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A Refined Quality of Service Engineering Model for Cloud based Applications

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Abstract
Recent years have witnessed the growing usage of cloud computing services in different aspects as it promises a wide change in how information is stored and used to run applications. This emerging trend has rapidly become a new computing paradigm of great interest for the software practitioner community. All cloud based applications needs to be delivered in higher level of quality than conventional applications due to the wide risk it faces. As cloud based applications are highly dynamic and versatile, therefore conditions can alter very quickly based on changes in user requirements. However, while searching for a standardized quality metric for cloud based applications, it has become evident that there is a dire need of a unified approach in this regard. From software quality perspective, the final quality of the cloud services is directly influenced by the quality of each service. Therefore, there is a high demand for devising a quality model for cloud application developers to measure and evaluate these services. This research critically evaluates the current quality models for cloud based applications and how these are implemented, deployed and integrated within various cloud services. Finally, by identifying gaps and current requirements, authors propose a refined quality of service engineering model for the cloud computing applications based on the existing cloud platforms.

Keywords: *Quality of Service Engineering, Cloud Computing, Software Quality, Quality of Service Model.*

I. INTRODUCTION

Recent years have witnessed the growing usage of cloud computing services in different aspects as it promises a wide change in how information will be stored and used to run applications. The cloud gives the ability of accessing and managing application and data via the internet from anywhere and at any time, no individual computer is needed as all the services are hosted in the cloud paradigm [1].

Cloud computing is a new technology which combine web technologies, computing paradigm and self-management capabilities. It shapes the future of software development as it promises to reduce the cost of operation and delivery, effective use of resources and reduce the development costs [2].

This emerging trend has rapidly become a new computing paradigm of great interest for the software practitioner community. As many cloud vendors introduce different integrated services, one such of these services is the Software-as-a-Service (SaaS) model in which all applications are hosted as a service in the cloud to customers who access them via the Internet. Another is Platform-as-a-Service (PaaS) which offers a platform for applications' development and deployment. SaaS and PaaS holds the potential to cause a big change in the development and delivery of software applications.

All cloud based applications needs to be delivered in higher level of quality than conventional applications due to the wide risk it faces. As cloud

based applications are highly dynamic and versatile, therefore conditions can change very quickly based on changes in user requirements.

However, while searching for a standardized quality metric for cloud based applications, it has become evident that currently there is no unified approach available for the said task. From software quality perspective, the final quality of the cloud services is directly influenced by the quality of each service. Therefore, there is a high demand for devising a quality model for cloud application developers to measure and evaluate these services.

II. LITERATURE REVIEW

Cloud computing has been widely recognized by the IT industry in the last few years and is gaining further importance as the technology is getting more advanced. As a result, it has become increasingly important for businesses and technical and research institutes to find ways of measuring the quality of their cloud based computer applications.

A. Quality of Service Issues in Cloud Computing Adoption

Ensuring the quality of the cloud service has become the main concern for both service providers and consumers. Consumers have become more dependent on the suppliers in most cases of cloud computing arrangement. Consumers are often unable to access data or operate a service due to poor performance, non-availability, and other related issues. It is essential for the cloud providers to build consumers' confidence as several quality issues need to be addressed in order to guarantee high quality service provision [3].

1) Lack of Standards

Being an emergent technology, cloud computing encounters numerous challenges in several contexts. Standards are needed towards a consistent adoption of cloud in several areas as a new way of delivering service. The cloud community is facing high demand for a set of open standards to keep up with the wide growth of cloud [4].

Lack of standardization in cloud context has become a wide significant aspect for many organizations and researchers. Several key aspects like lack of interoperability and interconnection between and within cloud providers, no standard for majority of data format implementations, no standard for establishing a security framework for different cloud environments requires focused attention for the formulation of open standards. Cloud development and deployment standards are pretty much independent from the current software engineering standards in practice. In the context of quality measurement and evaluation, there is no such standard to be followed when services are evaluated and tested [5,6].

Various organizations are focusing on developing cloud standards. Individual researchers are also seeking on developing such frameworks and models [4,7]. Following are some of the prominent organizations determined in the formulation of cloud standards:

a. National Institute of Standards and Technology (NIST)

It is focusing more on the US federal government cloud standards including cloud interface and integration among different aspects [8].

b. Distributed Management Task Force (DMTF)

Cloud management, operation across cloud, and enterprise platform are the main concerns of DMTF in developing cloud standards. System virtualization, security mechanisms and developing environments are also included within the DMTF area of developing cloud standards [9].

c. Cloud Computing Interoperability Forum (CCIF)

CCIF focuses on the global cloud community establishment where organizations can work together for a wide adoption of integrated cloud services [10].

d. Open Cloud Consortium (OCC)

OCC focuses on the performance improvement in various cloud environments across geographically distributed data storage. The Open Testbed is a

framework implemented by OCC for managing a testing sandbox for cloud computing [11].

2) Formal Agreements

In order to guaranty the quality of their service, cloud providers need to create a Service Level Agreement (SLA). It is a contract between a service requester (consumer) and a service supplier (cloud provider) that makes both parties agree on the terms and conditions regarding the quality of the requested service [12,13].

According to [13], the current SLA provided by the cloud venders has failed in establishing confidence among the service clients and service providers with support for only simple metric. [13] proposed a resource-level metric for identifying guarantees on CPU performance. This resource-level metric can be utilized within the infrastructure of the cloud providers for ensuring high quality of service performance but without taking in consideration of the integration with other services.

[14] presented some criteria and recommended it to be taken in consideration when designing a SLA for a particular service in the cloud computing environment as part of the main negotiation strategy between the service consumer and the provider. They recommend it to be used in SLA drafting for better trust and reliability. This framework is a good tool of reliability for selecting a high quality service, however it takes on consideration of the non-functional requirements only. Moreover, a test process for this framework needs to be simulated in order to be clarified.

3) Security of Data

Cloud service providers present service level agreements (SLA) as an assurance to their clients regarding the security of their data by describing different levels of security features and their complexity.

A survey done by [15] illustrate that security and privacy issues within the cloud concerns mostly five aspects of security including availability, confidentiality, data integrity, control and audit of data. According to the survey results, these five security aspects require more strategic approach of deployment within the cloud computing adoption. Moreover, new contracts between service clients and providers need to be adapted to change the way in dealing with privacy and security in the cloud.

[16] in their survey demonstrate the technical security issues by underlying several practices within the cloud including browser security, cloud service integrity and binding issues and identify the flood attacks on cloud systems.

B. Existing Measurements Methods, Models, and Frameworks for the Quality of Cloud Service

Majority of the available works are not catering for the requirements of cloud services but for certain targets only such as SOA (Service-oriented architecture) based systems. One such quality model for SOA is the QVDP model proposed by [17] as an integrated model for the Service-Oriented Systems to specify the expected quality levels of service delivery. However, [17] quality model considers SOA based applications only and identifies issues related to these services at a very conceptual level. Moreover, he also admits that this quality model is just to serve as a reference point for further developments in this area.

[18] have emphasized the issue of quality of service in distributing paradigms such as cloud computing, and have highlighted some of the challenges that are presented in the quality of service in cloud computing applications. They have indicated some research direction and have identified some research problems related to the quality of cloud services. However, they have not proposed any quality model for such cloud services in their research.

Technical Director EMEA at Precise Software [19], describes the inappropriateness of the traditional quality of service metric for measuring the cloud based services because of the highly dynamic nature and high agility of these services. Moreover, this traditional metric does not incorporate this fact that a cloud based application deployed once is aimed to be there permanently.

In his research [20] has proposed a quality model for evaluating Software-as-a-Service, but this model addresses only the very essential features of SaaS and simply provides a way to evaluate the services in a quantitative manner. This quality model tackles only one service without analyzing its influence and impact on the integration of other cloud services.

Another significant work that focuses on the quality of web services is by [21]. He has attempted to introduce a more standard approach for providing quality of service but its scope is very narrow as it focuses on role based admission control to achieve higher customer satisfaction.

Because of the reasons stated above, it has become increasingly difficult to evaluate and measure the quality of cloud services and provide judgment on its effectiveness. Therefore, this research aims to provide a more suitable quality model to evaluate and measure such services.

III. Analysis and Discussion

The analyses phase uncovered the effectiveness of best practices for harnessing the data from both primary and secondary data collection methods in order to meet the requirement of a highly accurate model. A semi-structured interview method was applied as primary data collecting method. To conduct these interviews, a number of experts with wide experience and knowledge of cloud based applications are approached. The participants included experts from cloud based application developers, cloud based application testers, software quality assurance engineers and data center engineers. A total of eight in-depth interview sessions had been conducted with cloud computing experts for the purpose of this research.

Various features and concepts within the stated domain are identified and reviewed based on the analyzed data. The findings of the analyzed data show a wide set of features and characteristics required for cloud-based applications, in addition to the factors that had been effecting the development life cycle of such applications. A process called coding method is utilized to generate patterns from the collected data. Using this coding approach, the collected data is categorized as per following themes:

- Features and characteristics of cloud computing that underlay the cloud-based applications' importance
- The adoption of traditional quality models and standards for the cloud as well as the impact of quality attributes for cloud applications
- Cloud-based applications' development and deployment challenges
- Confidentiality of Data within Highly Available and Reliable Operational Services
- The Need for Developing Elastic and Stateless Applications for the Cloud
- Performance Evaluation of Cloud-based Applications and Service Maintenance

The impact of different quality factors within various quality standards and models was analyzed and presented for effective artefact design criteria. In addition, the challenges of the current development and deployment approach were analyzed within various cloud platforms for determining the implementation mechanism for deriving the quality metrics of the proposed model. Various experts and specialists identified the need of an updated quality model because of the technology features and characteristics required at cloud. In addition to that, different cloud computing models such as software as a service, and platform as a service were reviewed separately in context of available quality models. The analyzed data proved that cloud based applications require extensively new supporting quality factors that differentiate them from the conventional software.

IV. Proposed Quality of Service Engineering Model for Cloud Based Applications

Based on the review and analysis of the research data, a quality model is proposed for measuring and evaluating cloud-based applications in which various measurements methods from standards and other quality models have been adopted for a valid

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measurement metrics that can be used for measuring the quality of the cloud services for cloud-based applications. Goal-Questions-Metrics (GSM) approach proposed by [22] had been adopted within the implementation of the proposed model's design levels, the design of the artefact includes five level hierarchy model with four mapping integration between each adjacent level for identified derivation relationship. Fig. 1 shows the five levels that describe the artefact design.

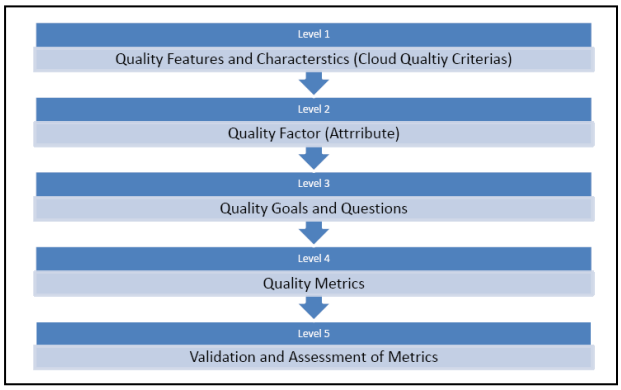

Figure 1: Artefact Design

The implemented artefact design shown above will be depicted with each set of quality features and characteristics of the cloud computing that identified within the analysis of research data, each implementation with each set of quality features and characteristics will be transformed into quality attribute in which quality goals will be established and each goal determined with one or more quality questions, each question then will be derived into quality metric for measuring the quality of the cloud-based application, these metric will be derived into quantitative manner. Each level of the designed artefact will be explained with parallel implementation for each level for the proposed quality model.

The identified features and characteristics of the cloud computing paradigm from the analyzed data has been transformed and mapped to more specific attributes. The derivation of the attributes is based on reviewing and analyzing the current software quality standards and models that are identified within the gathered data. The quality requirements and factors of the cloud computing should be extended based on the identified features to cover all the quality attributes.

The proposed transformation schema is shown in Fig. 2 in which the features and characteristics that had been presented within the analysis of the gathered data are mapped as a quality criterion to a number of six attributes that reflect the cloud-based applications major quality requirements definition, and the influence of most quality factors toward the development of such cloud-based applications and services.

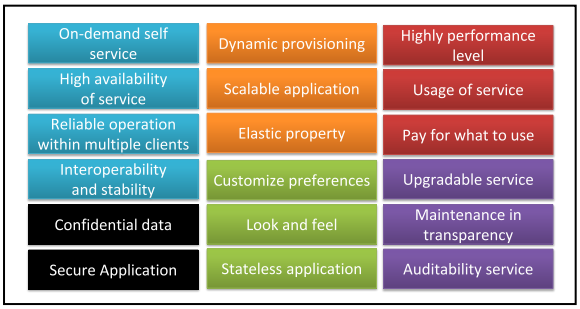

Figure 2: Quality Attributes Transformation Schema

Each of the derived attributes defines the necessity of its quality criteria in manner of a valid and reliable cloud-based applications, in addition to the mapping relationship, the derived attributes will be explained in order for a better understanding of how these attributes be measured based on its measurement areas. Definition of each attribute will be establish, the Goal-Question-Metric paradigm will be followed for identifying goals for each attributes, then questions will formulate in quantifiable terms, and metric could be then derived based on those goals and questions for each attributes.

Fig. 3 shows the derived quality attributes of the developed model. Six attributes have been identified: reliability, scalability, customizability, efficiency, confidentiality, and maintainability.

1) Reliability

Reliability of the cloud define the operational behavior of the cloud-based applications, it is more in context of the idea on how a number of multi clients utilizing the same service without effecting the operation of this service; mean time to failure and failure rate are both variables describing reliability by classifying service failure and the reason for

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unreliable state. In more mathematical manner, reliability of the cloud-based application can be defined as it is the probability that the utilized cloud service performs accurately to its required functions and operations within a given period of time for a defined specification, hence the define specification for the cloud environment is mostly depending on the size of the instant that the utilize service based on, and the cloud platform in which the service deploy into, in addition to the supporting services. In addition to that, availability of the cloud can be defined as a part of reliability of the cloud, since if there is no availability it definitely leads to unreliable cloud application.

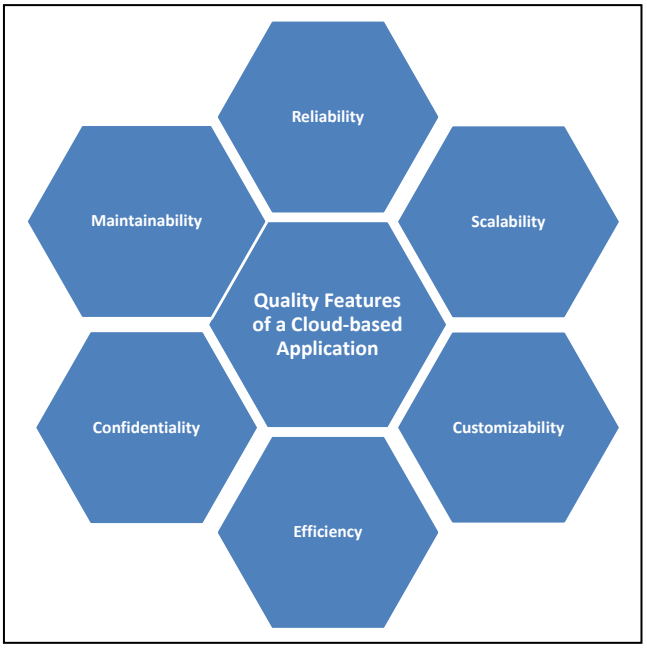

Figure 3: Quality Attributes in Proposed Quality Model

2) Elasticity

The power of the cloud can be defined by its ability to scale up within its demanded resources to handle a peak required service invocation rate; rescaling architecture of the cloud-based applications is a necessity requirement for dynamically scalable applications that depends on virtualization resources. The elasticity of the cloud does not describe how many server or virtual machines are allocated but it is all about designing an elastic applications regardless of the allocated physical resources. Cloud-based applications should become behaviorally elastic, so resources can be rescaled flexibly according to requirements. As elastic property is necessary to cloud platform for scaling up and down resources for data and applications, elastic capability should be defined within the architecture of cloud-based applications as it is a must have feature for deployment of such applications within cloud platform for maximum performance. Therefore, cloud-based applications should clearly specify the rules for using the elasticity properties within its services architecture. The elasticity of cloud-based applications can be designed based on two manner of scalability, scaling vertical in which cloud-based applications have the ability to integrated and perform with faster processors, ram, and other upgradable resources; and scaling horizontal in which cloud-based applications have the ability to integrate and perform with parallel allocated resources such as multi processors, and more server.

3) Customizability

One of the most cloud-based applications unique characteristics is its style architecture by being stateless for customization. In term of satisfaction, cloud-based applications developed based on the idea of flexibility within various requirements and different environments. Customized applications have the ability of acceptance and adapting for multiple clients in which they are known or unknown clients; therefore, this attributes measure the degree of adaptability and customization of cloud-based applications.

4) Efficiency

The efficiency of the cloud can be defined by the level of performance of the utilized service to its allocated resources, cloud-based applications performance determined by the usage amount of that application within its utilized up time. The level of performance mostly cannot be measured directly as it an external factor for the cloud; therefore, various measurable terms should be evaluated to indicate the level of performance, such as response time, and throughput of data. In order for cloud-based applications to perform effectively and to establish its required functionality probably, the amount of utilized resources should be allocated based on the functional requirements of that application for

specific environments. Therefore, these factors regarding the allocated resources need to be measured with the ability of cloud-based applications to utilize resources effectively.

5) Confidentiality

Confidentiality can be defined as the ease of cloud-based applications to be secure; the confidentiality of data can be measured by how many methods that cloud-based application developed with. Regarding the advanced technologies that cloud computing adopted with to ensure its security, various cloud platforms provides different methods to address information security of the deployed services. Engine Yard, Microsoft Windows Azure, Amazon Elastic Compute Cloud, Google App Engine, and Cloud Access are all cloud platforms that offer a set of security models and mechanisms to be architected with the developed cloud-based application to ensure confidentiality of data, and privacy of services messaging. Therefore, the level of confidentiality of the cloud-based application can be measured by the number of the security model and mechanisms that such service applied with.

6) Maintainability

Maintainability can be defined as the difficulty to modify a deployed cloud-based application in order to meet the need of new requirements, correct service failure request and fault error, and to be easy to adopt with changeable cloud platform new computing techniques. Maintainability within the cloud is mostly assigned with how cloud-based applications will be interacting with the ability of the cloud to be scaled up for utilizing more resources. The degree of maintainability can be measured by identifying the stability of a selected cloud-based application after modifying its deployed services. Such characteristic of service maintaining depends mostly on the complexity of the deployment methods and services of cloud-based applications.

V. RECOMMENDATIONS

The goal of this research is to improve the quality of cloud-based applications by developing a quality of service model that reflect the imperative quality factors of cloud computing. The following recommendations have been identified for ensuring a successful adoption of the proposed model.

- Identify the security mechanisms and models that the deployed environment of the selected cloud platform provides and compare it to the requirements specifications.
- Cloud application engineers need to cooperate with quality engineers as well as testers of the selected cloud-based application for high measurement results.
- Requirement specification should be defined and documented within SLA for the adoption of the developed quality model.
- Several techniques need to be utilized to get valid results of the requirement variables in the derived metrics.
- Cloud application engineers should be able to test the deployed cloud-based application within various deployment stages for a real time testing process.
- In order to have a valid evaluation process, evaluation need to be applied within each development phase for accurate gathering of metrics variables.

VI. CONCLUSION

In this research, the authors have proposed a quality of service model that is intended to provide a valuable assistance for cloud application engineers in context of evaluation and measurement procedure by improving and enhancing the evaluated cloud-based applications within its deployment platform. This research is particularly helpful for cloud based application developers and cloud venders to evaluate the quality of their services. A wide range of support and assistance is expected from the existing cloud venders and developers as well as quality experts to ensure the success of this research. As part of the future research, the proposed quality attributes can be expanded to include additional attributes that define other features of the cloud-based application to enhance the evaluation process and improve the measurement validation. Such new quality attribute

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can be derived from further investigation on different cloud computing features.

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