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Evaluation framework of reusability QoS metrics for Cloud based SaaS: an empirical study

Monika Sethi[1*], Jatender Kumar[2]

[1]P.G Department of Information Technology, GGDSD College, Panjab University, Chandigarh, India
[2]P.G Department of Computer Science, SGGS College, Panjab University, Chandigarh, India

**Corresponding author: monikasethi27@gmail.com, TEL: 9814858821*

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Abstract- Cloud based software-as-a-service (SaaS) is a new paradigm where services are offered over the internet. The service providers develop and deploy services that consumers can use to build their applications of high quality. As such, consumers can use these services in various applications and in various combinations. The main concern for every consumer is the quality of the service being provided by the service provider. There are number of quality attributes available to assess the quality of service. Some of the attributes are reliability, scalability, availability, reusability and coupling etc. After reviewing number of QoS attributes, we have found that Reusability and coupling of services, is a key QoS attribute to measure the value and Return on Investment (ROI) of the cloud based software service. In this paper we have proposed a reusability framework for cloud based SaaS and constructed their metrics scores. We have also done empirical evaluation on three different cloud based software services to show applicability of our proposed framework.

Keywords – Reusability, cloud based Software-as-a-Service, Quality attributes, Metrics, Cloud computing.

I. INTRODUCTION

The emergence of cloud computing has revolutionized the field of building applications with various cloud services [1]. It has enabled deployment of different types of resources (infrastructure, platform, software, etc.) as services and has associated benefits that can be delivered through them [1]. With the increasing popularity and usage of cloud based SaaS, the need for comprehensive mechanism to assess their quality has arisen. Any such quality model that targets the intrinsic characteristics of cloud based SaaS must identify, describe, and evaluate its key attributes.

The attributes described in Table 1 are intrinsic to the cloud based SaaS and can differentiate one service from the other. Service providers identify common features among various applications and model them as reusable features within the services deployed.

At the same time, service consumers can identify and subscribe the relevant services and use them to build multiple applications. Hence, reusability of a service is one of the most important attributes for both service providers and consumers. Services with high reusability would yield high return-on-investment [2]. To quantify the degree to which a service can be reused, a quality evaluation framework needs to be defined. Various quality parameters and metrics of reusability have been proposed and used for components in component-based programs, object-oriented and procedural programs. These programming paradigms may differ from the cloud-based services whose intrinsic characteristics require new quality models for Cloud based SaaS. Service providers and service consumers hold distinct views with which they perceive the reusability of a service.

Table 1.

Attribute	Description
Reusability	ability of a component or element to serve for the purpose of more than one application.
Adaptability	time taken by the customer to understand the software and adapt the services provided
Availability	percentage of time that the service is actively operating and available for users
Scalability	ability to handle increasing number of users or growing amounts of resources without degradation of service performance
Efficiency	indicator of effective utilization of the resources by the service
Reliability	ability of a system to keep operating with specified level of performance over time [3]

For a service provider, it is measured or estimated amount of usage of service, while for a service consumer it is

extent to which a service can be discovered, visible, perceived, and depends upon other service applications.
In this paper, we present an evaluation framework for reusability QoS metrics from consumers' perspective. Section I contains the introduction of the work. Section II provides an overview of related works on quality of service attributes. In section III we have proposed a framework of reusability QoS metrics for Cloud based SaaS and formulated metric scores. Section IV describes the empirical validation process of proposed metrics by applying data on cloud environment. In section V we have presented the assessment of the proposed reusability QoS metrics. We believe that the proposed set of metrics can be used for evaluating QoS for Cloud based SaaS in a quantitative manner.

II. RELATED WORK

ISO/IEC 9126 provides three types of software quality models: Internal Metrics, External Metrics, and Quality-in-use Metrics [4][5]. While these conventional quality models are generally applicable to many software systems, recent studies have proposed evaluation frameworks for reusability of SaaS and cloud-based services. Choi discussed applicability of service metrics for a system-on-chip from a perspective of consumer [6]. Though quality attributes derived from it are not directly applicable to cloud-based services, its consumer-oriented approach is useful. Garg proposed four quality attributes i.e. assurance, cost, performance and security [7]. The computation of the service attributes is done by collecting the QoS data from three IaaS cloud providers: Amazon EC2, Windows Azure, and Rackspace. Sang proposed that reusability is a key intrinsic characteristic of cloud services, and defined four quality attributes that contribute to reusability [2]. Based on these quality attributes, a metric for reusability was defined. Lee proposed software-oriented approaches to assure high scalability of services in cloud computing [8]. They proposed two effective scalability schemes i.e. service replication and migration. Jureta proposed a quality model, called QVDP, consisting of four sub models, quality characteristic, characteristic value, quality dependency, and quality priority [9]. This model represents dependencies and priorities between quality dimensions and quality characteristics. Washizaki proposed a hierarchical classification of factors, criterion, and metrics to access reusability [10]. They addressed the issue by taking black box components and their approach is based on limited information without knowing the internal details of the components or the source code. They identified three factors (understandability, adaptability, and portability) and four criteria (meta-information, observability, customizability, and return value). Based on the statistical analyses of a number of JavaBeans components, they proposed five different metrics or scores measuring meta-information, component- observability, customizability, completeness of its return value and its parameters. Initially these metrics are based on components, later when combined to access reusability, are close to the requirements of the cloud environment. But cloud services are much larger reusable units than components; so the factors and scores proposed by them need to be extended.

III. PROPOSED REUSABILITY QOS METRICS

Keeping in mind the general process of use and reuse of Cloud based software services and following the FCM model [11] and from multiple sources [12,13,14], we define a general framework for Reusability QoS metrics for Cloud based SaaS from a client perspective. First of all, we consider some software cloud-based services that can be applied to target application for observing usage of various services. We select those services that are highly visible and whose descriptions are highly understandable. From this step we derive two QoS metrics: service accessibility and service visibility. Secondly, we examine the overlap between available service and target application, and derive third QoS metric: service customization. Next step is to combine these customized services to address target application. Multiple services can be combined to create bigger applications. The services can then have two quality metrics: service self-sufficiency (not depending on other services for their function) and service dependability (being able to support other services for their functioning). After identifying the quality metrics we will now define the metric scores and their formulation for quantitatively analyzing the reusability in Cloud based SaaS.

Table 2.

Proposed metrics and its score	
Metrics	**Metric Score**
Service Accessibility	Accessibility Score (AS)
Service Visibility	Visibility Score (VS)
Service Customization	Customization Score (CS)
Service Self Sufficiency	Self Sufficiency Score (SSS)
Service Dependability	Dependability Score (DS)

In Table 2. We define QoS metrics to measure the reusability of Cloud based SaaS. Each metric score captures a distinct aspect with which reusability can be measured.

Service Accessibility: Cloud services come with a number of descriptive fields, containing the syntactic and semantic properties of a service that make the service comprehensible and accessible to the user. The service accessibility can be measured with metric accessibility

score (AS) represents the number of input parameters that are easily understandable to the user.

$$AS = \frac{\sum_{j=1}^{k} n_j}{k}$$
$$where\ k\ =\ total\ number\ of\ parameters,$$
$$n_j = \begin{cases} 1\ if\ j^{th}\ parameter\ is \\ \quad understandable \\ 0\ otherwise \end{cases}$$
$$AS\ \in [0,1]$$

Service Visibility: In Cloud based SaaS, the software is registered with service registries provided by the service providers and made publicly available. This makes the user aware about the service as it become visible and discoverable. It leads to higher subscription of the service by the users. The service visibility can be measured with the metric visibility score (VS)

$$VS = \frac{\sum_{j=1}^{k} u_j}{k}$$
$$where\ k\ =\ total\ number\ of\ users,$$
$$u_j = \begin{cases} 1\ if\ j^{th}\ user\ is\ able\ to\ discover \\ \quad particular\ service \\ 0\ otherwise \end{cases}$$
$$VS\ \in [0,1]$$

Service Customization: Cloud-based services are customizable to a varying degree. They modify themselves according to the user's requirements. They offered adaptability of service, which can be measured using a customization score (CS).

$$CS = \frac{\sum_{j=1}^{k} c_j}{k}$$
$$where\ k\ =\ total\ number\ of\ options,$$
$$c_j = \begin{cases} 1\ if\ j^{th}\ option\ is\ adaptable \\ \quad by\ user \\ 0\ otherwise \end{cases}$$
$$CS\ \in [0,1]$$

Service Self Sufficiency: Service Self Sufficiency means that to what extent the service is independent of other services. Self-sufficiency score (SSS) measure the cohesion of a service or its ability to be self-contained.

$$SSS = \frac{\sum_{j=1}^{k} e_j}{k}$$
$$where\ k\ =\ total\ number\ of\ elements,$$
$$e_j = \begin{cases} 1\ if\ j^{th}\ element\ is\ dependent \\ \quad on\ external\ services \\ 0\ otherwise \end{cases}$$
$$so\ SSS\ \in [0,1]$$

Service Dependability: Dependability score (DS) is measured by considering the number of services dependent on the service at hand, in all the business processes it is involved in. It is computed as:

$$DS = \frac{\sum_{j=1}^{k} r_j}{k}$$
$$where\ k\ =\ total\ number\ of\ services,$$
$$r_j = \begin{cases} 1\ if\ j^{th}\ service\ is\ relaibly \\ dependent\ on\ current\ service \\ 0\ otherwise \end{cases}$$
$$so\ DS\ \in [0,1]$$

IV. EMPIRICAL EVALUATION OF REUSABILITY FRAMEWORK

The QoS parameter scores, we defined to access reusability are not abstract concepts but readily usable as they can be estimated or measured directly and objectively. We are therefore in a position to perform an evaluation of various QoS parameters on multiple cloud software services. The evaluation will be done to access and compare the reusability of multiple cloud services.

Table 3.

QoS metrics	Numerator/ Denominator	Metrics
Accessibility Score (AS)	Num_AS	Number of easily understandable input parameters
	Dem_AS	Total number of input parameters
Visibility Score (VS)	Num_VS	Number of users able to discover service
	Dem_VS	Total number of potential users
Customization Score (CS)	Num_CS	Number of adaptability options
	Dem_CS	Total number of options
Self Sufficiency Score (SSS)	Num_SSS	Number of elements dependent on external services
	Dem_SSS	Total number of elements
Dependability Score (DS)	Num_DS	Number of other services reliably dependent on this service
	Dem_DS	Number of potential such dependent services

We apply these metrics to 3 different cloud services Google Maps [15], Bing Maps [16], and Ovi Maps [17]. We invited a group of 100 volunteers (computer science undergraduates), who were asked to access API of publicly available map services, and fill in a questionnaire regarding number of understandable parameters, adaptability options, etc

Table 4.

QoS Metrics	Metrics Score	Google Maps	Bing Maps	Ovi Maps
Accessibility Score (AS)	Num_AS	9	7	9
	Dem_AS	11	10	12
	Score	0.82	0.7	0.75
Visibility Score (VS)	Num_VS	89	60	73
	Dem_VS	98	71	84
	Score	0.91	0.85	0.87
Customization Score (CS)	Num_CS	6	3	2
	Dem_CS	7	4	3
	Score	0.86	0.75	0.67
Self Sufficiency Score (SSS)	Num_SSS	2	2	1
	Dem_SSS	8	6	5
	Score	0.75	0.67	0.8
Dependability Score (DS)	Num_DS	52	36	39
	Dem_DS	58	45	44
	Score	0.9	0.8	0.89

In Table 4, the reusability QoS metrics scores ranges between 0 and 1, where higher score indicates higher accessibility, higher visibility and higher adaptability. Higher self-sufficiency score will indicate that the service is more cohesive. Higher value of dependability score indicates that the service can integrate well to support other services.

We define the reusability of service as a combination of above defined five QoS parameter and their respective scores. We have assigned different weights to different parameters; the weights of five quality parameters measured above can vary depending on the kind of services being compared and their characteristics.

$$Reusability = AS.W_{AS} + VS.W_{VS} + CS.W_{CS} + SSS.W_{SSS} + DS.W_{DS}$$

where AS, VS, CS, SSS, DS are the QoS parameter score of Reusability and W_{AS}, W_{VS}, W_{CS}, W_{SSS}, W_{DS} are the weighted scores of five QoS metrics respectively. The weights should lie between 0-1 and the sum of all weights must be 1. We use W_{AS} = 0.3, W_{VS} = 0.3, W_{CS} = 0.2, W_{SSS} = 0.1, and W_{DS} = 0.1. By using the QoS metrics and their weighted scores, the comprehensive reusability score for the three cloud services is shown in Table 5:

Table 5.

Reusability QoS metrics	Google Maps	Bing Maps	Ovi Maps
AS	0.245	0.210	0.225
VS	0.272	0.253	0.260
CS	0.171	0.15	0.132
SSS	0.075	0.066	0.08
DS	0.089	0.08	0.088
Reusability	0.85	0.75	0.78

V. THEORETICAL ASSESSMENT AND APPLICABILITY

Many recent works have outlined the importance of effectiveness of software metrics and proposed criterion that must be encompassed by these metrics Ejiogu [18]. Here, we make a theoretical analysis of our framework using the approach from Washizaki [10]. We use 3 criteria from IEEE Std. 1061 [19], namely relevance, precision, and consistency. We used these criteria to propose our reusability QoS metrics scores. Further, our reusability QoS framework is practical in its approach and has real world applicability. We look at the validity of quality metric and the metric scores in which they are measured. In the previous sections we have derived five quality metrics: accessibility, visibility, customizability, self-sufficiency, and dependability.

Table 6.

Criterion	Definition	Assessment and Applicability
Practical real world applicability	The score needs to be applicable in real world projects and be computable in reasonable time depending on the application.	We applied and computed the scores in a case study proving its practical applicability.
Relevance	The score needs to have a logical relationship with	We formulated and computed the scores based on

	the quality parameter of the product being studied.	quality parameters inherent in the cloud-based services.
Precision	The score needs to be unambiguous in its computation and be bound within limits for enable interpretation.	Our score calculations are clean and the scores and bound within [0,1] as per definition.
Consistency	The score needs to be computed in units that are consistent.	We formulate score to be unit-less since the numerator and denominator have same units.

If a service exhibits a high degree of certain characteristic, it will possess high value of quality. All the metrics we studied above are key features exhibited by Cloud based SaaS. In the table 6 we have defined our four criteria and assess how our framework satisfies all these criteria.

VI. CONCLUSION

Cloud computing provides novel opportunities for enabling Software-as-a-Service paradigm. The service providers develop and deploy service that consumers can discover and use to build their applications. Service consumers can use these services in various applications and in various combinations. Reusability of service, hence, is a key intrinsic feature of cloud services. High reusability ensures high return-on-investment. In this work, we proposed a framework for evaluating reusability of cloud-based software services. From literature search, we complied characteristics of services in cloud computing and service-oriented architecture. From these characteristics, we derived five quality parameters that collectively contribute to the reusability of a cloud service: Accessibility measuring how effectively service consumers comprehend service functionality, Visibility measuring how easily services can be discovered by potential users, Customizability measuring how easily can customers adapt these services, Self-sufficiency measuring how modular the services are so that they don't depend on external services, and Dependability measuring how services can support and interoperate with other services to enable creation of larger processes. Based on these parameters and the mathematical formulation we propose, we performed an empirical study involving three cloud services and presented the results. From the empirical study results along with the theoretical assessment of quality parameters, we believe that our proposed framework is valid, precise, relevant, and practically applicable for evaluating reusability for Cloud based SaaS.

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Authors Profile

Monika Sethi pursed MCA Degree from Guru Nanak Institute of Management and Technology Ludhiana under Panjab Technical University Punjab in 2004 and MPhill degree in Computer Science from Periyar University Selam India in 2008. She is currently working as Assistant Professor in GGDSD College Chandigarh India. Her areas of interests include Cloud computing and Software Engineering
.

Jatender Kumar pursed M.Tech (Computer Science and Engineering) from Punjabi University, Patiala, Punjab in 2002 and MPhill degree in Computer Science from Periyar University, Selam, India in 2009. He is currently working as Assistant Professor in SGGS College Chandigarh, India. His areas of interests include Software Engineering and Fuzzy Logic

