

# Software Engineering Challenges in Cloud Environment : Software Development Lifecycle Perspective

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## ABSTRACT

The rapid development of cloud computing in information technology and the desire to use it in recent years is evident. The use of cloud computing in the field of software development is not an exception. But according to the new cloud computing technologies and their requirements, the use of conventional methods of software development is not possible. Cloud computing has significant impacts on software development life cycle (SDLC), facing software engineers with several challenges in every level of development. In this paper software development challenges in the cloud are studied from the perspective of software development lifecycle (SDLC). Categorizing the challenges will help to create an appropriate framework resolving the related issues.

**Keywords:** Software Engineering, Cloud Computing, Software Development Lifecycle.

## I. INTRODUCTION

For decades, when organizations needed to increase their computer systems' data and computation capacity, they had two options: buy more hardware or make the IT operation more efficient. Cloud computing is a completely different approach in providing resources to organizations in which the computing resource maintenance will not be a concern for the organizations [1]. Cloud computing engineering includes engineering disciplines in cloud computing. In cloud computing engineering, there is a systematic approach to standardization, commercialization and governance concerns [2].

The process of application and software development has different procedures and standards. With the emergence of cloud computing, since cloud computing has different standards, languages and frameworks, software development in this area has different challenges. On the other hand, providing various services by the cloud, creates different perspectives in application and software development. Since developers can take advantages from cloud, then cloud commercialization can create significant changes in software industry [3].

Using conventional methods of software development in cloud is associated with so many challenges. So before starting an application or software development in cloud, considering the challenges and problems in software development lifecycle, is necessary. This paper studies the software development lifecycle challenges in cloud.

The reminder of the paper is organized as follows. In section II we describe an overview of related work. Section III presents the definition and basic concepts of cloud computing and software development lifecycle. In section VI software development lifecycle in the cloud is studied. Section V investigates the software development lifecycle challenges in the cloud and finally section VI concludes the article and presents future work.

## II. RELATED WORK

Software development in the cloud environment has advantages such as agility, availability, flexibility, and cost reduction. However, according to the new concepts of cloud development, there are a lot of open issues in the field of requirements, design and architecture, testing, quality of service, development and implementation methods [1]. Therefore, a careful

examination of software development lifecycle challenges in the cloud is necessary. In recent years studies have been done in this area and we will review them in this section.

In [4] authors examine the constraints and challenges of cloud-based application development. In this paper challenges are studied based on the cloud service model as well as developer and service provider views and solutions to meet the challenges are presented. However, studies in this paper have no particular order and software development lifecycle is not taken into account. The authors of [5] categories the software engineering challenges base on cloud-search from user and provider view and in both of the views, software lifecycle (planning, designing and testing and management) is considered and associated challenges is presented. In this paper a general categorization of challenges is provided but it is constraint to a special methodology of software development and do not encompass a wide range.

In [6], authors present an agile software development model, considering the software development challenges from the developer and provider view. Although the study is comprehensive, but it is focused on role categorization and there is a little emphasize on development challenges.

There are other studies in the field of cloud software development challenges. Authors of [7-9] study these challenges generally and there is no comprehensive categorization of these challenges according to the software development lifecycle.

### III. CLOUD COMPUTING

Several definitions for cloud computing are listed. The definition of NIST of cloud computing is as follows [10]:

"cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

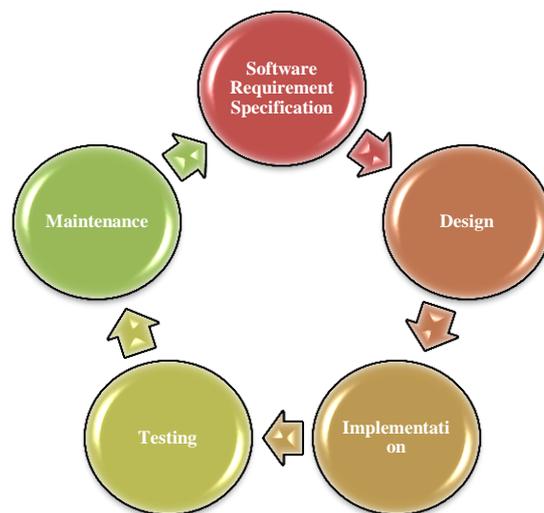
Cloud computing services are offered to the customers in three models:

- ✓ Software as a service: In this model the on-demand application is offered to the user through the internet.
- ✓ Platform as a service: Providing the platform layer resources including the operating system and its software development framework.
- ✓ Infrastructure as a service: Provisioning the on-demand infrastructure resources which are often a virtual machine.

According to offered service models, software development challenges can be in associate with different roles.

### IV. THE LIFE CYCLE OF SOFTWARE DEVELOPMENT IN THE CLOUD

To have the maximum productivity of the development of a new technology, it is needed to adapt them with related models and methods. So to increase the productivity of software development in the cloud, there should be a matching between cloud and software development lifecycle. There are several software development lifecycle models in software engineering [11]. In this paper, a software development model that has been created for cloud computing has been chosen as the basis [12]. Software development lifecycle in Green method is shown in Fig. 1. Various levels of the model are:



**Figure 1.** Green method Software development lifecycle [12].

#### A. Determining software requirements

Normal system requirements are classified in two categories: functional requirements and nonfunctional requirements. Functional requirements are more relevant to software business needs. In contrast, nonfunctional requirements are

qualitative, including security, performance, reliability, and availability. Determining software requirements in the cloud includes answering the some other issues as follows [7, 8]:

- Nonfunctional requirements associated the cloud like cost, performance, scalability.
- Certain requirements that need to be prioritized.
- Converting user-based requirement engineering to service-based requirement engineering.
- Other non-functional requirements like security, and communicational requirements.
- The impact of application cloud hosting environment in feasibility phase.
- The definition of appropriate cloud architecture.
- Identifying an appropriate cloud usage model for billing.

## B. Design

Designing phase is often classified to different categories like data, architecture, and procedure and interface design. However, many of the designs emphasize on granularity, abstraction levels, and data structure and software architecture. To Design cloud applications, designer must analyze error and parallelism [13]. So many design patterns are developed to cloud software development that is discussed in [14].

## C. Implementation

In software implementation in cloud, first of all cloud service model must be specified. Then considering the following is necessary [15, 16]:

- Data transfer
- Data storage
- Application access and service layering
- Backup and maintenance
- Access and emergency recovery
- Access and authentication and identification
- Select the appropriate service provider
- Evaluation and monitoring capabilities and access levels
- Risk assessment

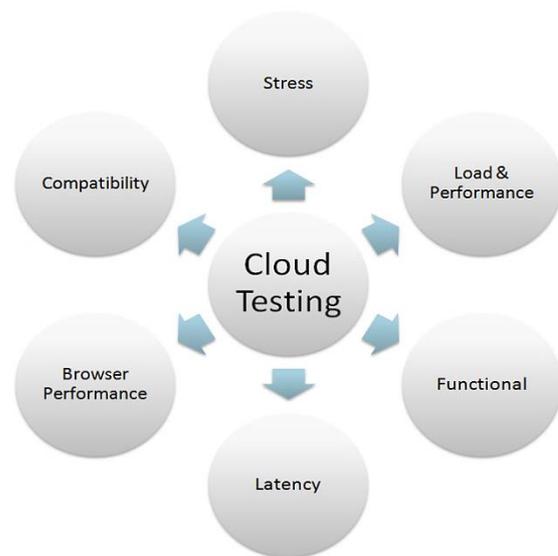
## D. Test

Software testing is an important part of software development lifecycle. Many companies spend about 40 percent of their resources to software tests that brings high costs [17]. Software test in cloud environment, due to resource availability and the diversity of the cloud is more difficult. Cloud-based tests are done with performance, security, workload and adaptability tests [18]. Also, because cloud sources are heterogeneous, the complexity of the test

and repairing the bugs needs much more energy. Different tools and method are developed to test cloud applications. The authors of [18] presented an overview of this tools and methods. The required tests in cloud environment are shown in Fig. 2.

## E. Support and maintenance

Infrastructure and applications must be supported efficiently till the waste of the system. In cloud environment, service providers are responsible for infrastructure and hardware control. Application and software maintenance depends on selected service model. In IaaS customer is responsible for application maintenance. Meanwhile, in PaaS cloud provider is responsible for the platform maintenance. In SaaS model, cloud provider is responsible for the application maintenance [12].



**Figure 1.** Cloud Testing approaches [19]

## V. SOFTWARE DEVELOPMENT CHALLENGES IN CLOUD

In different levels of cloud software development lifecycle, considering cloud computing characteristics, There are new challenges and concerns. In this section challenges will be expressed.

### A. Determining software requirement challenges

Software requirement challenges in cloud environment are divided to three following categories:

- Functional Requirements

Functional requirements are associated with applications and business model. But considering the use of cloud computing, there are challenges with functional requirements. These challenges are as follows [4, 6, 8, 13]:

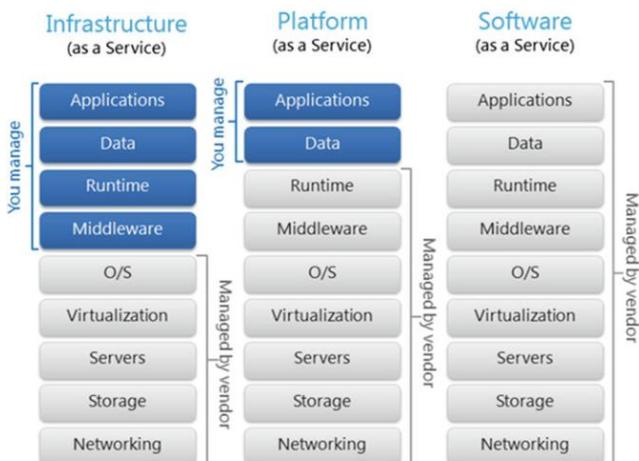
- Prioritizing specific requirements: specific SaaS requirements must be considered and prioritized.
- Non-functional requirements

In addition to the functional requirements and software related non-functional requirements, cloud computing needs to consider some other non-functional requirements like security and privacy, reliability, delay, expandability and availability. In order to understand these requirements, first the parameters under the control of customer and vendor in different cloud services model, must be identified. Cloud service models are shown in figure 3 in detail. This model shows the responsibility level of security and privacy and reliability for customer and vendor.

- Other requirements

The other requirements that are nor functional neither non-functional, and it is necessary to consider them in cloud software development, requirement analysis phase are as follows:

- Service Level Agreement (SLA): The customers should be assured about computing resources in the cloud and the quality of service and performance. These are often considered in form of Service Level Agreement.
- Vendor Lock-in: Regarding to different cloud service vendors, customers should be able to choose appropriate services from different vendors. There must be no vendor lock-in for customers.
- Lack of Standards for development: Cloud technology is in the early stages of its development. So there is no unique standard for its API and applications development.
- Cloud Evaluation: Includes enterprise readiness assessment to move toward the cloud. This assessment helps to determine business case and return of interest (ROI).
- Consumption patterns: determining and application's consumption pattern and work load in the cloud.



**Figure 3.** Responsibility level of security and privacy and reliability for customer and vendor [10]

## B. Design Challenges

Design phase in cloud software development has new challenges and concerns due to using virtual machines and the heterogeneous resources. Some of the challenges are as follows [13, 14, 20]:

- Choosing an appropriate design pattern: Choosing an appropriate design pattern in case of reusability is essential in cloud software development.
- Platform problems: Considering the heterogenous platforms, cloud software development must be appropriate for all the platforms and their connections.
- Parallel design: Considering the power of multi-core and multi-processor in the programming, is called parallel programming. Designer considering the parallelism in data level and work, should provide an appropriate design for the system.
- Design for Errors: Error detection is the most important issue in determining the application behavior in error scenarios.

## C. Implementation challenges

In cloud software development implementation phase, the following challenges must be considered [15, 20, 21]:

- The cost of data transmission to the cloud: Due to a lot of changes in business, information technology redesign is needed in cloud. This redesigning, costs too much.
- Topological dependencies problems: One of the most important challenges is moving from the static environment of network to the dynamic network architecture in which many of the topological dependencies change.
- Implementation risks: Various implementation risks like the usage of hybrid cloud services must be taken to the account.
- Virtual machine's communications: Design and implementation of an appropriate protocol to communicate between virtual machines is one of the most important challenges.
- Billing strategies: The billing strategies are user-centric already. But considering the dynamic services, the billing strategy must be service-centric.

## D. Testing challenges

Challenges and concerns that must be taken into account in cloud software development are as follows [18, 22]:

- Security test: Design and implementation of test cases for security is so important.
- Expandability and performance test: Expandability and performance are the most important goals for enterprises

using cloud. This must be possible for both infrastructure and service developments in cloud.

- Integrity related test: To test the integrity from the perspective of protocol connections, communication with legacy systems and their connections to the applications, appropriate test scenarios and criteria must be used.
- Innovation in testing: New features and requirements in cloud applications need innovative testing methods.
- Testing tools: Considering the various cloud applications, the suitable tool to test each of them must be identified and developed. In addition, there is no need to test all the qualitative characteristics with different tools.

### E. Support and maintenance challenges

In this section, cloud software development support and maintenance challenges in SaaS model are studied. These challenges are as follows [12, 23]:

- Development support: if software is developed and it needs more resources like storage or bandwidth, it's the responsibility of the provider to support the need. The provider is involved with resource allocation problems.
- Service Level Agreement: Service provider must efficiently manage the resources to be able to responsible for SLA requirements.
- Resource and cost optimization: Cloud software support must be able to forecast cost and resource solutions and reduce the maintenance costs.

**Table 1.** shows a conclusion of challenges to represent a focused insight on existing issues.

Software requirements			Design
<b>Functional</b> <ul style="list-style-type: none"> <li>▪ Prioritizing specific requirements</li> </ul>	<b>Non-Functional</b> <ul style="list-style-type: none"> <li>▪ Security and Privacy</li> <li>▪ reliability</li> <li>▪ Delay</li> <li>▪ Scalability</li> <li>▪ Availability</li> </ul>	<b>Other Requirements</b> <ul style="list-style-type: none"> <li>▪ SLA</li> <li>▪ Vendor Lock-in</li> <li>▪ Lack of Standards for development</li> <li>▪ Cloud Evaluation</li> <li>▪ Consumption patterns</li> </ul>	<ul style="list-style-type: none"> <li>▪ Choosing an appropriate design pattern</li> <li>▪ Platform problems</li> <li>▪ Parallel design</li> <li>▪ Design for Errors</li> </ul>
Implementation		Test	Support and Maintenance
<ul style="list-style-type: none"> <li>▪ The cost of data transmission to the cloud</li> <li>▪ Topological dependencies problems</li> <li>▪ Implementation risks</li> <li>▪ Virtual machine's communications</li> <li>▪ Billing strategies</li> </ul>		<ul style="list-style-type: none"> <li>▪ Security test</li> <li>▪ Expandability and performance test</li> <li>▪ Integrity related test</li> <li>▪ Innovation in testing</li> <li>▪ Testing tools</li> </ul>	<ul style="list-style-type: none"> <li>▪ Development support</li> <li>▪ Service Level Agreement</li> <li>▪ Resource and cost optimization</li> </ul>

## VI. CONCLUSION AND FUTURE WORK

Emergence of new technologies such as cloud computing has affected many aspects of enterprises and businesses. One of these aspects is application and software development in cloud. In this paper we examined software development challenges in cloud from the software development lifecycle perspective and all the challenges of each stage is discussed separately. The aim of studying challenges from this perspective is as follows:

- Proposing a new approach for cloud software developers to face the challenges.
- Classifying challenges to offer an appropriate solution based on the development phases.

Despite the challenges, the benefits of using cloud in software development are clear. Therefore, the future work will seek to propose an appropriate approach for existing challenges.

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