TRIANGLE-BASED QOE MEASUREMENT MODEL FOR VOIP APPLICATION

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ABSTRACT

Measuring the quality of IP network services that users are experiencing and maintaining their loyalty towards these services are the most important factors that service providers consider. The existing evaluation methods for calculating the Quality of Experience (QoE) are categorized into two groups named subjective and objective. The subjective approaches are expensive and time consuming. The focus of this study is on objective measurement of QoE for VoIP application, but the main problem with these approaches is that they do not consider all the network and service details in their calculation models. The purpose of this paper is to propose a new approach to calculate QoE based on the area of triangle. This model considers all aspects that affect the experiencing quality from user. The experimental results show that the calculated QoEs are more realistic than the conventional ones.

Keywords

Internet Protocol, Quality of Experience, Voice over Internet Protocol.

1 INTRODUCTION

Calculating the Quality of Experience (QoE) and Quality of Service (QoS) of VoIP application became more and more important for service providers with the growth of this application, because they are looking to maintain their customers' loyalty and competitive edge (Rix et al,2006).

For measuring QoE, there are currently two practical approaches in mobile networks as follows (Soldani et al, 2006):

1. Service level approach using statistical samples.
2. Network management system approach using QoS parameters.

The first approach focuses on statistical sampling and calculating the most accurate and relevant measurements according to that sample. In this approach, most of the quality measurement indicators rely on the application level to provide the real user's perspective. The Network Management System (NMS) approach focuses on different QoS metrics of the network and maps these KPIs onto different levels of perceivable QoEs.

The key performance indicators (KPIs) of QoE for VoIP application can be grouped under two main categories (Soldani et al, 2006). Table I summarizes these KPIs.

Table I: QoE Key Performance Indicators (Soldani et al, 2006)

Reliability	
QoE KPIs	Description
Availability	Availability of service anywhere.
Accessibility	The service is accessible anytime.
Retainability	The service connection is continuous.
Quality	
Delay	End-to-end delay.
Jitter	Variation delay.
Packet loss	Loose of packets during communication.

Interpretations and uses of QoE term are different. All of these approaches towards QoE provide frameworks to calculate QoE but not completely considering all of the network factors. For example the approach which is used by NOKIA is an evaluation model based on end-to-end delay (Nokia, 2004).

The presented model in this paper takes into account all key performance indicators of VoIP to calculate the QoE which is based on reliability (availability, accessibility and retainability) and quality (delay, jitter and packet loss).

The structure of this paper is as follows: In section 2 we describe briefly the VoIP QoE key performance indicators. Section 3 provides the current approaches on this subject. In section 4 we are going to introduce the proposed model. Section 5 shows experimental results and conclusions are drawn in section 6.

2 VoIP QoE KEY PERFORMANCE INDICATORS

This section briefly explains about QoE KPIs in VoIP applications which are grouped under following categories.

A. Reliability

Reliability in VoIP application context is the availability, accessibility and retainability of the end-user device, network service or application software (Soldani et al, 2006).

1. Service Availability

The availability of any network system is defined as the portion of the time that is in its operational state (ITU-T Rec E.850, 1988). Table II introduces some of the metrics in service availability.

Table II: Service Availability (ITU-T Rec E.850, 1988)

Metric	Description
Uptime	The average time that system is in its operational state, this term is often synonym of MTBF (Mean Time Between Failures).
Downtime	The average time that the system is not in its operational state. It is synonymous with MTTR (Mean Time To Repair).

Service availability is calculated as follows:

$$A_V = 1 - \frac{MTTR}{MTBF + MTTR} \qquad \text{Eq.1}$$

2. Service Accessibility

When a specific service is available in a particular area, it is important for users that this service is always up and accessible. Network accessibility is defined in terms of number of received ACK messages compared to the total number of requested messages (ITU-T Rec E.850, 1988).

$$A_C = \frac{\sum ACK}{\sum Messages} \qquad \text{Eq.2}$$

3. Service Retainablity

Retainability of network service is defined in continuity of its connection without any interrupts (ITU-T Rec E.850, 1988).

$$A_R = 1 - \frac{\sum N_i}{\sum N_t} \quad \textit{Where } N_i = \textit{number of interrupted call}, N_t = \textit{number of total calls}$$

Eq.3

B. Quality

Quality for VoIP application is considered as its QoS metrics. VoIP QoS metrics are summarized in Table III.

Table III: VoIP QoS Metrics (Iqbal and Mumtaz, 2009)

Metric	Description
Delay	In VoIP application the good perceiving voice is when the delay is less than 80ms.
Jitter	The range for delay variation which is acceptable is less than 30ms.
Packet loss	The acceptable range of packet loss for VoIP application is less than 1%.

3 QoE CALCULATION CURRENT APPROACHES

Current approaches to calculate QoE can be grouped into two categories names as subjective and objective.

In subjective matter, QoE is measured directly from the user’s satisfaction level towards a specific service and then is represented in terms of Mean Opinion Score (MOS) (ITU-T Rec P.800, 2006). In subjective qualification, a great group of people are gathered in a specific lab and their opinions about the quality of presented service are measured and are represented as a 5-point scale which spans from bad to very good. This scaling mechanism is called MOS.

Subjective assessment methods for QoE are so costly and require specific requirements which are not recommended for services that need large and regular assessments.

Another approach towards calculating QoE of VoIP and network services is the objective ones. These methods can be categorized under different methods such as the methods that consider the degradation of quality like E-Model (ITU-T Rec G.107, 2005), methods that consider the metrics of the network instruments like PESQ (ITU-T Rec P.862, 2001) and so on. The proposed objective methods are defined in a way that usually compares the original sample to the received one. Moreover, these objective methods consider the listening quality metrics of the network not the service quality metrics and even network itself which are availability, accessibility, retainability and network coverage.

4 QoE PROPOSED MODEL

A. Summary of the Model

This proposed model for calculating the QoE of VOIP application aims to consider not only sound quality metrics but also service and network quality metrics to calculate the more realistic measure for VoIP QoE.

For this model, each of factors that affect the quality of VoIP will be placed on one side of the three-dimensional axis. These factors are named as sound quality factors (VoIP QoS), service quality factors and network quality factor. Figure 1 depicts this 3-dimensional axis.

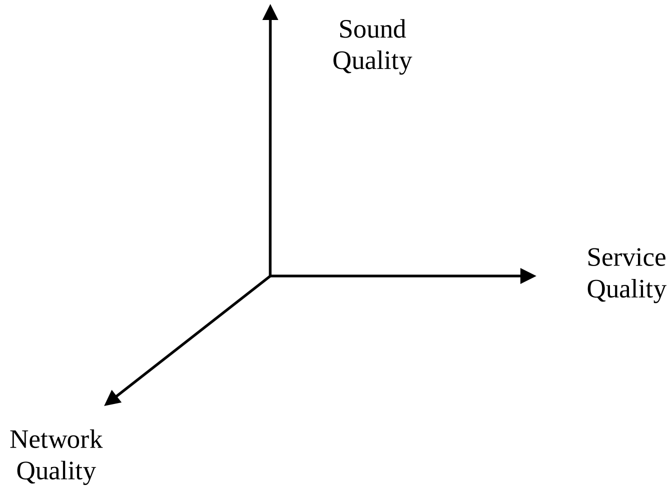


Figure1: VoIP 3-Dimensional QoE Model

Each of the factors on this 3-dimensional axis has a maximum and minimum value. When connecting these 3 axes together there will be a triangle that the area of this triangle will represents the QoE of our VoIP application with these provided quality factors.

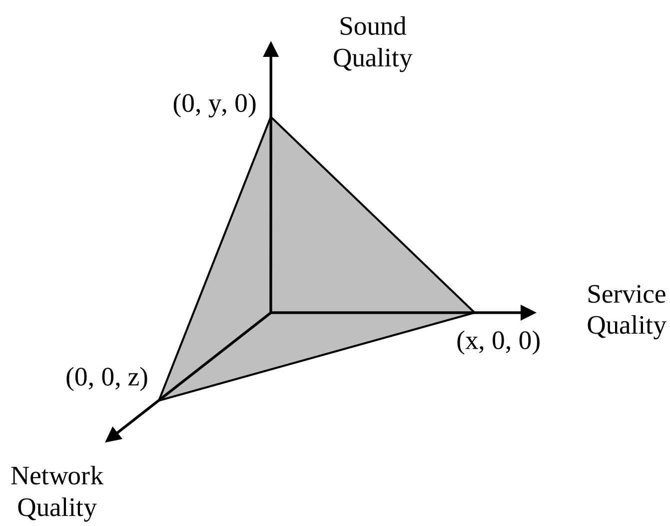


Figure 2: QoE Area of VoIP Application

In Figure 2, x, y and z are the maximum values of the VoIP quality metrics. The area of this triangle would be calculated by Heron's formula as follows:

$$QoE = \sqrt{S.(S-S_1).(S-S_2).(S-S_3)} \qquad Where \qquad \begin{cases} S_1 = \sqrt{x^2 + y^2} \\ S_2 = \sqrt{x^2 + z^2} \\ S_3 = \sqrt{y^2 + z^2} \\ S = \dfrac{S_1 + S_2 + S_3}{2} \end{cases} \qquad \text{Eq.4}$$

B. Service Quality Calculation

In order to measure the quality of service factors, we follow the triangle model for these metrics named as availability, accessibility and retainablity. Figure 3 depicts the calculation of service quality.

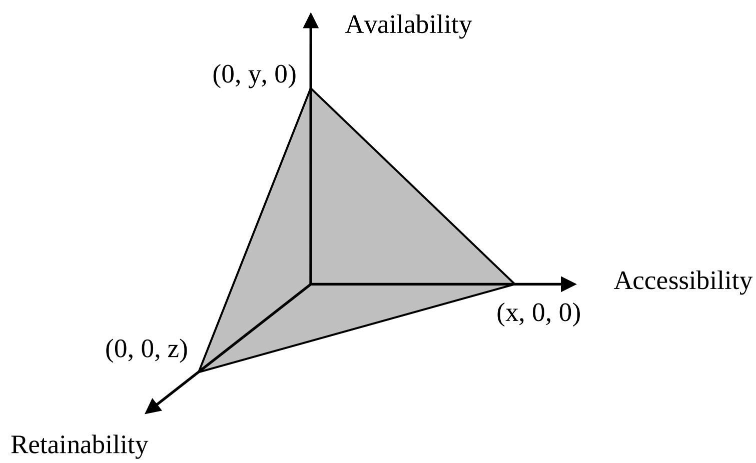


Figure 3: Quality of the Network Service

If we assume that the maximum value of each factor in Figure 3 is one, the value range for quality of network service would be as follows:

$$S_1 = S_2 = S_3 = \sqrt{1^2 + 1^2} = \sqrt{2} \qquad \text{Eq.5}$$

$$NetServiceQuality = \sqrt{\frac{3\sqrt{2}}{2}\left(\frac{3\sqrt{2}}{2} - \sqrt{2}\right)\left(\frac{3\sqrt{2}}{2} - \sqrt{2}\right)\left(\frac{3\sqrt{2}}{2} - \sqrt{2}\right)} \cong 0.86 \qquad \text{Eq.6}$$

The above calculation shows that the range of network service quality is as follows:

$$0 \le NetServiceQuality \le 0.86 \qquad \text{Eq.7}$$

C. Sound Quality Calculation

The sound quality of the VoIP application depends on its QoS metrics which are delay, jitter and packet loss. These metrics are controlled by service providers and are presented by MOS value. The measured value will be presented in percentage to be used in our model.

D. Network Quality Measurement

The quality of the network is totally depends on network radio coverage which is calculated as follows (ITU-T Rec E.850, 1988):

$$Coverage = 1 - \frac{MTTR}{MTTR + MTBF}$$

Eq.8

$$0 \le Coverage \le 1$$

E. VoIP Triangle QoE Model Values and MOS Mapping

All of the calculated and measured values of VoIP QoE factors including sound quality, service quality and network quality will be presented in percentage that we can assume their values between zero and one. Based on the Heron's formula the range of VoIP Triangle QoE model would be as follows:

$$0 \le QoE \le 0.86$$

If we map this calculated QoE to the 5-point scale MOS, the values would be:

Table IV: Mapping Triangle Model to MOS

Triangle Model	Satisfaction level	MOS
0.86	Very satisfied	5
0.645	Satisfied	4
0.43	Some users dissatisfied	3
0.215	Very dissatisfied	2
0	Not recommended	1

5 METHODOLOGY

In order to justify the proposed model the values of different network and service parameters are needed. But based on Nokia (2004), calculation and measurement of network and service quality is complicated and needs especial equipments and facilities. The purpose of this paper is to study the effect of network and service quality on measuring QoE level of VoIP application. Because the triangulation methodology needs the data from the same context, we used some measured data from Nokia (2004), for different parameters of network and service quality in both satisfactory and unsatisfactory conditions. The provided data is shown in following tables.

Table V: QoS and MOS Levels (Nokia, 2004)

Codec: G729	Frame Size: 10ms		
Packet Size: 20ms	Sampling Rate: 8000Hz		
QoS Factors	**Min Value**	**Max Value**	**Average Values**
Delay	11ms	11ms	11ms
Jitter	1ms	1ms	1ms
Packet loss	1%	1%	1%
MOS	4(0.8)	4(0.8)	4(0.8)

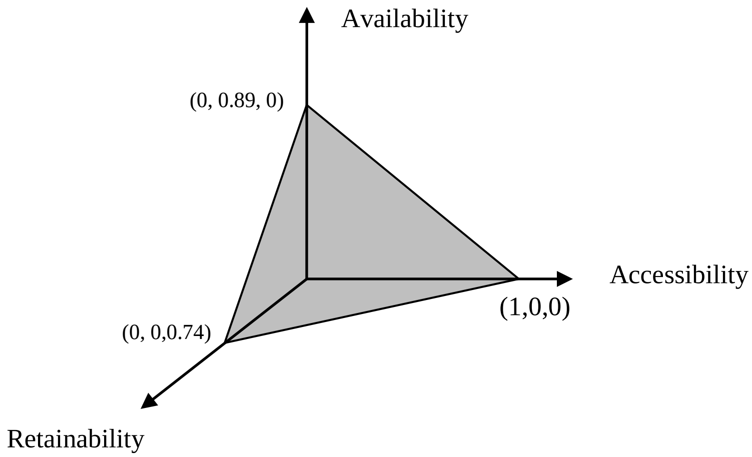
Table VI: Network and Service Quality Measures (Nokia, 2004)

Satisfactory Network and Service Parameter Values	
Service availability	0.89
Service accessibility	1.0
Service retainability	0.74
Network coverage	0.94
Unsatisfactory Network and Service Parameter Values	
Service availability	0.52
Service accessibility	0.36
Service retainability	0.31
Network coverage	0.62

6 EXPERIMENTAL RESULTS

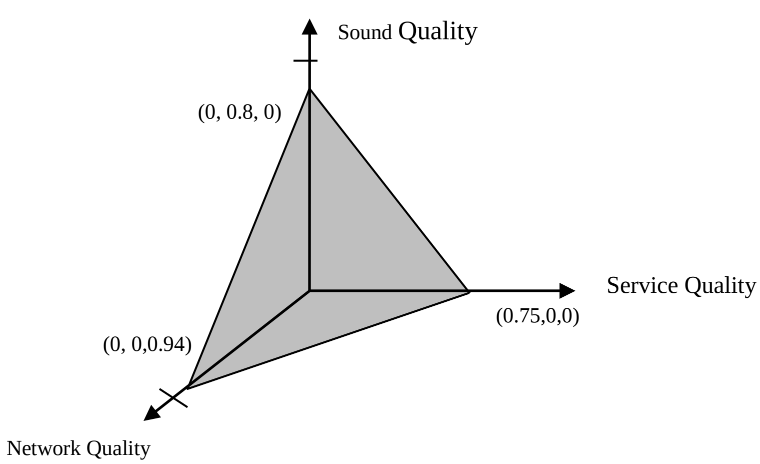
The calculation of QoE for presented VoIP experiments are as follows:

Experiment 1: In good network and service conditions:



$$\begin{cases} S_1 = \sqrt{0.89^2 + 1^2} = 1.33 \\ S_2 = \sqrt{1^2 + 0.74^2} = 1.24 \\ S_3 = \sqrt{0.89^2 + 0.74^2} = 1.15 \\ S = 1.86 \\ SerQuality = \sqrt{1.86(1.86-1.33)(1.86-1.24)(1.86-1.15)} \cong 0.65(75\%) \end{cases} \quad \text{Eq.9}$$

QoE of Experiment 1:



$$\begin{cases} S_1 = \sqrt{0.8^2 + 0.75^2} = 1.09 \\ S_2 = \sqrt{0.75^2 + 0.94^2} = 1.2 \\ S_3 = \sqrt{0.94^2 + 0.8^2} = 1.23 \\ S = 1.76 \\ QoE = \sqrt{1.76(1.76-1.33)(1.76-1.24)(1.76-1.15)} \cong 0.59(69\%) \end{cases} \quad \text{Eq.10}$$

The value of QoE in MOS for experiment one by just considering the QoS factors is 4, and by considering other factors including service and network qualities, the calculated QoE is 69% that if we map to MOS values it is still 4 but with more considerations of network and service attributes.

Experiment 2: In bad network and service conditions

$$\begin{cases} S_1 = \sqrt{0.52^2 + 0.36^2} = 0.63 \\ S_2 = \sqrt{0.36^2 + 0.31^2} = 0.47 \\ S_3 = \sqrt{0.52^2 + 0.31^2} = 0.6 \\ S = 0.85 \\ SerQuality = \sqrt{0.85(0.85-0.63)(0.85-0.47)(0.85-0.6)} \cong 0.13(15\%) \end{cases} \quad \text{Eq.11}$$

$$\begin{cases} S_1 = \sqrt{0.8^2 + 0.15^2} = 0.8 \\ S_2 = \sqrt{0.15^2 + 0.62^2} = 0.63 \\ S_3 = \sqrt{0.8^2 + 0.62^2} = 1.01 \\ S = 1.22 \\ QoE = \sqrt{1.22(1.22-0.8)(1.22-0.63)(1.22-1.01)} \cong 0.25(29\%) \end{cases} \quad \text{Eq.12}$$

For this experiment with bad conditions for network and service we calculated QoE with amount of 29% which if we map it to the MOS levels, we can see that the QoE of this VoIP service with these conditions is the level of 2 of MOS that means users will be dissatisfied with this service with these conditions.

7 CONCLUSION

Even though the nature of QoE is subjective, but it is very important for service providers to measure it. The proposed model for calculating QoE in this paper provides the capability of measuring QoE in real time for VoIP services. This model considers all aspects of quality that affect the receiving voice. This model presents a great span for enhancement of evaluation and measurement of perceived quality from VoIP users.

8 FUTURE WORKS

For the future studies, this model can be implemented and tested through simulators to get the better results. Also, this model can be deployed for other IP network services like IPTV, video streaming, etc.

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