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Full Length Research Paper

Quality of experience key metrics framework for network mobility user

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This paper presents a new framework of Quality of Experience (QoE) in mobile network. The user acceptance of a mobile application depends on the application's perceived QoE. Currently, there is no comprehensive framework which integrates QoE and Quality of Service (QoS). The components of framework consist of the network mobility users, traffic classification matrixes and QoE key metric. The performance evaluation of this framework for assessing QoE in service class and user class model is presented. The simulation results demonstrate the user satisfaction evaluated by the achieved QoE at different service classes and user classes. The new QoE score model can give deeper understanding of the mobile user interaction within the mobile environment; quantify the user's QoE and their relationship with QoS.

Key words: Mobile network, quality of experience, quality of service, key metrics, mobile user.

INTRODUCTION

The dominant network today is internet, and most of its traffic is based on IP. In such a network, it is sometimes required to provide priority for selected traffic to fulfill their needs. This should be done in a way that other traffic with lower priority does not encounter starvation. Quality of service (QoS) is the ability of network to classify its traffic and let them traverse the network based on their priority. It can also reserve network resources and manage to gain access to provide required priority for specific class of network flow (Nokia, 2004). To categorize traffic, we should know the factors which play an important role in defining QoS in a network. Network availability, band-width, delay, jitter and loss are those which are noteworthy.

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Abbreviations: AQoS, Application quality of service; **BE,** best effort; **CBR,** constant bit rate; **DiffServ,** differentiated services; **ertPS,** extended real-time polling service; **GoS,** grade of service; **IntServ,** integrated services; **KPI,** key performance indicator; **MN,** mobile network; **MOS,** mean opinion score; **MR,** mobile router; **nrtPS,** non-real time polling service; **NEMO BS,** network mobility basic support; **NQoS,** network quality of service; **QoE,** quality of experience; **QoR,** quality of resilience; **QoS,** quality of service; **rtPS,** real-time polling service; **UGS,** unsolicited grant service.

The way in which QoS is carried out in a network is in direct relation with applied architecture. Differentiated services (DiffServ) (Blake et al., 1998) and integrated services (IntServ) (Wroclawski, 1997) are two major QoS architectures. DiffServ classifies and marks packets based on the services they need while IntServ reserves network resources to provide QoS for selected traffic. Various mechanisms are applied for QoS provisioning, including the latest WiMAX technology, where it supported different QoS classes: unsolicited grant service (UGS), real-time polling service (rtPS), non-real time polling service (nrtPS), best effort (BE) and extended real-time polling service (ertPS) (Shu'aibu and Syed, 2011). These mechanisms include classification, congestion management, congestion avoidance, shaping or policing, link efficiency and dynamic resource allocation (Shu'aibu et al., 2011). In fact, QoS is a technical issue which considers quality in network standpoint.

There are many cases in which QoS techniques are applied very well. However, network users are not satisfied yet. It implies that the acceptable level of QoS does not always lead to user satisfaction (Mohseni, 2010). Besides the fact that QoS does not always lead to user satisfaction, services and applications are evaluated by the users, and those services or applications which meet user's expectation can gain more success and will be adopted widely (Katrien et al., 2010). Considering that

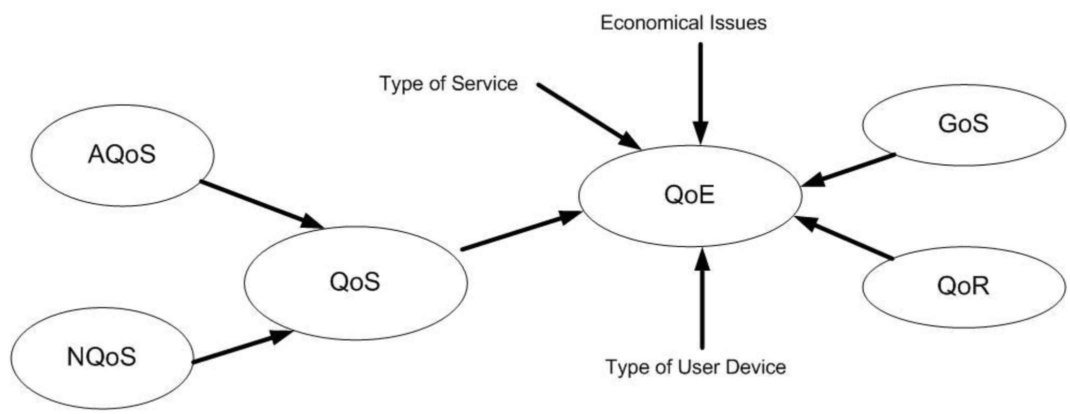

Figure 1. Factors affecting QoE.

the user's perception of a good service is essential, brings the quality of experience (QoE) to the notice of the users. QoE is considered as the usability of service perceived by a user and how satisfied is the user with the service. It is defined by International Telecommunication Union-Telecommunication (ITU-T) as "the overall acceptability of an application or service, as perceived subjectively by the end-user" (ITU-T, 2006). QoE is concerned with user expectations, requirements, and particular experiences. QoE is a final goal in the network which will be reached by adding network QoS (NQoS) and application QoS (AQoS), QoS (QoS = NQoS + AQoS), grade of service (GoS) and quality of resilience (QoR). Moreover, some other factors, such as the user end device type, type of service and economical issues, can have considerable effect on it as shown in Figure 1 (Stankiewicz et al., 2011; Siller and Woods, 2006). However, a poor QoE will result in user dissatisfaction. To promote QoE, a mechanism to measure it is defined. First, defining QoE key performance indicator (KPI) is important. Then, two practical approaches to measuring QoE are determined. A service level approach uses statistical samples and network management system uses QoS parameters (Soldani, 2006). The users express their experience by their feeling. For example, they may declare that they had a good, fair, or bad experience with the network services. Therefore, at the first step, it is important to map user experience to the technical metrics and the factors of QoS. The next step is to collect the KPI from entire network and compare to the desired level of QoE.

Mobile QoE (MQoE) is related to the delivery and consumption of mobile devices to and by the mobile users. QoS mechanisms for mobile networks have not been widely implemented. There are few factors that impact the implementation of QoS in mobile networks, such as dynamic topology, battery constraints and accessibility. MQoE is defined as satisfaction of traffic delivery and consumption of the mobile devices. The mobility users may know immediately either the services are good or bad (Falchuk and Famolari, 2010). Regardless to the type of network or application which a mobile user may use, this should be noticed while they are connected to a mobile network with their mobile devices. They may experience several handover or change of network domain (Noor, 2010) due to the nature of mobile networks. The service providers should apply MQoE where the users may not feel any inconvenience during these changes. To accomplish this goal, a clear understanding of subjective and objective contributing factors in user's satisfaction should be determined. It is also highly required to be able to map subjective factors to their counterpart objective ones and try to improve them while they are in close correlation with each other. Another reason for applying MQoE is growing demand for multimedia and real-time services over the mobile networks.

These days, mobility users who connect to the internet through their mobile devices would like to watch their favorite television series while they are on the move. Due to the fact that these services are much more sensitive to packet loss, delay or congestion in comparison with traditional services like E-mail (Wijnants et al., 2008), it is crucial to guarantee service quality in a way that brings about end user satisfaction. If they feel dissatisfied with the service, the service providers will be confronted with loss of their clients and consequently, reduction in their interest rates. As mentioned earlier, QoS mechanisms for mobile networks have not been widely implemented and those which are in use now should be in continuous evaluation by the users in order to enhance their efficiency. Besides that, continuous changes with which mobile users may face changeable network topology, and different number of users in each geographical area. This is a necessity for the service providers to know firstly about the threshold at which users consider a service unacceptable and secondly the degree of influence of each QoS factors on the user's expectation (Agboma and Liotta, 2008), which is where, MQoE comes to the fore.

Network resources are limited, and this limitation is

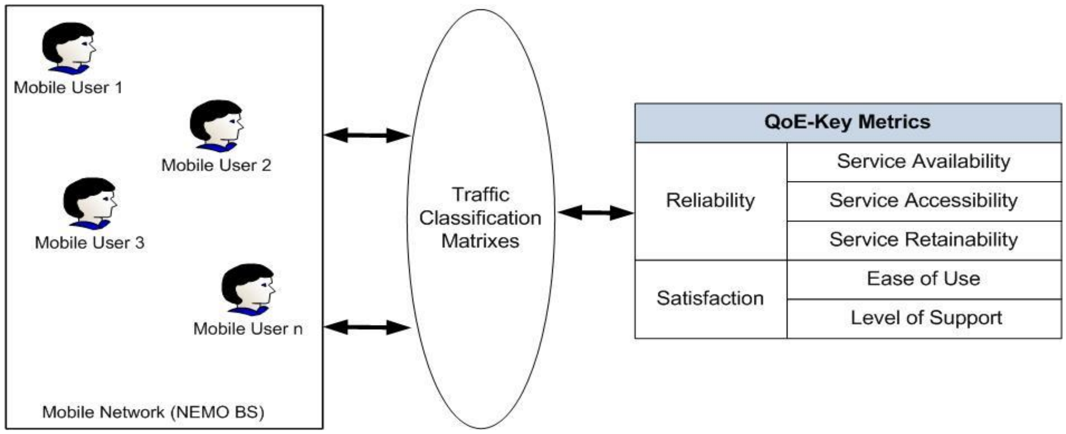

Figure 2. QoE key metrics framework in mobile network.

more noticeable when it is concerned with mobile networks. Assigning resources in a network based on pure QoS solution without employing QoE approaches may result in over resource provisioning or over service provisioning (Agboma and Liotta, 2010). In fact, MQoE can lead to better resource usage in mobile networks.

To recognize user's perception of a good service and measure it, and also identifying network factors and their degree of influence on user's expectation, we need a viable solution. This solution can be a mechanism which shows how a network provider can improve contributing QoS parameters to promote user's QoE. In fact, we should be able to show clearly the relation between objective and subjective parameters (Khandaraj, 2008) and map them to each other in order to translate user expectation to the network and application. This will be achieved through a well defined QoE framework. To provide better QoE for the mobile users, QoS should be evaluated and improved in relation to QoE parameters and user perception. In short, employing subjective and objective method together will lead to user satisfaction (Perkis et al., 2006; Siller and Woods, 2006; Yu, 2009). Perkis et al. (2006), for instance, presented a model to measure QoE of mobile multimedia services. He considered both measurable parameters which are objective and non-measurable parameters that are subjective or user-centric. He also considered availability and reliability of the service as the QoE key factor and tried to measure them in order to evaluate QoE. Bernardo et al. (2008) evalu-ated QoE and subjective user perception under a QoS-aware mobility mechanism. The mechanism is able to alleviate packet loss, network issue and improve sub-jective mean opinion scores, based on a user perception.

The aim of this paper is to introduce a novel framework that integrated the mobile network users and QoE matrix model. In this model, the specific requirements of the QoE key metrics that are reliability and satisfaction have been identified. An experiment was conducted to measure the user reliability and satisfaction with three different QoS classes.

MATERIALS AND METHODS

Mean opinion score (MOS) is defined to evaluate voice traffic. The conversational MOS is a prediction of the narrowband con-versational quality (MOS-CQ) of the audio stream that is played to the user. The listening quality of the audio played and sent across the network is taken into consideration. A large group of people would rate the quality of the conversation, including the levels of noise. The conversational MOS variety depends on the same factors, such as listening MOS, echo, network delay and jitter. There are two mechanisms to evaluate QoE, that is, objective and subjective assessments (Kandaraj et al., 2008). An objective of assessment is to focus on the network parameters, such as latency, throughput and error. Nevertheless, the subjective assessment requires an end-to-end performance which involved high-cost and time consuming to evaluate. The combination of the two assess-ments may provide excellent experience for the user. This is known as "a hybrid assessment" (Kandaraj et al., 2009).

The concept of NEMO Basic Support (NEMO BS) protocol is to provide continuous internet connectivity to the mobile network nodes via a mobile router (Vijay, 2004). Traffic from a correspondent node is intercepted by a home agent before being forwarded to a mobile router. The proper resource allocation is a key factor in provisioning of QoS in a network mobility context. The mobile network unpredictable movement gives a difficult task to the provision of QoS. In the model, service and user classes allow QoS guarantees and a simple implementation has been conducted (Noor and Edwards, 2009). Referring to this model, we have extended the model to measure QoE for the mobile users in the mobile network. A proposed QoE key metrics framework is illustrated in Figure 2.

The QoE key metrics framework consists of three main components: mobile network users, traffic classification matrixes and QoE key metrics.

1. Network mobility users: NEMO BS protocol consists of local fixed nodes, local mobile nodes and visiting mobile nodes. In this article, the mobile users are categorized as local mobile nodes. The mobile users can access any type of internet applications while they are on the move.
2. Traffic classification matrixes: The packet is classified using the traffic class in the IPv6 packet. The first 3 bits are used to define the classes, that is, service and user classes (Noor and Edwards,

Table 1. Traffic classification matrixes.

QoS parameter	Guaranteed	Assurance	Best effort
Service class	Premium	Intermediate	Default
User class	High	Secondary	Low
MOS matrix	Excellent	Good to Fair	Poor

Table 2. QoE key metric.

QoE key metric	
Reliability	
Service availability	Local and global coverage of the mobile network to the mobile network users. This is included a seamless handover of the mobile network for the mobile network users.
Service accessibility	The success rate of mobile user connections for any services.
Service retainability	The mobile network users are connected to the services provided with less than 0.0998% loss.
Satisfaction	
Ease of use	A key metric to determine how easy to use the services offered by the mobile network, specifically and Internet, generally.
Level of support	The mobile network provider where the mobile user will get a support from. This is to measure the level of response from the mobile network provider.

2009). The traffic is classified according to internet QoS application requirements. When the mobile users accessed particular application, it will map the traffic class with the pre-defined classification matrixes as shown in Table 1.

3. QoE key metrics: Two key metrics are defined, that is, reliability and satisfaction. The reliability consists of three sub-keys which are used to measure the service availability, accessibility and retainability. User satisfaction on the performance of application used are measured in a context of ease of use metric and level of support provided by the network services.

Table 2 shows the QoE key metrics that have been defined to measure the reliability and satisfaction.

QoE rules

The following rules are applied during the evaluation. It requires at least three forms of combinatory to build QoE expression rules:

Logical Equation Function:
Declare operator {and, or, not}
Service_Class {
<Premium, 100> and <reliability, range 100% to 80%>
and <satisfaction, range 100% to 80%>
<Intermediate, 110> and <reliability, range 79% to 50%>
and <satisfaction, range 79% to 50%>
<Default, 111> or <reliability, range 49% to 0%>
and <satisfaction, range 49% to 0%>}
User_Class {
<High, 100> and <reliability, range 100% to 80%>
and <satisfaction, range 100% to 80%>

<Medium, 110> and <reliability, range 79% to 50%>
and <satisfaction, range 79% to 50%>
<Low, 111> or <reliability, range 49% to 0%>
and <satisfaction, range 49% to 0%>}
MOS Function:
if prefer Service_QoS(1) or User_QoS(1)
Calculate <MOS, Excellent>
if prefer Service_QoS(2) or User_QoS(2)
Calculate <MOS, Good>
if prefer Service_QoS(3) or User_QoS(3)
Calculate <MOS, Poor>
end.

Experiment

An experiment was conducted using a network simulator (NS-2, 1989) to evaluate the QoE key metrics performance. A rail network case study was used to define a minimum number of mobile users, 50 and a maximum number of mobile users, 300. The experimental set-up consists of a mobile router which is attached to eight access points. In each car of the train consists of two access point where it could provide enough bandwidth to the mobile users. The constant bit rate (CBR) background traffic and MPEG video source were used. The maximum transmission packet size is 1024 bytes. CBR rate is fixed to 100 Kbps and the packet error rate is set to 0.05 intervals. Figure 3 shows the train infrastructure architecture.

RESULTS AND DISCUSSION

The results obtained from studying the QoE key metric reliability and satisfaction are shown in Figures 4 to 7.

First, the reliability key metrics for the service class for three groups, premium, intermediate and default are compared. The average service availability has shown higher percentage, 97.13% as compared to the average service accessibility, 84.98% and service retainability, 80.10%, as shown in Figure 4.

Meanwhile, the key reliability in the user class for high,

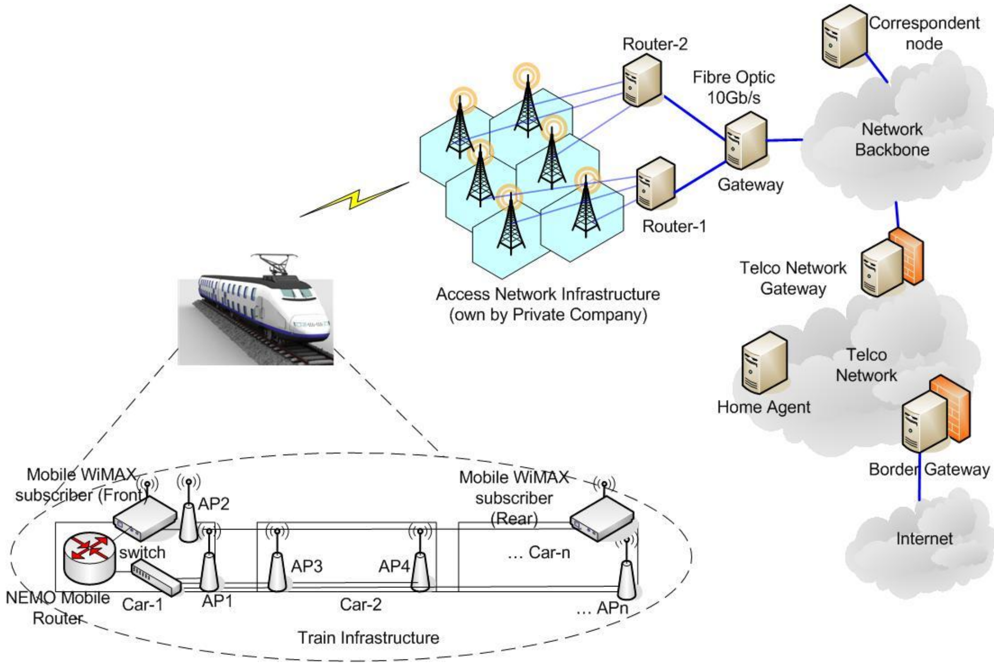

Figure 3. Train infrastructure.

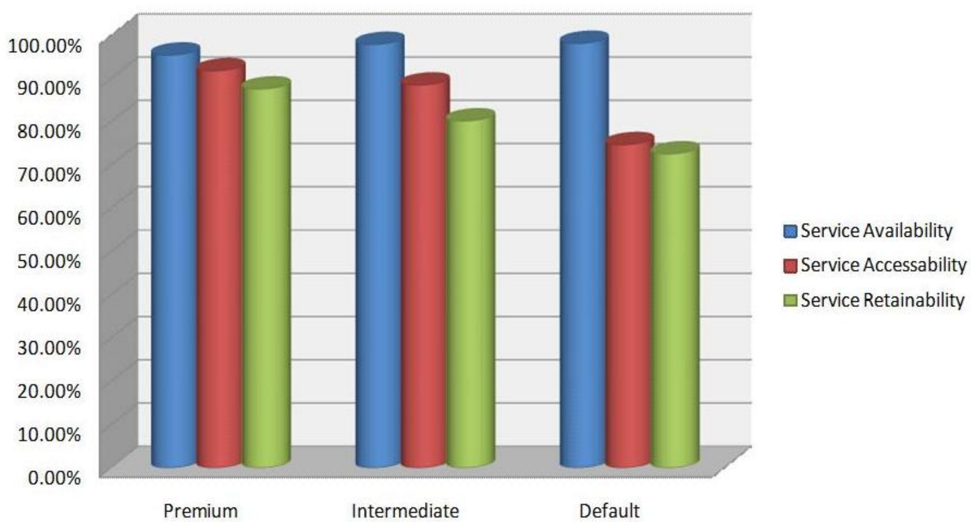

Figure 4. QoE key metric reliability (service class).

medium and lower classes are compared. The average service availability for user class is 97.11% which is not much different from the service class, availability. This is because the service availability is offered, no matter the classes the mobile users are subscribed to. In contrary, the average service accessibility and retainability for the three user classes are, respectively lower than the service classes (accessibility and retainability) 76.60 and 74.86%. The reason why service classes is better than user classes is because the providers always provide good services to the application accessed rather than the user group.

For measuring user satisfaction, the key metric satisfaction for the service class and user class are evaluated on how users perceive the service and how satisfied they are. To do so, two parameters on ease of use and level of support are used to measure the satisfaction. MOS for each parameter translated the user satisfaction by determining the connections arrival rate and packet transmission. This is evaluated at every

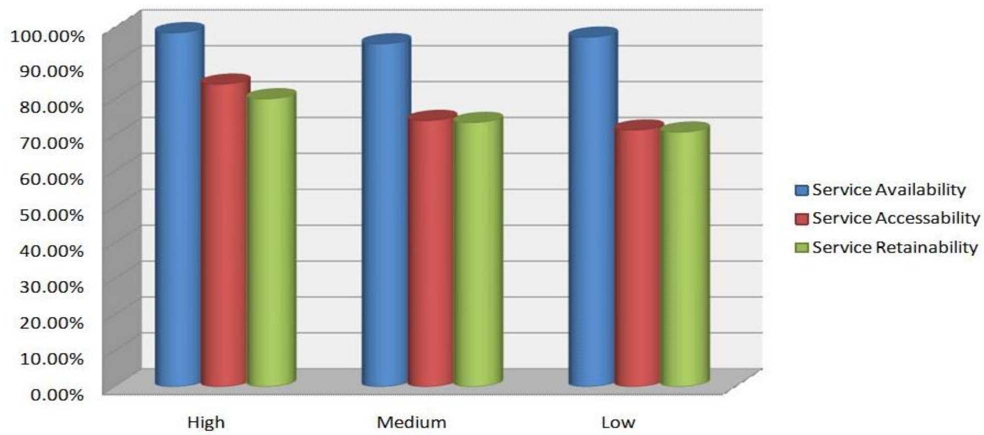

Figure 5. QoE key metric reliability (user class).

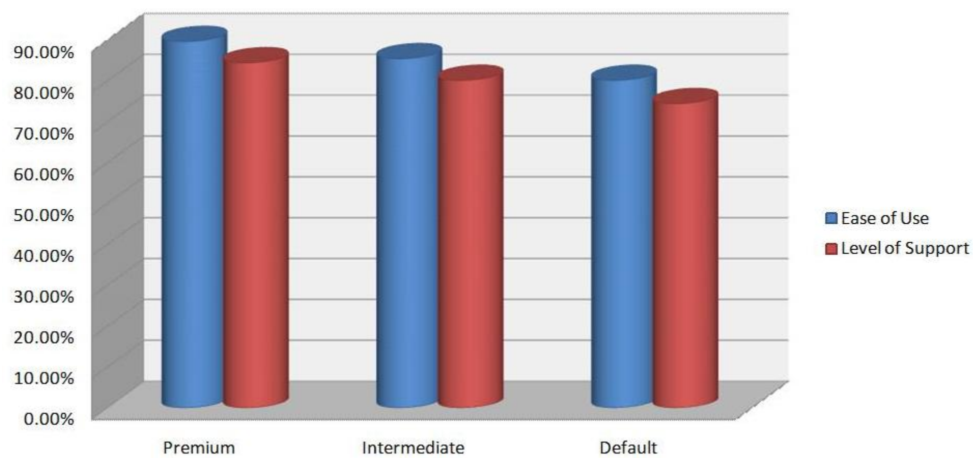

Figure 6. QoE key metric satisfaction (service class).

second. The results have shown further decrease on the average level of support in the service class which is 79.68% as compared to ease of use, 85.08%. It is noticed that, the user satisfaction decreases in the default class as compared to the premium class.

User with high priority have a high threshold, because the perceived quality have to be guaranteed strictly. This is shown in Figure 7, where the ease of use, 85.44% and level of support, 80.74% are higher in high user class than in medium class (ease of use, 80.45% and level of support, 68.77%) and low user class (ease of use, 74.54% and level of support, 59.45%). The reason why user satisfaction results in low user class less than the other user classes is because the threshold is smaller than the other classes and the users are less sensitive or less restricted in terms of quality.

The experiment will provide guidelines on how to analyze and interpret the analysis data within a service class and user class. From here, a QoE key metric analysis for MOS score is defined. The reliability and satisfaction percentage scale from 0 to 100% is determined from an excellent scale to a bad scale as shown in Figure 8. The QoE score model is a new evaluation method for user mobility, QoS performance in mobile network and the mobile network infrastructure. The new QoE score model can give deeper understanding of the mobile user interaction within the mobile environment; quantify the user's QoE and their relationship with QoS. The mobility users tend to have high QoE expectations to sensitive applications, such as streaming multimedia content, highly interactive web browsing, video conferencing and online gaming.

Conclusion

In this paper, a QoE key metric framework for network mobility is introduced. The mean opinion score is applied as a subjective quality evaluation approach with NEMO BS protocol in addition to a dynamic QoS provisioning for

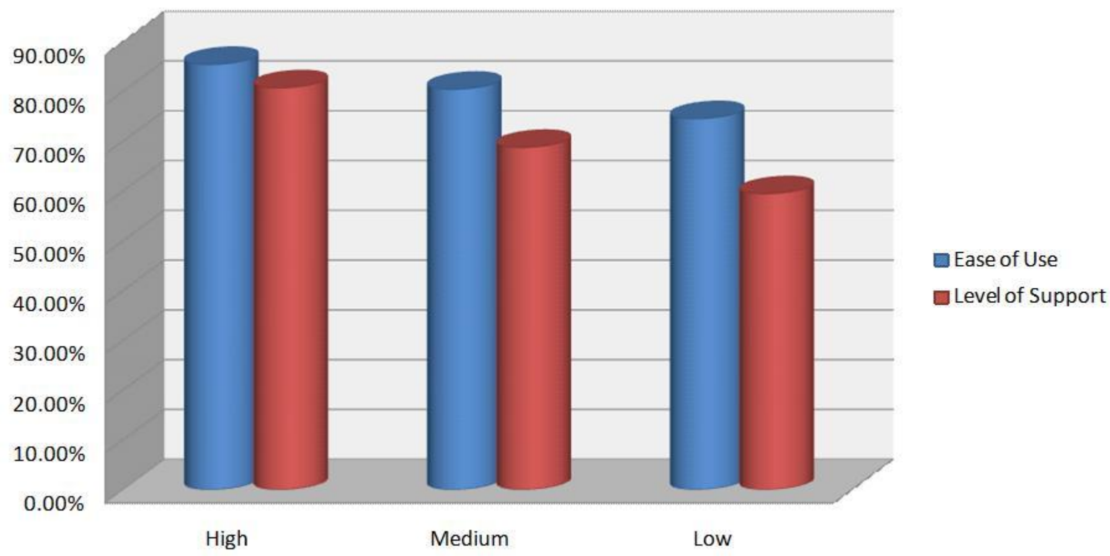

Figure 7. QoE key metric satisfaction (user class).

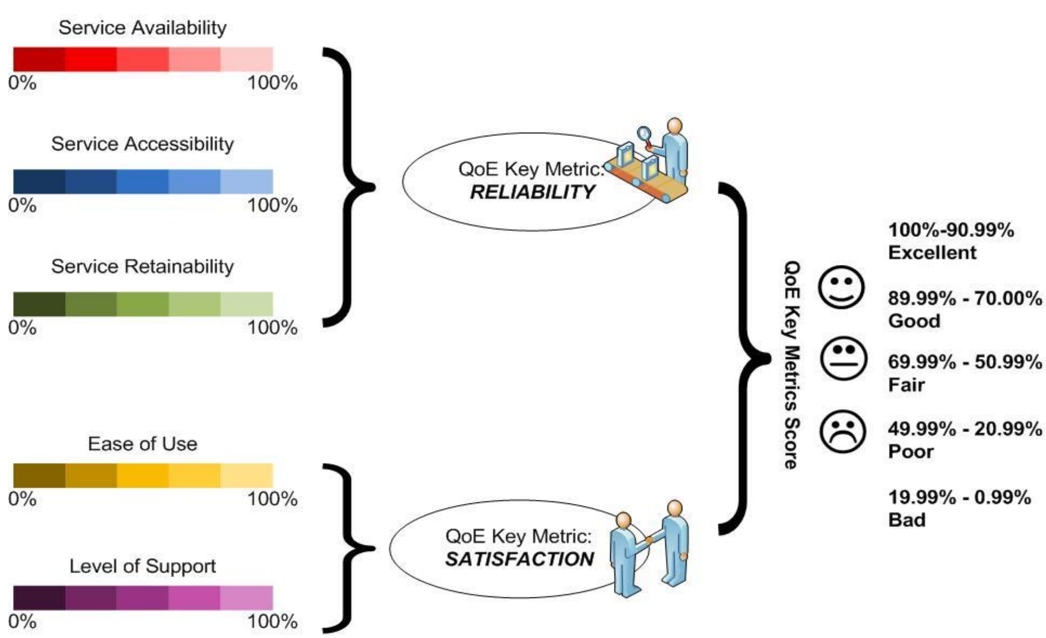

Figure 8. QoE score model.

network mobility architecture as an objective network base approach. Then, a traffic classification matrix which maps user reliability and user satisfaction as two major QoE key metrics, subjective part, to technical network issues, objective part, is presented. This framework is implemented to evaluate the users' reliability and satisfaction when they are on the move. The results showed the difference between service class and user class traffic chosen by the mobile users. In this way, a better resource provisioning for mobile users is performed as expected.

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