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Going beyond Conventional Software Testing: Cloud Testing

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ABSTRACT
Software testing is an important part of software engineering life cycle. Testing requires add-on resources that are often not readily available, contributing to an inefficient testing process. Running large no. of test cases can consume a lot of time and resources, often precluding their use in an interactive setting.
Cloud computing has changed the way of obtaining computing resources, and also has given a new direction to manage and deliver computing services, technologies, and solutions. Cloud computing creates an opportunity that offers testing as a service (TaaS) for SaaS and clouds. This lead to a new phase shift in conventional testing thereby identifying new issues, challenges and needs in software testing, particular in testing clouds and cloud-based applications. This paper gives a comprehensive view on cloud testing and cloud-based application testing that can be the possible answers to the common questions in conventional testing & clouds. Also, it examines the major issues, challenges, and needs in testing cloud-based software applications.

Keywords - Cloud testing, cloud-based software testing, testing cloud services, TaaS, SaaS, IaaS, PaaS.

1. INTRODUCTION
Cloud computing received significant role in the way computation and services to customers, For example, it changes the way of providing and managing computing resources, such as CPUs, databases, and storage systems. Today, leading players, such as Amazon, Google, IBM, Microsoft, and Salesforce.com offer their cloud infrastructure for services.
Cloud computing is a business and economical model. This model has been successfully deployed and executed for various commodities since its inception, but in recent years it has been more into IT products & services.

Consider the example of automobile to understand the usage of Cloud Computing. Take the case of carversus taxi cab. Both are vehicles for carrying people from one place to another. The difference is the business model for the services provided by them.

Owner of the car pay for the fuel & maintenance, and the car offer services solely to the owner. On the other hand, services provided by a taxi cab are "Travel as a Service". The taxi driver own the cab. As a customer, one has to pay to travel to use, there is no need of maintenance. The responsibility lies with the driver. This is why the Cloud is synonymous with "On Demand". You pay only on demand (when to require) it.

Fig 1. Taxi as "Travel as a Service"

IT industry over a period of time offers wide range of services – on demand. We often come across "Games as a service", "Java as a service", "Storage as a service" and even more.
Cloud computing received significant attention recently as it changes the way computation and services to customers, For example, it changes the way of providing and managing computing resources, such as CPUs, databases, and storage systems. Today, leading players, such as Amazon, Google, IBM, Microsoft, and Salesforce.com offer their cloud infrastructure for services.
A recent study of Market Research Media forecasts that U.S. government spending on cloud computing is entering an explosive growth phase at about 40% CAGR over the next six years. Expenditure will pass $7 billion by 2015. Merrill Lynch estimates that within the next five years, the annual global market for cloud computing will surge to $95 billion. Cloud computing not only brings new business opportunities, but also causes some major impacts on software testing and maintenance.
A major impact is known as Testing as a Service (TaaS) in Clouds. TaaS cloud infrastructures is considered as a new business and service model, in which a provider undertakes software testing

activities of a given application system in a cloud infrastructure for customers as a service based on their demands.

Although there are many published papers discussing cloud architectures, technologies, and models, design, and management, cloud testing and TaaS are still new subjects in software testing community. Hence, test engineers and quality assurance managers encountered many issues and challenges in testing modern clouds and cloud-based applications. Typical questions are listed below.

- What is cloud testing? And what are its special test process and scope, requirements and features?
- What types of cloud testing, environments, and forms do we need to perform for SaaSs/clouds and cloud-based applications?
- What are the major differences between conventional software testing and cloud-based software testing?
- What are the special requirements and distinct features of cloud-based software testing?
- What are the special issues, and challenges, and needs in cloud testing?
- What are the current practice, tools, and major players?

This paper is written to attempt to answer these questions.

The paper introduces basic concepts about cloud testing, including its scope, objectives, distinct requirements, features, and benefits. Also a comparative view towards conventional testing and cloud testing is also considered.

2. UNDERSTANDING CLOUD TESTING

Cloud Computing provides a cost-effective and flexible means through which scalable computing power and diverse services (computer hardware and software resources, networks and computing infrastructures), diverse application services, business processes to personal intelligence and collaboration are delivered as services to large-scale global users whenever and wherever they need.

Cloud computing is the next stage of the Internet evolution. A typical cloud must have several distinct properties: elasticity and scalability, multi-tenancy, self-managed function capabilities, service billing and metering functions, connectivity interfaces and technologies. In addition, a cloud supports large scale user accesses at distributed locations over the Internet, offers on-demand application services at anytime, and provides both virtual and/or physical appliances for customers. There are three types of clouds:

a) Private clouds, which are internal clouds based on a private network behind a firewall;
b) Public clouds, which are the clouds with public accessible services over the Internet; and
c) Hybrid clouds, which are made of different types of clouds, including public and private clouds.

2.1 WHAT IS CLOUD TESTING?

Cloud Testing is a form of software testing in which Web applications that leverage Cloud computing environments ("cloud") seek to simulate real-world user traffic as a means of load testing and stress testing web sites.

The ability and costs to simulate Web traffic for software testing purposes has been an inhibitor to overall Web reliability."

In short, cloud-based software testing refers to testing and measurement activities on a cloud-based environment and infrastructure by leveraging cloud technologies and solutions. It has three major objectives.

- ❖ To assure the quality of cloud-based applications deployed in a cloud, including their functional services, business processes, and system performance as well as scalability based on a set of application-based system requirements in a cloud.
- ❖ To validate software as a service (SaaS) in a cloud environment, including software performance, scalability, security and measurement based on certain economic scales and pre-defined SLAs.
- ❖ To check the provided automatic cloud-based functional services, for example auto-provisioned functions.

To test cloud compatibility and inter-operation capability between SaaS and applications in a cloud infrastructure, for example, checking the APIs of SaaS and their cloud connectivity to others.

2.2 WHY IS CLOUD TESTING IMPORTANT?

Comparing with current software testing, cloud-based testing has several unique advantages listed below.

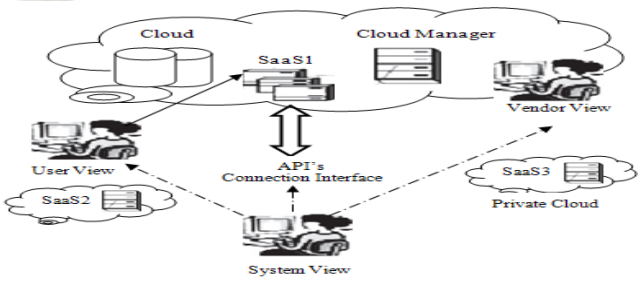


Figure 2: Different Views for Cloud-based Software Testing

- ✓ Reduce costs by leveraging with computing resources in clouds – This refers to effectively using virtualized resources and shared cloud infrastructure to eliminate required computer resources and licensed software costs in a test laboratory.
- ✓ Take the advantage of on-demand test services (by a third-party) to conduct large-scale and effective real-time online validation for internet-based software in clouds.
- ✓ Easily leverage scalable cloud system infrastructure to test and evaluate system (SaaS/Cloud/Application) performance and scalability.
- ✓ Reduce its capital and licensing expenses as much as 50% to 75% using virtualized resources.
- ✓ Reduce operating and labor costs as much as 30% to 50% by automating development and testing resource provisioning and configuration.
- ✓ Shorten its development and testing setup time from weeks to minutes.
- ✓ Improve product quality and reduce the detected defects by as much as 15% to 30%.

2.3. FORMS OF CLOUD-BASED SOFTWARE TESTING

There are four different forms of cloud-based software testing. Each of them has different focuses and objectives.

- Testing a SaaS in a cloud – It assures the quality of a SaaS in a cloud based on its functional and non-functional service requirements.

- Testing of a cloud – It validates the quality of a cloud from an external view based on the provided cloud specified capabilities and service features. Cloud and SaaS vendors as well as end users are interested in carrying on this type of testing.

- Testing inside a cloud - It checks the quality of a cloud from an internal view based on the internal infrastructures of a cloud and specified cloud capabilities. Only cloud vendors can perform this type of testing since they have accesses to internal infrastructures and connections between its internal SaaS(s) and automatic capabilities, security, management and monitor.

- Testing over clouds – It tests cloud-based service applications over clouds, including private, public, and hybrid clouds based on system-level application service requirements and specifications.

Figure 2 shows three different views of software testing in a cloud environment.

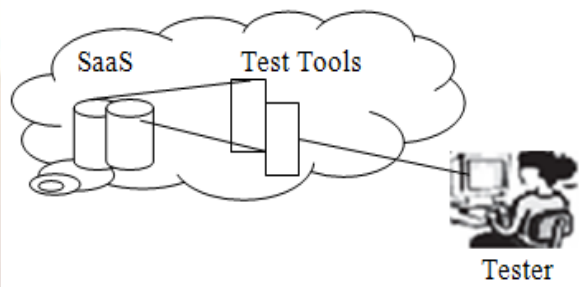
The first is the vendor view, which presents the testing view from the engineers of a cloud vendor. They perform vendor-oriented software testing tasks. The next is the user view, which presents the consumer-oriented testing view from cloud-based application users through web-based user interfaces. They conduct testing and QA jobs to assure the quality of provided application services in a system-oriented test view in a given cloud infrastructure where different cloud-based applications may interact with each other. They need to perform different testing tasks to assure the quality of the cloud-based application systems over clouds, such as cloud-based application integration, end-to-end system function testing, system performance and scalability over different clouds.

Figure 3, shows three types of cloud environment:

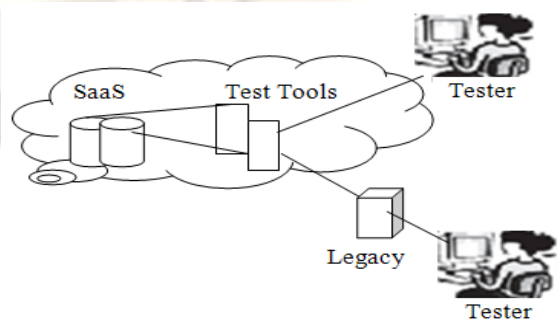
- ➢ A cloud-based enterprise test environment, in which application vendors deploy web-based applications in a cloud to validate their quality in a cloud infrastructure.

- ➢ A private/public cloud test environment, in which vendors deploy SaaS applications SaaS in a private (or public) cloud to validate their quality.

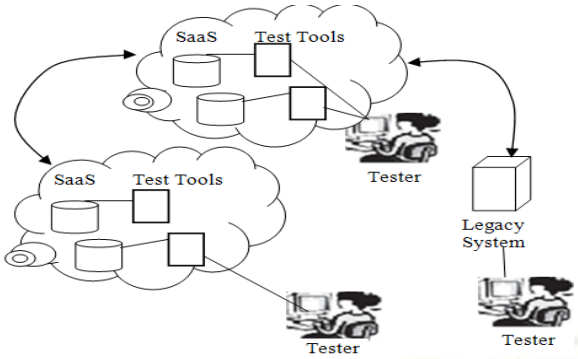
- ➢ A hybrid cloud test environment, in which vendors deploy cloud-based applications on a hybrid cloud infrastructure to check their quality.



(a) Private / Public Cloud Test Environment



(b) Cloud based Enterprise Test Environment



(c) Hybrid Cloud Test Environment

Figure 3: Different Cloud Test Environment

Different tasks performed in three types of cloud testing below.

- ✓ **Cloud/SaaS-oriented testing** - This type of testing activities usually is performed inside a cloud by engineers of cloud/SaaS vendors. The primary objective is to assure the quality of the provided service functions offered in a cloud (or a SaaS program). These engineers must go through unit testing, integration, system function validation and regression testing, as well as performance and scalability evaluation. Since clouds and SaaS usually provide certain service APIs and connectivity interfaces to their customers, it is required task for engineers to validate these APIs and connectivity in a cloud environment. In addition, testing cloud-based or SaaS-based security services and functional features must be tested. Furthermore, performance testing and scalability evaluation in a cloud is very important and critical to cloud/SaaS vendors because this assures the quality of cloud elasticity to support SaaS and cloud services inside a cloud.

- ✓ **Online-based application testing on a cloud** - This type of testing activities usually is performed to check online application systems on a cloud by using with cloud-based large-scale traffic and user accesses. This is a common usage of cloud technology to help current online application vendors to conduct online-based system function testing and performance evaluation on a cloud by taking the advantage of cloud environment so that diverse and scalable computing resources in a cloud can be used without using any in-house test laboratory. When applications are connected with legacy systems, the quality of the connectivity between the legacy systems and the under-test application deployed on a cloud must be validated.

- ✓ **Cloud-based application testing over clouds** - This type of testing refers to the engineering activities performed to assure the quality of a cloud-based application crossing different clouds. When applications are developed to be deployed and executed over different clouds, new testing tasks are needed to assure its quality. Unlike the previous two types, the primary testing objective here is to assure the quality of the end-to-end application over clouds.

This suggests that the system-level integration, function validation, performance evaluation, and scalability measurement must cope with different cloud technologies. This definitely complicates the tasks for checking system compatibility, interoperability, and connectivity between different clouds.

3. CLOUD TESTING

Unlike testing conventional web-based software, testing clouds and cloud-based software has several unique testing quality assurance objectives, requirements, and distinct features.

3.1 Features in Cloud Testing

There are four new requirements and features in cloud testing.

- **Cloud-based testing environment**
  This refers to use a selected cloud infrastructure (or platform) as a base to form a test bed equipped with diverse and scalable computing resources, system infrastructures, and licensed tools, which are allocated using auto-provision based on static/dynamic requests. Both virtual and physical computing resources can be included and deployed inside.
- **Service-level-agreements (SLAs)**
  In cloud computing, all clouds, SaaS, and applications usually provide diverse services to their end users and customers with well-defined service-level-agreement. Naturally, these agreements will become a part of testing and quality assurance requirements, such as system reliability, availability, security, and performance agreements.

- **Price models and service billing**
  Since utility computing is one of basic concepts and features in cloud computing, so price models and utility billing becomes basic parts and service for testing as a service. In other words, required computing resources and infrastructures (including tools), and testing task services will be charged based on pre-defined cost models and • Large-scale cloud-based data and traffic simulation - Applying and simulating large-scale online user accesses and traffic data (or messages) in connectivity interfaces is necessary in cloud testing, particularly in system-level function validation and performance testing.

3.2 Testing as a Service (TaaS)

There are several distinct features in cloud testing. One of them is testing as a service (TaaS). This is an innovative concept, and it refers to providing static/dynamic on-demand testing services in/on/over clouds for the third-parties at any time and all time (365/7/24).

One of the primary objectives is to reduce the IT budget of businesses to focus their core businesses by outsource software testing tasks to a third party using TaaS service model. TaaS involves the on-demand test execution of well-defined suites of test material, generally on an outsourced basis. The execution can be performed either on client site or remotely from the outsourced providers test lab/facilities.

TaaS has received wide attention due to its advantage in its scalable testing environment, cost reduction, utility-based service models, and on-demand testing services.

The work-flow of TaaS includes the following major TaaS service capabilities.

- TaaS process management, which offers test project management and process control.
- QoS requirements management, which supports book keeping and modeling of software testing and QoS requirements, including quality assurance modeling.
- Test environment service, which provides on-demand test environment services to establish the required virtual (or physical) cloud-based computing resources and infrastructures, as well as the necessary tools.
- Test solution service, which offers diverse systematic testing solutions (such as, test modeling and test methods), and test-ware generation and management services.
- Test simulation service, which establishes on-demand test simulation environments with selected facilitates (such as tools), and supports the necessary test data/message generation.
- On-demand test service, which provides on-demand test execution services based on selected schedules and test wares.
- Tracking and monitor service, which allows test engineers to track and monitor diverse program behaviors at different levels in/on/over clouds for the testing purpose.
- TaaS pricing and billing, which enables TaaS vendors to offer customers with selectable testing service contracts based pre-defined pricing models, and billing service.

Figure 4: Workflow of TaaS

3.3 Cloud Testing VS. Conventional Software Testing

Table 1 below show comparison between Cloud Testing and conventional software testing based on different parameters.

Parameter	Internet-Based Software Testing (i.e. Distributed/Web-Based System Infrastructure)	Cloud-Based Software Testing
Primary Testing Objectives	Assure the quality of system functions and performance based on the given specifications Check usability, compatibility, interoperability.	Assure the quality of functions and performance of SaaS, Clouds, and applications by leveraging a cloud environment. Assure the quality of cloud elasticity & scalability based a SLA.
Testing as a service	In-house internal software testing as engineering tasks.	Real-time on-demand testing service offered by a third-party. Online testing service based on a pre-defined SLA.
Testing Environment	A pre-fixed and configured test environment in a test lab.	An open public test environment with diverse computing resources. A scalable private test environment in a test lab.
Testing Costs.	Required hardware costs and software (license) costs Engineering costs in a test process.	- Based on pre-defined SLA's - pay as you test (Cloud testing cost) - Engineering cost in SaaS/cloud/application vendors.
Test simulation	- Simulated online user access - Simulated online traffic data	- Virtual /Online user access simulation - Virtual /Online traffic data simulation
Functional Testing	- Validating functions (unit and system) as well as its features	- SaaS/Cloud service functions - End-to-end application functions
Integration Testing	- Function based - Component based - Architecture based	- SaaS based integration in cloud - SaaS integration between clouds - End to end integration over clouds
Security testing	- Function based security features - User privacy - Client / server based security - Process based security.	- SaaS/Cloud security features, - User privacy in diverse web clients - SaaS/Cloud API and connectivity security - Security testing with virtual /real-time tests in vendor's cloud
Scalability & performance testing	- Performed a fixed test environment - Simulated user access and test data. - Online monitor and evaluation.	- Performed in a scalable test environment based on SLA - Apply both virtual and real time online test data - Online monitor, validate and measurement.

Table 1: Comparison between Cloud testing and Conventional software testing

4. Major Issues in Cloud Testing

There are a number of major issues; some of them are discussed below:

- **On-demand test environment construction** – How to set up a testing environment systematically (or automatically) for on-demand testing services in a cloud? Although the current cloud technologies support automatic provision of required computing resources for each SaaS (or application) in a cloud, there are no supporting solutions to assist engineers to set up a required test environment in a cloud using a cost-effective way.

- **Scalability and performance testing** - Although many published papers discuss system performance testing and scalability evaluation in the past two decades, most of them address issues and solutions in conventional distributed software or web-based software systems. Since these systems are set up with pre-configured system resources and infrastructures, performance testing and scalability evaluation are usually conducted in a static and pre-fixed system environment (such as a test lab.), so the existing evaluation metrics, frameworks, and solutions did not consider the special features in cloud testing, such as dynamic scalability, scalable testing environments, SLA-based requirements, and cost-models.

- **Testing security and measurement in clouds** – Security testing has becoming a hot research subject with many open questions in current software testing community. Since security becomes a major concern inside clouds and security services become a necessary part in modern SaaS and cloud technology, engineers must deal the issues and challenges in security validation and quality assurance for SaaS and clouds.

- **Integration testing in clouds** - One of the major reasons is the existing software and components are developed without Enabling technology and solution to support and facilitate systematic software integration. In a cloud infrastructure, engineers must deal with integration of different SaaS and applications in/over clouds in a black-box view based on their provided APIs and connectivity protocols.

- **On-demand testing issues and challenges** - In TaaS, software testing services must be controlled and managed based on on-demand testing requests. This kind of new testing service model raised several issues and challenges.

- **Regression testing issues and challenges** - Supporting on-demand software validation in clouds must address the regression testing issues and challenges caused by software changes and bug-fixing. However, most existing research in software regression testing pays most attention to re-test a specific software version in a pre-configured test environment.

5. CONCLUSION AND FUTURE WORK

Cloud testing is becoming a hot research topic in cloud computing and software engineering community. As the advance of cloud technology and testing as services, more research work must be done to address the open issues and challenges in cloud testing and TaaS. More innovative testing techniques and solutions, and QoS standards are needed to support on-demand testing services in a scalable cloud infrastructure. The paper includes discussion about cloud testing in terms of its special requirements, benefits, and features as well as the comparison with conventional testing.

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