Call Quality Measurement and Application in Telecommunication Network

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***Abstract*— The measurement of call quality from end users perspective is emerging area of research on speech quality in telecommunication networks. The research is focussed on deriving the call quality parameters from end-users perspective and visualize, escalate the critical call quality. Also proses the method of redemption of call charges based on call quality parameters perceived. The research proposed and developed measures certain call parameters during the call and provide average scores at the end of the call. Call quality for the bundle of calls is derived based on the aggregation of successful call parameters which gives the overall call quality measure. The call parameters used in our research were Signal Strength, the successful call rate, normal drop call rate, handover drop rate. GPS coordinates are also used to locate the location and quality of the individual calls. The methodology of extracting the parameters used is basically the signal strength and number of successful and un-successful calls in a bundle of 10 calls. At the end of 10th call the average parameter value has been computed for each of the parameter mentioned that are used for deriving the final call quality. A model using the sms feature for tackling the critical quality and escalation has been proposed and developed as a part of the system. The results of the call quality correlation with the subjective scores are also presented. Various call charging methods based on call quality perceived by the end-user are proposed, which satisfies the subscribers and helps the operators to reduce the churn and increase the ARPU. Finally, the simulation results of the proposed and developed system are presented.**

***Index Terms*— Call Quality Measurement, Signal Strength, Successful Call Rate, Normal Drop Call Rate, Handover Drop Rate, LAC (Location Area Code), Bandwidth Quality, Mobile Computing, Reliability, ARPU (Average Revenue per User)**

I. Introduction

Traditional speech quality measurement techniques use the subjective listening tests called Mean Opinion Score (MOS). It's based on the human perceived speech quality based on the scale of 1 to 5, where 1 is the lowest perceived quality and 5 is the highest perceived quality.

Subjective listening tests are expensive, time consuming and tedious. So, currently most of the systems use objective evaluation of speech quality using some mobile computing techniques. Objective testing systems are use automated speech quality measurement techniques. The three well known objective measurement techniques are Perceptual Speech Quality Measure (PSQM), Perceptual Analysis Measurement System (PAMS) and Perceptual Evaluation of Speech Quality (PESQ).

II. Related Work

Objective speech quality measurement techniques mostly are based on input-output approach [1]. In input-output objective measurement techniques basically works by measuring the distortion between the input and the output signal. The input signal would be a reference signal and output signal would be a received signal.

Input-output based speech quality assessment in objective speech quality measurement gave good correlations with reaches up to 99% in some cases [2]. Estimating the speech quality without the presence of input signal or reference signal is latest area of research.

Input-output based speech quality assessment in objective speech quality measurement gave good correlations with reaches up to 99% in some cases [3]. The performance of objective measurement is basically achieved by correlating their results with the subjective quality measure.

Estimating the speech quality without the presence of input signal or reference signal is latest area of research.

Jin Liang and R. Kubichek [4] published a first paper on output-based objective speech quality using perceptually-based parameters as features. The results were quiet appreciable with 90% correlation. R. Kubichek and Chiyi Jin [5] used the vector quantization method with 83% correlation achievement.

An output based speech quality measurement technique using visual effect of a spectrogram is proposed in [6]. An output-based speech quality evaluation algorithm based on characterizing the statistical properties of speech spectral density distribution in the temporal and perceptual domains is proposed in [7]. The correlations results achieved with subjective quality scores were 0.897 and 0.824 for the training data and testing data set respectively.

A time-delay multilayer neural network model for measuring the output based speech quality was proposed by

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Khalid Al-Mashouq and Mohammed Al-Shayee in [8]. The correlation achieved for speaker and text independent was 0.87.

In this Paper we presented our work for determining the call quality parameters such as average signal strength, successful call rate and successful handover rate with respect to signal strength and successful rate. Then final call quality is computed from the extracted parameters.

This research is continuation of the work that has been proposed in [9][10][11][12][13][14][15]. The basic bandwidth quality measurement is proposed which can be used by both the operator and the user to evaluate the bandwidth quality of a particular operator.

III. CALL QUALITY

The research is focused on call quality measurement. Measuring Call Quality to ensure the quality of mobile network and its reliability is essential. The proposed system is the outcome of our rigorous research to ensure that the network is meeting certain quality parameters. The system logs the signal strength information for every 5ms if there is change in the signal strength information. The system records the number of successful and un-successful call attempts made for every ten call attempts. The successful and un-successful call attempts are classified based on whether the call is successfully connected by the network. The call drop information such as normally dropped from either of the party or dropped due to handover during the cell change is also recorded.

The average signal strength of successful calls, normal dropped and handover dropped with there average scores are recorded. The overall successful call rate score is also derived based on below scale:

successful calls 9-10 score : 5(Excellent)
successful calls 7-8 score : 4
successful calls 5-6 score : 3
successful calls 3-4 score : 2
successful calls 1-2 score : 1(Very Bad)

Normally dropped call rate score is derived based on below scale:
Normal dropped calls >8 score : 5(Excellent)
Normal dropped calls < 7 & <8 score : 4
Normal dropped calls < 6 & < 7 score : 3
Normal dropped calls < 4 & < 6 score : 2
Normal dropped calls < 4 score : 1 (Very Bad)

The call quality is derived from the scores computed from the above parameters as below:
(Average signal strength score of all successful calls + successful call rate score + normal dropped calls rate score)/3 .

The landmarks that were marked with red colors are the calls dropped due to handover and the landmarks that were marked with green colors are normally dropped calls. The different colors landmarks help one to easily visualize and analyze the calls.
The system has the ability to send the signal strength information to the particular number. It has the provision of setting the mobile number, to which the sms would be sent automatically at the end of call. The system has the option of setting to send the sms always, less than bad etc. at the end of 10 calls the call statistics would also be sent as sms.
Figure 1: Signal Meter flowchart illustrates the complete process of signal meter system.

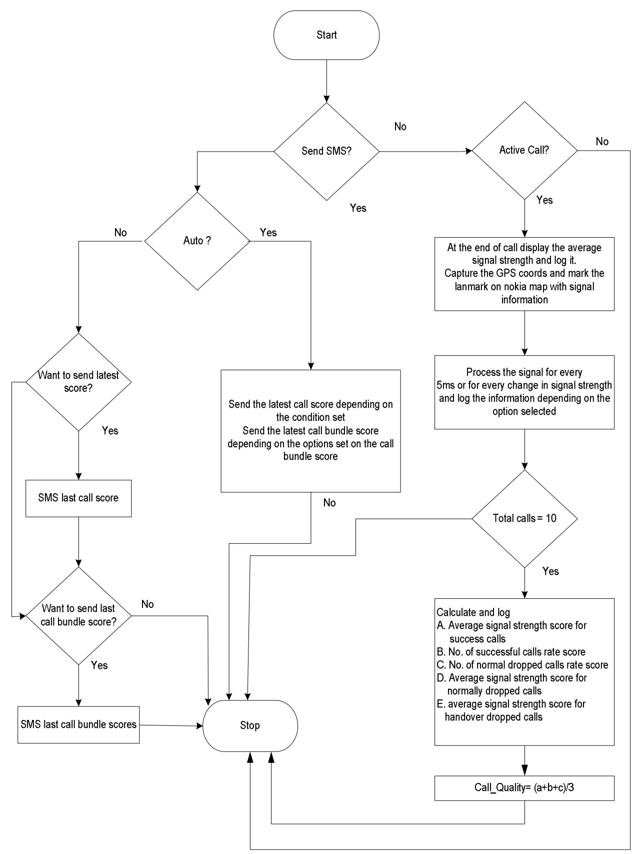

Figure 1: Signal Meter flowchart

A generic algorithm of our signal measure algorithm is presented below:

Signal_Measure( )

1. Get the preferences for log_change, log_location
2. Get total_calls, Call_attempts_failed, call_attempts_successfull, normal_dropped_calls, handover_dropped calls
3. if (total_calls =10) reset all variables to zeros
4. if (call_attempt = failed)
   total_calls=total_calls+1
call_attempts_failed=call_attempts_failed+1
5. While (phone_status != idle && call_attempt = successful)
6. total_calls=total_calls+1
7. call_attempts_successful=call_attempts_successful+1
8. if(gps_coords available)
   Get the gps_coords

```
9.  Get the date, time, cell_id.
10. Get the signal_strength
11. if (log_change= 5ms)
    write("signal_measure.log",date, time, gps_coords,
    cell_id, signal_strength)
12. if (log_change= when changed) and
    (signalstrengthchange=yes)
    Write("signal_measure.log",date, time, phone status,
    signal strength)
13. End of While
14. End of call
15. Calculate average_signal_strength
16. If (average_signal_strength <= -95 &&
    average_signal_strength >= -120) SignalQuality=
    Extremely Bad
     Elseif (average_signal_strength <= -85 &&
   average_signal_strength >-95) SignalQuality=Bad
    Elseif (average_signal_strength <= -75 &&
    average_signal_strength > -85)
    SignalQuality=Average
    Elseif (average_signal_strength <=-65 &&
    average_signal_strength > -75) SignalQuality=Good
    Elseif (average_signal_strength <= -55 &&
    average_signal_strength > -65) SignalQuality=Very
    Good
17. Write("signal_measure.log",date, time, phone status,
    average_ signal_strength)
18. if (sendSMS = auto && whenSMSsend = always ||
    sendSMS =auto && whenSMSsend < bad)
     sendSMS(average_signal_strength,
     SignalQuality,call_drop_information)
19. Write (SignalQuality)
20. If (GPS_Coords Available)
    If (call_dropped = Normal)
     Normal_dropped_calls=Normal_dropped_calls+1
     Landmark_color = green
     Else  landmark_color = red
     handover_dropped_calls=
    handover_dropped_calls+1
      Open(nokia_map)
     Plot(gps_coords, landmark)
21. if (total_calls = 10)
     Score_handover_dropped=
    sum(handover_dropped_quality)/handover_dropped_
    calls)
    Score_normal_dropped=
    sum(normal_dropped_quality)/normal_dropped_calls
    score_successful_attempts=
    (sum(handover_dropped_quality+sum(normal_dropp
    ed_quality)) /total_successful_attempts
22. If (call_attempts_successfull< =2)
    Score_successful_call_rate = 1
    Elseif (call_attempts_successfull< =3 &&
    average_signal_strength >=4)
    Score_successful_call_rate = 2
    Elseif (call_attempts_successfull< =5 &&
    average_signal_strength >=6)
    Score_successful_call_rate =3
    Elseif (call_attempts_successfull< =7 &&
    average_signal_strength >=8)
    Score_successful_call_rate =4
    Elseif (_attempts_successfull< =9 &&
    average_signal_strength >=10)
    Score_successful_call_rate =5
23. If (handover_success_calls< 40%)
    Score_handover_success_calls_rate = 1
    Elseif(handover_success_calls<40%&&
    handover_success_calls>60)
    Score_handover_success_calls_rate = 2
    Elseif (handover_success_calls <60% &&
    handover_success_calls >70)
    Score_handover_success_calls_rate =3
    Elseif (handover_success_calls <70% &&
    handover_success_calls >80)
    Score_handover_success_calls_rate =4
    Elseif (handover_success_calls >80)
    Score_handover_success_calls_rate =5
24. Calculate
    average_call_quality=(score_successful_attempts+sc
    ore_successful_call_rate+score_handover_success_ca
    lls_rate)/3
25. Write("calls_stats", total_call_attempts_failed,
    total_call_attempts_successful,
    score_successful_attempts,
    normal_dropped_calls,score_normal_dropped,
    handover_dropped_calls,score_handover_dropped,sc
    ore_successfull_call_rate,score_handover_success_ca
    lls_rate, average_call_quality)
26. if (sendSMS = auto && whenSMSstat_send = always
    || sendSMS =auto && whenSMS_call_failed < 5) ||
    whenSMS_handover_dropped < 2)
     sendSMS(num_calls_unsuccessful,
     num_calls_successful,
     num_of_calls_dropped_handover,
     num_normal_dropped)
27. If (log location = internal memory)
    save signalmeter.log to c:/data
    save calls_stats.log to c:/data
    else save signalmeter.log to e:/data
    save calls_stats.log to e:/data
28. if(sendSMS = Manual && want_to_send_sms= yes)
    set(mobile_number)
    sendSMS(signal_stength,
    SignalQuality,call_drop_information)
29. End of Program
```

The below Table 1 shows final call quality classification based on the score for a bundle of 10 calls.

Table 1: Call Quality Score

Score	**Classification**
<1	Extremely Bad
1 - 2	Bad
2- 3	Average
3- 4	Good
4 - 5	Excellent

IV. CORRELATING WITH SUBJECTIVE SCORES

The results of SM are compared with the MOS (Mean Opinion Scores) of the same calls for which the call quality scores are computed using SM. For each individual call the MOS is observed and classified based on Table 2. The classification for MOS and SM are relatively same. Hence the average call quality computed for the below mentioned calls are compared with subjective average scores. The comparison is done in two folds as shown in Table 3 and **Table 4**. This is to ensure the call quality scores correlates with MOS scores in all the cases from low number of calls to high number of calls at different locations. The SM (Signal Meter) call quality based on the parameters computed as mentioned in section 2.

Table 2: MOS Classification

MOS	Quality
1	Extremely Bad
2	Bad
3	Average
4	Good
5	Excellent

Table 3: Call Quality Vs MOS

No. of Calls	MOS (Average)	MOS Quality	SM (Average Call Quality)	SM Quality
10	3	Average	2.7	Average
20	4	Good	3.8	Good
30	4	Good	3.9	Good
40	5	Excellent	4.8	Excellent
50	5	Excellent	4.8	Excellent

Table 4: Call Quality Vs MOS

No. of Calls	MOS (Average)	MOS Quality	SM (Average Call Quality)	SM Quality
100	4	Good	3.6	Good
200	5	Excellent	4.6	Excellent
300	5	Excellent	4.8	Excellent
400	5	Excellent	4.9	Excellent
500	5	Excellent	4.8	Excellent

The correlation between SM call quality and MOS scores shows that SM quality scores are very close to the MOS listening scores. Therefore, the SM can used to carry out the subjective evaluation of call quality instead of using human being which would be cumbersome.

V. CHARGING RATE VS QUALITY

The new charging rates are proposed based on the four call quality parameters derived in [16]. The proposed tariff structures as per the parameters are improved version proposed in [14].The variable X is the normal charging rate per minute, 'n' is the number called minutes in the bundle of 10 call attempts.

The Table 5 below is the new charging rate proposed based on average signal strength of successful calls in a bundle of 10.

Table 5: Proposed charging rate Vs Average signal strength of successful calls

Average signal Strength of success full calls Score	Charge
5	X*n
4	X*n
3	X*n*0.75
2	X*n*0.5
1	No charge

The Table **6** below is the new charging rate proposed based on successful call attempts in a bundle of 10.

Table 6: Proposed Charging Rate Vs Successful call Attempts

Successful Call Attempts Score	Charge
5(Very good)	X*n
4 (Good)	X*n
3 (Average)	X*n*0.75
2 (Bad)	X*n*0.5
1 (Very Bad)	No charge

The Table **7** below is the new charging rate proposed based on average signal strength of normal dropped calls in a bundle of 10.

Table 7: Proposed Charging Rate Vs Normal Dropped Rate

Normal Dropped Rate Score	Charge
5(Very good)	X*n
4 (Good)	X*n
3 (Average)	X*n*0.75
2 (Bad)	X*n*0.5
1 (Very Bad)	No charge

The Table **8** below is the new charging rate proposed based on total call quality of calls in a bundle of 10.

Table 8: Proposed Charging Rate Vs Call Quality

Call Quality	Charge
5(Very good)	X*n
4 (Good)	X*n
3 (Average)	X*n*0.75
2 (Bad)	X*n*0.5
1 (Very Bad)	No charge

VI. SIMULATION RESULTS

2011/04/21 - 13:20:35 : : Current network info LocationAreaCode = 352 CellId = 12211
2011/04/21 - 13:20:36 : : Signal strength is = 80 dBm, 7 bars
2011/04/21 - 13:20:58 : : Signal strength is = 83 dBm, 7 bars
2011/04/21 - 13:20:59 : : Signal strength is = 82 dBm, 7 bars
2011/04/21 - 13:21:07 : : Signal strength is = 77 dBm, 7 bars
2011/04/21 - 13:21:12 : : Signal strength is = 81 dBm, 7 bars
2011/04/21 - 13:21:44 : : Signal strength is = 79 dBm, 7 bars
2011/04/21 - 13:21:46 : : Signal strength is = 82 dBm, 7 bars
2011/04/21 - 13:21:47 : : Signal strength is = 78 dBm, 7 bars
2011/04/21 - 13:21:49 : : Call drop observer -> Event : Call state is changed. Phone status: Idle
2011/04/21 - 13:21:49 : : Average signal strength is 80 dBm (Average)

Sample Call Statistics

2011/04/24 - 07:45:33 : : 0 call attempts failed
2011/04/24 - 07:45:33 : : 10 call attempts successful :: Score: 3 (Average)
2011/04/24 - 07:45:33 : : 10 calls was normally dropped :: Score: 3 (Average)
2011/04/24 - 07:45:33 : : **********************

The below Figure 2 and Figure 3 depicts the landmarks of successful calls with colors in green and red showing the normally and handover dropped calls.

Figure 2: Landmarks for Normally dropped calls

Figure 3: Landmarks for normal and handover dropped calls

VII. CONCLUSION

The proposed research uses the parameters in measuring the call quality in mobile telecommunications networks. This research presents comprehensive amalgamation of research from different call quality measurement parameters proposed with final average call quality measurement, correlating the call quality scores with subjective scores, call quality escalation, landmarking the call quality,and tariff proposition based on call quality parameters proposed. The research proposed and published is highly useful for telecom industry to understand call quality from end-users perspective and take the necessary measures proposed to reduce the churn and increase the ARPU. The research proposed could also be used by the telecom regulatory authorities to monitor whether the operators are meeting the required license criteria of quality of network from end users perspective. Further, it can be used as consumer protection tool to ensure that tariffs correlate with call quality.

REFERENCES

[1] ITU-T Rec. P.862, "Perceptual Evaluation of Speech Quality (PESQ), An objective method for end to end speech quality assessment of narrowband telephone networks and speech codecs," 2001.

[2] Aruna Bayya and Marvin Vis. "Objective measure for speech quality assessment in wireless communications," *Acoustics, Speech, and Signal Processing, ICASSP-96*, IEEE International Conference 1996, vol.1, p-p. 495-498.

[3] Aruna Bayya and Marvin Vis. "Objective measure for speech quality assessment in wireless communications," *Acoustics, Speech, and Signal Processing, ICASSP-96*, IEEE International Conference 1996, vol.1, p-p. 495-498.

[4] Jin Liang and Robert Kubichek, "Output-based Objective Speech Quality," *Vehicular Technology Conference,* 1994 IEEE 44th vol.3, p-p. 1719-1723.

[5] Chiyi Jin and Robert Kubichek, "Output-Based Objective Speech Quality Using Vector Quantization Techniques," *Signals, Systems and Computers, Conference Record of the 29th Asilomar Conference*, IEEE 1995, vol.2, p-p. 1291-1294.

[6] Chen, G. and Parsa, V. "Output-based speech quality evaluation by measuring perceptual spectral density distribution," *IEE Electronics Letters*, 40, p-p. 783-785, 2004.

[7] D. Picovici and A.E. Mahdi, "Output-based objective speech quality measure using self-organizing map," *IEEE Proceedings of ICASSP-2003*, vol. 1, p-p. 476–479, 2003.

[8] Khalid A. Al-Mashouq and Mohammed S. Al-Shaye, "Output-Based Speech Quality Assessment with Application to CTIMIT Database," *17th International Conference on Computers and Their Applications* CATA-2002.

[9] Akram Aburas, J. G. Gardiner and Z. Al-Hokail, "Symbian Based Perceptual Evaluation of Speech Quality for Telecommunication Networks," *The 6th International Conference on Computing, Communications and Control Technologies*: *CCCT 2008,* Orlando, Florida, USA.

[10] Akram Aburas, J. G. Gardiner and Z. Al-Hokail, "Perceptual Evaluation of Speech Quality-Implementation Using a Non-Traditional Symbian Operating System," *Accepted for publication in the 5th IEEE-GCC Conference on Communication and Signal Processing*: *IEEE-GCC March 17 – 19, 2009,* Kuwait City, Kuwait.

[11] Akram Aburas, J.G. Gardiner and Zeyad Al-Hokail, "Emerging Results on symbian based perceptual evaluation of speech quality for telecommunication networks," CCCT 2009, Orlando, Florida, USA

[12] Akram Aburas, Professor J.G. Gardiner and Dr. Zeyad Al-Hokail, "Transitional Results on Symbian Based Call Quality Measurement for Telecommunication Network," ICPC 2009, Taiwan.

[13] Akram Aburas, Professor J.G. Gardiner, Prof Khalid Al-Mashouq and Dr. Zeyad Al-Hokail, "Results of Ongoing Symbian Based Call Quality Measurement for Telecommunication Network," Telfor 2009, Belgrade.

[14] Akram Aburas, Professor J.G. Gardiner and Dr. Zeyad Al-Hokail, "Call Quality Measurement for Telecommunication Network and Proposition of Tariff Rates," CCCT 2010, Orlando, Florida, USA.

[15] Akram Aburas, Professor J.G. Gardiner, Prof Khalid Al-Mashouq and Dr. Zeyad Al-Hokail, "Perceptual Evaluation of Call Quality and Evaluation of Telecom Networks," STS-2010 Conference, Riyadh, KSA

[16] A. Aburas, K. Al-Mashouq, "Call Quality Measurement Vs Subjective Scores," CCCT 2011, Orlando, Florida, USA.