International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 7, No.4 (July-2018)
http://dx.doi.org/10.12785/ijcds/070402

User Quality of Experience (QoE) prediction in Heterogeneous Mobile Networks

Mbemba HYDARA[1], Ahmed Dooguy KORA[2], Didier YANKAM[2] and Antoine GNANSOUNOU[2]

[1] *Department of Mathematics and Computer Science, University of Gaston Berger, St.Louis, Senegal*
[2] *Ecole Superieure Multinationale de Telecommunications (ESMT), Dakar, Senegal*

Received 14 Dec.2017, Revised 13 Mar. 2018, Accepted 25 Apr. 2018, Published 1 July 2018

Abstract: Quality of experience (QoE) is a key indicator in assessing the level of satisfaction of services offered by network operators. Mobile operators use several generation of technologies; these are not only based on the dynamic evolution of the networks but also the need to satisfy user expectations under intense competition. This study propose a methodology that will give subjective rating of communication taking place using two different technologies based on key performance indicators (KPI) parameters of 3G and 4G networks generations. Our approach goes beyond simple initiation of communication maintained by the same technology but involves several communications scenarios, which for various reasons may require switching from one generation of mobile network to another. In our proposed model, the ability to process survey results from a user QoE evaluation perspective is validated by our selection and use of appropriate combination of KPIs for each technology. The formula used will allow operators to predict duration that an Inter-Radio Access Technology (RAT) communication must have in each generation of mobile network services. This may help maximize customer loyalty and satisfaction based on selection of specific parameters.

Keywords: Heterogeneous,Mobile,Networks,QoE,Vertical handoff,Assessment

1. INTRODUCTION

The 1990s marked the beginning of real revolution in the field of telecommunications; an unbridled development which had the effect of changing the way of life of society at the same time giving rise to new needs. The emergence of several technologies and their deployment ushered in an increase demand on services.

While one technology is being deploy another is announced. Inevitably, operators have no options but to provide high communication quality under more complex and dynamic networking conditions [1].These developments are evidence of the co-existence of the various network technologies such as (2G/3G/4G) with variable weighting by country and zones around the globe. A heterogeneous network consists of different Radio Access Technologies (RAT), which includes among others High-Speed-DownlinkpacketAccess (HSDPA), LongTermEvolution (LTE), Wireless Local Area -Network (LAN), and Worldwide Interoperability for Microwave Access (WiMAX) networks [2].

The interaction between these technologies sometimes comes with the same service offer using same terminal in a complementary manner. The complexity resulting from these technologies by extension have consequences on the engineering, operations, maintenance and services in general. The challenge is how to navigate between these technologies seamlessly.

This is typical of a situation were a subscriber terminal is subject to change of technology communication; or coverage of one of the technologies being affected by the physical position of the user. To achieve the best connectivity and quality of service (QoS), a handover process should execute seamlessly so that ongoing sessions can be maintained [3]. A handover is a process where an ongoing call or data session of the mobile user is transferred from current network to a new available network. It is categorized into horizontal (HHO) and vertical handovers (VHO).

The former is when a mobile user is switched between same Radio Access Technology (RAT) for example (Wi-Fi to Wi-Fi) symmetric and the latter when user is switched between different RATs such as (Wi-

E-mail address: Hmbemba@utg.edu.gm,Ahmed.kora@esmt.sn,,Yankamdidier@gmail.com, Antoine.gnansounou@esmt.sn

MAX to LTE) asymmetric [3],[4]. Today, commercial industry tools have capabilities that allow us to predict quality of listening; hence, the challenge to navigate seamlessly between these technologies is possible. These tools ensure accuracy between predicted values in objective ways and those actually perceived by (subjective) users. This approach is possible even in the case of Inter-Radio Access Technology (RAT) appeals. The quest for a unified theory to reconcile the two forms of quality assessment methods is yet to be fully addressed.

The relevance of our approach is demonstrated by simultaneous collection of subjective and objective data in an attempt to determine an objective formula. For example, the main user lambda should be able to realize his communication or connection with the best satisfaction. That is to say, be able to switch to the desired network at the right time to maintain better quality of service. The network operator should also be able to guarantee QoS delivery based on the terms and condition of the license agreement.

The responsibility of Regulatory control of quality of service to users' falls under the purview of Telecommunications Regulatory Authority in each country. It is enforced through periodic campaigns and the findings presented to operators for corrective action if and when necessary. Due to market competition and fear of sanctions, operators carry out similar campaigns and usually require financial and human resources. To measure quality of the network, several tools and techniques are available in the industry for use in both objective (measurement and monitoring) and subjective (evaluation campaigns) assessments. Each of these methods has advantages as well as disadvantages.

This article proposes a formula that will give subjective rating of communication taking place using two different technologies based on KPI parameters of 3G and 4G network services. Our approach takes into account objective and subjective evaluation methods. The rest of the paper is organized as follows: Section 2 explores related works; Section 3 discusses QoS/QoE assessment methods. Section 4 expands on the proposed bi-generational conversion approach. Section 5 analyzed the results of the simulation and finally Section 6 draws conclusion.

2. REVIEW OF RELATED WORKS

Mobile devices establish connection with the network via several telecommunications operators. Users on the other hand have expectations about services they receive from operators [5]. These expectations combined with additional factors determine 'users' quality of experience (QoE) of a given system or service. The term quality of experience is often misunderstood and narrowly associated with QoS [6]. ITU Rec.E.800 [7] defines QoS as 'the totality of characteristics of telecommunications services that bear on its ability to satisfy stated and implied needs of the combined effect of service expectations or experience of the user". From a service provider's perspective, a concept by which network parameters are define, measured and controlled to achieve a level of service satisfaction.

The European Telecommunication Standard Institute (ETSI) takes a similar approach to that of ITU's in their definitions, based on 1988 version of the E.800 REC [8]. The Internet Engineering Task Force (IETF) has even more than ITU and ETSI, taken a network centric view of QoS with the following definition [9], 'a set of service requirements to be met by the network while transporting a flow'. In this definition, there is no mention whatsoever of 'users'. Quality of Experience (QoE) in contrast, is defined as: 'the overall acceptability of delivered service as perceived subjectively by the end user' [10]. Researchers characterize the term QoE as a multi-dimensional construct with subjective and objective factors intertwined in the user interaction as associated with perception, emotion, behavior, need, context, system and networking [11]. The concept is widely accepted and influenced by both system users and context centric factors [12].

QoE modeling has important benefits, for example, because of its ability to measure and predict allows the possibility of moving from systems oriented quality evaluation methods into a more user centric approaches. Several studies on QoE have been published using different methods and techniques. For example, in classification and regression method, machine learning, data mining and statistical modeling algorithms have been employed for the prediction of QoE [13]. QoE models are limited to QoS parameters [14]. In [15], Wu et al. gave a comprehensive account of QoE modeling problem. The authors proposed a conceptual model using QoE and QoS constructs. In their method, the parameters considered are concentration, attention and technology acceptance. However, this model did not take into account other context parameters such as location of user, type of mobile device used, and time of the day etc.

On the contrary, Mitra et al. [16] argues that 'inclusion of several context parameters in a QoE model could lead to an increase in QoE measurement and prediction accuracy especially in users' real-life environments. Therefore, the major challenge for operators and now customers is no longer based on the notion of 'the network offering the best quality of service', but the one best perceived from the point of view of the customer with better quality of experience (QoE).For example, users often have expectations about services offered to them by different operators. If they (users) are not satisfied with their quality of experience, they may switch to different operator or stop using a particular application all together.

Using subjective and objective tests, QoE measurement can be performed [17]. Subjective tests involve direct data collection from users in the form of user ratings. For a given communication situations, service prescriptions and levels of QoS, the goal is to provide objective and subjective measures of users experience [18]. Quality of experience (QoE) is comprehensively explained in ITU International Standards. The goal of measuring quality parameters in the next generation networks with their impact on QoE is featured under ITU-T SG-12. A detail methodology for conducting subjective tests is also captured in [19], where the method for subjective test is presented. It defines a methodology for measuring users QoE based on Mean Opinion Score (MOS) rating. MOS is widely used for subjective voice and video quality assessment where human test subjects, grade their overall experience on the Absolute Category Rating Scale (ACR).

3. QoE ASSESSMENT METHODS

Quality of experience (QoE) often emerges where quality of service is no longer sufficient. Due to difference in human perception, a user does not usually perceive a service in the same way as his peers. In [20], QoE is defined as 'the overall acceptability of an application or a service, as perceived subjectively by the end user'. This definition is considered in some quarters as incomplete hence various institutions made the attempts to close the gap. For example, the European Network on Quality of Experience in Multimedia Systems and Services (QUALINET) through its white paper on Quality of Experience [21] endeavor a more comprehensive definition of Quality of Experience. It refers the term as the 'the degree of pleasure or annoyance of a user with respect to an application or a service'. It is the result of the fulfillment of expectations with regards to utility and or enjoyment of the application or service in the light of its personality and its present state'. This definition tends to place the customer more central and closer to users perception of the offered service. To better evaluate this perception of the user, several methods have been developed and grouped into Subjective surveys and objective methods.

The commonly used test methods are conversational opinion tests and listening opinion tests.

A. Subjective Surveys

TABLE1. SUBJECTIVE ASSESSMENT METHODS

Conversation- Opinion Test	Goal to produce as far as possible condition of services perceived by users. It is carried out in the laboratory. Conditions before and after experiment must be recorded and correctly preserved.
Listening –Opinion Test	Slightly less realistic than previous. The recommended test method for listening tests is Absolute category rating (ACR)
Quantal Response Detectability Tests	Allow to evaluate the threshold values of certain quantities and the corresponding probabilities
Degradation Category Rating (DCR)	Compares the system to be measured with a high quality fixed reference and the degradation (from 'inaudible to very annoying") is noted on a five (5) point scale
Comparison Category Rating (CCR)	Variant of DCR method. Compares the system to be measured with a high quality fixed reference (in the case of CCR, with a scale that goes from "much better" to 'much worse")
Threshold Method	Performs direct comparison of the target system with a reference system, such as modulated noise reference apparatus (MNRU).

The first requires special provisions, hence the second method was preferred, 'listening opinion tests' [22]. In [23], there is a distinction between the two types of subjective experiences; Passive and Active. In the active or interactive experiments, at least two participants were engaged in a conversation using means available to them. In these cases, participants follow certain protocols in accordance with a set plan. A statistical sample of 100 participants were used; 50 males and 50 females young and old. In [24], the text to be pronounced for the recording must be short, simple and clear. They must be chosen in a random manner, with no relationship between them to allow the evaluator concentrate solely on the quality of what he or she perceives'.

In our study, we opted for a passive listening opinion tests. We conducted a conversation in an environment familiar to participants, while raising the key performance indicators of each conversation, and have listened to a panel that provided us with their feelings through the notation proposed to them. With the passive environment, their opinions were given based on the scale provided to them. The scoring of the conversations heard by the users was done on several different scales.

The absolute Category Rating (ACR), alternative Discontinuous Category Rating (DCR), the assessment by Comparison Category Rating (CCR) and the threshold method [25]. For our case, we applied a five (5) point ACR Scale (Absolute Category Rating) in TABLE 2 [26], [27].

TABLE 2 ACR RATING SCALE

Listening Quality Scale		
Score	**Quality**	**Disturbance**
5	Excellent	Inaudible
4	Good	Perceptible, but not disruptive
3	Fair	Moderately Disruptive
2	Poor	Disruptive
1	Bad	Very disturbing

B. Objective Method

In addition to subjective factors, which have the main disadvantage of being costly, other methods have been developed based on certain parameters. These methods are develop by entities such as ASCOM's with the Speech Quality Index (SQI), SEVANA's Passive Voice Quality Analysis (PVQA), or those that have been standardized by ITU POLQA (Perceptual Objective Listening Quality Analysis) [28], which replaced the Perceptual Evaluation of Speech Quality (PESQ) [29]. The advantages of POLQA with respect to PESQ that justify its replacement are as follows:

- Maintain good evaluation level despite background noise
- Equations with commas or periods takes into account speech level in samples (KHz)
- Sensitive to linear distortions
- Create new scale for SWB signals and SWB (48) and from our analysis, we retained various parameters for use in the implementation.
- Super Wideband (SWB) level from 50KHz to 14KHz of our formula
- Allows comparison between the AMR codec used in GSM/3G and the EVRC codec used in the CDMA 2000.
- Takes into account two different sampling frequencies depending on the band;NB(8KHz)

TABLE 3. FEATURES OF THE DIFFERENT METHODS

	POLQA	**PESQ**	**PVQA**
Operating mode	Defined two operating modes: ▪ Super Broadband mode with the following bandwidths: ➢ Super broadband ➢ broadband ➢ Narrow broadband ▪ Narrowband mode for narrowband networks.	Defines several versions in order to compare notes of different technologies: ➢ PESQ-Wide Band (WB) ➢ PESQ-Narrow Band (NB)	Uses two operating modes: ➢ Non-intrusive calculation of MOS ➢ Bulk Fault Detection throughout the audio test
Input parameters	They take as input at least three parameters: ➢ The original file as it should be issued (issuer registration) ➢ The "degraded" file that has already passed through a transmission system (recording what the receiver perceives) ➢ The sampling rate		The PVQA uses 6 input parameters: [24] ➢ "Pvqa.lic" which is a license file issued by Sevana. ➢ Analysis and / or "graph" are the parameter that defines the mode of operation of PVQA. ➢ "ENG_F_40.wav.csv" is the name of the report file where PVQA will store information about the alterations found in the defined slots. ➢ Settings.cfg is a PVQA parameter file prepared and provided by Sevana. ➢ ENG_F_40.wav is an uncompressed wav file for testing ➢ 0.799 is the time interval in seconds that the PVQA will use to analyse for depreciations on the one hand and then to predict the MOS score.

Parameters used in the algorithm	POLQA uses 6 parameters; ➢ a frequency response indicator (FREQ) ➢ a noise indicator (NOISE) ➢ a reverberant room indicator (REVERB) ➢ Three internal indicators; propagation time, the quantization step and a voice noise indicator	❖ The PESQ used three parameters, namely ➢ A propagation time indicator ➢ A distortion indicator due to coding ➢ An indicator of transmission error in the voice	Ownership Algorithms
Adjustment	The Root Mean Squared Error (RMSE) method.	The correlation coefficient (CC)	Reserve Owners
Chosen field	Used for the comparison of different networks: 3G and 4G networks ➢ VoIP and NGN networks offering HD quality voice services such as "broadband" and "super-broadband" phone calls, the 7 kHz and 14 kHz frequency range	Desirable for: ➢ Networks still using G.711 audio codecs, law a, law u. ➢ Networks with low bandwidth from 300 to 3400 Hz of bandwidth. ➢ Also supports the WB (frequency range ➢ 7 kHz) using PESQ ITU-T P.862.2.	Desirable for IP networks [25] subject to license.
Future for different standards	New standard in force It has a relatively fast operating capacity and is more accurate than the previous ones. It solved some problems inherent in previous versions.	It will still be used for a number of years because of its backward compatibility and because many countries still have narrowband networks.	-

Quality of Service (QoS) is one of the ingredients that advertisers sell to customers. Under the law, the duty of the regulator to monitor quality of service is an indication of “good health” of a network. ITU defines QoS as ‘the ability of a network or part of the network to perform functions related to communication between users” [26]. During a call, the mobile phone exchanges data with the network. In the upstream direction, it is the results of measurements made by the mobile phone sent to the network.

In optimization standards, KPIs are grouped into five (5) distinct classes: Accessibility, Mobility, Integrity, Continuity and Availability [27],[28]. Between the parameters that mobile phone exchanges with the network, we chose 3 indicators: CPICH RSCP (Common Pilot Channel Received Signal Received Power), CPICH $^{Ec}/_{N0}$, RSRP (Reference Signal Code Power), RSRQ and BLER. The RSRP and CPICH RSCP as their names indicate, these two indicators are different and show the level of power received from the pilot channels.

The Reference Signal Strength Indicator (RSSI) indicates power level over full length of the bandwidth. Whereas RSRP and the RSCP, indicate the level of attenuation undergone by the signal of a user with respect to the channel used. The channel here takes into account the useful signal, noise and interference. The RSRP (4G) represents the received power level of the user cell in a Radio Block (RB) and the RSCP (3G) represents the received power level of the pilot frequency [30].

These two indicators are good for our test because their comparisons help decision-making in cases of technology change (handover inter RAT). Although providing essential information, the two notions do not provide information on the quality of the link or connection. The reference Signal Received Quality (RSRQ) and the CPICH $^{Ec}/_{N0}$, are ratios between the power of the received signal in the active cell (4G) RSRP or the (3G) RSCP and the other received signals (RSSI in both generations) that are considered to be noise. They are measured only when the mobile phone is in dedicated mode (in this case, it is a voice conversation). The measured RSRQ varies between (-19.5dB and -3dB in 0.5dB) steps. The term $Ec/_{N0}$, is a composite term: the Ec represents the energy received by the chip and the N0 being the total noise. The image commonly used to describe this term is the estimate of the Signal-to-Noise ratio hence the following formula:

$$E_c/N_0 = \frac{RSCP}{RSSI}$$

The Block Error Rate (for both technologies) measures transmission errors and is therefore effective at the physical layer. The terminals must support the BLER measurement. Therefore, the main measurement function of the BLER is to provide feedback for the external loop power control operation. In order to control the power, the second shortest seconds are allocated to the remote user of the base station after the scrambling codes, knowing that theoretically one more chip corresponds to a distance of 70m (in 3G).

The BLER when at 4G, its normal conditions of usage are 2% in an inbound synchronization and 10% in outbound synchronization [31], [32].

4. QOE PREDICTION APPROACH FOR COMPLEX NETWORKS

Quality of experience prediction tool allows us to extract particular information from the file in question, and in our case are the parameters we need. The extraction software also allows us to save the information as an Excel file. The Excel file once embedded, the Mean Opinion Score (MOS) can be calculated using MATLAB line connection Toolbox to establish a predictive model. Besides, the Tems Discovery, other appropriate tools such as ATIX also have capability to process information. Tools such as Excel, Magic 3 were also used during the simulation.

2) In the second step, we created a montage using specialized software called MAGIC Music Editor 3 to achieve the goal of determining variation in duration and generation. For example, duration of 3 minutes etc. Different timings were set for each network. In carrying out the test, we used 200 inter – RAT calls. For each of these calls, we recorded the KPI parameters. As stated above, calls were made on both 3G and 4G. We then proposed establishing a formula in two levels. The first level, a score of the conversations on each generation and the second combined the two previous levels to give an overall rating. These two formulae were based on the experimental results we had before. As a reminder, we identified three parameters for each of the generations (3G, 4G); the following formulae were derived using statistical model in the excel tool.

- In 3G: CPICH RSCP, CPICH $^{Ec}/_{N0}$and BLER
- In 4G: RSRP, RSRQ and BLER

We realized that some of these parameters have a proven similarity. We can express the RSRP based on the RSRP. The RSRQ is given by the following formula:

$$RSRQ = 10\ x \log\left(N\ x\ \frac{RSRP}{RSSI}\right)$$

With N as number of RB

For the 3G, thanks to the use of software prediction, we expressed the BLER according to the CPICH $^{E_c}/_{N_0}$. In our evaluation of the case study, a network receiver can switch from 3G to 4G in vice versa during a call (vertical handover). However, where a caller does not change position using same technology no vertical handover takes place. Geographically transmitting and receiving are supposed to be vertical handover. In our case study, both the caller and receiver remain in the same mobile network enabling different technology (3G-4G); in which case horizontal handover does not apply. The following diagram gives us more precision;

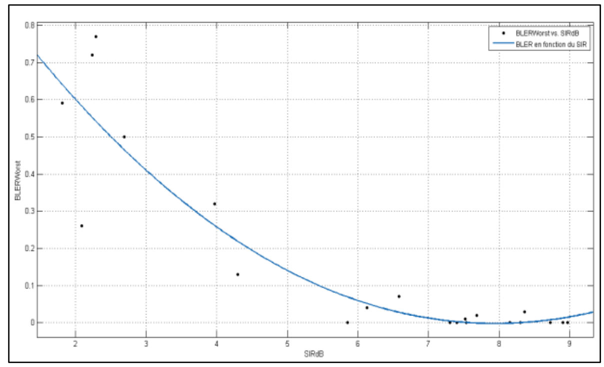

Figure 1. Prediction of the BLER according to the CPICH $^{E_c}/_{N_0}$

With the following features:

$BLER = -0.0001932x^3 + 0.02053x^2 - 0.2894x\ 1.098$
- With x$BLER = -0.0001932x3 + 0.02053x2 - 0.2894x\ 1.098$ - With x for CPICH $Ec\ N0$ /
Goodness of fit:
- Adjusted R-square: 0.9001

Goodness of fit:

- **In 4G** : RSRQ and BLER
- **In 3G** : CPICH $^{E_c}/_{N_0}$ and BLER

$$F(x, y) = p_{00} + p_{10}x + p_{01}y + p_{20}x^2 + p_{11}x.y + p_{02}y^2 + p_{30}x^3 + p_{21}x^2.y + p_{12}x.y^2 + p_{03}y^3$$

With

A. *4G-Formula*

- F(x, y) represent theMOS_{4G}
- x stand for RSRQ
- y stand for BLER
- $p_{00} = 0.009207\ (-0.09232, 0.1107)$
- $p_{10} = 0.02309\ (-0.09239, 0.1416)$
- $p_{01} = 0.08078\ (-0.09239, 0254)$
- $p_{20} = 0.04276\ (-0.07421, 0.1597)$
- $p_{11} = -0.02266\ (0.08342, 0.09985)$
- $p_{02} = 0.2011\ (0.08342, 0.3188)$
- $p_{30} = -0.0103\ (-0.07697, 0.05637)$
- $p_{21} = -0.1665\ (-0.3239, -0.009187)$
- $p_{12} = -0.07132\ (-0.2338, 0.09119)$
- $p_{03} = 0.07205\ (-0.03726, 0.1814)$

A. *3G-Formula*

- F(x,y) represent BLER
- x stand forMOS_{3G}

- y stand for CPICH RSCP
- $p_{00} = 0.02309\ (-0.1191, 0.1653)$
- $p_{10} = 0.07869\ (-0.1095, 0.2668)$
- $p_{01} = -0.118\ (-0.3382, 0.1021)$
- $p_{20} = -0.01746\ (-0.1141, 0.07923)$
- $p_{11} = -0.07472\ (-0.2962, 0.1467)$
- $p_{02} = 0.1687\ (0.07715, 0.2604)$
- $p_{30} = -0.01542\ (-0.07503, 0.04419)$
- $p_{21} = 0.07461\ (-0.161, 0.3103)$
- $p_{12} = 0.009085\ (-0.2753, 0.2935)$
- $p_{03} = -0.03633\ (-0.1236, 0.05097)$

B. General formula

$$MOS_{global} = \frac{\alpha}{\alpha + \beta}(MOS_{4G}) + \frac{\beta}{\alpha + \beta}(MOS_{3G})$$

Where

- αrepresents the duration of the communication in 4G
- β represents the duration of the communication in 3G
- MOS_{4G} represents the score that would be obtained if the conversation was only in 4G
- MOS_{3G} represents the score that would be obtained if the conversation was only in 3G

The HVCR formula acquired was validated when we compare between subjective values and the ones predicted.

TABLE 4. COMPARISONS OF SUBJECTIVE AND PREDICTED VALUES

Call Number	Subjective MOS	MOS Predicts	Percentage in 4G (%)	CPICH RSCP (dBm)	SIR (dB)	BLER (Worst - %)
1	4,166666667	3,315492958	85,91549296	-73,9	7,7	0
2	3,833333333	3,837837838	86,48648649	-66,4	8,3	0
3	3,333333333	2,996721311	83,60655738	-75	4	0,3
4	3,333333333	3,492307692	84,61538462	-77	6,2	0
5	3,166666667	3,4	75,6097561	-76,3	8,8	0
6	3,333333333	3,913043478	78,26086957	-74,4	8,9	0
7	3,833333333	3,497560976	75,6097561	-62,3	2,2	0,2
8	3,333333333	3,8	71,42857143	-69,5	8,2	0
9	4,166666667	2,981818182	84,84848485	-79,7	4,4	0,1

In order to appreciate the Global Mean Opinion Score (MOS3g/4g) for the duration of communication of 3G and 4G technologies based on the rating for the communication, we presented our approach and results in the following section.

C. *Approach*

In our calculation of MOS (3G-4G), we consider different cases of time allocation of the respective technologies in order to simulate the global MOS of the subscribers. This is very important since it could help predict appropriate quality allocation based on the technology while proceeding to a handover. The simple case is while both technologies (3G, 4G) are allocated equal times during the communication, the following expression is used;

$$\alpha / (\alpha + \beta) = 0.5 \quad (1)$$
$$\beta / (\alpha + \beta) = 0.5 \quad (2)$$

The second case corresponds to y when 4G is allocated three quarter of the time slot and x when 3G is allocated quarter of the time. This can be expressed as follows:

$$\alpha / (\alpha + \beta) = 0.75 \quad (3)$$
$$\beta / (\alpha + \beta) = 0.25 \quad (4)$$

The third case correspond to y when 4G is allocated a shorter duration (one fifth) of communication and 3G a longer duration (four fifth). These cases are respectively simulated in figures 2, 3, 4 in accordance with clause A.4.5.ITU P.800 standard. According to this clause, graphs should be plotted showing Mean Opinion Score (MOS) as a function of the parameters under test'. Our test results show the vertical axis Z as in figures 2, 3, 4 represents the mean opinion score (MOS) of 3G-4G as depicted in 3D graphic plots. The results of the survey demonstrate that being able to predict duration of time for a complete conversation using 3G/4G helps improve quality of satisfaction of users.

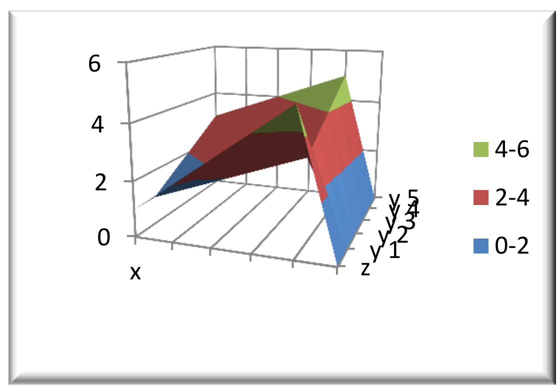

Figure 2. Graphic plots of global $MOS_{3G/4G}$Communication

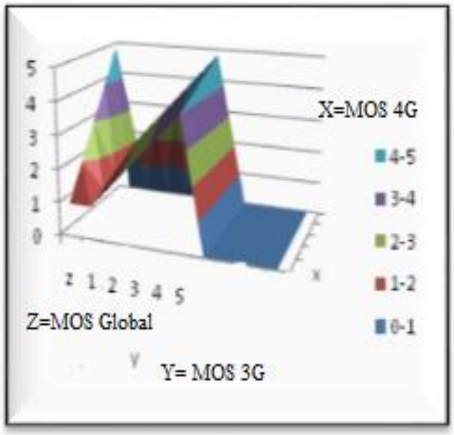

Figure 3. Graphic plots of global $MOS_{3G/4G}$ Communication

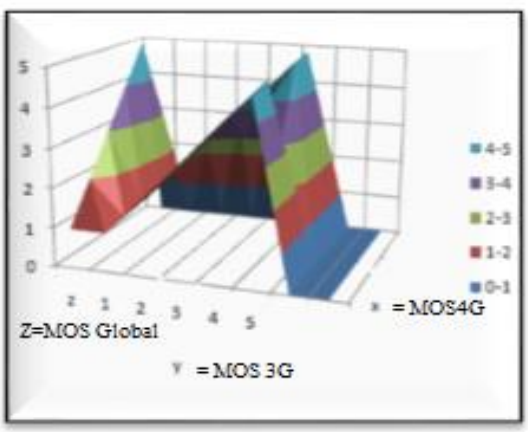

Figure 4. Graphic plots of global $MOS_{3G/4G}$Communication

E. Analysis of figures 2, 3, 4

With the foregoing, the different cases of time allocations of the respective technologies (3g, 4g) simulate the mean opinion scores (MOS) depicted in Fig. 2,3,4 graphic plots. In Fig. 2 for example, when value of x and y = 1 or 2, the communication link or connection is considered unacceptable. If equal 3 or 4 and $y \geq 3$ or y = 3 or 4 and $x \geq 3$. The communication is still considered poor. If x= 4 and y = 2 or above or y = 4 and x at least 2 or above, the communication is considered good. This is true because the quality of the communication is excellent at least when half of the time is utilised. To be acceptable, the communication should last at least half of the time. However, it should also be noted that while the communication might be excellent for 4G, it may be poor for 3G.Fig. 3 illustrate any value of x when y is 1, the communication is considered unacceptable.

Even if y is 2, it is still considered bad. The communication of both x and y can only be acceptable when x and y values are 3 or above.

In Fig. 4 when y = 1 indicate global quality is bad for any quality of 3G during the communications. The global quality is still bad for y = 2 in particular for x = 1. For better rating of 3G ($x \geq 2$) with y = 2 (MOS) during the same communication leads to a global poor quality of the communication. The communication becomes acceptable only when y and x are 3 or above.

5. Conclusion

The major challenge for operators and now customers is no longer based on the notion of "the network offering the best quality of service', but the one best perceived from the point of view of the customer with better quality of experience. Through this study, we have produced a model that will allow operators to better estimate or predict the duration that an inter-Radio Access Technology (RAT) communication must have in each generation of mobile technology. This will help maximize customer satisfaction at the same time increase loyalty based on specific parameters.

References

[1] A. Gotchev. K. Mueller. G. BozdagiAkar, D. Strohmeier, A. Boev, A. Tikanmäki, A., and Oksanen "MOBILE3DTV: State of the art of technology and standards, Project No. 216503; 2011, pp 1-30

[2] W. Abdellaziz, K Abdellatif, M.Abdelfettah et al. 'Group vertical handoff management in heterogeneous network: W*ireless Communications and Mobile Computing*, 2015, Wiley Online Library (wileyonlinelibrary.com).DOI: 10.1002/wcm.2599

[3] l. Joha, k. Loveneet, S. Sandhu Amandeep "An overview of Vertical Handover process and Techniques, *Indian Journal of Science and Technology, (IJST)* Vol.9 (14), April 2016 DOI: 10.17485/ijst/2016/v914/86601

[4] l. Joha, k. Loveneet, S Sandhu Amandeep, "An overview of Vertical Handover process and Techniques, *Indian Journal of Science and Technology, (IJST)* Vol.9 (14), April 2016 DOI: 10.17485/ijst/2016/v914/86601, 2016

[5] R. Schatz & Hossfeld, Tobias & Janowski, Lucjan & Egger-Lampl, From Packets to People, "Quality of Experience as a New Measurement Challenge: *Telecommunications Research Center (FTW), Vienna, Austria* 219263 Sebastian (2013) 10.1007/978-3-642-36784-7_10

[6] Waleed, N. Mahmoud, S. Mona, "Multi-Access Interference Mitigation Using Multi-Level Power Control Algorithm in OFDMA Cellular System, *IJCDS*, Vol. 5, No.6, Nov. 2016

pp. 1-7

[7] P. Le, Callet, S. Moller, and A. Perkis (Eds), "Qualinet White Paper on Definitions of Quality of Experience, 2012, Lausanne, Switzerland

[8] R. Jain, "Quality of experience Multimedia, IEEE, Nov 11, 2004

[9] ETSI" ETR 003 Network aspects; general aspects of quality of service (QoS) and network performance (NP), 1994

[10] E. Crawley, H. Sandick, R. Nair, B. Rajagopalan, 'A framework for QoS based routing in internet, IETF RFC 2386, 1998

[11]W. W. Wu, A. Arefin, R. Rivas, K. Nahrstedt, R. Sheppard, and Z. 'Yang, "Quality of experience in distributed interactive multimedia environments: toward a theoretical framework. *In conf. of the seventeen (17) ACM international conference on Multimedia*, pages 481–490, New York, NY, USA, 2009

[12] Sun J. 'Football on mobile phones: algorithms, architectures and quality of experience in streaming video. *PhD. Thesis,* Umeå University, 2006

[13] W. Wu, A. Arefin, R. Rivas, K. Nahrstedt., R. Sheppard, and Z. Yang: 'Quality of experience in distributed interactive multimedia environments: toward a theoretical framework. *In Conf. on Multimedia of the seventeen (17) ACM international conference*, pages 486–490, New York, NY, USA, 2009.

[14] A. Bhattacharya. W. Wu., and Z. Yang, "Quality of Experience Evaluation of Voice Communication: An Affect-Based Approach, *Human-Centric Computing and Information. Sciences*, Vol. 2, issue 1, 2012 pp. 1–18.

[15] T. Hossfeld, S. Kapov Lea., E. Heegaard Poul. M. Varela., T. Chen Kuan., 'On Additive and Multiplicative QoS-QoE models for Multiple QoS Parameters, Workshop report on Perceptual Quality of Systems, Aug 2016, pp.29-32, Berlin, Germany

[16] K. Mitra., C. Åhlund, A. Zaslavsky,"A decision-theoretic approach for quality of experience measurement and prediction, *In Conf. Multimedia and Expo (ICME*), *IEEE*, July 2011, pp 1–4,

[17] Methods for subjective determination: ITU Recommendation P.800

[18] Vocabulary for performance and quality of service Amendment 2: New definitions for inclusion in Recommendation ITU-T P.10/G.100 (2008)

[19] Methods for Subjective determination of transmission quality. 1996 - ITU-T Recommendation P.800:

[20] Methods for Subjective determination of transmission quality 1996, Recommendation P.800.ITU-T

[21] P. Le Callet., S. Moller., A. Perkis. (Eds) "Qualinet White Paper on Definitions of Quality of Experience (2012)", Lausanne, Switzerland

[22] ITU Mean Opinion Score interpretation and reporting, Recommendation P.800.2, 05/2013

[23] ITU Méthodes d'évaluation subjective de la qualité de transmission, Recommandation P.800, 08/1996

[24] ITU-T Recommendation P.800: Methods for Subjective determination of transmission quality. 1996

[25] ITU-T, Methods for subjective determination Recommendation P.800.

[26] Perceptual objective listening quality assessment, Recommandations ITU, P.863, 09/2014

[27] I. Nafiz Bin Hamid1, L.Yahia, H. Mugumya Twarik, S. Nafiu "Towards an Efficient Radio Network Planning of LTE and Beyond in Densely Populated Urban Areas, IJCDS, 4, No.2 (Apr-2015) http://dx.doi.org/10.12785/ijcds/040205

[28] AB Abdullah, R Vaidyanathan, E Ariwa, W El-Medany 'Introduction to Special Issue: Design and Performance of Networks on Chip' *ICJDC, Vol.5 (2)* 2015

[29] Www. Sevana, Biz, accessed date 20/01/2017

[30] ITU, 'Terms and Definition of quality of service and network performance including dependability, 08/1994.26/08/2016

[31] H.Tobias, H.Poul E, V.Martin,'QoE beyond the MOS: Added value using quantiles and distributions, in Conference, 2015, Doi-10.1109/QoMEx. (2015.714142) pp.1-7

[32] Www. Tech-invite.com, Accessed date 27/08/2016

Mbemba HYDARA is a PhD student in Computer Science with the University of Gaston Berger- Senegal. In 1998 – 2000 he graduated with Advanced Diploma in Telecommunications and Networking. In 2003, he received a Masters' Degree in International Law with the University of Derby in the United Kingdom (UK) and in 2010 received a second Master of Science (MSc.) Degree in Forensics Computing & Security. He is IRCA- ISO27001 - ISMS Auditor/Lead Auditor registered. His current research is in the area of Telecommunications Quality Audit & Security.

Ahmed D. KORA is a graduate in Physics Sciences in 1998 from "Faculté des Sciences Techniques" at "Université d'Abomey–Calavi", Bénin, where he got his Diplôme d'Etude Approfondie (DEA) in Material Sciences in 2000. In 2003, he received a Master "Réseaux Télécoms" degree from "Ecole Superieure Multinationale de Telecommunications" (ESMT) and Ph.D. degree in telecommunication from the University Of Limoges, France, in 2007. He is currently with the ESMT and Head of Research and Innovation Department. His research area covers communications, radio and optical networks system architecture, universal access, mobile network quality of service and quality of experience, low cost IT systems for development, etc. Prof. KORA is IEEE member and member of Fiber Optic Association.

YANKAM is a graduate in Telecommunications and Networks from Ecole Superieure Multinationale des Telecommunications (ESMT) Dakar-Senegal where he received a Master's degree in 2016.

In 2012; he finish his first degree in Telecommunications Engineering with SUP'PTIC ''Ecole Nationale Superieure des Postes, des Telecommunications et des Technologies de l'Information et de la Communication" Yaoundé-Cameroon. He is also a Cisco Certified Network Associated in Routing and switching (CCNA).

Antoine GNANSOUNOU is a graduate in Mathematics from "Faculté des Sciences techniques" at "Université d'Abomey - Calavi", Benin where he received his "Maitrise ès Sciences Mathématiques" in 1991. In 2000, he received a "Réseaux Télécoms" master degree from "Ecole Superieure Multinationale des Telecommunications" (ESMT) and in 2007 a master of Research in complex systems simulation, Telecommunications at "Université Cheick Anta Diop de Dakar (UCAD)".