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Software Testing On the Cloud

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----------***ABSTRACT***----------
Software testing is one of the five main activities in software engineering life cycle and has always been a major challenge for many software projects. Testing software requires enormous resources; this is due to increasing technological complexities, rising cost and security issues. Over time software testing has undergone a long drawn evolution cycle, from ad-hoc practices it evolved to centralised managed test centre approach and then to creating a test centre of excellence within the organisation. The recent stage in software testing evolution is brought about by cloud computing technology. Cloud computing has caused a shift in the provision and use of computing services; away from the traditional desktop form to online services. It has impacted several research fields, including software testing, by providing ready-made computing services to save time and cost. As applications are becoming more complex, it is imperative to look at Testing as a Service solution which is cost-effective and is becoming a popular model for software testing. Cloud computing technology provides more effective, robust and scalable software testing techniques as a service through Testing as a Service model (TaaS).

Index Terms*—Cloud, Cloud testing, Testing as a Service, Software testing*

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I. INTRODUCTION

SOFTWARE Software testing is a vital aspect of software development process. It is carried out on the software to check its quality and make sure it does what it is intended to do. Software testing provides an independent and objective view of the software, which gives an understanding of the risk of its implementation. It is essential in ensuring the validity and functionality of a software product. Software testing requires a very costly and dedicated infrastructure and resources that get to be used occasionally. The expensive resources and infrastructures needed for software testing are either not used or underutilised after testing [4]. The most constant thing in software product and services is evolution. This evolution is mainly due to new technologies and user/customer requirements; one of such technologies is Cloud Computing. Cloud Computing is a computing technology in which dynamically scalable and often virtualised resources are provided as a service over the internet. Nowadays, software is growing in complexity which makes it very difficult and costly to build and maintain testing facilities that imitate real-life environment in-house. Performance and scalability testing of, for example, school registration portal and banking application require extensive resources as the systems are stressed with requests from hundreds of users in the case of the former while thousands in the case of the later within a short time interval. The developers have to set up a test harness to emulate the actions of users in the above scenario; this requires expensive computing resources. In situations like the above, cloud technology brings respite to software testing [5], cloud computing environments are used to simulate a real-world scenario. Cloud testing which refers to software testing using resources from the cloud infrastructure is obtained on-demand at a reasonable cost due to pay-per-use nature of cloud computing, and it has a lead-time that is near impossible with own data centre [4]. Virtualisation, a technology of cloud computing, was first used in creating virtual computing resources for different operating systems (OS) to test software on various platforms [4].

Initially, Cloud computing was used to carry out load and performance testing on web sites, but as the technology matures all kinds of software testing can be done on the cloud [6]. Cloud technology provides a cost-effective solution to software testing, even though it has its challenges.

1.1 CLOUD COMPUTING

NIST gave the definition of Cloud Computing as ”A model for enabling convenient and on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, application and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [10]. It is a computing style in which often virtualised and dynamically scalable computing resources are provided as a service over the internet. Emerging as a new technology in organisations

and also the next stage in internet evolution, Cloud computing offers mutually virtualised hardware and software resources that swarmed remotely and are endowed with a use-on-demand service model [2]. With Cloud Computing, computing power and infrastructure, applications and business processes can be delivered to end-user wherever and whenever needed. This is because it is bonded with Distributed computing, parallel computing and Network storage technologies [8]. Cloud computing exhibits certain essential characteristics that make it conform to the realities of the time; this includes on-demand self-service, rapid elasticity, measured services and resource pooling [9]. A typical Cloud Computing system has six-layer components: client, service, application, platform, storage and infrastructure [9]. The services provided by Cloud Computing are categorised into three categories:

- Software as a Service (SaaS): This can be described as a distribution model where a cloud computing provider hosts applications and make them available to users (customers) over the internet [9]. Instead of installing the software on the computer, the end-user simply accesses it over the internet but has no control over the infrastructure running the application. This model removes the complexity of buying, maintaining and updating a software [8]. Internet connection is the only thing needed by the customer. Examples of this service are; google apps, slack, dropbox, ZenDesk, Bigcommerce, etc [32].
- Infrastructure as a Service (IaaS): In this model, computing services like storage, processing and network are provided by IaaS provider for users to deploy and run their applications [8]. Users get the services on-demand and then deploy their system on the resources [4]. A user has the flexibility of controlling and running software over the resources [7]. Examples are Rackspace, Magento 1, AWS EC2, Google Compute Engine (GCE), etc [32].
- Platform as a Service (PaaS): In PaaS, the development environment is provided to the user by the cloud providers [7]. The users can then deploy their problem solutions on the platform. They have the privilege of developing an application that can run on the infrastructures provided but have no control over the infrastructure. However, they have absolute control over the applications they create and a degree of control over the configuration settings of the hosting environment [8]. Examples for this service category are Apache Stratos, Window Azure, OpenShift, AWS Elastic Beanstalk, etc [32].

1.1.1 TYPES OF CLOUD COMPUTING

It is very important to consider the types of cloud computing while getting a cloud service. These types of cloud computing are also referred to as the deployment model [4], and they include:

- Public cloud is a computing service provided by a cloud computing service provider to the general public. These services can be available to any user who wants to use them; all they have to do is pay for the services consumed.
- Private cloud, in this, the infrastructures are provided for the exclusive use of a single organisation. The organisation may be the owner of the infrastructure, or a third party may own them.
- Community cloud in this type, the infrastructures are provided for the use of a particular group of users from organisations that constitute the specific community.
- Hybrid cloud is the combination of two or more of the models above.

II. CLOUD TESTING

Cloud testing is a vital aspect of cloud computing and a rapidly developing area of research in Software Engineering. It refers to software testing using resources from the cloud infrastructure. In this kind of testing, software to be tested takes advantage of cloud infrastructure and technologies to simulate real-world scenario [13]. Cloud computing has affected all aspects of software life cycle, including software testing [12]. Testing as a Service (TaaS) is a terminology that gets accepted in Cloud computing just like SaaS, IaaS and PaaS; it includes both testing on (using) the cloud and testing of the cloud [1]. TaaS is a model in which testing activities are purchased or hired on customer's demand from the third party which has all the testing resources for a real-world environment. This model gains more recognition when technology and customers' requirements become more complex, and the need for high quality, error-free, easy-to-use and flexible software arises. Production of such software requires extensive testing according to specific criteria in a specific environment. Managing such an environment by organisations is very difficult and costly because every client's requirements are different, this makes hiring a third party who has the tools, simulators and hardware to test the software easier and cost-effective for organisations [14]. Before now, cloud testing was thought to be just performance or load testing, but recent researches have shown that almost all software testing can be done on the cloud [15] [3] [4]. TaaS has removed the burden of installing and maintaining the test environment and sourcing of test support; this, in turn, reduces the expenses of software production [15].

2.1 WHY CLOUD TESTING?

Cloud testing has become very important in software development nowadays, and the need to perform testing as a service (TaaS) cannot be overemphasised. In traditional software testing, the organisation needs to have the hardware and software for testing, and it is very costly to maintain the hardware and software and also to renew their licence. Cloud technology brings succour by providing a way to test the software in a very challenging and dynamic environment using the pay-as-you-use feature of the cloud, this cuts the cost of software production. [17]. Virtualisation, an important characteristic of cloud technology provides a way to test software on different environment like different operating systems, configuration and platforms [16] [17] without any installation on the user's computer. Requirements changing is an integral part of software development in this age as such, scalability feature of cloud technology plays a vital role by expanding or shrinking the resources needed for testing, which in turn adjusts the cost. Supporting-ondemand automated service of the cloud helps in providing support anytime and from anywhere [16]. Using cloud testing can help improve the efficiency of software testing by reducing the time to build the test environment.

2.2 CLOUD TESTING TOOLS

There are many tools available to test software on the cloud. These tools are categorised into three (3) base on its application; these include web-application and services, mobile application and services, and multimedia application and services [30]. Some of the tools are free while some are not; the tools are as follows:

- SOASTA CloudTest is a production performance testing tool for Web applications. It can simulate thousands of virtual public cloud infrastructure service. Today most web applications are created using an agile methodology which involves a high rate of change and frequent builds. The performance or load testing of this kind of software using traditional or conventional method is different from testing in the production environment in terms of scale, user profile, configuration and network environment. Running this test can achieve a high level of accuracy and confidence compared to conventional test [13]. This application is employed both on web and mobile application and services testing, it is also a licence software [30].
- ITKO LISA: This product is designed to improve the effectiveness of software development team, especially those involved in cloud computing and custom applications [13]. The main target of LISA is to provide virtual services and cloud-based environment of application development, verification and validation. Its developers claim it reduces software delivery time by 30% using its innovative approach to support continuous integration for development and testing [27]. The core of LISA's architecture is virtualisation technology which provides virtualised services by simulating the target system's dynamic behaviour so that they can respond as live systems [17] [13]. iTKO LISA test version is applicable to both web and multimedia applications and services testing uses for performance and load testing; it is also a commercially licence software [31].
- LOADSTORM: This is a tool that is simple in nature and less costly. It is used for load testing of webbased and mobile applications. It has features that can be used to test the functioning of a website or mobile application under extreme traffic [17]. This software is used in web-application and services for performance testing.
- BLAZE METER: This tool is used in measuring load testing and peer-to-peer performance of mobile applications, websites and application programming interface. Blaze meter provides real-time reports for performance and load tests [29]. It is also compatible with an open-source Apache JMeter, which is also a testing tool [28].
- APPTHWACK: This simulator is used for testing android, iOS and web applications on real devices. An application programming interface of Appthwack, Rest API, provides a way of testing the application through clients other than the official site. In this tool, testing can be customised, and a detailed report of the test generated [13].
- iGATE PATNI: Two organisations, iGATE and Patni, came into alliance and gave birth to one of India's biggest IT companies, iGATE Patni. This company provides TaaS solution, which is a cloud-based framework for dynamically scalable and low-cost test automation [12]. The company claims that cloudbased test solutions can help "manage a wide range of test projects of varying scale and duration, from very small test tasks to large projects involving continuous testing." [18]

2.3 TESTING PERFORMED ON THE CLOUD

The following are categories of cloud testing:

2.3.1 FUNCTIONAL TESTING

This is performed to check the functionalities of the system; the system could be meant for deployment on platforms other than cloud. It is done to make sure the system meets the user requirements, and because it captures the user requirements, it is also known as black-box testing [15] [25]. Functional testing is a quality assurance test that dealt with all the user requirements, provides the ability to make sure the system works as

expected and give both the developers and users assurance that the system meets user requirements [15] [19]. Functional testing of both internet-based and non-internet-based applications can be performed on the cloud [13]. The following are part of functional testing
[17]:

1) System Verification testing: this type of testing ensures that the system behaves as expected and works well when different modules of the system are coupled together. It makes sure that the system gives the expected output when given an input.
2) Integration Testing: In this test, multiple units or a group of units are taken and grouped into a single unit so that a test can be performed on them [16].
3) Unit testing: This test is performed on a single unit or a group of related units. It is often referred to as testing of a function. On-demand software testing service can be utilised in this type of testing. Symbolic execution concept, a cloud environment concept, facilitates automatic case generation for unit test [4].
4) Interoperability and Acceptance testing: this type of test is conducted to make sure the developed solutions meet the specified requirements and are accepted by the user. The interoperability part of the test is done to make sure the application work on different platforms and that there are no issues in moving the application from the cloud to an on-site premises [17].

2.3.2 NON-FUNCTIONAL TESTING

This testing is also known as performance testing technique; it is done to ensure that the application meets the performance expectation of the user [11]. The scope of nonfunctional requirement testing is broader in cloud testing than in traditional testing [17]; it includes:

1) Availability Testing: The major need for a cloud environment is its round-the-clock availability. There should be no downtime in such a way that it will adversely affect the customer.
2) b. Security Testing: Providing security to businesscritical data is very important for any cloud service provider providing cloud testing services due to an increase in security breaches in businesses. Identifying methods by which hackers breach the security
of systems can go a long way in guaranteeing the security of cloud solutions [11]. In doing this, there is a need for the well plan penetration testing procedure that covers the following key inputs [26]:

- Applications: there is a need for identifying and including user interfaces and Application programming interfaces (APIs).
- Data Access: there is a need for the appropriate procedure on how the penetration testing should be performed, that is either through the application layer or directly to the databases.
- Network Access: at the network level, identifying how best the network can protect the application and data.
- Virtualisation: to Identify how well the virtual machines isolate available workloads.
- Compliance: it is necessary to identify the laws and regulations needed to comply with within the application or database.
- Automation: Identify the automated penetration-testing tools that are specific to compatible with a cloud-based environment.

3) Performance testing: This is the software testing that determines whether the application works well under its estimated workload. The target of this test is not to look for bugs but to take care of all performance bottlenecks. The most important aspect of performance testing is to inspect the application's pace, firmness and scalability. Pace determines whether the application responds quickly; firmness determines whether the application remains the same under changing situations and scalability, which determines the highest user load a system can handle. Stress testing and load testing are both forms of performance testing. They require imitation of genuine load scenario. They involve testing of application's efficacy in giving consistent performance under intense circumstances such as heavy network traffic and heavy load [15]. Cloud computing solution has made imitation of genuine load and heavy network traffic very easy and less costly.

2.4 CLOUD TESTING VS CONVENTIONAL TESTING

The comparison between software testing on the cloud and traditional (conventional) software testing is explained below:

The only cost in cloud-based software testing includes testing service and engineering costs while the cost in conventional software testing includes engineering, hardware and software costs [15]. The main thing behind software testing on the cloud is to improve business value, reduce cost and its flexibility and scalability on demand while conventional software testing is rigid. It takes many days to configure testing environment in conventional software testing while it takes a few minutes to hours to configure in cloud-based testing [16]. There are well-defined standards in conventional software testing while the standards are yet to be universally defined for testing on the cloud, on the other hand, the security of data is more guaranteed in conventional

software testing than in cloud testing [11]. It takes longer to test software in traditional software testing than in cloud testing [11].

2.5 RISK OF CLOUD TESTING

Even though cloud testing is interesting and presents a very easy and economical way of testing software, some potential risks are associated with it. They include [13] [1]:

1) Lack of Standards Vendors of public clouds already have their architecture, infrastructure and operational procedure with support for a few interoperability, which produces big problems for organisations when migrating to the cloud. This is as a result of lack of unified standardisation to integrate public cloud resources with internal data centre of organisations [13].

2) Security Security of data is the most important concern of the public cloud. Since cloud testing takes place over the internet, attack(s) may happen [13]. The way a software comes to its logical information and other back-end procedures will be logged-in during the test; this makes that information vulnerable to leak either by the staff of the cloud providing company or by external attackers.

3) Performance Since many users share public cloud, there could be a time when a user has to wait for the required bandwidth that is being used by another user. Sometimes there could be disruption of service due to network failure or maintenance by the service provider.

4) Infrastructure In some cases, some providers offer limited services like storage, configuration, technology, network and bandwidth; this creates lots of difficulties when running real-time test.

5) Usage Improper usage of the cloud testing environment can increase cost, like indiscriminate encryption of data as this will consume additional CPU and memory usage, which in turn translates to cost.

III. RELATED WORK

In [20], the researchers created a survey on software testing techniques in cloud computing. They define cloud computing in general, its characteristics and the need for cloud computing. Furthermore. In [21], the authors gave a background on cloud computing and software testing on the cloud. Then, they classified the activities performed in the cloud-based testing area, defined the terminology that they used. However, both of them did not discuss the tools used in cloud testing.

The authors in [3] defined cloud computing and cloud testing and then analysed which software testing projects can be done on the cloud, why the need for software testing on the cloud and how it can be done. They did not talk about the types of cloud testing. The researchers in [4] presented a classification in the current research studies and investigated the correlation of software testing with different deployment models of cloud computing. They believed that interoperability testing presents opportunities for further research while acceptance testing has not been studied thoroughly as such needs to be well structured in order to benefit from the cloud. [17] Defined cloud testing, enumerated on cloud testing environment and types of cloud testing, why cloud testing is needed and tools for carrying out testing on the cloud. They also elaborated on the challenges of testing on the cloud; however, they did not suggest ways of overcoming the challenges. The authors in [11] gave a brief review of cloud testing techniques. The authors also talked about what cloud computing is all about, what cloud testing is and its challenges. They made a comparison between cloud testing and conventional software testing. Gao et al. [22] summarised and compared some different commercial products and solutions that support the cloud testing approaches. Some researchers like [24] [1] [14] focused on the challenges of cloud testing. The authors in [24] explained some challenges with cloud testing as security and integrity of testing data, understanding and interpreting test results and choosing testing tools. The authors in [1] highlighted the recent cloud testing architecture, tools and research issues. [14] On the other hand, believed that the perception of software testing as a service would improve the quality of software services. [23] Assert that software testing can be deemed as a service rather than be seen as a line of responsibility in software development. They are of the view, TaaS has two major aspects: a service to developers and a service to end-users. In their paper, they discussed software testing as a service from software quality assurance perspectives.

IV. CONCLUSION

Cloud computing is under constant evolution, thereby continuously bringing new opportunities and challenges to the computing services, software testing included. Software testing on the cloud is active and will continue to be an active research area in the near future. This paper gives a brief explanation of Cloud computing, discusses what software testing on the cloud is all about, why it is needed, challenges associated with it, tools for the testing and few research gaps concerning testing on the cloud have been identified in the literature. Lots of concerns were identified in this paper, like the quality and security of the software being tested on the cloud. Quality of software is a subjective attribute due to varying user expectations; therefore, there is a need to develop a methodology that will guarantee the quality of overall testing on the cloud. Security, on the other hand, is very vital in today's computing services as cloud computing is gaining more momentum, as

such, a way of guaranteeing the security of the software being tested on the cloud needs to be developed. The non-disclosure agreement between the cloud service providers and their customers that exist in the European Union countries needs to be mandatorily signed and enforced worldwide to prevent leakage of information on the service provider's side. Highly sophisticated encryption needs to be deployed by the service providers to prevent attack and theft of client's information. Comparison between cloud testing and conventional software testing was elaborated in the paper, and it shows that cloud testing even though emphasises more on non-functional and few functional tests, it has many advantages over the conventional testing. In the overall review, this paper finds that cloud testing saves time, effort, money, and there is room for more research.

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