Review and Analysis of Cloud Computing Quality of Experience

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Abstract. Cloud computing is gaining growing interest from industry, organizations and the research community. The technology promises many advantages in terms of cost saving by allowing organizations and users to remotely gain access to a huge pool of data storage and processing power. However, migrating services to cloud computing introduce new challenges in performance and service quality. Quality of service (QoS) is and has been used as a means of monitoring cloud service performance. However, QoS is based on network parameters which do not necessarily reflect users' quality of experience. This paper discusses cloud computing quality of experience as perceived by the person using the cloud-based applications and services. We also review a selected current contribution to the quality of experience (QoE). We have expert reviews undertaken to identify six key performance indicators (PKIs). Based on these six KPIs, we sent our surveys, collected feedback and analyze data to confirm that QoE measurement can meet organizational goals, user satisfaction and stakeholders' requirements.

1 Introduction

Cloud computing is a new phenomenon in information system and communication technology and has gained a lot of interests from industry, organizations and the research community. Moving services to cloud mean that applications that used to run on users' PCs will reside in data centers distributed across different continents. Cloud computing promises economic benefits. However, migrating services to cloud computing introduce new challenges in service performance, quality and reliability; traditionally service level agreements are used as a means of guaranteeing the delivery of acceptable service performance level. Existing QoS metrics and service level agreements (SLAs) offered by cloud service providers do not include anything about the performance of service from user point of view and are not adequate to meet users' quality of service expectations [16]. Organizations are unlikely to adopt cloud computing if users' experience is not as good as it was before moving to cloud or performance does not meet users' perceived quality of experience and performance expectations [8]. However, due to subjective nature of users' quality of experience, measuring, capturing and quantifying QoE remains an open research question. In this paper, we review selected current contributions to QoE. The remainder of this paper is struc-

Safdari F. and Chang V..
Review and Analysis of Cloud Computing Quality of Experience.
DOI: 10.5220/0004982800830088
In *Proceedings of the International Workshop on Emerging Software as a Service and Analytics* (ESaaSA-2014), pages 83-88
ISBN: 978-989-758-026-0

tured as follows: Section 2 describes QoE. Section 3 provides an overview of the related work on QoE. Section 4 presents the results and discussions from the expert review and the survey. Section 5 concludes this paper.

2 Quality of Experience (QoE)

Many definitions for QoE have been proposed in literature. In [15] QoE is referred to as 'the basic character or nature of direct personal participation or observation'.

Descriptions in [6] states QoE as 'a concept comprising all elements of a subscriber's perception of the network and performance relative to expectations'. Synthesis in [17] gives the following description for QoE: 'QoE is a multi-dimensional construct of perceptions and behaviors of a user, which represents his/her emotional, cognitive, and behavioural responses, both subjective and objective, while using a system.'. ITU-T [9] defines QoE as 'overall acceptability of an application or service, as perceived subjectively by the end user'. There is no a universally acceptable definition of QoE [15], QoE is outlined in various literatures as a subjective measure.

To model and measure QoE appropriate QoE metrics need to be identified. While network performance parameters and QoS metrics are well-defined, in contrast QoE metrics are not well understood and remain an open research question. A large volume of publications has been dedicated to the study of QoE. In section 3, we review a selected list and summarize their findings and proposals.

3 Summary of Existing QoE Studies

Casa et al., [2] studied QoE in remote virtual desktop services. Authors outlined a three layer QoE evaluation framework, consisting of user layer, application layer, and network layer. Network layer deals with QoS parameters such as bandwidth, application layer includes response time, screen compression rate, and colour parameters. User layer is based on user feedback using Mean Opinion score (MOS). They performed subjective experiment using 52 participants. Their experiment was focused on users' overall experience and round trip time. Their main finding is the correlation between QoE and application QoS requirement. Interactive applications are more delay sensitive, high RTT degrades user quality of experience. This indicates a direct correlation between network bandwidth and QoE, low bandwidth has negative impact on user experience.

Chen et al., [5] argue that obtaining user feedback after they used an application is not the most appropriate mechanism. They proposed a QoE capture framework called OneClick where users click a particular button indicating they are not satisfied with the quality of an application. They assert that dissatisfaction refers to all QoE dimensions and QoE is application specific as applications have different QoS requirements. Authors in [5] investigated QoE a group of 52 users using 'The Box', a Dropbox-like application in a controlled lab environment. They observed a correlation between poor user QoE and low network bandwidth. [8] state that QoE has the potential to become the new guiding standard for cloud computing quality management.

Authors argued that understanding and managing QoE of cloud services involves a multidisciplinary view including network, user, and business aspects. Technical factors that influence cloud computing QoE vary from application to application. QoE-based classification of application based on level of interactivity, usage domain, and service complexity is presented.

A QoE management framework was proposed [12], where five steps are outlined: Service classification provides service contents; Main quality parameters extraction selects key quality metrics; user feedback collection, QoE analysis predicts reasons affecting service quality and Performance upgrade. The framework uses simple real-time oneclick [5] feedback mechanism. They performed an experiments using a 100-second video streaming, only two network parameters, delay per packet, and packet loss were measured. Their findings indicate increase in packet delay and packet loss result in poor QoE. On the other hand, it is not easy to measure QoE in a unified form because many factors affecting QoE [14]. Authors affirmed that taking into account all factors could result in a complex QoE metrics; simple QoE metrics are more practical. An in-service feedback QoE framework is introduced, which runs over a multi-agent environment, and abstract functions of different agents were discussed.

Kist and Brodie [15] did a case study using two groups of seven and eleven students to identifying the effect of QoS on QoE. Their findings indicate that flow (level of interruption to concentrate on a task), achievability (sense of completing the task), and extra time needed to complete the task were directly affected by QoS. Their findings are rather generic as there is no mapping of QoE and different QoS metrics. Statements in [16] assert that QoE will play a major role in the success or failure of cloud service. The authors argue that understanding QoE requires a multi-disciplinary view of network, user and business aspects. A conceptual view of cloud services QoE landscape is proposed, which consists of three main branches: user profile, application, and network QoS.

In table 1 we summarized a list of factors identified by different authors that could have an impact on QoE.

Table 1. Summary of authors' views on factors affecting QoE.

Reference	User demographics	User personality	User interface	Device usability	Application characteristics	Volume of data	Response time	Delay	Jitter	Bandwidth	Packet loss	CPU Consumptions	Service reliability
[2]	✓	✓		✓	✓		✓	✓		✓	✓		
[3]				✓									✓
[6]					✓					✓	✓		
[8]	✓	✓			✓					✓	✓		
[9]	✓				✓	✓			✓	✓	✓		
[13]					✓			✓	✓	✓	✓		✓
[15]				✓				✓		✓	✓		
[16]								✓		✓		✓	
[17]	✓		✓		✓	✓		✓	✓	✓	✓		

4 Results from the Expert Review and Survey

QoE is an area that requires the support of results from surveys and quantitative analysis demonstrated by Chang [3], who identifies six key performance indicators (KPI) for IT success and explains how these six KPIs can be used in measuring the success of IT project delivery. The demonstrated examples by [3] are relevant to QoE, in which expert reviews have been involved. Based on the extension of the work, we have presented the summary of the importance of six KPIs as follows.

- Relevance for usability for Cloud QoE adoption is important with the support of real use cases.
- Achieving good performance is an essential for Cloud QoE adoption.
- Security concern is a main reason for some organizations not to adopt Cloud Computing which researchers describe challenges and issues to be improved.
- Data accuracy is important to compute accurate results so that organizations have a higher trust and confidence in Cloud QoE adoption.
- Service and data portability are highly relevant to Cloud QoE adoption that researchers demonstrate their usefulness for QoE.
- Scalability is a core characteristic for Cloud and the ability to scale up and down resources promptly for different demands is essential for Cloud QoE adoption.

These six KPIs are essential for the development of QoE adoption and measurement. While feedback from experts are important, the feedback from users (in this case, students) are essential for the development of QoE adoption and measurement. Questions are based on these six PKIs. Each participant was asked their opinions and rated the importance of these six KPIs. In this case, we identified that students are likely to use or get involved in QoE at some stage, which explains why students take part in this study. As a result, we sent out surveys and collected feedback from students about their feedback about Cloud QoE adoption.

Analysis of variance (ANOVA) provides statistical test of whether means of several groups are equal and can generalize t-test or F-test for two or more groups [4]. ANOVA can be used when these two cohorts have close means and each group has two sets of data. Table 6 shows the ANOVA analysis with F-test for cohort group one, where “grp_with_Cloud” is the shorter version of “group_with_Cloud”. Cohort group one has F-value = 2.78 and Prob > F is 0.1148 (the smaller, the better). The R-squared value is 0.7875 (the higher, the better) and the root mean square error (MSE) is 2.74874 (the lower, the better). These key results confirm that the statistical analysis agrees that the use of Cloud QoE adoption help students in their motivation for learning. Statistical results confirm a good extent of accuracy in analysis by having high R-squared values; low root mean square values and high F-test values. These results confirm that we can achieve the stakeholders’ requirements in the first stage of QoE investigation. The p-value is below 0.1 and is considered a good result. To ensure smooth delivery, p-value should be as small as possible. In this case, variations in p-value have been explained by the variations before and after using Cloud QoE adoption. Based on direct feedback from some participants, Cloud QoE adoption can enhance learning and understanding of the subject involved.

Table 2. ANOVA Analysis for the Student Cohort Group.

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Number of obs = 30 R-squared = 0.7875
Root MSE = 2.74874 Adj R-squared = 0.5042

Source Partial SS df MS F Prob > F
------------+----------------------------------------------------
Model 168 8 21 2.78 0.0943
grp_with_Cloud 168 8 21 2.78 0.0943

Residual 45.3333333 6 7.55555556
------------+----------------------------------------------------
Total 213.333333 14 15.2380952
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5 Conclusion and Future Work

This research has focused on the literature on the current state of QoE of cloud computing. The assessment of cloud computing QoE cannot be based only on datacenters performance efficiency, SLA, and network QoS parameters due to the fact many different intermediate networks and providers are involved in providing users access to cloud services. Many factors affect QoE, having a framework that capture all individual factors could result in a complex QoE management model. It is more practical and efficient to capture and model users' overall acceptability of quality of service in real-time. Individual applications and services have different QoS requirements. It is important to monitor network parameters and QoE for individual application and identify parameters and factors that influence QoE for a given application. This provides a fundamental start towards developing a model understanding correlation between QoE and network performance metrics. Apart from the consolidation of literature, we present that the use of expert reviews and the survey analysis help shake up the research for QoE adoption. We confirm that the six KPIs essential and statistical results for the proposed QoE framework to ensure that stakeholders, users and students are well engaged in the development work. Their feedback will be useful for a successful delivery of QoE implementation to ensure that adoption and measurement can meet the organizational goals, user satisfaction and stakeholders' requirements. We also identify more user groups that require QoE, collect their feedback and analyze our collected data.

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