Analysis of Quality of Experience Frameworks for Cloud Computing

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Summary
Cloud computing frameworks were proposed to collect the Quality of Experience (QoE) of users and deliver the Quality of Service (QoS) according to needs as declared in Service Level Agreement (SLA). This paper presents review followed by analysis of famous QoE frameworks for cloud computing based on the certain features such as deployment parameters, network and client monitoring, QoE data analysis, reporting tools and dynamic policy change. During the study of QoE frameworks it has been learned that all the frameworks have limited scope. None of them supports qualitative data analysis, policy change. The frameworks also lack in monitoring of the user device for resources and services that are received at the client side. The QoE review submitted by the users is essential and needs an appropriate place within the framework for cloud computing.

Key words:
Quality of Experience, Quality of Service, Cloud frameworks, Monitoring

1. Introduction

Nowadays cloud computing became popular technology around the world due to its on-demand services for resource sharing. The business organization purchase services from cloud service provider. These services include, computing devices, storage, operating system environments, virtual servers, and utility software to manage their business. Cloud computing is derived from Grid Computing. Grid computing is based on the collection of computing resources that are accessed from one or multiple locations to accomplish a particular task [1]. Whereas, cloud computing provide high computational power with more features such as permanent storage and hardware resources. Cloud computing is famous to provide infrastructure as a service (IaaS), application software as a service (SaaS) and platforms for application development as a service (PaaS) [2]. According to the NIST (National Institute of Standards and Technology) Cloud Computing Definition, *"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (such as, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"* [3]. Cloud computing models for the infrastructure such as SaaS, PaaS and IaaS are shown in Figure 1. The SaaS provides service for the consumer and business such as email, database application software and accounting for end users. SaaS does not provide access for technical management of cloud to the user; it is managed by cloud management [4]. PaaS is based on the development tools, which can be used by developers to configure and technically manage the cloud according to the requirement. PaaS also provides a programming environment to developers to manage the cloud environment. IaaS is fully dependent on access to cloud infrastructure and like servers, network and storage devices. So in IaaS, the developer has permissions to manage and change the cloud infrastructure.

2. Services

2.1. Software as a Service (SaaS)

Software as a service is a utility from cloud service provider for consumers to use web based software without using high speed servers and installing software at home computers [5]. This service can be used from a web browser or thin client interface and this software is running on the cloud infrastructure. In SaaS, user has limited privileges to access particular software and user centered-configurations. However, it does not control or manage the basic cloud infrastructure such as servers, operating systems and network.
The SaaS is advanced model of application service provider (ASP) and on demand computing software delivery [6]. Instead of providing solution to everyone in different ways SaaS provide one solution for all. It provides add on features in software based on the user feedback, which is then available for all users. In cloud environment main characteristics of SaaS are (i) access of commercial software via web (ii) management of software at central location (iii) one to many software delivery model (iv) users are free from the efforts for software updates and patches (v) different pieces of software can be integrated via Application Programing Interface (API).

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2.2 Platform as a Service (PaaS)

The PaaS is a category of cloud computing model, which provides platform as an environment for application development. Where, developers can use required libraries, programming languages, services and other GUI based tools from the cloud [7]. In PaaS user can access the services via web based tools or web browser and can change and control the underlying components such as programming languages, libraries and other services. However, the user does not have control on the underlying cloud infrastructure such as operating system, storage and network.

Web developers and software developers can get benefit from PaaS because there is no need to install costly hardware such as high computational servers, network devices and storage. All of these utilities can be purchased from the cloud service providers. PaaS provides five the following features for developers:

i. It provides a multi-tenant architecture that includes centralized software, operating systems and hardware resources as well as a shared database.
ii. PaaS provides predefined UI (User Interface) components and flexible application development characteristics like "drag & drop" by which less coding is required.
iii. PaaS offers a customized database with options to create objects. It defines the type and relationship between the objects and the configuration of data. It also offers a simple web browser with a "point and click" declarative paradigm.
iv. It provides robust engine workflow, which automatically executes the process with definition and specification of business rules.
v. PaaS service facilities are easy for development of applications by providing basic elements for such as data perseverance and workflow abilities that are necessary to the creation of any business application [8].

2.3 Infrastructure as a service (IaaS)

IaaS is the main part of cloud environment, which provides hardware resources such as storage, network devices and servers [9]. There is no needs to install hardware but one can use hardware infrastructure of cloud on pay per use [10]. Users do not control and manage the physical infrastructure but have control on the operating system and deployed software with a limited control on the network devices. Cloud service providers are responsible to maintain physical infrastructure such as pool of hardware resources connected across data centers via servers and networks. On the other hand, the client has access to virtualized resources to build their own computing/IT environment. IaaS has four core characteristics:

i. In IaaS resources are distributed as service and user can demand for IaaS services like computing resources, storage and network resources. All the resource management is invisible to the user.
ii. It allows dynamic scaling and its infrastructure can be scaled at any quantity any time.
iii. IaaS provides a measured service model, which means it has a variable cost and utility price model. Cloud system automatically tracks and monitors the resource usage at the consumer and at the service provider.
iv. Single hardware is shared with multiple users with abstractions and no one knows exact location of hardware or resources.

QoE by users these days is important for organizations to improve the services and products. "*The QoE is a measurement of user factors like feelings enjoyment, perception, satisfaction and cognition for given service or product [11, 12]*". "*QoE is all about user experience about service or product which received from the vender [13]*". QoE can be captured by using two methods. First is subjective and the second is objective. Subjective QoE methods for data collection are based on the web surveys, interviews and questionnaires [14, 15]. Objective QoE is further divided into two methods. First, the human physiological data, which can be captured by Magnetic Resonance Imaging (MRI) and Electroencephalogram (EEG) test and second, based on the technical parameters for QoS data [16, 17]. Objective QoE is more accurate and inexpensive. However, many organizations use subjective QoE for services or products because it is easy to capture as compared to objective QoE. Some of the researchers preferred objective QoE for more accurate data [18, 19]. QoE based cloud framework was developed to provide QoS for multimedia services, gaming services, resources to end users and analysis of big data in multi cloud environment. The framework used for monitoring cloud environment and agents is used to collect data of ongoing services and operations from cloud to the end users.

This paper presents a review of some existing QoE frameworks for cloud computing. The rest of the paper is organized as follows. Section 2 presents a brief description of various QoE frameworks. Section 3 presents a comparative analysis of various QoE frameworks and section 4 concludes the paper.

3. QoE frameworks for Cloud Computing

QoE/QoS frameworks are designed and developed for cloud computing to analyze the user needs and their satisfaction level about the cloud services. The framework is proposed by Xiafei Wang [20] for cloud-assisted mobile video services to provide QoS for video quality to end users according network conditions without buffering and

delay. Private agents are constructed for active mobile user in cloud environment to prioritize the video streaming services without "non-buffering" and "non-terminating" for mobile users. Private agents are elastically initiated and optimized in the cloud platform. Cloud side Scalable Video Coding (SVC) technique is used, which enables and fluctuates the video quality for mobile users based on the available bandwidth. This framework also supports Social Network Services (SNSs) for activities of mobile users and it pursues to pre-fetch the video clips in advance from user's private agent to the local storage of the device.

The CLAMS (A Cross Layer Multi-Cloud Application Monitoring-as-a-Service) framework was proposed by Alhamazani et al. [21], which monitors QoS of applications of clouds by using agent technology. The framework utilized the functions of SNMP (Simple Network Management Protocol) and sigar for monitoring QoS of applications (e.g., Database Server, Web Server) across the layer and distributed on multiple clouds such as Amazon AWS and Microsoft Azure. The results show that implementation of proposed framework is feasible and does not enforce major overheads on the applications.

Follow Me Cloud: FMC Interworking Federated Clouds and Distributed Mobile Networks framework was proposed by Tarik in [22]. The proposed framework migrates all or part of a service from current cloud datacenter to other datacenter without disrupting the services. Service shift to other datacenters is done by replacing the IP addresses with service identification. A service is consists of unique identifier of UE within Third Generation Partnership Project (3GPP) mobile network and it is recognized by service ID upon establishment of a session. IP address is changed for UE mobility and the load balancing in FMC is due to a change of data anchor gateway in the mobile network. The proposed FMC framework ensures the best QoE by migrating a service or part of it to other better datacenter and enabling mobile cloud services to follow the mobile users during the mobility.

Another Cloud computing framework, which is based on QoE named as Cloud2Bubble and was proposed by costa et al [23]. The framework provides ability for the development of smart systems. It leverages the current technologies such as sensors and personal devices. It senses the environment and collects data of user services from cloud to client. The aggregated data of user is used for enabling the delivery of personalized services for users based on their preferences and needs. This framework is proposed to provide QoS to every single user profile according to needs, particularly, when multiple users request for the same devices in different times. QoE test is not conducted to validate the proposed framework.

Mobile Cloud Gaming (CMG) framework was proposed for multi user gaming environment for the mobile users through cloud sever instead of client server architecture [24]. The purpose of framework is to provide an idea to shift mobile user load to cloud server due to the inherent hardware constraint of mobile devices (for example, memory and graphics processing). The framework is based on the objective and subjective QoE measures. The QoE was analyzed on parameter such as video settings, game genres, the conditions of the wireless network, client and server by using the CMG approach. Mobile Game User Experience (MGUE) model is developed for subjective QoE validation of framework. They also proposed a Game Mean Opinion Score (GMOS) for measurement QoS of end users.

4. Performance Analysis of QoE frameworks for Cloud Computing

This section presents a comparative analysis of the existing QoE frameworks for cloud computing in terms of various characteristics such as deployment parameters, analysis support, network and client monitoring, reporting, policy change [25] and types of QoE support as described in Table 1.

Deployment parameter is the core parameter of framework. It is proposed like Network level Quality of Service (NQoS) & Application Level Quality of Service (AQoS) and Peak Signal to Noise Ratio (PSNR)/ Video Quality (VQ). Mostly frameworks support internal cloud environment monitoring which includes parameter such as CPU resources, memory, and network and storage usage. The external monitoring support contains only network but no framework support client device monitoring. All frameworks given in Table 1 only support quantitative data analysis of collected QoE but none of the frameworks has functionality of qualitative data analysis. Reporting tool provides information to administration for degradation on the services and only Cloud2Bublle [23] supports this function. The rest of frameworks does not have reporting tool. Wang [20] and FMC [22] frameworks have same parameter NQoS for collecting QoE but rest of the frameworks having different parameters such as AQoS, PSNR (Peak Signal to Noise Ratio) and VQ (Video Quality). Wang [20] and CLAMS [21] frameworks used objective QoE/QoS for monitoring contents and FMC [22] and Cloud2Bubble [21] used subjective QoE. Only CMG [22] used both objective QoS/QoE and Subjective support. Remaining all frameworks have limited functionality compared to CMG frameworks.

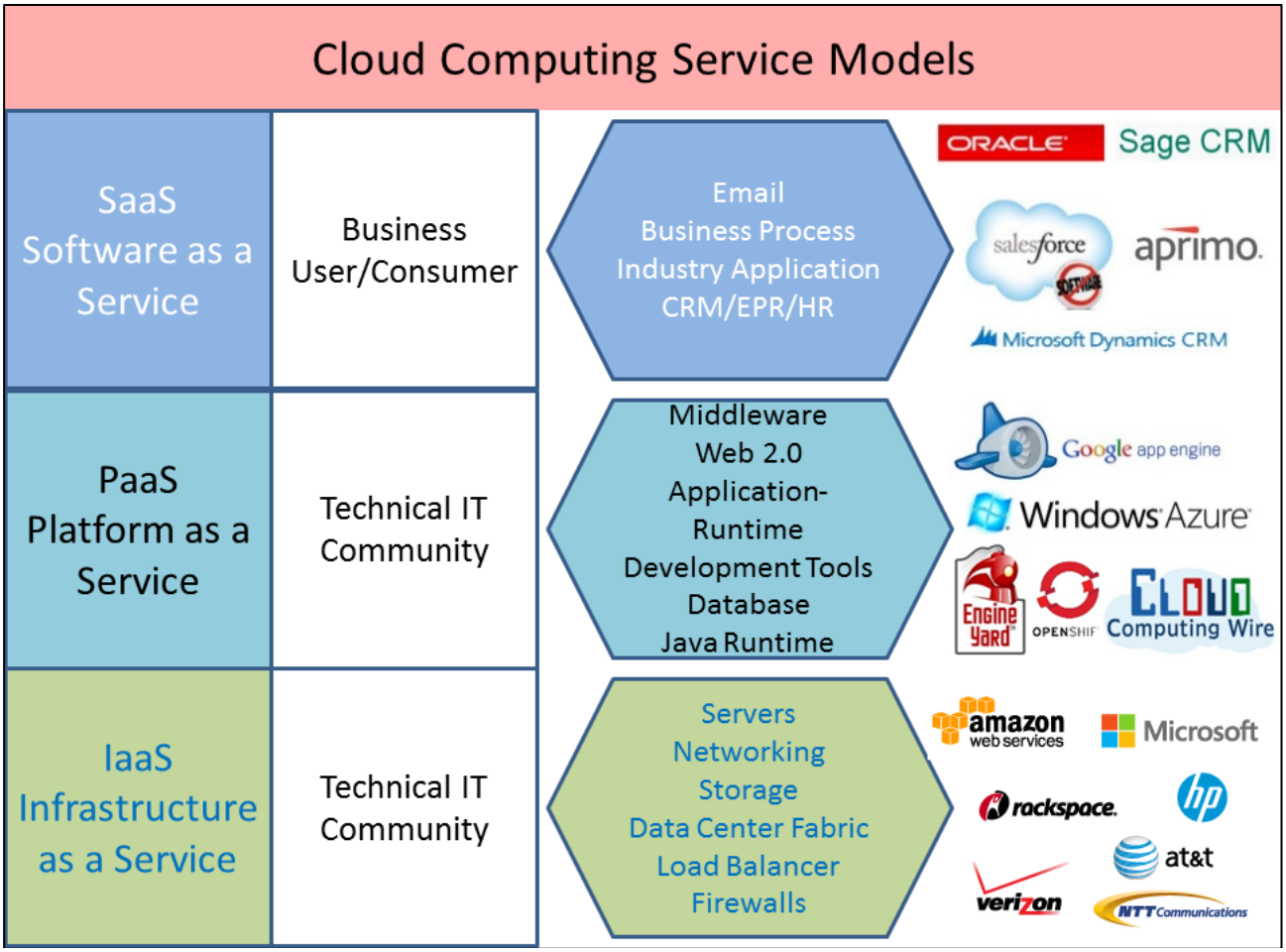

Figure 1: Cloud Computing Service Model

Table I. Comparison of previous QoE frameworks with different parameters and features

QoE/QoS Cloud Frameworks	**Wang**[20]	**CLAMS**[21]	**FMC**[22]	**Cloud2Bubble**[23]	**CMG**[24]
Parameters	NQoS	AQoS	NQoS	NQoS & AQoS	NQoS & PSNR/ VQ
Network Monitoring Support	Yes	Yes	Yes	Yes	Yes
Analysis Support	Quantitative	Quantitative	Quantitative	Quantitative	Quantitative
Reporting	No	No	No	Yes	No
Policy Change	No	No	No	No	No
Client Device Monitoring	No	No	No	No	No
Remarks	Objective (QoS) Evaluation	Objective QoS Evaluation	Subjective Evaluation	Subjective Evaluation	Objective & Subjective Evaluation

5. Conclusion

In this paper, we evaluated and discussed some of the QoE frameworks for cloud computing. During the research, certain characteristics such as Monitoring of QoE, Deployment parameters, data analysis, reporting and policy change support have been analyzed of QoE frameworks for cloud computing. It is witnessed that only CMG framework supports both objective QoS/QoE and subjective QoE for monitoring and assessment. However, it does not support reporting, policy change and client device monitoring which the essential requirements of QoE framework for cloud are computing. All remaining frameworks support only one type of QoE, either subjective or objective and also do not support client device monitoring and policy change on the behalf of collected QoE. None of the frameworks has ability to provide all functions as mentioned in Table 1. In future, more development is required to make an efficient QoE framework, which capture both QoE type objective and subjective measures. Additionally, data analysis for negative and positive feedback from end users and dynamic policy of cloud, which changes at the time of peak usage may also be put into the consideration.

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