Measuring Parameters for speech quality in cellular networks

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***Abstract*—The rapid growth of cellular networks in recent years results into the need of optimization of networks, so that they provide a better service to customer without any interruption. The needs of a Cellular operator include proper delivery of data and voice to the Mobile Stations or user equipments. Speech quality experienced by the end user can be regarded as one of the most significant quality aspects of mobile communication. This paper includes a review of the Key Performance Indicator (KPI) parameters based Speech Quality Index (SQI) in details that are used to enhance the ability of the cellular network to provide techniques to improve Quality of Service. Speech Quality methods can categorized based on measure and performance evaluation which motivate why speech quality measure is important and possible in given radio link status. SQI is technique that allows cellular network to provide measurement of speech quality that has applications from equipment installation to daily network maintenance and benchmarking, it is an important contributing factor to the success of a product and to the success of the communication itself.**

***Keywords*— drive test (DT), key performance indicator(KPI), speech quality index(SQI)**

I. INTRODUCTION

Monitoring and evaluating in cellular network is fundamental to the success of every cellular operator. Measurements help them to meet their Objectives. Key Performance Indicators (KPIs) is one important tool in the cellular network. KPI gives good indication of network performance. KPIs are organized data collecting and collating, where the Operator can monitor and evaluate their performance and drive for continuous improvements towards meeting their objectives.[1] Whereas Speech Quality Index is a method to measure and monitor the speech quality in the network based on radio quality information.[2] The use of SQI technology for Global System for Mobile (GSM) and Wideband Code division Multiplexing (WCDMA) is increasing, and there are compelling reasons to use this technology. SQI is a sophisticated measure which is dedicated to reflecting the quality of the speech. The speech quality on the uplink is determined by continuously monitoring the uplink radio conditions for each ongoing call in the network. The information element SQI, which we obtained estimates the speech quality in the cellular network as perceived by a human listener. In this paper we explain parameters for SQI algorithms for GSM. We can design the SQI algorithm for WCDMA in the same spirit, and its implementation is similar though necessarily not identical.[3] Speech quality in GSM networks is measured by means of the many parameters like RxQual, Bit Error Rate (BER), Frame Error Rate (FER) and L3 messages. Traditionally we use RxQual parameter to measure the speech quality, however, it suffers from a number of drawbacks which make it an unreliable indicator of speech quality.[4]

There are two different measurements of speech quality in communication networks performed with intrusive and non-intrusive means.[6]

A. Intrusive method:

This method to measure speech quality is based on a comparison of both, original and transmitted signal using proper algorithm, e.g. International Telecommunication Union (ITU)-T P862 (PESQ). By using intrusive method it gives more accurate results in comparison with the quality assessed by the average listener that is acquired from listening tests. Due to high cost and time consumption, sometimes Intrusive method are not feasible and hence there is the need of Non-intrusive method.

B. Non-intrusive method:

The non-intrusive method estimates the quality just from the transmitted sample.[7] It is easy to see the difficulty of such an algorithm to give reliable results. Research into non-intrusive quality measurement usually entails comparisons between the test signal and normative behavior of clean speech, amongst other distortion-sensitive features.[8] The main advantage of the non-intrusive method is cost efficiency; the measurement is conducted within real

network data and states. Measure can be "unlimited" number of speech samples that can be assessed for the quality for the total accuracy improvement. There is no need to call establishment unlike in the intrusive method. It is therefore recommended to use a combination of both, intrusive and non-intrusive methods. Vocal quality is an interaction between an acoustic signal and a listener.

II. NETWORK PERFORMANCE

Every cellular network provider uses their Performance measurement that is fairly unique. There are many parameters that can be measured. These measurements can be correlated to each other, so the number of permutations is infinite[11] and therefore the question arises that which is the right choice. KPI are defined by the network operator based on their business needs and these derived from the behavior of the network. Services will be optimized and detected errors will be eliminated. All in all it is correct to say that the purpose of performance measurement is to troubleshoot and optimize the network. Optimization involves monitoring, verifying and improving the performance of the radio network. Its fitfully from the last phase of radio network planning, i.e. during parameter planning. [12]. A cellular network covers a large area and provides capacity to many people, so there are lots of parameters involved that are variable and have to be continuously monitored and corrected. As network is always growing through increasing subscriber's numbers and increases in traffic. This means that the optimization process should be on going, to increase the efficiency of the network leading to revenue generation from the network. Radio Network planner's first focus on three main areas

- Coverage
- Capacity
- Frequency planning

After that radio network planner have to focus on

- Site selection
- Parameter planning etc.

In the optimization process many issues arise, sites are already selected and antenna locations are fixed, but subscribers are continuously increasing in cellular network. As the time passes Optimization task becomes more and more difficult. Once a radio network is designed and operational, its performance is monitored.[13] we choose the key performance indicators to compare the performance. The main focus of radio network optimization on areas such as

- Quality control
- Power Control
- Subscribe traffic
- Handovers
- Resource availability measurements

KPI is defined as key performance indicator for NP(Network Performance) or DP (device performance)[14]. In simple words we can say that KPI is value which is computed using formula. KPI is always a significant assessment standard for network performance for wireless communication. There can be different kind of input for the KPI. There is different kind of KPI and these KPI can be correlated with each other. Due to lack of definition framework and methods for KPI, it's difficult for existing network performance KPI to cover all important aspects of network to make fair evaluation of network performance. In Cellular network KPI can be classified in three categories [15] which are:

- Accessibility
- Retainability
- Quality

Accessibility means that user being able to access the radio resources which include set up a call or data assignment channels. Retainability covers how good the connection is and the ability to keep up a call. Quality can be measured with speech frame error rate. They can all be measured at the radio level and easily be transformed into a measurement of service quality.

III. PERFORMANCE INDICATORS

A. Recived Signal Strength Indicator (RSSI)

The most important consideration in cellular network is signal strength, which we can measure as the power present in a received radio signal. RSSI is usually invisible to the user of the device containing the receiver, but directly known to the users of wireless networking.[16]

B. Recive Singal Quality (RxQual)

RxQual is value that is considered as a basic measurement in cellular network and it represents the quality of the received signal. The values are based upon all frames on the Slow Access channel (SACCH) multiframe, where the bits may have been mixed up along the RF path or lost due to fading or interference. This means that if Discontinuous transmission downlink(DTX DL) has been used, the values will be invalid for that period since they

include bit-error measurements at periods when nothing has been sent resulting in very high BER. It simply reflects the average BER over a period of 0.5s. The number of bit errors is accumulated in a BER sum for each SACCH multi-frame and the result is classified from 0 to 7 according to the BER-RxQual conversion table. We use RxQual in GSM and is a part of the NMR (Network Measurement Reports).

C. Carrier-to-Interference ratio (C/I)

The C/I is the quotient between the average received modulated carrier power C and the average received co-channel interference power I, i.e. cross-talk, from other transmitters than the useful signal. In GSM we often use the Rxlev instead of RSSI. The distinction in these term is that we generally use RSSI for analog signal and Rxlev for digital networks.

D. Bit error rate (BER)

In cellular network bit errors rate is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage.[17]

E. Handover

Handover success rate gives the percentage of the successful outgoing handover attempts. A higher value of the 'handover failure' would result in higher values of the Dropped Call Rate (DCR). DCR is the ratio between the drop in traffic channels during the conversation to the number of successful 'seizers' on the cells or areas.

F. Layer 3 messages (L3)

L3 messages manages all function necessary to circuit switched call control. The functions performed at this layer are call establishment procedures for mobile-originated calls and mobile-terminated calls, in-call modification, call reestablishment, dual tone

Figure 1: Paging Procedure

multi frequency(DTMF) control procedure for DTMF transmission. The contents contain by this are call control (CC), short message service(SMS) and supplementary service(SS). Simple example of L3 message is paging procedure which is shown in fig 1 below

Different methods to evaluate measuring speech quality

A. The Mean Opinion Score (MOS) Scale

A common measure for subjective speech quality is the Mean Opinion Score (MOS) scale, defined in the ITU-T standard P.800.[18] In MOS test we have a person who listen to short speech sample consist of four to five sentences. On the basis of this test the person grade the sample from number 1 to 5 where 1 is perceived as lowest quality and 5 is highest perceived quality.

B. Modulated Noise Reference Unit (MNRU)

Modulated Noise Reference Unit (MNRU) Scale is defined by the ITU-T standard P.810.[19]. MNRU describes how a speech sample can be distorted in a mathematically deterministic way by Adding multiplicative band-limited white noise to get distortion. . Extra samples have been distorted by adding different amount of MNRU distortions. MNRU output is combination of input speech and noise.

C. Perceptual Evaluation of Speech Quality (PESQ)

PESQ implements an algorithm which compares an original speech sample with another recorded speech sample. Original speech sample known as "reference signal" and recorded speech sample known as "degraded signal". MOS like score calculated in PESQ by identifying the differences, and by modeling the characteristics of the human perception.

PESQ assumes that time alignment delay of system is piecewise. Delay changes are allowed in soundless periods and in speech. PESQ maps the signals into a

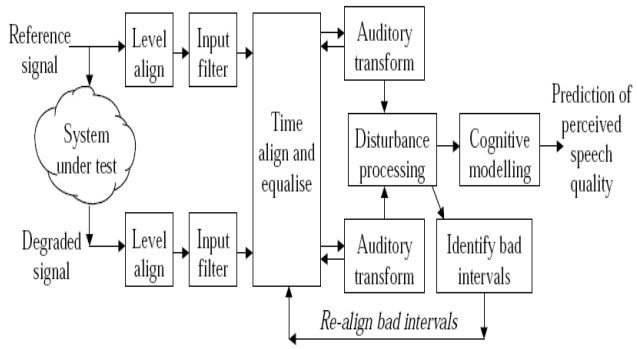

Figure 2:Structure of PESQ

representation of perceived loudness in time and frequency. It include various steps like bark spectrum, frequency equalization, equalization of gain variation and loudness mapping. Absolute difference between the degraded and the reference signals gives a standard of audible error. [20]

PESQ localized errors dominate perception, integrates disturbance over several time-frequency scales using a method designed to take optimal account of the distribution of error in time and amplitude.[21] The disturbance values are aggregated using an L_p norm, which calculates a non-linear average using the following formula:

$$\mathrm{Lp} = \left\{ \frac{1}{N} \sum_{m=1}^{N} \mathrm{parameters[m]}^{p} \right\}^{\frac{1}{p}}$$

First we summed the parameters across frequency using an L_p norm and it gives a frame-by-frame measure of perceived parameters value here we use the disturbance in the form of parameters. This gives us frame disturbance which is multiplied by two weightings. The first weight is inversely proportional to the total number of values we obtain, second weight gives the parameter value raised to power of correlation coefficient. We use the different values of coefficient to calculate L_p norm.

After weighting, the parameters is averaged in time using L_p norms. Thus the aggregation process uses this L_p norms, in general with different values of p to map the disturbance to a single figure. The reason for using L_p-norm is that for each parameter, variations may be perceived in a different way with respect to the resulting speech quality. High values for *p* emphasize parameter variations.

IV. EVALUATION AND PERFORMACE CRITERIA

The aim of our work is to develop a model for speech quality estimation, based on parameters available in the *Operation and Maintenance Centre* (OMC) and in the measurement reports from mobile stations.[23] Such a model will immediately provide an estimate of speech quality for any part of the network, since the measurement reports of the parameters are always available for the whole network.[24]

Usually the following tasks are consider by cellular operator to improve the QoS of network:

1) firstly to obtain better existing network capacity and coverage.

2) then improve the offered service quality for fulfillment of customer demands.

3) finally maintain the KPIs under pre-defined threshold, and to standardize and benchmark the network performance with that of competitor's network to attract more customers; keeping a balance between cost and quality.

As the users in the existing network become more and more and the resources become limited.[25] The main purpose of Base Transceiver Station (BTS) is to send events like call initiation, call drop, traffic channel demand, traffic channel assignment, traffic channel release and many more to base station controller(BSC). To measure these events we different counters(CT). When an event occur it either increments or decrements a specific value. The counters are computed by BSC over a measurement period typically of one or two hours and stored in Operation and Maintenance Centre(OMCR database). OMCR is also used to configure and control different Base Station Subsystem (BSS) entities and relevant Radio Frequency (RF) parameters. These counters are collectively used in KPI formulations.[26] Now the Counter data i.e. the raw data from which we collect, doesn't illustrate any useful information until and unless we calculate it using some formulation in the form of a KPI. Hence evaluation criteria use these collected data and KPIs to depict network QoS as a whole. KPIs can be taken as a tool to measure network performance where different KPIs merge together to form a report from this we measure the quality of speech. SQI reports are generated (using these KPIs) on daily, weekly, bi-weekly and monthly basis. Moreover, KPIs are used as a basic unit for network QoS monitoring.

Another method to estimate the performance of BTS is through field testing and surveys via Drive Test (DT). During DT, radio network optimization teams use particular equipment contains Global Positioning

System (GPS), special type of handset known as drive test phone having the special functionality to report command set[27], and laptop with software tool to check the network performance for a specific geographic area. Based on these GSM Network service providers analyze the network performance and evaluate service quality indicators. These indicators can be used for the following mentioned purposes:

1) To identify and locate BSS occasional faults to guarantee physical resource availability.
2) To help to analyze the radio situation, detect radio network problems in one or more BTS and finally devise a way to optimize the network and adopt corrective actions like new frequency allocations, antenna tilt adjustment, and parameter modification in OMCR database etc.
3) To monitor system variance and behavior in terms of
successful attempts, congestion, traffic load etc.
4)To predict the upcoming traffic evolution and network expansions as per increasing number of mobile users.
5) To attract more users at the cost of better Quality benchmark network with another competitor's network.

To measure and monitor the network performance, BSS vendors have implemented specific software application/feature which is integrated with OMCR and post processes the raw counters into readable information. These software/application can be of two types one is link analysis in which we monitor the live performance of the network and other post analysis in which we record the live data and after that we analyze that data. The purpose of performance evaluation is to analyze all traffic stats. DT results optimization plan which contains all changes and preparation need to BTS/BSC modification and these modification can be includes antenna mechanical and electrical tilt adjustment etc and if necessary we made changes.

After getting all these test results we measure the speech quality index using correlation between different parameters. This information prepare optimization plan and implement it over a cluster of cells. Results of changes are then compared to the reference threshold values; if the results are satisfactory then the proposed changes are approved & final implementation is done over that cluster of cells.

V. CONCLUSION

In this paper, we judge the network performance and evaluate the Quality of Service (QoS) regarding end user perspective, data services are gaining more significance in mobile communication systems like UMTS and GSM but speech telephony remains the most frequently used service. All GSM operators use KPIs, with the help of these KPIs we derive the different formulations. Various parameters have been mentioned and in order to evaluate performance, we mainly outlined these parameters applicable to find the formulation to all of them. Using these formulation we can find the speech quality of the cellular network, guarantees that the effort the users have to put forward in order to correctly perceive the communication is low.

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