A Conceptual Framework for QoE Measurement and Management in Networked Systems

Alex Frank Mongi
The University of Dodoma
College of Informatics and
Virtual Education
P.O Box 490
Dodoma, Tanzania

ABSTRACT
Network management of real time applications demands a new approach for an effective service quality provision. The traditional approach of network management based on Quality of Service (QoS) parameters like jitter, throughput, delay and loss cannot give enough details of how user quality demands. Therefore network management approach must start from user's point of view to the network side. This kind of approach is called a user-centric network management approach which ensures that end users quality of experience (QoE) is maintained. Most of network management systems have manage and monitor network performance without knowing what users are experiencing. This paper propose a framework to measure and manage QoE in networked systems. It is clear that a network which can identify user's quality requirement and optimize itself will simply meet users' demands, and hence users' satisfaction which is define as QoE. Another key issue which has not been implemented by existing systems is the issue of compensation. If network systems at the time of requesting cannot offer resources enough to meet users' demands, then users should be compensated. In achieving those requirements, the proposed framework is designed with five key elements which are QoE-predictor, Network Management & Mediation System (NMMS), Resource Allocations &Management System (RAMS), Service Level Agreement Management System (SLAMS) and Billing System (BS).

General Terms
Networked System Architecture, QoE management framework

Keywords
QoE-predictor, QoS, RAMS, NMMS, SLAMS,OPEX

1. INTRODUCTION
A tremendous growth of internet applications such as multimedia, social networks, on-line games and video over internet protocol causes the quality measure to shift from network centric to user-centric approach. The network centric quality measure technique refers to the network quality management based on quality of service (QoS) parameters such as delay, jitter, packet loss and data-rate in a networking layer. In other words QoS refers to the techniques network management can be performed objectively to ensure quality to the end users from network operator point of view. However, this approach has not always been successful due to the user-centered applications such as multimedia, online gaming and video over IP [3] [7]. The user-centric quality measure in communication network is known as quality of experience (QoE). It is a subjective measure which evaluate the collective effect of service performance which determine the degree of user satisfaction. It assess perceived usability, service integrity, retain ability and accessibility of a networked service. Therefore in measuring quality to an end user, the concept of quality of experience (QoE) is the most appropriate term due to its inclusion of various factors which are not included in network centric management techniques through QoS parameters. However, still research studies are trying to find out the best framework which might integrate most influencing factors in measuring and monitoring QoE as accurate as how a real human would perceive quality when interacting with networked systems.

2. NETWORKED SYSTEM
Networked systems are communication infrastructure which can basically be divided into access domain, transmission domain as well as application domain as shown in figure 1. They all together work in a dependable way in order to deliver services to end user devices. If one part of the networked system does not work effectively, then end users will perceive a poor service quality and therefore users' expectations of a better service won't be fulfilled. In a competitive business environment, if users are not satisfied they may turn to another service provide. Whence in order to reduce the rate of churn in mobile networks, service providers need to know, provide and manage users' quality of experience. Most of framework to manage quality, does not focus on how to integrate end users in management framework. However, users are the perfect quality measure and therefore to get reliable and accurate framework to measure and manage quality there must be a way to integrate end users [10].The networked system is subject to user and it's performance is evaluated according to user's satisfaction which is translated as QoE [8] [17].

Access network is a network infrastructure that runs to user and provide service connectivity through end user device. The most widely deployed access technologies include wired technologies such as ADSL and wireless technologies such as WCDMA, CDMA2000x together with Wi-Fi [5] [16]. The core network consists of transmission infrastructures which transmits and routes aggregated data traffic using high capacity exchanges and multiplexers. Data is usually carried at very high speed compared to access network, and provide connectivity to external networks through media gateway. The dominant transmission technologies used at core network are Microwave radio and fiber optic cable using Synchronous Digital Hierarchy (SDH) and Dense Wave Digital Multiplexing (DWDM) technologies. The application domain is actually built by a group of application servers which offers different services. Servers may be hosted in the same network or located in other public networks such as internet.

Application servers may be web, mail, real-time service, proxy, file servers and others. These applications have made life of people to become dependent on communication

networks. Applications like air ticketing, online shopping, video streaming, social networking, and video conference have gained a great share in communication industry. Moreover, they require a guaranteed level of quality and users' perception about offered quality is a key success towards market penetration. The network management systems as discussed by [16] [17] only monitor network performance from access point to the transmission network nodes as shown in Figure 1. According to Huawei the network information collected by management systems does not reflect end users' preferences and therefore a very crucial point is missed out, which is user centric network management [7]. This work propose a framework which if implemented may offer a user centric network management so that user QoE may be managed and optimized.

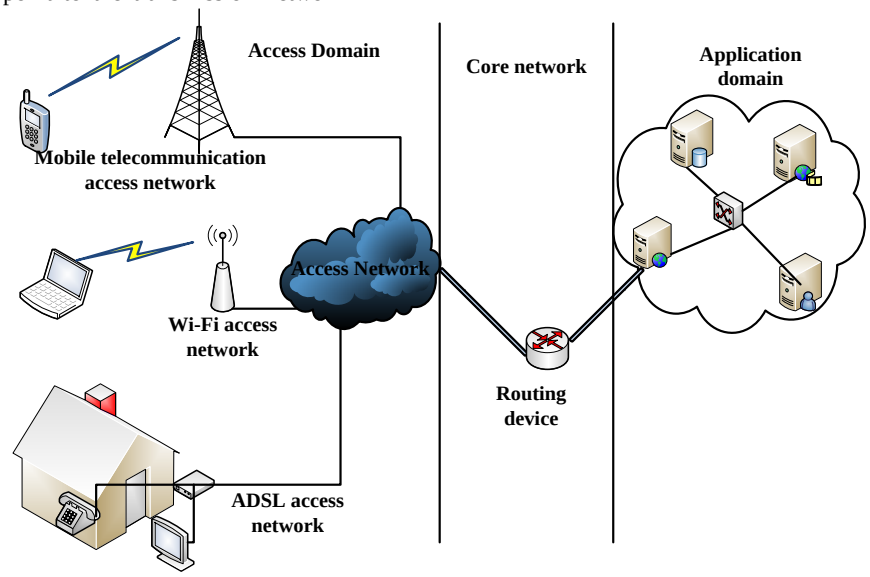

Fig 1: Networked System Management Domain

3. RELATED WORKS

3.1 A review of QoE Framework

This part presents a review of QoE management framework proposed by previous researchers and thereafter compare each one and propose another framework which will mimic shortcomings observed in the reviewed works. The first work to be reviewed was done by [1] proposed a QoE management framework for multimedia streaming applications in wireless networks. The technique was based on resource allocation management which was defined by QoS parameters and specific key quality indicators. It was characterized by seven steps which has to be passed through during the process of QoE management. However in networked systems, QoE is not only influenced by QoS parameters alone. The proposed framework could work alone when integrated between management systems to manage quality traffic flow. In case of managing user perceived quality, a user domain must be a part of the framework [17] [18]. Another work done by [12] extended the idea for mechanism of quality management of multimedia users. The developed framework aimed at managing and optimizing QoE in next generation networks based on multimedia applications. It was named QoE- aware real time multimedia management (QoE2M). The key functioning blocks constituting the framework are signaling management, mapping management, adaptation management, network analyzer, quality estimator, artifact prediction, protocol resource allocation and mobility control. The framework considered various QoE inputs, however some key inputs from user side such as Service Level Agreement (SLA), user profile in terms of preferences and service payment schemes are left out, which are among of important QoE influencing factors. Another study done by [6] proposed a framework to link QE with an appropriate measuring methods. In this study the QoE influencing factors such as user profile, ICT product, use process and context were identified. However, further work need to be done showing how the framework can be adopted into live network management systems. According to [4], [9] and [11], more factors which influence QoE must be considered when making a QoE framework. The mentioned inputs to QoE framework are emotions, technology, server, end device, user factors, experience and expectation. A proposed QoE framework by [14] tried to do a combination of network factors, user mobility function and traffic classification in studying user QoE score. The framework was intended to evaluate user's perceived reliability and satisfaction of services when they are in movement as their QoE indicators. However, things like network integrity, accessibility which also are key QoE indicators were not considered within the framework. A work done by [2] proposed a framework to monitor quality of experience for networked services based on a client-server communication model. The server side contains a QoE database, Web QoE, policy management, monitored QoE, and QoE agents which all links to QoE admin as shown in [2]. The framework tries to assess both objective and subjective factors of QoE. However, their framework requires user feedback so that quality optimization can be performed. In this case it becomes not easy since most of users don't respond as it has been observed by [13] that about 90% of users don't give claims about poor service, they just switch to another service provider.

3.2 Analysis and Comparison of Reviewed QoE Frameworks

A communication network performs its task to fulfil user's demand, satisfaction or desire. The ITU-T Recommendation of networked systems quality measurement define quality the term Quality of Experience as an acceptability of overall network performance towards subjective quality assessment as perceived by end users [8]. For that matter, a QoE management framework must take care of important domain which exist in communication ecosystem. Most of the

reviewed QoE framework considered some few aspects of factors affecting QoE. In network management of business oriented communication systems three key aspects which are user domain, networked system domain and business domain must be integrated into management systems. Table 1 present a summary of reviewed works showing where the concentration was and proposing a new way forward. The factors which were used to make framework for measuring and managing QoE are divided into user factors, networked system factors and business factors. Most of reviewed work have tried to respond to the relationship which can be deduced between Networked System factors such as delay, jitter, data rate, and packet loss towards overall user satisfaction. However considering network factors alone cannot be sufficient in developing QoE frameworks for monitoring and measurement purposes [7]. Two reviewed work added user factors in their study together with networked system factors to understand end user satisfaction [2][3]. Content and business factors were not included in QoE frameworks of all analyzed works as can be seen in Table 1. A user in communication systems can be satisfied based on content factors such quality, availability and content usability. Business factors such as service cost and customer support may also affect users' quality perception. For that reason, this study proposes QoE framework which integrate user, content, network and business factors.

Table 1: Comparison of reviewed works

		Factors considered in QoE framework			
S/N	**Reviewed work**	**User factors**	**Content factors**	**Networked system factors**	**Business factors**
1	Addressing user Expectation in mobile context [1]	√		√	
2	QoE framework for network services[2]			√	
3	Linking an integrated framework with appropriate methods for measuring QoE [6]	√		√	
4	QoE management framework for real time multimedia applications[12]			√	
5	QoE key metrics framework mobility user[14]			√	
6	Proposed framework	√	√	√	√

4. PROPOSED FRAMEWORK

4.1 Overview of QoE Management Framework

This proposed framework is an automatic QoE manager, which does not required users' feedback to be given manually. The key functions proposed in the framework are QoE-predictor , Resource Allocation and Management System (RAMS), Service Level Agreement Management (SLAMS), Network Management & Mediation System (NMMS) and Billing System.

4.1.1 QoE Predictor

QoE-predictor perform duties of imaging how a user would be satisfied/unsatisfied according to network conditions, user profile and application (content) type accessed from application servers. The prediction may use different approaches such as statistical prediction, machine learning, neural networks and other imagine techniques. Having knowing user required QoE will enable the network to self-optimize itself so that user's satisfaction may be fulfilled

4.1.2 Resource Allocation and Management System

In networked systems resources may be one of the factors which may cause quality degradation if they become scarce.

Always resource are not at disposal of the network and therefore a proper designing must be followed to assure an acceptable quality at minimum cost. Resource provision may affect Network integrity which then is translated by users in terms of QoE as a poor or good depending on the situation experienced. For instance an increase of users in a site causes the contention ratio to rise, which as a result the available throughput to each users decreases. If the condition is not improved, more congestion on the link may create another quality setback due to packet loss may cause real-time application such as video conference, Voice over IP and online gaming to stop operating due to degraded network quality.

To guarantee a quality based resource proportion and the desired quality to end users a Resource Allocation and Management (RAMS) has to be dynamic to traffic according to user's profile and application accessed. Users should be

given priority according to the class they register such as Gold, Silver and Bronze with charging rates being highest, higher and normal respectively. On that bases resources such as bandwidth, is allocated according to user desired quality, QoE_i, user profile (class) and application (content) type requested.

4.1.3 Service Level Agreement Management System

It keeps the agreement between users and service provider about the quality of service and prices to be charged. The current practice does not facilitate the customer side if receives the below quality services. For instance when one connects to a mobile data bundle, the service is charged according to the volume of data downloaded regardless of what quality associated during session time. The proposed framework considers session quality as one of important parameters in and the charging policy should reflect on this so that customer satisfaction is kept as a priority.

4.1.4 Billing System

Billing System (BS) perform service charges and keep track of all user's information with regard to their billing. Information such as application/ services, user class and appropriate rate per service and user class are stored in a BS. In commercial networks the BS is the most sensitive node in communication business. The tariff plans are programed at this node together. In maintaining user's perception of services offered through a particular network, a billing system should perform a dynamic charging according to agreement between user and service provider. If a user is well served by networked system by meeting expected QoE, then full tariff should be charged otherwise should be deduced as agreed in SLAM policy.

4.1.5 Network Management and Mediation System

The Network Management and Mediation System (NMMS) acts as the judge who does the justice between the two parties which are service providers and customers. Quality of experience is affected by the customer's expectation which is always moderated by what customers pay to get the service. Studies revealed that always customers who pay highly expect more quality of service than those who pay less. If the QoE management framework may be able to measure active QoE against what can be offered by the network, and changes network settings to offer sufficient resources according to the required QoE and not according to the available QoE, then customers will be delighted. The NMMS coordinates all nodes performance as shown in Figure 2 to optimize user's QoEi. The inputs to the frameworks are network conditions, user profile and content/application type. Network conditions are characterized by network integrity {data throughput, loss, error rate and delay jitter}, network retain ability and accessibility. User profile refers to user class subscribed and privileges which can be provided. The content type refers to the kind of application queried such as web browsing or multimedia streaming.

4.2 Sequence of Message Flow to show QoE Management and Measurement Process

The process of QoE management and measurement can be is summarized by the exchange of commands as shown below.

- Seq 1: The QoE-predictor learn network conditions, content type and user class. Then it compute user expected/required QoE.
- Seq 2: QoE-predictor send information to the NMMS.
- Seq 3: NMMS asks the SLAMS about agreed threshold level for user i for a particular service.
- Reply Seq 3: The SLAMS feedback NMMS
- Seq 4: NMMS then asks RMAS whether it can allocated resources to user i, to meet required QoE_i,
- Reply Seq4: RAMS feedback NMMS.
- Seq 5: NMMS sends information to BS: If required QoE_i can be provided, then BS uses normal charging plan otherwise uses exempted charging plan,
- Reply Seq 5: BS reply to NMMS about task performed, and conversation stops.

The proposed QoE framework aims at managing and maintaining network performance according to users' expected quality demands. Resources allocated to satisfy users should be able to meet minimum quality demands. Both overprovision and under provision have major impacts in network management in terms of operation expenditure (OPEX) and users dissatisfaction respectively. The proposed framework tries to make sure that users are satisfied at minimum available resources. QoE-predictor model will be installed in mobile agents to collect required statistics and computes users 'QoE.

Decentralized QoE prediction at the mobile agents assists in reducing computation complexity at the server side. The processed information from mobile agent is then sent to QoE server located at Network management center. The communication model which exist between mobile agent and QoE server is the client-to-server model. QoE server contains four systems which are NMMS, RAMS, SLAM and BS as described in QoE framework.

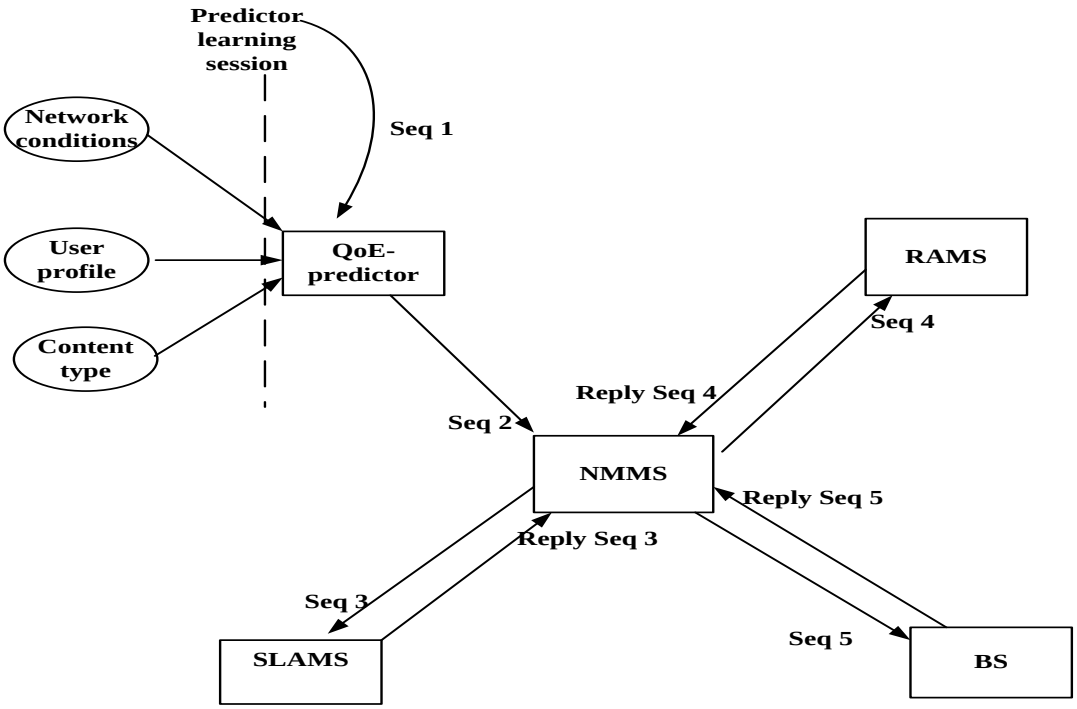

Figure 2: QoE Management Framework

5. CONCLUSIONS

In this paper the conceptual framework of measuring and managing QoE in networked systems has been introduced. It contribute towards the effort of developing user-centered network management system. The framework focus on the integration of users with central network management systems in order to maintain network performance which will satisfy users demands. Moreover, the framework has introduced a way to compensate users who were not served according to the initial agreement between service provider and user (customer) using SLAMS. Such plan is not existing in operational management systems. Network management practice for the long time has been isolating end users. It has been performed under the assumption that users will always be satisfied based on certain network conditions. However, being able to offer what is needed brings customer satisfaction and not offering what is thought is needed without having a prior knowledge. This framework will bridge this gap by enabling the network management systems to understand users' demand at a given time of accessing network, and try to offer performance which meet these demands. The future work of this study is to investigate appropriate prediction techniques which can be used in QoE-predictor to learn user profile, network conditions together with content type and compute the estimate of users' expected quality (QoEi). The later work will also look at development of other important blocks of the system.

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