefit from the computing resources offered and managed by a Cloud service provider.

### III. REQUIREMENTS

In this section we list and discuss the requirements for better Cloud services. These requirements are: security, privacy, availability, auditing, flexibility, archiving, scalability, and quality of services (QoS).

#### A. Security

The resource pooling characteristic of Cloud computing allows users to dynamically share physical and virtual resources. It can be acquired by following a multi-tenant model which relies on virtualization [30]. High security concerns are usually associated with virtual environments which include virtual components such as hypervisors for running virtual machines and virtual networks for virtual machines communications [8].

An organization that has its own IT components in its premises can apply and monitor proper security policies and controls especially for identity management. Consequently, it is a priority to choose a Cloud service which supports suitable and adequate access control and authentication mechanisms. That is essential since data must be kept secure in the multi-tenant Clouds where it is stored along with other parties' data. In addition, it is necessary to make sure that the service providers themselves cannot access the users' data. Therefore, issues arise as an organization's security requirements and policies cannot be fully reflected in Cloud environments [6]. This is mainly due to the wide range of security needs and the high computation and communication costs of applying strong security measures.

#### B. Privacy

Organizations are often uncertain when it comes to managing and storing sensitive information in the Cloud. Indeed, privacy is an important Cloud computing issue to be addressed in the direction of raising users' trust in the Cloud computing paradigm [22]. The geographic location of data stored in a Cloud environment is usually not revealed to users. This lack of transparency raises high concerns especially that privacy regulations and policies differ from one country to another. In addition, data stored in Clouds may be at risk of unauthorized usage by the service provider. Due to the fact that proper means to prevent such usage have not been founded yet [23], service providers must present the necessary guarantees to the users. In addition, service consumers should be able to protect their private data from other users, while service providers should not be able to access private consumers' data. Yet again, making this possible is a difficult task and may result in various issues.

#### C. Availability

Most organizations require maximum availability levels of their computing resources provided by the Cloud services. Service and data availability is crucial especially for institutions which cannot operate unless their resources, applications and data are available. One example of such organizations is financial and banking institutions. It is

argued that using Cloud services based on well-equipped IT infrastructures can provide higher availability than owning and maintaining infrastructures within the organization [15]. Cloud services have recently experienced failures resulting from several factors including security attacks, infrastructure outages and natural disasters. Cloud computing environments need to make serious provisions to react quickly and efficiently to such outages and ensure continuity of Cloud services. Therefore, the ability to efficiently and seamlessly recover from outages is an important factor to consider when comparing Cloud services [12].

#### D. Auditing

Audits are regular and indispensable mechanisms performed in various institutions. They require monitoring and recording all operations performed within an organization's system and keeping close track of all activities. Nevertheless, appropriate auditing capabilities for the Cloud computing paradigm have not been founded yet [23]. Various issues including storage needs, authenticity and correctness of the audit logs need to be resolved while not affecting the overall performance and availability of the services. Furthermore, adding trustable auditing facilities to Cloud services would certainly enhance the approval rate of this paradigm from the enterprise point of view [2].

#### E. Flexibility

The ability of an enterprise to rapidly respond to varying business requirements depends on the flexibility of its system. Cloud computing service providers should be able to offer flexible plans and services that allow an enterprise to quickly and efficiently adapt to changes in their goals, customer demands and global changes. Consequently, a Cloud service characterized by high flexibility would be the choice for dynamic businesses where new services and applications are continuously requested [18].

#### F. Archiving

Archiving provides long-term storage of data that is no longer momentarily needed. Keeping archived data imposes high storage demands and also require additional backup and restore features for the consumers. Furthermore, it may also impose some additional costs on the services. Hence, a Cloud computing service with an archiving feature and easy access to archived data is among the essential requirements for many organizations whose operations involve archiving large amounts of data that may be needed for later use.

#### G. Quality of Service

Some applications and service consumers in the Cloud require high QoS guarantees to meet their objectives and maintain their operations [5]. In this case, Cloud services providers need to consider and meet different QoS parameters and policies for different types of consumers. Such coverage is usually negotiated and agreed upon in the Service Level Agreements (SLAs). In this case, the service providers need to deploy QoS-based resource allocation mechanisms to support different SLAs.

There are different QoS parameters to consider in any service such as response time, reliability and trust/security. Generally, these QoS parameters need to be dynamically updated from time to time due to regular changes in industry operations. Therefore, Cloud service providers need to provide a usable set of features that allow consumers to build and modify their QoS policies as needed.

#### *H. Scalability*

The capability to scale (grow while maintaining acceptable performance) is one of the most important factors in providing successful Cloud services. Cloud scalability is mainly enabled by increasing the capacity and number of IT resources such as compute nodes, network connections, and storage units. Scalability requires dynamic configuration and reconfiguration as well as an automatic resizing of used virtualized hardware resources [27]. In addition, it requires maintaining an acceptable level of performance regardless of the size and utilization levels of the services.

Different types of businesses and organizations have different levels and patterns of growth. Some organizations have stable growth in their computation and storage capacity needs while others have bursty loads where they have very high needs at some times and very low needs at others. In addition, some organizations may start with low requirements, yet may experience sudden growth jumps at unpredictable times. The steady growth can be easily handled; however, in the latter two cases, a high degree of scalability support is a very important requirement.

### **IV. CASE STUDIES**

In this section, we discuss a number of Cloud application domains and identify their main requirements in light of the list identified in Section III. These domains include governmental institutions, research labs, financial service industry, healthcare providers and entertainment industry.

#### *A. Governmental Applications*

Governments incorporate several agencies and departments with various missions and responsibilities. Those entities depend on large and expensive IT infrastructures to support their work. In most cases, the actual use of such equipment is very low on average. Cloud computing offers efficient solutions that can reduce the expenditures of owning IT infrastructures. It also allows governments to focus on providing better services and information management [13]. With Cloud computing, IT costs will be determined only by used resources. Whenever an IT component is needed for a certain task or project, it can be added with minimal effort and time. This will certainly increase the system's scalability and allow governmental institutions to concentrate on their services rather than spend time dealing with IT operations and issues. Moreover, similar applications are currently implemented within large infrastructures at every department. Based on their resource sharing characteristic, Cloud services can eliminate such redundancies and facilitate the collaboration among different institutions. Consequently, more governmental organizations are considering Cloud computing services [28].

On the other hand, governmental operations involve sensitive data including citizens' information. Hence, security and privacy are top requirements when assessing the risks associated with relying on Cloud services [21]. Resources must be well-protected against security attacks and unauthorized access. In addition, Cloud services must reflect privacy policies and regulations knowing that they differ from one country to another and from one organization to another. Furthermore, governmental data and applications should be accessible at anytime. Therefore, availability is also an important requirement. Moreover, governments require archiving facilities in their systems as all data must be kept and is usually needed for later use. Audit operations are also essential for governmental departments. Accordingly, for convenient and efficient government operations, the Cloud computing environment considered should have strong security and privacy features, should be highly reliable and available, and should support sufficient audit and archiving facilities.

#### *B. Large-Scale Computations*

Data analysis and visualization, computer simulations and many other applications are essential for many research activities in most fields of study. Successful outcomes depend on using the right large-scale data management and analysis methods, high performance software as well as suitable high-performance IT infrastructures. For instance, genomic research relies on the analyses of huge amounts of multi-dimensional data. Analyses involve complex computations performed on advanced IT infrastructures. The cost of such IT equipment is often very high and cannot be afforded by small laboratories. In addition, the need for such computations is not always continuous; it comes in bursts based on the rate and outcomes of the experimental work being done. As a result, Cloud computing services may be the perfect solution for such demands. In addition to being a pay-per-use service, Cloud computing is based on a high level of virtualization thus can provide fast computation results at low costs [25].

Business intelligence systems present another case where large-scale data analysis and high performance computing is important. These systems are used to provide decision makers in enterprises with analysis and summaries about internal and competitor information [20]. The latter certainly amplifies the correctness of business decisions based on the enterprise capabilities and on the market information. Once more, such needs are usually intermittent and vary from time to time, thus warranting the use of Cloud services to satisfy them as they offer suitable IT resources to support fast computations associated with large-scale data analysis. Therefore, enterprises do not have to own complex IT infrastructures to perform such operations. For cases limited to analyses and computation of large-scale data sets, organizations are less concerned with security and privacy. A Cloud service that can provide correct and fast results with good availability and performance is most likely suitable.

### C. Financial Services

Financial institutions rely heavily on data and applications management in their operations. Consequently, having IT infrastructures that can support the scale of these operations at their peak is fundamental. However, the cost of owning such advanced IT resources and maintaining them does not correspond to their average usability. By following a pay-as-you-go model, Cloud computing helps in reducing the cost associated to owning and maintaining the IT equipment. Moreover, by providing scalable IT resources, Cloud services can improve the performance of systems in the financial service industry [26]. Usually, data and applications are shared among different branches and partners of a financial organization. A high cost is also associated with this sharing capability, while Cloud services can provide this feature at significantly lower costs [10].

For a financial institution to approve a Cloud service, there are crucial requirements to be considered. Financial data must be kept secure and confidential. Therefore, the service must be characterized by high security and privacy levels. Due to the dynamic nature of the financial industry which is reflected in the continuous need of deploying new services, a flexible Cloud service is highly important. Financial firms cannot operate unless their system is available. Hence, service availability is an important feature for financial firms. In addition, Cloud services must include auditing capabilities to keep track of financial transactions since it is an indispensable procedure performed in these firms. All information and operations of the financial systems must also be kept for future reference and analysis, which infers that financial organizations will certainly look for efficient archiving facilities in Cloud services.

### D. Healthcare Applications

Creating, managing, storing and sharing Electronic Health Records (EHRs) are essential tasks performed in healthcare nowadays. An EHR is created by an entity in a healthcare institution and comprises a patient's personal and health information [9]. Generally, powerful IT infrastructures are deployed in healthcare organizations. A large fraction of healthcare expenses is assigned for these infrastructures which also require time and effort for maintenance and support. The services offered by Cloud computing allow healthcare organizations to concentrate on providing high-quality services without worrying about IT deployment and management [29]. In addition, sharing electronic health records among healthcare providers and partners is important but also very costly. Cloud computing can also decrease the cost associated with this requirement.

The acceptance of Cloud computing by healthcare providers is conditioned by various requirements reflected by the special nature and usage of health records. Health records are highly confidential; hence, it is fundamental to protect them against security attacks and unauthorized access. Moreover, patients' data must not be revealed to any unauthorized party and Cloud services must comply with this privacy rule [17][29]. An EHR should be accessible whenever needed especially in cases of emergencies. As a result, a healthcare provider would certainly look for

services that are reliable and highly available. Added to that, it is strongly required to have archiving features in Cloud services as all patients' information must be archived.

### E. Online Entertainment

Cloud computing can be used to host video-on-demand services [14] and multiplayer online games [4][11] for entertainment companies. Entertainment companies can rely on the Cloud to avoid the high-cost of owning and maintaining servers and network infrastructures to support these online entertainment products. There are many important factors that determine the success of these entertainment services in the Cloud. The high availability of services is a very important aspect for maintaining the satisfaction and interest of the customers using these services thus maintaining continuous revenue for the entertainment companies. Ensuring QoS is another important factor for providing successful entertainment services in the Cloud. For example, in multiplayer online games, all action taken by one player must be reflected to all other players within a very short time. This requires a special type of services supported by specialized infrastructures and careful services implementations in addition to strong QoS policies support.

Unlike other industrial sectors, the entertainment industry usually needs highly scalable services. This is mainly due to the fact that the load on these services differs based on the time of day or due to introducing new videos or games. For example, the load can be very high during the weekends or the first week of introducing a new online game. The load can also increase when new movies for famous actors or important sporting events are premiered.

## V. REQUIREMENTS SUMMARY

As the case studies discussed above show, different applications and organizations have different views of what they need from a Cloud environment. In addition, various requirements are important, yet they have different importance levels for different types of organizations. Accordingly, when considering the utilization of Cloud services as part of the organization's IT solution, it is important to have a clear understanding of the needs and specific requirements of the organization and then identify the suitable Cloud services to be used. Table 1 offers a summary of the general requirements and their importance to the various sectors, while the following provides the detailed discussion of these requirements.

Archiving is an important Cloud feature for governmental institutions, the financial services industry, and healthcare providers. All three sectors need to keep full record of their operations for future reference such as tax reporting, history tracking, data analysis, etc. Therefore, all information must be kept even if not currently used or needed. This feature is not as essential for large scale computations since obtaining the results of specific computations is the main goal and in most cases the data used is either transient or does not need to be kept for a long time. However, some applications may need to archive data if it has significant value of it is hard to reproduce.

TABLE I. REQUIREMENTS SUMMARY

	Governmental Applications	Large-Scale Computations	Financial Services	Healthcare Applications	Online Entertainment
<b>Archiving</b>	High	Low/Medium	High	High	Medium
<b>Audit</b>	High	Low	High	High	Low
<b>Availability</b>	Medium/High	Medium	High	High	High
<b>Flexibility</b>	Medium	Low	High	Medium	Low
<b>Privacy</b>	High	Low	High	High	Low
<b>Security</b>	High	Low	High	High	Medium
<b>QoS</b>	Medium	Medium	Medium	Medium	High
<b>Scalability</b>	Medium	High	Medium	Medium	High

Auditing is an essential operation performed in governmental and financial institutions to keep formal record of all transactions and their results. This makes it important to have this feature available in the Cloud services they use. When considering healthcare records, auditing, becomes less important, yet may be useful in some cases such as keeping track of important information like addictive medications prescriptions. Auditing is also unnecessary for research labs and the online entertainment industry.

Service and data availability are crucial for healthcare providers, financial institutions, and the online entertainment industry in most of their work. Generally, these institutions cannot afford an interruption in their services at any time of day. The potential to suffer from financial losses or significantly reduced profit margins; jeopardize a human life; or lose paying customers is unacceptable. Yet, in the government sector, although availability is still highly required, some marginal interruption of services may be tolerable. Furthermore, performing computations for research labs on the Cloud can tolerate some delays without significant losses in case of service unavailability.

Cloud services must rapidly respond to the dynamic nature and evolving needs of financial services; therefore, it is a necessity to have flexible Cloud services. Such feature will allow the financial institutions to quickly adapt to business needs and introduce/modify/remove services as necessary. Moving to governmental institutions and healthcare providers, flexibility is required, but not as crucial as in financial firms. This is due to the fact that most applications and goals in these organizations are fairly stable and change at a much slower pace. Considering the research community, flexibility is less important in terms of adapting quickly to changes, but some level of flexibility to modify and upgrade the applications is needed.

Privacy and Security are key requirements in governmental, financial and healthcare institutions where operations involve highly sensitive and confidential data. Protection against unauthorized access and usage must be applied to all data. In addition, it is important to protect the privacy of both the users and the organizations using the Cloud services. Furthermore, strong measures are needed to ensure the integrity and non-repudiation. In contrast, when only performing computations in the Cloud for research labs, privacy and security concerns are minimized. However, they may be of some concern when the data and computations are confidential or highly sensitive. Moreover, in the

entertainment industry, privacy is of some importance to protect the personal information of the users, while other security measures are rarely needed.

When considering QoS, the highest demand for strong and flexible QoS policy enforcement comes in the entertainment sector. Ensuring continuous streaming of movies, instantaneous reflection of changes in an online game are among some of the areas where QoS is extremely important. Entertainment companies are highly competitive and cannot afford to lose paying customers for poor services. For all other sectors, QoS has some level of importance depending on the type and importance of the applications being used. For example, most financial, governmental, and healthcare information are small in size and can be made available with minimum QoS requirements. However, in some special cases, for example, when transferring a patient's medical record which includes x-ray pictures and other images for an emergency procedure, may require a higher level of QoS to ensure timely delivery.

In contrast, scalability is important for the financial and entertainment organizations to accommodate for the growing user base and data/media in use. Generally these institutions experience high customer demands and in many cases grow very rapidly. Therefore, it is important that the services they use on the Cloud can grow as fast as the demand, while maintaining good performance levels. For example, in the entertainment sector, it is important to be able to deliver a movie to 1000 customers simultaneously as efficiently as it is delivered to only 10. The other sectors like governments, healthcare institutions and research labs usually have a more stable user base and may experience slow growth patterns over extended periods of time. Therefore, it is easier to scale the services for such demands.

## VI. CONCLUSION

Cloud computing is continuously gaining more attention due to the advantages that it presents to organizations in terms of reducing the effort, time and cost associated with owning, operating, and maintaining IT infrastructures and applications. In the direction of tackling the issues delaying the adoption of this paradigm, we have identified the enterprise requirements expected to be met by Cloud services. These requirements commonly comprise security and privacy, availability, flexibility, QoS and scalability in addition to auditing and archiving capabilities. Considered cases where Cloud computing is undoubtedly advantageous

include governmental institutions, research-based large-scale computations and data analysis, financial service industry, healthcare providers, and the online entertainment industry.

Assessing the level of importance of the above requirements shows that high levels of security, privacy, availability and archiving are essential to governmental, financial and healthcare institutions. Audit capabilities are important to governmental and financial organizations and slightly less important to healthcare institutions. In addition, service flexibility and scalability are critical for financial firms. On the other hand, concerns are limited to a satisfactory availability and scalability levels for large-scale computations where the goal is to get correct results.

The aim of the presented interpretation is to assist organizations in making the right choice of service provider which corresponds to the minimum trade-off of their essential requirements. The next step is to start addressing each requirement individually to provide the suitable techniques and models that will help design and implement them efficiently. As a result, we aim to provide a road map for the design of efficient models to offer all the requirements for a specific domain or sector efficiently and in a cost-effective manner.

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