

An Investigative Study of Software Testing in the Cloud

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Abstract— Cloud computing has become a new computing paradigm that effects several different research fields, including software testing. Testing cloud applications has its intrinsic features which demand for novel testing methods and tools. We all are aware that cloud computing also facilitates and provides opportunities for the development of more effective and scalable software testing techniques. With this paper we present a systematic survey of published results attained by the union of these two research fields. We provide an viewpoint about contributions, trends, opportunities, challenges and possible research directions. We have provided a review of software testing over the cloud literature.

Key words: Cloud Computing; Software Testing; Cloud Testing; Cloud-Based Software Testing; Testing Cloud Services; Testing As A Service

I. INTRODUCTION

Cloud computing has indisputably become a computing paradigm that helps the development and usage of highly flexible, elastic services on-demand, and very high speed network access. Those attributes are forcing many organizations to move their businesses to a cloud supported platform.

Software testing has been one of the practice areas for migrating to cloud environment. Virtualization, which is an heart of the technology of cloud computing, was initially used for quickly creating virtual computing resources with different operating systems (OS) to test software applications on various platforms. In order to test a new software generally requires costly server, storage and network devices only for a limited time. These computing resources are either not used or underutilized after testing, thus resulting extra cost on budget.

In few application domains, software testing requires huge resources. For instance, to test the performance and scalability of a banking application, the system must be put under stress with requests from millions of users in a short span of time. This is a realistic scenario that should be tested due to the reason that people rush to their bank accounts regularly on every payday. Mimicking such a scenario would mean that the provider has to set up a test harness which includes the user database to emulate the actions of millions of users. Similarly, mobile application providers frequently have to deal with maintaining the quality of their services over various combinations of platforms.

The computing platforms may have various browser technologies with different back-end support running on various mobile OS. To provide a reliable service, cloud computing service vendors have to test their services on all these platforms.

Test automation remains a hot topic to be considered when software testing is considered over the cloud. There are various test automation tools in the market,

which address different requirements in a testing life-cycle which includes, automated test data generation, test case design, test execution and test evaluation. We try our level best to investigate in a fair manner that will motivate the migration of those tools to the cloud.

Yet another major feature to be considered while considering Cloud computing is economies of scale. It has provision for a pay-per-use type of service, thus eliminating the upfront monetary investment in such cases. Development teams can benefit from utilizing test tools when they need it and as much as they need it, thus saving considerable amount of license fees.

II. CLOUD COMPUTING

Cloud computing is a relatively new term, which defines a new concept for service delivery in almost all aspect of computing. It provides 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 quickly provisioned and released with minimal management effort or service provider interaction.

Cloud computing has been powered by the developments in technology virtualization, distributed computing mechanisms, robust utility computing, web and software services technologies. It is fundamentally based on two key concepts.

- 1) The first one is Service-Oriented Architecture (SOA), which is the delivery of an integrated and configured suite of functions to an end-user. The functions can be both loosely or tightly coupled. SOA allows common users to easily search, use and release services on-demand and at a desired quality level. Workflows allow integration of services to deliver a business-valued application.
- 2) The second key term is virtualization. Virtualization implements abstraction and isolation of lower level functionalities and hardware, which increases portability of higher level functions which are sharable and aggregation of the physical resources is also made possible.

A. Essential Features

Cloud computing shows the following essential features.

- On-demand self-service is a wonderful characteristic for consumers because it provides them the flexibility of provisioning a service exactly when they need it. The services provided over the cloud are called as measured services which mean that consumers will pay for how much service they consume, the amount of service is measurable; so there is no need to reserve huge and redundant computing resources.
- Rapid elasticity permits the users to easily and quickly provision new services and release them, enabling them to pay for what they utilize and how much they use it. Cloud computing has remuneration at the providers'

end also. A cloud computing provider saves its computing resources in a location in order to serve multiple consumers by incorporating a *multi-tenant* provisioning model.

B. Service Delivery Models

There exists multiple definitions for delivery models of cloud computing services three are widely used in the field.

- Software as a Service (SaaS) delivery model is termed as providing software applications/services over cloud infrastructure for users. These applications are accessible from various technological platforms through an easy-to-use client interface such as a web browser.
- Platform as a Service (PaaS) delivery model helps users to deploy their solutions to the cloud by instrumenting platforms such as application servers and database services provided by the Cloud Platform Provider.
- 3. Infrastructure as a Service (IaaS) is the bottom level of service model in cloud delivery models. In IaaS consumers gather computing services and can deploy their own custom-configured systems in these resources potentially duplicating their own existing infrastructures.

C. Deployment Models

The deployment model of a cloud platform is necessary to consider when delivering or procuring on-line services. Public cloud infrastructures are provisioned for use by any consumer; infrastructure exists in the proximity of the provider. Private cloud infrastructure is provisioned for exclusive use of a single organization and can be owned by a single organization, a third party, or some aggregation of them. Community cloud infrastructure is provisioned for exclusive use by a specific community of users from companies that constitute the particular community. Hybrid cloud is a composition of two or more of the models above.

D. Software Testing and Virtualization

Software testing is an integral part of the software development life cycle that span over all the development phases. One of the core difficulties in software testing is deploying and maintaining a real-world test platform at the beginning of an application project. Virtualization technology has been used in testing various software since its inception in 1960's. IBM's CP-40 project might be considered as the pioneer of virtualization technology.

Developments in network infrastructure triggered a burst in Web-based service delivery. They define on-line software testing as a model of software testing used to test an application provided as a service to customers across the web. This model advocates a demand-driven software testing market by enabling organizations and individuals to provide and acquire testing services on-demand. The concepts that affect software testing as an on-line service are domain knowledge, skills, infrastructure, pricing, communication and security. Cloud testing cuts cost related to installing and maintaining testing environment. It also develops a new market where the providers and consumers can reach skilled test engineers on-demand.

III. RESEARCH METHODOLOGY

The main purpose of this paper is to study research activities done in cloud-based testing area identify any gaps or open issues that remain, and address those issues at a high level. There are currently two different issues on "cloud testing" and both cases can be considered as valid cases of "Testing as a Service":

- 1) Testing the cloud-resident applications
- 2) Providing testing software as services in the cloud
- 3) Mechanisms which include both of the above, i.e., testing cloud-resident applications by means of cloud-resident testing services.

The concept deals with how applications perform in terms of functional correctness and how fast when they are transformed to cloud. The latter deals with changing of the testing process itself into the cloud. This idea enabled us to differentiate the problem domains of the literature. After investigating the available literature we could identify major problem domains which in turn depend on the problem/solution domain. The problem domains that we identify enable us to make a difference between whether the Cloud testing service is provisioned for cloud-resident applications or for other platforms (e.g., mobile applications, desktop applications etc.).

During our development of this paper, we identified the following keywords and phrases to be useful:

- Cloud application validation: This means the application software in cloud which is used by end user should behave as per the user's intuition following vendor policy.
- Cloud application verification: This includes the security testing for finding out how robust the cloud software stands against threats from malicious users.
- Software testing cloud: Testing the whole cloud component treating it as a Software under Test (SUT). Traditional methods of testing like black box testing should be performed.
- Testing cloud applications: Acceptable amount of Cloud application validation and verification constitutes this terminology.
- Verification cloud: This is generation of a application which resides in cloud and has the ability to test the functionality of the other cloud services. The verification cloud should be designed in such a way that it cannot be downloaded from cloud servers of respective vendors.

It can be observed easily that testing in desktop application contains static elements for verification, validation but in cloud testing the participating entities are highly dynamic in nature. This challenge has to be overcome facing the dynamism in the cloud environment.

- Cloud Test Case Design: This refers to construction of the functional test cases by considering aspects like nature of the input data and desired nature of outcome after test execution.
- Cloud Test Case Generation: This includes series of test cases for execution with same data in one cycle. Duplicate test cases should not be generated, this should be taken care of.
- Cloud Test case Execution: Running the test cases available after test case generation wrt to correct

environment like supported by hardware, other software complainant to business agreement between service provider and end user.

- Cloud Test case Evaluation: This refers to finding the quality of the test cases developed for testing the cloud applications. Evaluation may be done on basis of various metrics like fault detection ability or finding large number of bugs in minimum amount of time etc. The literature available till now does not have a reliable metric for test case evaluation in cloud computing.

IV. CONCLUSION

Cloud computing and software testing are most challenging fields where popular research is being actively pursued. Conventional software testing strategies are being adapted for the cloud. But the main challenge remains for testing in the Cloud because cloud computing itself is under constant evolution, subsequently introducing new opportunities and challenges for software testing research. In this paper, we have presented a concise report on current research studies, identified deficiencies in the available literature and investigated the correlation of software testing with different deployment models of cloud computing. Researchers in this field can extract information from our paper. It has been found that acceptance testing is an open research area for testing over the cloud. Testing Cloud task management can also be among the potential areas for further research. We came to know that interoperability testing needs more importance as a research area to make sure that reliable services can be composed by means of integrating services from different service delivery models. The future research will be focusing on filling these gaps for achieving a comprehensive verification and validation model in cloud computing. We will specifically work on issues that facilitate cloud as a platform for acceptance and unit testing, and further more study should be carried on for the optimization of the existing automated test tools for even more feasibility use over the cloud.

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