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Roadmap to Testing the Cloud
Techniques, Methodology, and Tools

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***Abstract* – Cloud computing has recently received a significant attention and started attracting companies, general users, and developers. With the increase of the popularity of this paradigm, the importance of testing the cloud started to emerge. Many authors came up with paper about testing technologies applied to the cloud, however; there is no clear methodology to follow in order to complete a cloud test. This paper presents an overview of cloud computing, cloud testing techniques and tools. It presents a roadmap to testing the cloud. This consists of a five-step process to test cloud services in a logical and effective way. This work has for a goal to provide new testers on the cloud with the necessary information to start their test.**

Keywords – Cloud computing; testing; testing the cloud, cloud testing; cloud testing tools; functional testing; non-functional testing

I. INTRODUCTION

As we can all witness, nowadays, the popularity of cloud computing is growing in a significant way. Due to the advantages it offers, more companies take the decision to migrate their data to the cloud and different providers compete with each other's with their cloud computing services. Used mainly to store and compute, the cloud is considered as the new trend in Information Technology (IT). As the use of cloud for application use has been growing recently, a need for testing these applications has emerged. However, since cloud computing is still a relatively new paradigm, there is still not much work done about testing and cloud computing. Although we could notice an emergence of an important number of testing tools these last few years, those tools are, however, not well organized enough to allow testers to get the big picture of testing in cloud computing. Besides, there still remains some confusion concerning the difference between the two terms "cloud testing and testing the cloud". Because of all this, testers may find some difficulties when dealing with cloud computing, which could cause an increase in the cost and a decrease of the efficiency of testing.

In this paper, we present a cloud testing methodology consisting of five phases or steps that testers could apply and follow to test cloud services with a focus on testing for Software as a Service. Section 2 covers the related works. In Section 3, we present an overview of Cloud Computing and some of the services that cloud providers offer to the users. Section 4 discusses the difference between testing the cloud and cloud testing. Section 5 briefly explains the motivation behind testing in the cloud while Section 6 presents testing techniques classified in two categories, functional and non-functional testing techniques. Section 7 outlines the Cloud testing methodology and the benefits and tools of cloud testing are shown in Section 8. Finally, Section 9 draws conclusions.

II. RELATED WORK

The field of cloud computing is very recent in the history of information technology. Testing this paradigm is even more recent. Some papers addressed testing the cloud in variant ways. Gao, Bai, and Tsai [4] give an importance to the needs of cloud testing. However, they provide no information about the methodology to follow in order to complete a cloud testing. On the other hand, Chan et al. [8] focus on modeling a cloud application. They provide only one testing technique on the cloud that is based on cloud graph and its nodes. This technique is advanced and complex; the testers should be already familiar with the cloud testing paradigm in order to conduct this technique. Parveen and Tilley [2] provide a solution for the use of large computing resources for regression testing which is migrating software testing to the cloud. This way, regression testers will benefit from the elasticity of resources on the cloud. This paper focuses migrating software testing for regression and not for other types of testing.

III. CLOUD COMPUTING OVERVIEW

Cloud computing is a new computing paradigm that consists of a large number of systems connected together in a public or private network, providing a scalable and dynamic infrastructure for application services, data, and file storage services. The backbone of this technology is based on the idea of IT capability/reusability. Cloud computing introduces the infinite and elastic resource scalability, on demand "just in time" provisioning and the pay-as-you-go principle. That is, using the cloud, we use as much or as less we need, only when we want, and pay only what we use. Cloud computing provides other economic advantages for clients and for providers. Using this new paradigm, clients have no upfront commitment in buying/leasing hardware [1]. They can scale their usage according to their need and demand, and have fewer barriers to entry for startups. Cloud computing also increases the utilization of datacenter resources which is of the benefit of the providers [6]. Figure 1 depicts the cloud computing categories of services that are provided nowadays: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).

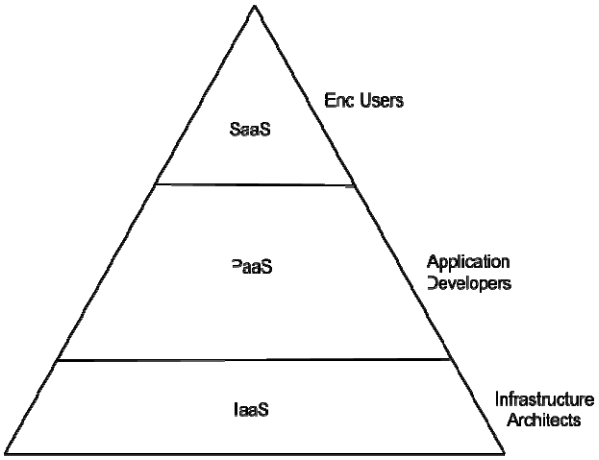

Figure 1. Cloud Computing Models and Their Users

Software as a service offers a complete application to the customer for use on demand. This kind of service is nowadays offered by several companies such as: Google, Microsoft, etc. Platform as a Service (PaaS) offers a development environment or a layer of software which will be encapsulated in order to be offered as a service. The customers can build upon these platforms higher level of services (customer's own applications). Infrastructure as a Service (IaaS) offers storage, computing capabilities, and networking equipment for customers to deploy their own software on this infrastructure [2]. The lead companies in this area are Amazon web services and 3 Tera [13]. Out of the mentioned services, users of cloud computing benefit from a reduce cost, an increased storage offered by cloud providers, and a high flexibility of adopting and adapting applications.

IV. TESTING THE CLOUD VS. CLOUD TESTING

Before going into the details of the methodologies of testing the cloud, it is vital to understand the difference between testing the cloud and cloud testing.

A. Testing the cloud

Testing the cloud indicates the verification and the validation process of application, environment, and infrastructure that are used on demand by customers [3]. It consists of insuring that the services conform to the expectations that customers await from cloud computing. In short, testing a cloud is testing all of its offering. The traditional testing is appropriate for on-premise applications; since all the services offered on-premise should meet its functional requirements. However, it is necessary to site all the types of testing that can be carried out to test the cloud: (1) Availability testing in order to ensure that cloud services are available at all time with no interruption or downtime. (2) Security testing is needed in order to prevent unauthorized access to data. (3) Interoperability testing that is linked to cloud computing will ensure that the cloud applications and services work and execute in multiple cloud platforms and environments. In order to tackle the testing of the cloud services, a deep understanding of the technical and commercial sides of cloud testing is necessary.

B. Cloud Testing

On the other hand, cloud testing or also known as Testing as a Service (TaaS) is offering testing products, services, and tools over the cloud for customers to use it on demand. The providers of such a service offers functional and non-functional testing of various applications and products offered. So far, there are two types of cloud testing services: On-Premise and On-Demand. Testing as a service is available in both on demand and cadence/measure service (on-premise) [3]. Using Testing as a Service reduces the cost of test design, execution and maintenance. This service is a unified framework offered to make use of all the successful testing artifacts such as: test data, tools and processes. The concept of offering testing as a service over the cloud was adapted commercially by many providers offering tools such as: IBM rational and HP Mercury to customers in order to use them following the pay-per-use approach.

V. TESTING IN CLOUD – MOTIVATION

As more and more people tend to use the cloud for application use, environment and infrastructure, the validation and verification of the proper workings of these services are necessary. According to IBM statistics, cloud services reached $42 billion by the year of 2012 [2], and according to Gartner, cloud services will reach the $150 billion by 2013 [2]. These huge numbers lead to see the necessity of testing and ensuring the conformity of these services that have been snowballing for the recent years. It became crucial to assure the quality of the business services being built and deployed in the cloud. To achieve this quality goal, testing is to the rescue. Either this testing of cloud offerings is done at the premise or over the cloud; the techniques and leads to testing in cloud would stay the same. Testing in cloud will allow the users to mitigate the risks and errors when applications are deployed to the cloud. Besides, the use of cloud computing for testing means less costs and fewer expenditure.

Now that testing the offerings of the cloud is compulsory, specific techniques, methods, and tools will need to be applied to this new type of testing. The conventional testing tools were not designed to test this complex and dynamic computing environment. An adaption of old techniques and tools needs to be performed in order to make these methods fit this different type of computing environment. At some point, new tools and methods should be introduced to test some specific offering of the cloud. In this paper, the focus is on testing methodologies for software as a service (SaaS); testing cloud application on demand (pay as you go).

VI. TESTING TECHNIQUES

The cloud testing methodology is the set of techniques, tools and processes to be followed while undergoing tests for cloud services [4]. Some of these methods and techniques will be an adaptation of conventional techniques, and others were specially developed to fit the testing needs of cloud services.

While dealing with cloud computing application testing, it is necessary to take into consideration the background

technology and architecture of this paradigm. It is also important to understand that the attributes of quality in cloud computing are different from those of conventional applications. To meet the different quality attributes of cloud computing, an adaptation of some traditional testing techniques and/or the introduction of new ones were necessary. Figure 2 depicts how cloud testing techniques are divided into two main categories: cloud functional testing and cloud non-functional testing.

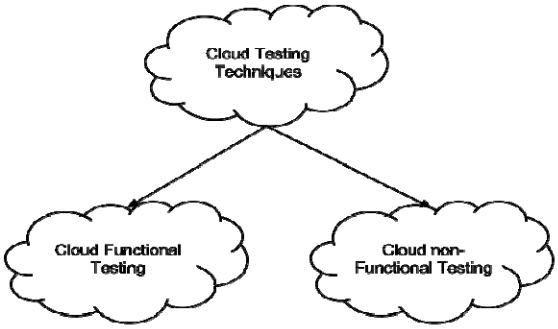

Figure 2. Cloud Testing Techniques

A. Functional Testing

Testing the requirements of the cloud application is still significant to ensure that the service offered by the cloud meets the requirement drawn by the customer. The cloud functional testing should take into consideration the imposed requirement of whether the cloud application is expected to be hosted in a public, hybrid, or private clouds [2]. Cloud functional testing is composed of a set of testing types as depicted in figure 3: availability and accessibility testing, requirement testing, security and privacy testing, and compatibility testing.

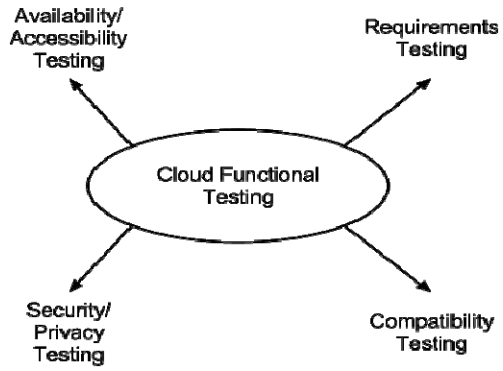

Figure 3. Cloud Functional Testing Types

The workings of functional testing should also be done in a similar environment to the one in which the application will be hosted; this might require testing in the cloud or using an environment simulation. The functionalities or attributes to be tested should conform to the cloud needs and include the following attributes: security, performance, speed, and application functionalities [4].

In addition to adapting conventional functional testing techniques to testing cloud services, testers started to increase the testing scope to include components and considerations that will shape functional testing to be specific to cloud services. One of the main concerns is privacy. The cloud functional testing should ensure the privacy of the application information when used in cloud depending on the access level of the cloud (private, public, or hybrid). At the cloud, the main functional concern is security. Testing should ensure that the data and information traversing the cloud within the application are safe and secure (confidential, integral, and authentic).

Moreover, accessibility and availability go hand in hand and should be ensured by testing. The cloud service should be available at all times and accessible to the intended users across the geographies. The testing should also ensure the compatibility and interoperability of the cloud service [2]. According to Website Performance Monitoring and Load Testing Company [12], testing should ensure the compatibility of a cloud service across various platforms, infrastructure, browser (in case of web application), and operating systems.

B. Non-functional Testing

Non-functional testing for cloud services differs from the traditional techniques. The scope of testing is wider since it includes performance, load, stress, and capacities issues that are specific to cloud services [4]. Figure 4 illustrates these different types of cloud non-functional testing.

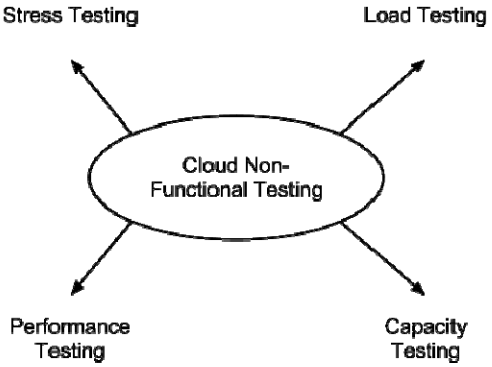

Figure 4. Cloud Non-Functional Testing

Performance testing over the cloud tests the response times of actions in the cloud service tested, finds thresholds and limitations by taking into consideration the nature of traffic on demand. Load testing tests the cloud service stability in reaction to increasing load from different location and user operations that reach multiples of hundreds. Besides, there is stress testing that is imposed by the cloud characteristics since it is necessary to test the service against breaking points to verify and validate the maximum expected capacity [2].

While the system is under load, failover test which is a type of non-functional testing should be undergone. These failover tests are done under peak anticipated load to determine how the cloud service reacts to such a condition.

These testing techniques are all used to achieve the common cloud test objectives:

- Stress objective: systems functioning at maximum load capacity and beyond.
- Performance objective: effective response time variance over time and load.
- Capacity and reliability objectives: controlling performance degradation over different load levels and long periods.

Another side of cloud computing is multi-tenancy which refers to when only one instance of the application is running on the server having multiple clients using it at the same time. Including this feature in the testing ensure that multiple users can access the service successfully without causing issues to one another [5].

VII. CLOUD TESTING METHODOLOGY

In order to test the cloud, we provide a methodology that introduces a way to undergo any kind of the testing techniques described before in a logical and effective way [5].

The methodology proposed is composed of five phases during which the tests are undertaken. The five testing phases are described as follows:

A. Test planning:

At this level, the tester should gather the requirements of the cloud service by interacting with the client. This includes categorizing the cloud application to be tested in one of the following categories [5]:

- A part of the application is migrated to the cloud.
- The application is completely migrated to the cloud.
- The application is completely built on the cloud.

The planning should take into consideration the infrastructure, network, application, data used, and end user experience. The focus of testing cloud applications needs to validate the following attributes: multi-tenancy, elasticity, security, accessibility, interoperability, and scalability.

The tester should then identify load testing and performance testing requirements. By this point, the test manager should specify the module of the cloud service to be tested and start a test strategy. Reporting this information is done by producing a test requirement document.

B. Test design:

This phase requires the testers to know all about the cloud test environment and should determine the test entries (input test cases) and the exit criteria (expected output). The testers should provision the testing environment and finalize it [5]. A test schedule is needed to keep track of the testing process and needs to be produced at this stage. It is also necessary to have test scenarios to guide testing by this stage. This phase is documented using a test plan report. By this phase, the infrastructure should be provisioned and test scenarios should be finalized. The testing team should have a specific date by which the test execution will start.

C. Test execution:

Once the test plan is validated by the quality and risk assurance manager or the test manager, the test procedure needs to be executed. The test cases are applied to the cloud service following the plan and test scenarios. Test results should be collected as the test execution goes. These results should be recorded in a test result report in order to be delivered so that the test results are considered. This phase ends when all the tests are executed and validated.

D. Test analysis:

This phase is a returning point to phase number two. The test execution may reveal that changes should be done to the test plan or the schedule. At that point, these alterations should be made into the schedule or the plan and redeliver them as a second version of that document.

E. Delivery:

At this phase, interaction between the test manager and the client occurs. All the reports are delivered to the client at this level including recommendations and performance reports. These reports contain testing metrics and results, test log, and screenshots for future use.

Figure 5 depicts a summary of the phases of cloud testing methodology.

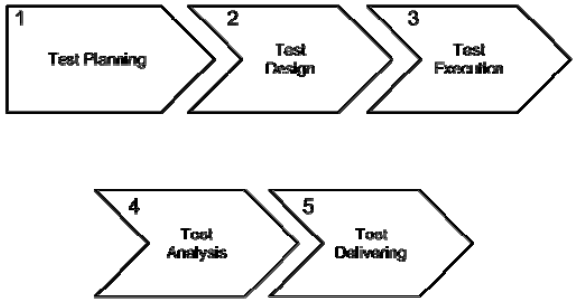

Figure 5. Cloud Testing Methodology – Steps

VIII. CLOUD TESTING : BENEFITS AND TOOLS

A. Cloud Testing Benefits:

Cloud applications and services can be tested using the specific techniques described in section V either on premise or over the cloud. In this part of the paper, we will see why it is better to go for testing as a service or cloud testing. Cloud testing is using testing as a service from a cloud provider.

Testing as a service (TaaS) offers a large pool of benefits. Testing in the cloud makes testing environment available, visible and makes its control and automation possible [5]. Using testing as a service in the cloud makes all the testing resources pooled and virtualized which provides an efficient implementation that is independent of any infrastructure. Besides, users and testers can benefit from the elastic scaling of this service which means that the testing environment can be scaled up or down depending on the user's needs. The testing cloud service offers the maintenance of a set if test beds which assures a complete assurance of the application maintenance. At last whenever we talk about services offered

at the cloud, we immediately think of the cost benefit. Testing as a service does not make the exception here. Using testing as a service over the cloud reduces the cost since the pricing policy is "pay as you use" which makes the pricing of the testing tools tailored to the user or tester's need.

Working over the cloud, the configurations and environment takes few minutes compared to the configuration on the premise that takes more than a day [5]. Over the cloud, the configuration parameters for the network can be personalized and automated which is not possible while testing on the premise where the tests are generally manual. Now that we compare the testing operations done over the cloud and the traditional one on the premise, we can conclude that the advantages of testing over the cloud outweigh testing on the premise in the old traditional way. Over the cloud, testing is offered with some tools to operate automated tests.

Table I summarizes the most important benefits of the cloud testing along with a brief description of each benefit.

TABLE I. CLOUD TESTING BENEFITS

Benefits	Description
Flexibility	Different levels of tests can be executed on separate environments → No waiting
Elastic scaling	Test environment can be scaled up or down depending on the tester's needs for resources
Reduce Cost	Pricing is tailored to the tester's resource need because of the pay as you use rule → flexible pricing

B. Commercialized Cloud Testing Tools:

Testing tools that are used to test the conventional applications needed to be re-evaluated when applied to applications hosted in a cloud in order to take into consideration network analysis, application and environment changes implied by the cloud deployment, and the interoperability of the applications towards other platforms and infrastructures [8]. Besides these conventional tools, there are specific tools that were developed to test cloud services and applications. In this part of the paper, we will go through some very distinct tools that commercialized for cloud testing.

1) Selenium

Selenium is a known and widely used open source test tool [11]. It enables users and testers to perform functional tests of their applications at the selenium Integrated and Development Environment (IDE). It is specialized on web applications and tests them over various browsers (Firefox, Chrome, and Internet Explorer) [9]. It provides functional tests, load and performance test. It reduces the test operating costs. It also provides browsing compatibility tests and multiple operating environments. In addition, it does the transformation from selenium tests to java unit tests and provides writing tests in different kind of languages such as: C#, Java, Python, etc. Selenium provides the following components: Selenium IDE, Selenium Client API, Selenium Remote Control, Selenium WebDriver, and Selenium Grid. Figure 6 shows the download link from which Selenium can be installed for Mozilla Firefox browser.

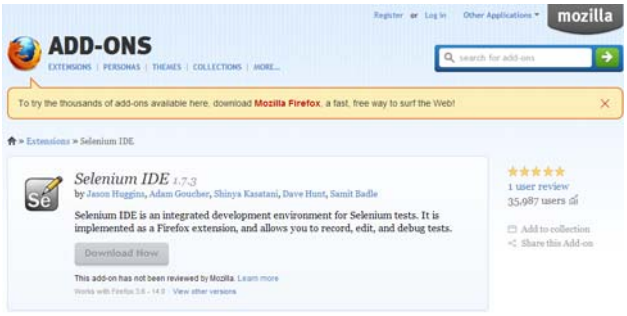

Figure 6. Downloading Selenium IDE for Mozilla Firefox

2) CloudTest

CloudTest is a cloud testing tool developed by SOASTA. It was designed to assure performance and reliability through accurate and precise load tests. It provides an integrated platform for testing web and mobile applications. It can be deployed anywhere on a single server, different physical servers or cloud servers. It maximizes scale and flexibility provided by the cloud [10]. It is also a dynamic web application that combines an innovative Ajax-based user interface and distributed web services to support test creation, test execution, and test result analysis. It provides function testing, load testing, performance testing, and web UI/ AJAX Testing. Figure 7 shows the interface of CloudTest tool developed by SOASTA.

Figure 7. CloudTest Testing Interface [10]

IX. CONCLUSION

The importance of testing the cloud is growing in terms of importance as the interest in cloud computing and the migration of applications and services to the cloud increases. Although it is possible to adapt conventional testing techniques to be used in cloud testing, and even though there are tools that could support testers in their task, the big picture of cloud testing still remains unclear. In this paper, we discussed different techniques and tools used in cloud computing and presented a methodology in terms of a roadmap that helps the tester perform his tasks in the cloud in a simpler, more logical and more efficient way. Also, from the comparison between testing on premise and testing over the cloud, we could conclude that testing over the cloud is more beneficial as it offers some useful features such as availability, visibility, automation and infrastructure independency at a reduced cost.

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