

Software Testing Approach for Cloud Applications (STACA) – Methodology, Techniques & Tools

Md. Nurul Islam
Department of Computer Science
Jamia Millia Islamia (A Central University)
Jamia Nagar, New Delhi, India
mnislam@jmi.ac.in

S.M.K. Quadri
Department of Computer Science
Jamia Millia Islamia (A Central University)
Jamia Nagar, New Delhi, India
quadrismk@jmi.ac.in

Abstract- As earliest the software defects uncovered and fixed in STLC, the lesser the amount required to fix it. With the advent of cloud computing a lot of new opportunities for business opens, especially in the field of software testing & maintenance. The cloud testing methodology is the set of techniques, tools and process to be followed while undergoing tests for cloud service. A new methodology is proposed to test the cloud which is known as SUPeR methodology, deals with cloud security, user acceptance, performance and business requirements. Successful implementation of SUPeR methodology for cloud testing might establish a strong foundation for an organization to lead in the market. Software vulnerabilities give rise to the cyber-crime and related risk associated with it just due to lapses in security policies, which increases the security breaches in the business. Efficiency of a system can be measured in terms of performance testing. While selecting a test tool, users must keep certain characteristics of cloud testing tool in consideration, like platform compatibility, available support, flexibility and service cost. It might be possible that an organization has to deal with a number of challenges while adopting cloud computing services.

Keywords - cloud computing; cloud testing; software testing; cloud service; testing tools;

I. INTRODUCTION

Software testing is a process of assuring software quality by reducing the residual risk by certain extent after testing the software. Testing is a “risk mitigation” exercise to release the product defect free. Testing basically deals with verification and validation technique to maintain the quality of software product, its correctness and completeness.

Verification+ Validation=Software Testing

Software testing is phase of Software Development Life Cycle (SDLC). To find out the defect in Software Testing Life Cycle (STLC) earlier, it depends on the ability to adopt testing activities in early phase of STLC. The cost of removing defect prior to release the product into market is lesser than the cost of removing defect after the system goes into operation [1]. As earliest the defect uncovered and fixed in STLC, the lesser the amount required to fix it.

Evolution of Information & Communication Technology (ICT) has changed the way of living by gaining the access of technology in all concerns of life, like the way to interact & communicate, learn & educate. Similarly there is

revolutionary change occur in the software industry to adopt various kind of devices for applications. It becomes challenge for software professionals to maintain the software testing task with the pace the technology is growing to be complex, within limited IT budget and in a short span of time along with maintaining security constraints. As the business applications demands growing, it becomes challenging task to set up their own infrastructure for testing facilities that mimic real time environment. Cloud computing provides solution to meet the requirement of software testing environment by allocating testing resources over cloud environment. Thus cloud computing open up the new opportunities for software testing by reducing the cost of test setup environment for testing applications, on ‘pay-for-use’ basis of cloud infrastructure.

Testing is new opportunity as a service in the cloud, it is also known as Testing as a Service (TaaS) in Cloud. TaaS becomes the new service model along with (SaaS, PaaS, IaaS), based on the customers’ requirements & demands services are provisioned from cloud service provider which overtakes the software testing activities [2].

Cloud computing becomes next evolution after invention of internet technology. There are some special characteristics that makes the cloud computing so popular which includes: Multi-tenancy, Self-managed function capabilities, Elasticity, Scalability, Connectivity interface and technology.

II. BACKGROUND

A. Cloud Computing Overview

Cloud computing has been defined in different ways by a number of experts and scholars:

- ❖ Cloud computing is latest trend in computing where IT resources are provisioned over internet by cloud service provider to the consumer.
- ❖ The Cloud is an IT Service independent of geographical location & service delivered by cloud service providers.
- ❖ A technology through which user can access their services remotely.

- ❖ Cloud computing is one such technology that have change the way the consumer can utilize the IT resources to develop and consume the applications.

According to NIST Cloud Computing is defined as “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”. This cloud model is composed of five essential characteristics, four deployment models and three service models.

B. Essential Characteristics

These essential characteristics are the key factors used to judge whether the offered services fulfill the cloud computing criteria.

1) *On-demand self-service*: Computing resources like server execution time and network storage can automatically be provisioned to the cloud consumer without the interaction of service provider.

2) *Broad network access*: All the cloud communication is based over network services and access through devices like (mobile phones, tablets, laptops, and workstations).

3) *Resource pooling*: Computing resources are shared and accessed by multiple consumer beyond the boundary of location, at higher level location can be specified (i.e. country, state, or data centre), computing resources includes processing, storage, memory and network bandwidth.

4) *Rapid elasticity*: Computing Capabilities can automatically be provisioned and released elastically.

5) *Measured service*: Resources are controlled and optimized automatically in Cloud system, to leveraging the measuring capability (e.g., storage, processing, bandwidth, active user accounts). It is used to provide the transparency for both cloud provider and consumer for utilized resources to assess the usage (e.g. monitored, controlled, audited, and reported).

C. Service Models

1) *Software as a Service (SaaS)*: This service is provided to the consumer for accessing the cloud application with the help web browser or program interface. Users need not require to install the application. Consumer does not have control over the cloud infrastructure including network, servers, operating systems, storage. e.g. Google Docs, G-mail etc. Advantage: Ease of use (Users need only a browser to access the services), Cost (Data Centre resides with in the cloud), Scalability. Disadvantage: Security Concerns.

2) *Platform as a Service (PaaS)*: This service is provided to the consumer for deploying their own applications over cloud infrastructure, supporting tools like (programming languages, libraries, services) are being provided by cloud service provider. Consumer does not manage the underlying infrastructure including (e.g. network, servers, operating systems, or storage), but has certain degree of control over the deployed applications. e.g. Google App Engine (GAE). Advantage: Low cost of ownership, lower administrative overhead, increased business and IT alignment, scalable

solution; Disadvantage: Data security, Challenges to integrating Cloud Solution.

3) *Infrastructure as a Service (IaaS)*: This service is provided to the consumer with all computing resources and infrastructure includes (processing, storage and networks) to deploy and run its application. Consumer have maximum possible control over capabilities such as OS, applications, storage and limited control over selected networking resources(host firewalls). e.g. Amazon Elastic Compute Cloud (EC2).

Cloud Computing stack also includes additional service layers namely Human as a Service (HaaS) and supporting services.

Human as a Service (HaaS) service is provided by group of people dispersed over geographical location using the cloud technology to achieve a target as a group for specific task. uTest is as suitable example for Crowdsourcing, professional group of tester may avail this service on demand as a community to provide testing solution to its customer [3].

Cloud computing boost the organization to sustain their services by enabling highly efficient backup and recovery system for the use in service crisis by establishing flexible and scalable platform, providing high performance services and its availability, accessibility and reliability [4].

D. Deployment Models

There are four types of cloud models are defined by NIST, based on its characteristic and functionalities:

1) *Private cloud*: This cloud model is dedicated to serve single organization exclusively and may be deployed and managed within customer premises or at service providers' end.

2) *Public cloud*: This Cloud model is open to all for use. It is owned and managed by medium and large organizations usually at the cloud providers' premises.

3) *Hybrid cloud*: Hybrid cloud is a mixture of two or more cloud models (public, community, or private) to maintain the portability of applications as well as serve data.

4) *Community cloud*: This Cloud model is exclusively used by several organizations for any specific purpose to share common concerns (e.g., mission, policy, security requirements) and needs. It may be owned and managed by one of the organizations in the community. It may exist on or off premises.

According to NIST, five key players engaged in the whole cloud computing services architecture: cloud provider, cloud consumer, cloud carrier, cloud auditor and cloud broker.

Cloud Consumer - A person or organization that avails the services (SaaS, PaaS, and IaaS) from service providers. Cloud Provider- A person, organization committed to provide services to cloud consumers. Cloud Broker- An entity serves as middle man or vendor that maintains relationship between the cloud consumer and cloud provider and takes care of cloud services its use, performance and delivery. Cloud Auditor- A cloud auditor may be the consumer or any independent, those who takes care of the cloud service

assessment, its functioning, performance and security. Cloud Carrier- The intermediary that provides connectivity and transport of cloud services from cloud providers to cloud consumers.

This paper is organized in the following sections. Section 3 discusses related to cloud testing lifecycle, its statistics and phases. Section 4 presents the methodology for cloud testing development, SUPerB methodology is used to validate the cloud application w.r.t its security, user acceptance, performance along with fulfilling the business requirements. Section 5 describes the software testing techniques includes functional & non-functional and ability testing. Section 6 briefly discusses about the selection of software testing tools.

III. CLOUD TESTING LIFECYCLE

Cloud testing is a process of software testing based on the resources and infrastructure provided by cloud computing. Resources may be any capabilities like hardware, software, applications, infrastructure to carry out the test to meets the expected performance, scalability and on-demand services.

Some useful statistics of cloud providers and consumers [5]:

- It is expected that in 2018 cloud service market will grow by 21.4% (\$186.4 billion) in comparison with 2017 which was (\$153.5 billion) worldwide, according to Gartner, Inc.
- It is expected that ○ cloud services partially will fully adopt by 2021. Gartner, Inc.
- It is expected that by 2021 only 10 service providers will cover 70% of IaaS demands, which was 50% in 2016. Gartner, Inc.
- 71.3% of all cloud services are used by 5 top service provider (Salesforce, OneDrive, Exchange Online, SharePoint Online and Yammer) are enterprise-focused and 28.7% are consumer ones. The top 5 consumer apps are YouTube, Facebook, Twitter, LinkedIn and Pinterest. [6].

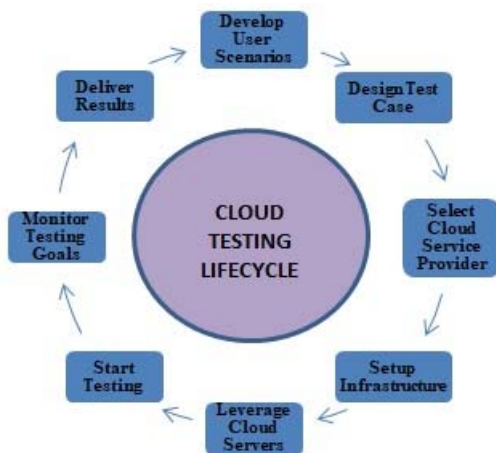


Fig.-1 Cloud Testing Lifecycle

Cloud testing lifecycle provides the following testing activities. To accomplish the test task smoothly jobs are assigned as per their experience to carry out the expected result. Test admin plays the key role to manage the complete testing lifecycle [7]. Test scenarios and test cases may be designed and generated by test admin. Automated test script may be generated by the test professionals, if required. Once the cloud service provider is selected, users account may be created for testers. Then cloud service provider may setup the test environment, tester may proceed the test. On completion of the test process, cloud testing providers deliver the result. Activities of cloud testing lifecycle are as follows:

A. Develop User Scenarios

It is the actual requirement of organizations and users to ensure that the application under test is fully verified by different stakeholders. Following steps may be considered while creating test scenarios [8].

- Explore the complete requirement documents for the system under test.
- Collect all related requirements relevant for users, like objectives and actions.
- Different scenarios can be proposed for specification requirements justifying the software features.
- Traceability matrix is designed for every possible test scenarios verifying the users' requirement.
- The test scenarios can be verified by test expert and users.

B. Design Test Cases

A Test case is set of actions performed on application to verify its functionality. e.g. Consider login functionality of application with few suitable cases:

- Test Case 1: Test the response on entering Invalid User Id & Invalid Password.
- Test Case 2: Test the response on entering valid User Id & Valid Password.
- Test Case 3: Test the response by press login button by keeping the password blank.

Following steps may be considered while drafting test cases:

- The documents for requirement to be tested.
- The details of the system to be tested.
- All the test related setup are to be tested such as OS, software version, hardware requirement, security related concern and data files etc.
- While considering the expected result, keep in mind the input, action and output.

C. Select Cloud Service Provider

Every organization has their own specific requirement and evaluation criteria, based on those criteria an organization select the cloud provider. There are some common characteristics for assessing the quality of service provider [9].

These characteristics may help to choose a service provider that will be beneficial for an organization to deliver best quality service for which cloud is expected.

- Service assurance & commitment.
- Security policies & recovery mechanism.

- Migration policy & user support.
- Technological soundness.
- Cloud certification & standard.
- Service availability, performance and reliability.
- Service level contract & Agreements.

D. Setup Infrastructure

While installing cloud infrastructure, architect must consider the key requirement needs to be address the cloud strategy [10].

- Heterogeneous system support – The existing IT infrastructure must be integrated by the cloud service provider to fulfill the data center's need.
- Dynamic Work Load and Resource Management – Services and capabilities can be dynamically provisioned on priorities basis to transfer the workloads to meet out the Service Level Agreement (SLAs).
- Service Management – Ease of service functionalities that can be quickly managed and deployed by the end user.
- Reliability, Availability and Security – A system or a service can be considered as reliable if it is available in crisis or available in all circumstances, failure of one of more components can't hamper the complete service. Resource pooling, sharing and multi-tenancy are cloud characteristic that shares the resources over cloud needs to be integrated with highly secure mechanism to protect the transaction.
- Integration with Data Centre Management Tools – Existing IT data centers needs to be integrated with cloud service providers' solutions. Like virtualization tools i.e. VMware and Citrix, for large scale data centre its IBM and HP.
- User Interfaces (Administrator, Developers and End User) – It is administrator interface that provide single window for all physical resources, virtual instances, service offerings, multiple cloud users, help in monitoring and managing the services offered by the cloud service provider.

E. Leverage Cloud Servers

Cloud computing is boon for IT industry if it is used properly. Selecting right IT management support providers may surely help to improve business transaction. To maximize the benefits of cloud computing, keep in mind the following tips [11].

- Budget cloud computing investment carefully.
- Introduce functionality via cloud computing.
- Boost accessibility with cloud computing.
- Prepared for disasters with cloud computing.

F. Start Testing

Testing team or test admin can proceed testing. e.g. test tool like 'Selenium WebDriver' or 'TestComplete' an automation tool operated with Amazon cloud service, user can build automated test flow. Below Steps may help to Automat test studio perform the actions [12].

- Establish connection with Amazon EC2
- Cloud instances initiated for testing use.
- Test files and data uploaded for user of instance.

- Use TestComple to execute the test instance.
- Test result exported to download it from instance to local drive.
- Kill the instance.

G. Monitor Testing Goals

After the test execution the testing team will compare the expected outcome and actual outcome to find out the variation from the goal.

H. Deliver Results

Finally the execution results are documented, considering all the test cases executed and updated, defect logs are created, preparing test closure report duly signed by the client.

Responsibilities of Cloud Consumers and Cloud Providers:

TABLE I. Cloud services, users and activities with example

Services	Service user	Usages	Consumer activities	Providers activities	Consumers examples
SaaS	Business users, Individuals	To complete business tasks	Use application or service for business process operations.	Installation, maintenance & support for applications over cloud	ERP, CRM, Human resource, Content Management, E-mail, Financial Management etc.
PaaS	Developers & deployers	Create & deploy applications & services	Develop, test, deploy & manage applications hosted in cloud	Provide & manage cloud infrastructure, middleware for consumers	Business intelligence, Database, Application development, Deployment testing & integration etc.
IaaS	System Manager	Create platform & services for testing applications	Install, manage & monitor services for IT Infrastructure.	Provide & manage physical storage, network & hosting environment & infrastructure.	Storage, Service Management, Backup & Recovery etc.

IV. METHODOLOGY FOR CLOUD TEST DEVELOPMENT

The purpose of methodology for test development is to make sure that test outcomes, behaves and looks as expected, by formulating the strategies and approaches to test a particular product. Software testing methodology is a collective approach to make sure the product is fully tested and trusted. Software testing methodology is concern with testing of unit that may form the basis for integration testing of modules which may further extended toward the system testing, along with the non-functional and management testing.

According to the IDC survey, applications availability, performance and security are the major priority for IT service providers. The cloud architecture is fully depends on the services in which security and performance are the major challenges at all service models.

The ‘Scalability as a Service’ is coined by the Gartner group by considering the demands of consumer from cloud computing. Real time resource provisioning is key characteristics’ for which the cloud services are in demand. The benefits of scalability and elasticity can be availed by virtualization technique that can be provisioned or released the Virtual Machine (VM) services on demand [13].

Even though the cloud services become indispensable for organizations, cloud security is still a major challenge for both cloud consumer and provider. What consumer expect from the service provider? It might be a highly secured system that fulfill all business requirements to achieving higher performance while executing the functionalities of the system. So a software or application is considered to be successful if it is accepted by users i.e. user acceptance, strong security mechanism, excellent performance and achieving the goals by capturing the business requirements. To achieve these goals a new testing methodology have been proposed, which will consider all such features known as SUPerB methodology for cloud testing. SUPerB is new term coined for test methodology for cloud computing which covers both functional and non-functional aspect of testing techniques. SUPerB methodology deals with Security, User acceptance, Performance and Business requirements of cloud testing.

- **Security:** It validate that all the security mechanism are properly implemented. It addresses the policies that remove the vulnerabilities in software.
- **User Acceptance:** Whatever be the effort imposed on a particular product it is useless, until it is not accepted by the users. It covers all basic criteria’s that fulfill the users’ requirements.
- **Performance:** Performance of a system can be measured in terms of working efficiency, its characteristics can be measured in the terms of load or stress transaction frequency, throughput or response time.
- **Business Requirements:** Goal of applications functionalities can only be achieved by capturing the business requirements of an organization. It includes availability testing, usability testing and interface testing.

PASS methodology of cloud testing covers only non-functional aspect of testing like Performance, Availability, Security and scalability [13].

Cloud Computing is often considered as a mechanism to execute performance test or load test for Software as a Service (SaaS) as utility computing ,they also discussed about various cloud testing method performed on cloud [14].The cloud testing methodology is the set of techniques, tools and process to be followed while undergoing tests for cloud service [15].

V. SOFTWARE TESTING TECHNIQUES

The purposes of conducting the test using various techniques are to ensure the quality of product that are

expected, it is basically categories in three groups: Functional or Essential testing, Non-Functional or Desirable and Ability or management testing techniques.

A. Functional or essential testing

Cloud based software testing refers to the testing and measurement by leveraging cloud technologies and solution to assure the quality of cloud applications including functional services, business process and system performance as well as scalability of cloud[2]. Cloud testing can be perform for anyone from anywhere. Functional testing follows all the process to maintain and assure the quality of product by considering all the features and functions of a system S/W&H/W [7].

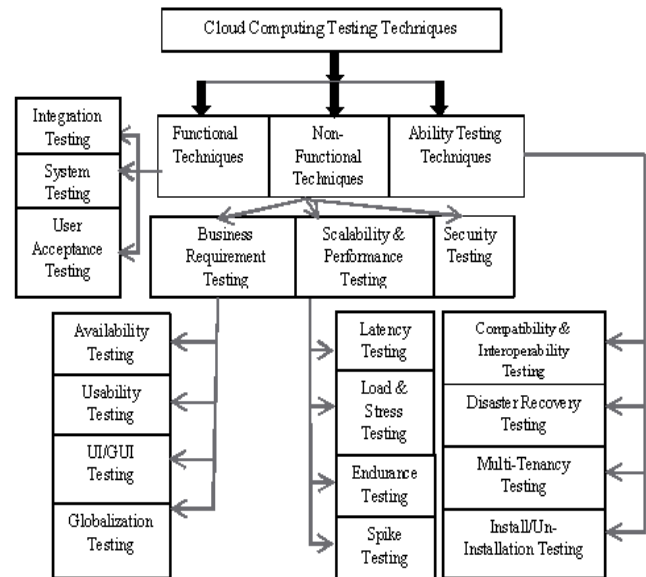


Fig. 2: Cloud Testing Techniques

1) **System Testing:** System testing is used to evaluate entire system to ensure the expected result by testing the functionality from end-to-end. It is critical to prove the system functions while designing the system components, work together with expected input and output results high quality cloud system [2]. It is a process of functional testing used to test application behavior.

2) **Integration Testing:** The whole segment of application can be grouped together through integration to ensure the expected behavior. Integration testing become very demanding for cloud computing since the computing capabilities(services, storage, data, network) are shared among different vendors, considering the cloud common characteristics like multi-tenancy, connectivity interface and scalability. It is helpful to test based on users scenarios, like logging into application.

3) **User Acceptance Testing:** User acceptance testing is mainly used to assess the product functionality before came into market. It includes all the basic business criteria that meet the user’s requirement. The QA team may set pre-written scenarios and test cases that may be used to test the application. This testing may be carried out at both location ‘in-house’ or ‘off –Campus’.

B. Non-Functional Testing

The purpose of conducting this test is to make sure the non-functional attributes of web applications that meet the desired requirements, such as user interface, performance and security. In cloud, the applications versatility degree is much more extensive than in ordinary execution testing systems [16].

1) *Business Requirement Testing*: Organizations may successfully achieve their goal of application functionalities, depends on capturing and examining the cloud business requirements prior to making decision to migrate on cloud environment. Business requirement assessment is utmost important for an organization going to adopt the cloud technology, such requirements can be achieved by walk-through, reviews (formal, informal), meeting and conducting workshops [19].

2) *Availability Testing*: This type of cloud testing is performed to check whether the service may available in all consequences (Load, Stress, Security lapses) from the vendor or cloud service provider round the clock.

3) *Usability Testing*: This type of cloud testing used to examine the users' understanding and way to operate the application. Usability testing consider the five aspect of testing - learnability, efficiency, satisfaction, memorability, and errors.

4) *Globalization testing*: This type of cloud testing is used to checking whether the cloud application is globally accepted, having facility to change language and setting according to geographical location [18].

5) *Security Testing*: It is one of the most indispensable and demanding task for/on/over (foo) the cloud services. It is used to validate whether all the security mechanism are properly implemented in the software or not. Software vulnerabilities give rise to the cyber-crime and related risk associated with it just due to lapses in security policies which increases the security breaches in the business. It is suggested that the application security may be designed and developed with the same pace with functional requirements. Security testing may consider while testing the application its confidentiality, integrity, authentication, availability and nonrepudiation.

6) *Scalability & Performance Testing*: Scalability is used to measure enhanced/released capabilities. It is used to make sure the services have the flexible capability of resource allocation as per requirement. Performance testing is mainly concern with quality of service, efficiency, and to resolved bottleneck of the product rather finding new bugs. Its characteristics can be measured in the form of load or stress testing, transaction frequency, throughput or response time. Different sources may contribute to degrade the applications performance e.g. congestion in network, client/users' awareness, poor connectivity.

7) *Load & Stress Testing*: Load testing is used to test application by flooding the excess number of users concurrently to access the application and to verify its performance. It is used to analyze the functionality and performance of web application. It handles the situation of

application crash, dead lock or resource starvation. Stress testing is used to test the applications response beyond its peak load. By performing stress testing we may be able to find the point where the system gets failure under certain load condition. It is used to check the optimal behavior of application in varying condition.

C. Ability Testing Techniques or Management Testing

Ability or Management Testing is used to ensure that user may be capable to receive the desired services from cloud vendor/provider 'on-demand'. The term management is used as it performs the management like services as Compatibility & Interoperability, Disaster Recovery, Multi-tenancy.

1) *Compatibility & Interoperability Testing*: It is used to check whether the application is compatible with different operating environment with varying needs of software and hardware. Since the cloud capabilities may be hired from different stakeholder. Interoperability means system is capable to work in flexible conditions without any issue, not only with different platforms but it may work seamlessly when moving from one cloud infrastructure to another.

2) *Disaster Recovery Testing*: Cloud services may be available round the clock without any interruption, if any kind of failure occur in the system like network services outages, break down due to over loaded users, system failure, then how long it will take to recognize the failure, identify the failure and how long it will take to recover all kind of losses including data. Since disaster is unpredictable, the purpose of disaster recovery testing ensures the loss is minimum and recovered in minimum possible time.

3) *Multi-tenancy Testing*: Since Cloud offering are shared among the different users, multi-tenancy ensure that, when a single instances are used by multiple users, then how it maintains the control over data and imposing the sufficient security mechanism. A cloud offering are supposed to be thoroughly validated for every consumer/client while a number clients are active at any particular point of time [17].

VI. SOFTWARE TESTING TOOLS

These are the certain characteristics for selecting cloud testing tools such as Platform compatibility, available support, flexibility and service cost.

1) *Platform Compatibility*: It is a process of verifying the tool's ability to interact with various devices.

2) *Available Support*: Compare the support provided from service providing team in terms of behavior, expertise and commitment toward solution in case of any technical hurdles occur at client site.

3) *Flexibility*: Check whether the tools' considered for support covers the following administrative needs.

4) *Cost of Ownership*: Assess the long term investment of purchasing the computing resources.

A. While comparing the automation testing tools tries to find out the answer of the following:

- (i) Whether the tools are operated over multiple platforms?
- (ii) Whether the tool is remotely accessible?
- (iii) Can the tool be used across multiple platforms for single test execution?

(iv)How many scripting engines does the tool support?
 (v)Whether the tool is GUI or object oriented? (vi)Whether the tools support automation? (vii)Cost of purchasing is reliable? (viii)Whether tools fulfill the functional requirement?

B. Tools are categorized as per cloud testing techniques i.e. Functionality, Performance, Security and Interface [18].

1) *Web Automation Tools*: Selenium IDE, Selenium WebDriver, Sikuli Script, Visual Studio (CodedUI).

2) *Mobile Automation Tools*: Appium, Calabash, Robotium.

3) *Desktop Automation Tools*: Specflow, Cucumber.

4) *Service Automation Tools*: SoapUI, HttpWebRequest.

5) *Performance Testing Tools*: Load & Stress.

(a) Qtest (b) Apache JMeter (c) LoadUI (d) Load Runner (e) NeoLoad (f) Loadster (g) Load impact

6) *Web Functional/Regression Testing Tools*: (a) Selenium (b) Katalon Studio (c) TestComplete (d) QTP (UFT) (e) CasperJS (f) Screenster (g) SoapUI (h) Sahi

7) *Web Site Security Testing Tools*: (a) Site-Digger (b) Brakeman (c) NTO-Spider (d) NMap (f) OWASP

8) *Cross Browser Testing Tools* (a) IETester (b) Browsera (c) IE NetRenderer.

CONCLUSION

Cloud computing open up the new opportunities for testing the web applications. It is highly demanded service among cloud applications. At the same time cloud services experiences a lots of challenges and issues which needs to be resolved. A new methodology known as SUPerB is proposed for cloud computing which covers both functional and non-function aspect of testing techniques. This paper will help to provide the in-depth approach for test automation, its techniques and tools, as well as to design a framework for test automation. The contribution of this paper is to explore all the phases of the cloud testing life cycle explicitly.

REFERENCES

[1] R. Rajani and P. Oak, Software testing: Effective methods, tools and techniques. New Delhi: Tata McGraw-Hill, 2010, pp. 9 & 49.
 [2] J. Gao, X. Bai, and W.-T. Tsai, "Cloud Testing- Issues, Challenges, Needs and Practice," Software engineering: an international Journal (SeiJ), vol.1, no.1, pp. 9–23, Sep. 2011.
 [3] L. M. Riungu, O. Taipale, and K. Smolander, "Research Issues for Software Testing in the Cloud," IEEE Second International Conference on Cloud Computing Technology and Science, 2010.
 [4] M. N. Qadri and S. Quadri, "Mapping cloud computing in university e-governance system," International Journal of Intelligent Computing and Cybernetics, vol. 11, no. 1, pp. 141–162, Dec. 2018.
 [5] "Gartner Forecasts Worldwide Public Cloud Revenue to Grow 21.4 Percent in 2018," Gartner IT Glossary. [Online]. Available: <https://www.gartner.com/newsroom/id/3871416>.

[6] A. Kohgadai, "12 Must-Know Statistics on Cloud Usage in the Enterprise," Skyhigh, [Online]. Available: <https://www.skyhighnetworks.com/cloud-security-blog/12-must-know-statistics-on-cloud-usage-in-the-enterprise/>.
 [7] A. Shrivastva, S. Gupta, and R. Tiwari, "Cloud based Testing Techniques (CTT)," International Journal of Computer Applications, vol. 104, no. 5, pp. 24–29, 2014.
 [8] "How to Write Test Cases: Sample Template with Examples," Meet Guru99 - Free Training Tutorials & Video for IT Courses. [Online]. Available: <https://www.guru99.com/test-case.html>.
 [9] "8 criteria to ensure you select the right cloud service provider," The Cloud and the EU GDPR: Six Steps to Compliance | Cloud industry forum. [Online]. Available: <https://www.cloudindustryforum.org/content/8-criteria-ensure-you-select-right-cloud-service-provider>.
 [10] S. Liang, "7 Requirements for Building Your Cloud Infrastructure," CIO, 21-Dec-2010. [Online]. Available: <https://www.cio.com/article/2412506/cloud-computing/cloud-computing-7-requirements-for-building-your-cloud-infrastructure.html>.
 [11] "5 Ways to Leverage Cloud Computing for Your Business," Network Installation, Network Cabling, Wireless Networking.[Online].Available: <https://www.csm-corp.com/5-ways-to-leverage-cloud-computing-for-your-business/>.
 [12] "Cloud Test Automation Tutorial," Security Scans Types | ReadyAPI Documentation. [Online]. Available: <https://support.smartbear.com/articles/abs/cloud-test-automation-tutorial/>.
 [13] GPS/GNSS History | Spirent Federal Systems. [Online]. Available: <https://www.spirentfederal.com/ip/blog/>.
 [14] T. Siddiqui, and R. Ahmad, "Cloud Testing - A systematic Review," International Research Journal of Engineering and Technology (IRJET), vol. 02, no. 03, pp. 397-406, 2015.
 [15] B. Falah, A-E El Ayadi and O. Atif, "Roadmap to Testing the Cloud Techniques, Methodology, and Tools". IJCSET, pp.84-89, Mar. 2013. Available at: <http://www.ijcset.net>.
 [16] V.K. Shah, G. Ghosh and A. Kende, "A Comparative Study on Various Software Testing Techniques in Cloud Computing," International Journal of Research in Engineering & Advanced Technology (IJRETAT) , vol. 4, no. 2 , pp. 93-99, Apr-May 2016.
 [17] S.R.M, "Cloud Computing Testing Backgrounds and challenges based on its environment" Research & Reviews, [Online]. Available: <http://www.rroij.com/open-access/cloud-computing-testing-backgrounds-and-challenges-based-on-its-environment-7-12.php?aid=38863>.
 [18] H. Hyuseinov and J. Kyuchukova, "A Complete Automated Software Testing Tools Comparison," Mentor Mate.[Online].Available: <https://mentormate.com/blog/complete-guide-automated-software-testing-tools-comparison/>.
 [19] "Testing Techniques and its Challenges in a Cloud Computing" [Online]. Available: <http://www.thesij.com/papers/CSEA/2013/July-August/CSEA-0103550201.pdf>.