A Subjective - VoIP Quality Estimation Model for G.729 Based on Native Thai Users

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Abstract— **VoIP is very useful but it there are quality issues when delays or losses occur in the network. Thus, VoIP quality assessment for voice quality assurance or improvement is important. Voice quality assessment is mainly divided into objective and subjective methods. However, several researchers prefer subjective methods to objective methods because the term 'voice quality' is very subjective. According to that idea, this paper proposes a model for estimating VoIP quality provided by G.729, a common codec used over WAN, that has been created from subjective Mean Opinion Score (MOS), obtained from Thai users who use Thai, which is a tonal language and certainly different from other languages. For experiment and data gathering, the conversation-opinion tests with 354 native Thai users was conducted using a VoIP testbed system and G.729, under 17 test conditions, covering packet loss of 0 - 10% and packet delay of 0 - 800ms. Then, the gathered data was used to create the subjective MOS estimation model. Furthermore, a different set of subjective MOS data have been gathered from 64 native Thai users as the test set for the model evaluation. For model fitting, Matlab was applied, whereas Mean Absolute Percent Error (MAPE) was used for model evaluation. After obtaining the subjective MOS model, MAPE was calculated to evaluate the model. It has been found that the MAPE is 12.39%, which means this model is good (10% < MAPE < 20% means good). However, the MAPE may vary, depending on the test set. In conclusion, this paper presents a model of VoIP quality estimation for G.729 based on Thai users who communicate using the Thai language, called ThaiVQE-G.729 for short. After evaluating the performance of this model, it has been confirmed that it is a good model. Therefore, this model is reliable and suitable to estimate MOS of G.729 in the Thai environment. Besides, this concept might be a prototype for other countries (e.g. China, Japan and Korea), due to the perceptual voice quality can be affected by language and culture.**

Keywords— **VoIP, Subjective Tests, MOS, G.729, Thai**

I. Introduction

At present, Voice over IP (VoIP) networks is an important application in the world of telecommunication, which is a group of technologies for the delivery of voice communications and multimedia sessions over Internet Protocol (IP) networks. Although it is very useful it still has limitations e.g. voice quality issues. It is known that, voice over IP (VoIP) needs tighter delivery guarantees from the networking infrastructure. Therefore, VoIP quality assessment is important.

Generally, there are two main methods to assess voice quality, subjective and objective methods. Firstly, subjective methods involve human listeners to evaluate voice quality. Listeners listen to a set of speech samples and then give their opinion. The result from the subjective assessment with a group of listeners is the well-known metric called MOS that has been defined as the ITU-T standard [1]. This method is the most reliable for quantifying measures of perceived quality of voice, and user assessments of quality are elicited and collected directly from typical users of a service. Secondly, these methods do not require human intervention. The result from these methods may not correlate well to a human's perception of voice quality, such as, Perceptual Analysis Measurement System (PAMS) and Perceptual Evaluation of Speech Quality (PESQ) [2]. They are machine-executable programs. It is assumed that those objective measurement methods are based on English or Western languages.

Therefore, this paper proposes a model for VoIP quality estimation provided by G.729. It has been created from subjective MOS values that were obtained from Thai users who use Thai, which is a tonal language and certainly different from other languages.

II. Background

A. *VoIP Overview*

VoIP stands for Voice over Internet Protocol is a voice communication through the Internet network using the Internet protocol. The voice signals will be changed into voice packets transmitting through the network that's used for data communication instead of using the traditional public switched telephone network or system. VoIP has a lot of advantages over the traditional telephone system. For example, VoIP helps organizations to reduce the costs of telephone calls, particularly international calls.

For signaling, there are two VoIP standards, H.323 standard, developed by the International Telecommunications Union-Telecommunications section (ITU-T) and Session Initial Protocol standard (SIP) developed by the Internet Engineering Task Force (IETF) [3-4].

B. Thai User, Tonal Language

Thai is the official language of the Kingdom of Thailand. It is the native language of Thai people. For the Thai alphabet, there are 44 consonants, 18 vowels. For tonal feature, there are 5 tones, which consist of the middle tone, the low tone, the falling tone, the high tone and the rising tone, as shown in Figure 1 [5-6].

Unlike the English, Thai is a tonal language, if the tonal feature changes; it changes the words as shown in Table 1.

C. Mean Opinion Score (MOS)

The key metric for voice quality evaluation is Mean Opinion Score or MOS, which has been defined as a standard by ITU-T [1, 7-8]. For the opinion rating, in an ACR subjective test will obtain the human user's view of the quality of the network. MOS rating is expressed as a number in the range from 1 (bad) to 5 (excellent) [1, 9], where 1 is lowest perceived audio quality and 5 is the highest perceived audio quality measurement. The rating of MOS is based on an opinion scale as shown in Table 2.

D. Subjective Measurement Methods

In general, subjective measurement method is to measure or evaluate voice quality with accuracy and high reliability, this method is to predict listener satisfaction with listening [9]. However, subjective measurement method can be divided as follows:

*1) **Conversational Opinion Tests:*** these tests are prepared in the laboratory and tested in different conditions [2, 10]. There will be a creation of effects in the VoIP testbed system such as loss, delay and echo, and then the result will be obtained as the MOS-CQS. Each test requires two subjects who have to sit in separate sound-proof rooms and then talk to each other before finally rating the individual score, using 5-point scale. Also, each condition requires participants at least 24-32 subjects to test.

*2) **Listening Tests:*** Listening Tests as measures of system performance that can be classified as ACR, DCR and CCR, which must be conducted in the lab [2]. The MOS scores refer to the listening quality, this is usually referred to as MOS-LQS. Participants listen to the audio files and then they have to rate an audio files using a 5-point scale. Each test condition should be conducted with at least 16 subjects [9].

*3) **Interview and Survey Test:*** In order to obtain the result from the interview and survey test with high accuracy, each test condition requires at least 100 subjects [1, 11]. That means the tests are costly and require high endeavour and collaborations.

E. Literature review

From surveying several previous works, it can be summarized as follows:

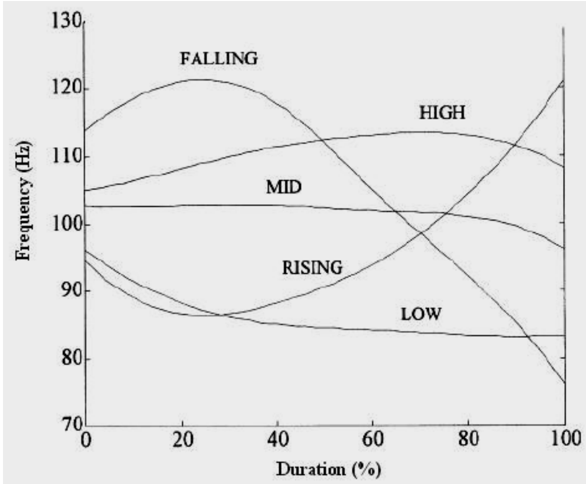

Figure 1. F_0 contour of five tones in standard Thai language

TABLE 1. EXAMPLE OF THAI WORDS

Thai Tone				
Mid	Low	Falling	High	Rising
คา (κηα⇐⏋) to be stuck	ข่า (κηα⇑⏋) galangal	ข้า/ค่า/ฆ่า(κηα⇓⏋) I or me /value/to kill	ค้า (κηα⇔⇔⏋) to trade	ขา (κηα◊⏋) a leg

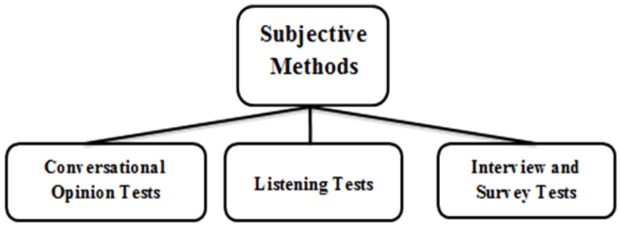

Figure 2. Subjective methods

TABLE 2. RATE THE QUALITY OF THE SPEECH

Quality of the speech	Score
Excellent	5
Good	4
Fair	3
Poor	2
Bad	1

Z. Cai et al. proposed a comparison of MOS evaluation characteristics for Chinese, Japanese and English by G.722 but excluded Thai language [12], while J. Ren et al. compared voice quality from G.711 and G.729 between Chinese and English before proposing the language impairment factor [13]. Of course, they studied without Thai speech samples. For the research work that used Thai speech in their studies, J.-H.

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Chen et al. compared several codecs with two codecs, BV16 and BV32 codec [14, 15]. The objective MOS values provided by BV16 and BV32 were compared using 12 speech samples from 12 languages and Thai language. However, both works are comparative studies of voice quality from the BroadVoice codecs and other codecs.

In additional, objective techniques that use computational models to approximate subjective QoE (MOS) have been widely studied for VoIP applications. For example, P. Calyam et al. proposed the GAP-Model that produces online based on online measurements. The subjects were asked to rank their subjective perceptual QoE (i.e., MOS) of streaming and interactive video clips shown for a wide range of network conditions configured using the NISTnet WAN emulator and used codecs i.e., G.722 and the H.263 video codec [16].

Besides, J. Ren et al. proposed a new neural network models for predicting VoIP speech quality [17]. In that study, G.729 and G.711 were used to encode the speech samples then determined MOS by PESQ and used as the inputs to the neural network model. Also, M. AL-Akhras et al. proposed the ANN model using PESQ score to predict effective equipment impairment factor from packet-loss probability and burst ratio [18]. S. Mohamed et al. proposed a method to use the ANN to model and evaluate in real time how human subjects estimate the audio quality when distorted by changes in the quality-affecting parameters and selected codecs [19].

There is one work that is very similar to this paper. It is the paper from L. Sun and E.C. Ifeachor [20]. One major contribution of that work is proposing the voice quality prediction models for G.729 and other three codec using a nonlinear regression surface fitting and the objective MOS from PESQ. There are ten parameters for each model.

It can be seen from above that those previous work did not propose a voice quality prediction model from subjective MOS. Therefore, there is room for study based on subjective tests intensively for voice quality estimation modeling, from subjective MOS provided by G.729, a recommended codec for WAN. This study is actually extended from [21] that studied with only G.711, a recommended codec for LAN.

III. METHODOLOGY

A. *Experimental Setup and Data Gathering*

The experiment has been conducted using conversation-opinion tests with Thai users, totally 354 subjects. Of course, the codec is G.729, which is the recommended codec for VoIP over WAN [22], whereas the VoIP testbed system was the same as [21, 23-25]. It mainly consists of Asterisk (a VoIP server) and Dummynet (a network emulator). The conditions for testing consist of 17 test conditions, as shown in Table 3, covering packet loss of 0 - 10% and packet delay of 0 - 800ms. Each condition requires 24-32 subjects, following [21, 23]. However, the condition s#1, s#2, s#3 and s#4 are the same as in [24-25]. Thus, data of those conditions could be applied from the previous works.

For data gathering, the subjects were the students in KMUTNB. In each round, two subjects were invited to sit in separate soundproof rooms at the studio zone of the Central Library that was setup as a laboratory, to have a conversation about 3-5 minutes with Richard's task, following [21, 23-25]. After finishing, each subject must give the individual score for calculation of the subject MOS, called MOS-CQS [8].

B. *Model Fitting*

After gathering data from a lot of subjects, the data was examined, whereas the extreme data, called outliers were discarded. For example, in the case of best condition (packet loss of 0 %), regularly rate of individual scores were 3-5 but there were few subjects who gave 2, which is classified as the extreme or irregular data. Therefore, those outliers had been discarded for reducing the standard deviation of the MOS. Then the validated data was used for model fitting using the surface fitting tool in Matlab, following [20-21]. Next, evaluation of the best-fit model has been conducted comparing with a different set of subjective MOS that were gathered from 64 native Thai users who tested with 4 conditions; e.g. 1% loss and 0.2 s delay and 3% loss and 0.4 s delay.

IV. RESULT AND ANALYSIS

A. *MOS-CQS and ThaiVQE-G.729*

MOS-CQS, as shown in Table 4, obtained from the conversation-opinion tests with 354 native Thai users totally (190 female, 164 male), average age was 22 years old. Then, the equation of ThaiVQE-G.729 has been calculated using a surface fitting tool in Matlab. The equation with the Root Mean Squared Error (RMSE) of 0.551 (the low one) and the Sum of Squared Error (SSE) of 105.7 (the lowest) is the best-fit equation. The surface chart of that equation is shown in Figure 3. Therefore, the equation (4-1) with the degree of X = 2 and Y = 2 has been chosen, whereas it is re-presented in (4-2).

B. *Analysis: Evaluation of ThaiVQE-G.729*

Methodology to evaluate the performance of model, the Mean Absolute Percent Error (MAPE) was applied (MAPE < 10% means excellent, whereas 10% < MAPE < 20% means good) [26]. The data of the test set collected from 64 native Thai users is shown in the Table 7. After calculating the test set, it has been found that the MAPE of the best-fit equation is 12.39%.

TABLE 3. INFORMATION OF ALL SCENARIO UNDER-TEST

		Delay (ms)		
		0 ms	**400 ms**	**800 ms**
Loss (%)	0.0%	S#1	S#2	S#3
	2.0%	S#4	-	-
	3.0%	-	S#5	S#6
	4.0%	S#7	-	-
	5.0%	-	S#8	S#9
	6.0%	S#10	-	-
	10.0%	S#11	S#12	S#13

TABLE 4. CONVERSATION-OPINION TEST RESULT

		Packet Delay (s)								
		0			0.4			0.8		
		N	MOS-CQS	SD	N	MOS-CQS	SD	N	MOS-CQS	SD
Packet Loss (%)	**0**	24	4.13	0.54	28	4.00	0.61	24	3.88	0.45
	2	30	3.83	0.38	-	-	-	-	-	-
	3	-	-	-	32	3.81	0.64	26	3.62	0.57
	4	24	3.75	0.68	-	-	-	-	-	-
	5	-	-	-	30	3.70	0.47	26	3.54	0.58
	6	30	3.53	0.57	-	-	-	-	-	-
	10	24	3.42	0.58	28	3.36	0.56	28	3.29	0.53

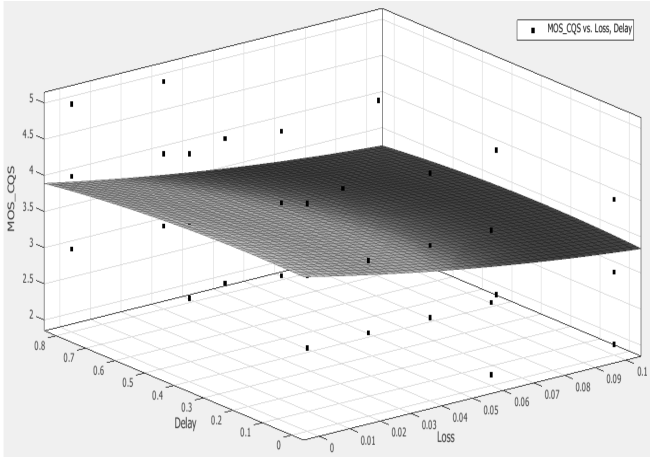

Figure 3. the surface chart of ThaiVQE-G.729

TABLE 5. THE MOS-CQS IS CALCULATED USING SURFACE FITTING TOOL IN MATLAB AND SELECT THE EQUATION THAT THE RMSE IS LOWEST.

Degree X	Degree Y	Coefficients (with 95% Confidence bounds)	RMSE	SSE	Equation
1	1	p00 = 4.024, p10 = -6.334, p01 = -0.1671	0.5506	106.4	f(x,y) = p00+p10*x+p01*y (1)
1	2	p00 = 4.029, p10 = -6.916, p01 = 0.1058, p11 = 1.504, p02 = -0.435	0.5510	105.9	f(x,y) = p00+p10*x+p01*y+p11*x*y+p02*y^2 (2)
2	1	p00 = 4.084, p10 = -9.501, p01 = -0.2318, p20 = 25.71, p11 = 1.296	0.5512	106.0	f(x,y) = p00+p10*x+p10*y+p20*x^2+p11*x*y (3)
2	2	p00 = 4.064, p10 = -9.463, p01 = 0.09978, p20 = 25.12, p11 = 1.376, p02 = -0.4274	0.5510	105.7	f(x,y) = p00+p10*x+p01*y+p20*x^2+p11*x*y+p02*y^2 (4-1)

$$MOS-COE_{TH} = (4064 - 9463x + 99.78y + 25120x^2 + 1376xy - 427.40y^2)/10^3 \quad (4\text{-}2)$$

Where: $MOS\text{-}CQS_{TH}$ is subjective MOS from Thai user
x is packet loss percentage (%)
y is packet delay (s).

TABLE 6. TEST CONDITIONS FOR THE MODEL EVALUATION

Scenario	N	MOS-CQS	SD
1% Loss & 0.2s Delay	16	4.00	0.52
3% Loss & 0.4s Delay	16	3.75	0.45
5% Loss & 0.6s Delay	16	3.56	0.51
7.5% Loss & 0.8s Delay	16	3.44	0.63

TABLE 7. $MOS\text{-}CQE_{TH}$ MODEL EVALUATION RESULTS

Comparative Evaluation	MAPE
$MOS\text{-}CQE_{TH}$ versus Test set	12.39%

V. DISCUSSION

According to Table 4, it can be seen that, referring to the best condition of packet loss (0%), MOS values for packet delays of 0 s, 0.4 s and 0.8 s are 4.13, 4.00 and 3.88 respectively. The differences of MOS values between 0 – 0.4 s and 0.4 – 0.8 s are 0.13 and 0.12 respectively. While, referring to the worst condition of packet loss (10%) in this study, MOS values for packet delays of 0 s, 0.4 s and 0.8 s are 3.42, 3.36 and 3.29 respectively. The differences of MOS values between 0 – 0.4 s and 0.4 – 0.8 s are 0.06 and 0.05 respectively. It can be summarised that delay effects tend to impact voice quality obviously in the case of no loss effects, whereas delay effects do not impact voice quality dramatically in the case of high loss effects (e.g. 10%).

From Figure 3 and Table 5, the surface chart of the equation (4-1), the light grey area is MOS of > 3.60 approximately, which is consistent with the minimum level for acceptability [27]. However, the equation (4-1) was selected instead of the equation (1) although its RMSE of equation (1) is the lowest (0.5506) but its SSE is the highest (106.4), whereas the SSE of (4-1) is only 105.7, the lowest. Equation (4-1) has been re-presented as (4.2) with all coefficients in Table 5. It is the representative of the mathematical model of

ThaiVQE-G.729. This model was evaluated with the test set, consisting of four scenarios. Finally, the MAPE of 12.39% has been calculated. That means the ThaiVQE-G.729 model is a good mathematical model.

Nevertheless, the major difficulties of this study were collaboration with a lot of participants and data gathering, whereas the outliers must be considered and gotten rid of.

Advancing beyond the previous work [21], this is the study with G.729 that requires lower bandwidth than G.711, which is the reason that G.729 is recommended for VoIP over WAN, due to VoIP is mainly used for long distance or domestic and international calls for cost saving.

However, MOS obtained from the subjective tests in this paper seems inconsistent with the ITU-T Recommendation G.114, particularly in cases of high rates of packet delay and packet loss. For example, the subjective MOS of 3.88 from G.729 referring to packet delay of 0.8 s only. It is 2 times of the worst packet delay of 0.4 s that has been recommended in [28]. This may be caused by factors of language and culture [29], which will be investigated as future work.

VI. Conclusion and Future Work

This paper presents a model for estimating VoIP quality from G.729. It has been created from subjective MOS, obtained from conversation-opinion tests with 354 native Thai users who use the Thai language, referring to packet loss and packet delay effects.

From the model evaluation, the MAPE of < 13% is described as good, MAPE < 20%. Therefore, this model has been confirmed to be reliable and suitable to estimate MOS of G.729 in the Thai environment. However, the MAPE may vary, depending on the test set. This concept might be a prototype of subjective MOS model with G.729 for other countries (e.g. China, Japan and Korea); due to the perceptual voice quality can be affected by language and culture. Besides, it can be an alternative tool for VoIP quality estimation, instead of using expensive existing tools.

However, this model should be compared with existing methods (e.g. E-model) to evaluate its performance, which could be future work. Moreover, it also requires further development to become a real-time measurement tool.

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