Improving the Minimization Drive Tests using Voice Quality Index

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***Abstract*— In order to ensure acceptable quality of service, cellular networks operators conduct field work, called drive tests, to detect geographic regions with some kind of problem. These woks represent high costs in terms of time and money, and additionally they can not be performed along the entire coverage area. In this sense, the 3GPP in Release 10 presents a study named Minimization Drive Test (MDT), which aims to reduce costs in the operator, because in the MDT, the end users devices are used to collect the network parameters. In this paper we propose to add an additional parameter in MDT project, which is related to the voice signal quality index. Experiments in GSM cellular networks are conducted, in which the RF parameters and the Mean Opinion Score (MOS) index are collected and determined in the mobile device. Results show that RF parameters are not necessarily correlated with the MOS index values. Furthermore, a network architecture that include the MOS index is presented, where is demonstrated the technical feasibility of implementation in a commercial cellular network.**

***Index Terms*— Cellular Network, Drive Test, Voice Quality, KPI, Quality of Experience.**

I. Introduction

Currently, in cellular networks there are several services such as video conferencing, location based services, social network and others applications. However, the greatest traffic, and as consequence the greatest economic gains of cellular operators correspond to voice communication services.

Although, mobile operators are supervised by national regulatory agencies of telecommunications services, the quality of voice communications does not have an acceptable quality in all the geographic regions where the cellular operator provides the service. The operation and maintenance tasks, such as drive tests, generate high costs for the operator and also they are not enough to detect all coverage problems in the network.

This problem occurs mainly because the parameters of quality indicators - KPI (Key Parameter Indicators) used by regulatory agencies do not reflect the real satisfaction of the end user. These KPI parameters are not related directly with both voice and video signal quality.

Quality of Experience (QoE) [1], [2], [3] is defined as the characteristics of sensations and perceptions indicated by the users. Users give different opions regarding products or services, and these opinions can be good or bad. Thus, QoE is the end result of the interaction of people with their enviroments [4] and it aims to provide information to improve the products or services.

Specifically in Brazil, the National Agency of Telecommunications (ANATEL) supervises the performance of mobile operators with 12 indicators [5], of which none of them consider the QoE. Likewise, there is no indicator that monitors the voice quality after the call was established. Thus, the call is established correctly, but the impairments at different cellular network points do not allow a proper voice communication.

On the other hand, there are studies [6], [7] that present solutions for monitoring the quality of voice calls, which collect network parameters and detect the points in the network with problems. But these solutions are complex, and therefore they are difficult to be implemented in commercial cellular networks.

This paper aims to demonstrate the importance of including the MOS index [10] of a voice call in the 3GPP - MDT project [8]. This is due to the fact that the RF parameters, such as signal strength reception, co-channel interference (C/I), and others, not always are correlated with the MOS index. Thus, MDT not only will be focused to detect coverage holes in the network, where calls can not be established, additionally MDT will be able to monitor the voice call quality and therefore the real user QoE.

In this context, the remainder of this paper is structured as follows. Section 2 presents the Key Parameter Indicators used for assessing the Service Quality of Cellular Networks in Brazil. Section 3 describes the main characteristics and procedures of the MDT solution. Section 4 introduces the Proposed Network Solution Architecture and Methodology. Section 5 shows the results. Finally, section 6 presents the conclusions.

II. Key Parameter Indicators used for assessing the Service Quality of Cellular Networks in Brazil

Acording to Anatel reports, the number of cellular equipments in Brazil was 262 millions at the end of January of this year. This amount indicates that there is 1.33 cellulars for one person. On the other hand, the number of prepaid users represent about 81% of the total celullar users of cellular networks in Brazil [9]. The main service used for prepaid subscribers is the voice call service, but this service does not always have an acceptable quality level.

Quality control of all cellular networks operators in Brazil is supervised by ANATEL. The Anatel Resolution number 335 of April, 2003 [5] established the definitions, methods and frequency of collection of Personal Movil Services (PMS) quality indicators. The goals of the Anatel resolution 335 are presented in PGMQ-SMP (General Plan of Quality for the Personal Mobile Service) document. Table I summarizes the indicators and quality targets for PMS, which ate currently in force in Brazil.

TABLE I

KEY PARAMETER INDICATORS OF PMS IN BRAZIL

Index	Description	Target Value
PMS 1	Rate of complaints	1%
PMS 2	Rate of coverage and congestion	4%
PMS 3	Rate of call completion by call centers	98%
PMS 4	Attendance by telephone / electronic service	95%
PMS 5	Rate of completed calls	67%
PMS 6	Rate of call set-up	95%
PMS 7	Rate of call drops	2%
PMS 8	Rate of user response	95%
PMS 9	Rate of response to requests for information	95%
PMS 10	Rate of personal service to the user	95%
PMS 11	Rate of Assistance to the user accounts	5%
PMS 12	Rate of failures recovery	95%

As can be seen from Table 1, none of the 12 PMS indicators is related with the voice signal quality. These PMS are more related to the service assistance of the call center of cellular operators, and in the cases when the voice call was not established due congestion or coverage problems.

As stated before, the user' QoE is related to the voice signal quality that users receive at the end device. Thus, in some cases a phone call is established properly, but the voice signal quality is bad, and users can not perform a regular phone call conversation. These kind of voice quality problems are not considered by one of the 12 PMS presented in Table 1.

III. MINIMIZATION OF DRIVE TESTS SOLUTION

In order to improve the quality of service of cellular networks, operators send field engineers to perform tasks such as drive tests. Thus, radio frequency (RF) parameters are collected to discover some coverage holes or weak coverage in their networks. It is important to note that the drive tests can not be performed in all the coverage area, because some areas are access restricted. Also, drive tests are expensive in both time and money.

In this context, MDT solution deals with the two problems mentioned above, because user equipments (UE) from the real subscribers are used to collect network parameters. As a consequence, the costs regarding to drive tests are reduced considerably, and the network measurements can be performed in all different places of the network coverage area.

A. Main characteristics of MDT solution

The main characteristics and functions of the MDT are [8]:

- There are two MDT modes to capture the network parameters:
  i) o Logged MDT, where the UE captures the RF parameters, then they are stored for a certain period of time before the data is sent to the MDT server, which is also name Trace Control Entity (TCE). This MDT mode is performed when the UE is in idle state.
  ii) Immediate MDT is referred when the UE captures and reports immediately the RF parameters to the MDT server. This mode of MDT is performed when the UE is in active state (i.e., the UE has a connection with the RAN node).
- Collection and report of network parameters by the UE. The measurement logs captured for the UE consist of multiple events, which are logged in different timestamps. The time period to capture and report the parameter need to consider the UE battery consumption and the RF links load.
- Regions with problems can be the target of MDT measurements. Network operators can select some specific geographical regions to perform the MDT measurements.
- UE geographical location. The UE geographical location is important to determine the regions with a weak coverage. It is clear that this information depends of the UE capability.
- Timestamp in the measurement logs. A timestamp need to be correlated with every event of the parameters captured.
- UE characteristics. The network operator can select some UE based on their capabilities to perform MDT measurements.

B. MDT architecture

Figure 1 depicts the MDT network architecture defined in the 3GPP Rel. 10. A brief description of the network nodes in this figure are presented below:

- Home Location Register (HLR) / Home Subscriber Server (HSS) are the data base of the subscriber profiles in a cellular network. According to 3GPP specifications, HSS supports the network control layer with subscription and session handling, providing the following capabilities: mobile management, user security, user identification handling, access authorization, service authorization and service profile. HSS is used in all IMS solutions, and provides authentication and authorization functions.
- Signal Transfer Point (STP), which is a signaling point that is responsible only for the routing functions within an SS7 network.
- Mobile Switching Center (MSC) - Serving GPRS Support Node (SGSN) / Mobility Management Entity (MME).

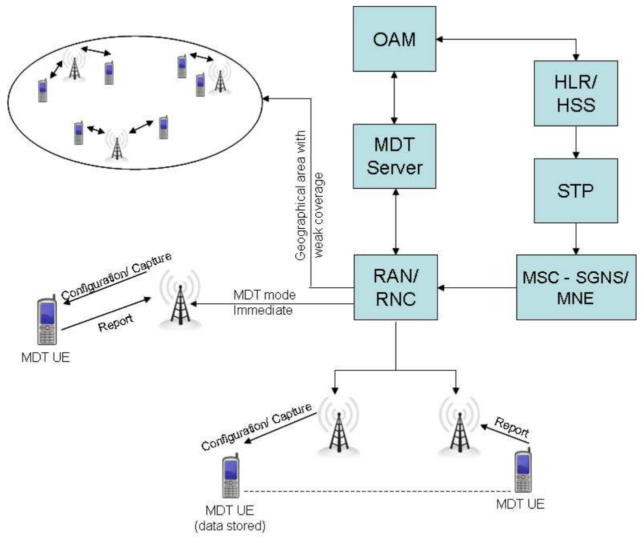

Fig. 1. Network Architecture of MDT.

The MSC is a telephone exchange that makes the connection between mobile users within the same or different mobile networks, and fixed networks. The SGSN is a main component of the GPRS network, which handles all packet switched data within the network, e.g. the mobility management and authentication of the users. The SGSN performs the same functions as the MSC for voice traffic. The MME is the key control-node for the Long Term Evolution (LTE) access-network and also provides the control plane function for mobility between LTE and 2G/3G access networks.

- Radio Access Network (RAN) / Radio Network Controller (RNC), The RAN is the base station controller in LTE networks and the RNC perform the same tasks in Universal Mobile Telecommunications System (UMTS) networks.
- MTD Server is the node in charge of collects all network parameters from de UE. This node is also called Trace Control Entity.
- Operations, Administration, and Maintenance (OAM) node perform the tasks involved with operating, administration and maintaining using different tools.

It can be observed from Figure 1, the both MDT operation modes, the immediate and logged procedures. Also, a target geographic area with a possible weak coverage is analyzed using the MDT solution.

IV. Proposed Network Solution Architecture and Methodology

In order to analysis the voice quality, the E6474A (Wireless Measurement Software) and VQT (Voice Quality Test) tools were used. These tools use the ITU-T Recommendation P.862 [11]. A microcomputer with the VQT tools installed is connected to an audio card and an UE. The server sends and receives the audio files over a cellular network under test. Then, the original and degraded signals are compared and a MOS score is assigned. This MOS score is between 0.5 and 4.5 being the higher the value the better the quality of voice signal transmitted.

The mobile phone originates a phone call to the quality server, which starts a process estimation of voice quality using the PESQ algorithm. Thus, a MOS value is determined for each of test calls. Figure 2 shows the test scenario used for capturing the MOS scores in different coverage areas of a commercial cellular network.

Additionally, during the same calls in which the voice quality tests were performed, RF parameters were also collected for comparison purposes.

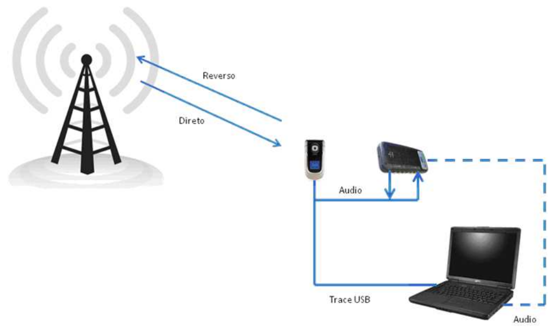

Fig. 2. Test scenario for Voice Quality Assessment in a Cellular Network.

Figure 3 shows simplified network architecture of the proposed system, based on [8], in which is included the MOS index.

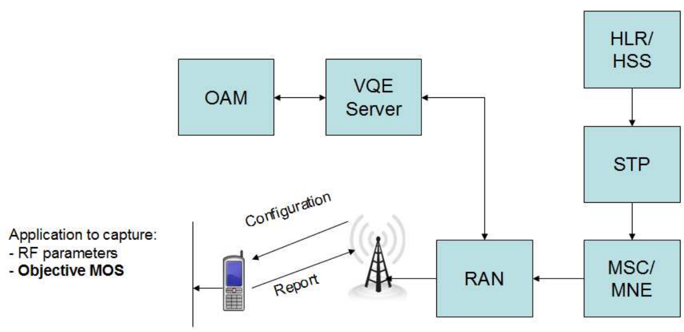

Fig. 3. Simplified Network Architecture of MDT including the MOS index.

It is worth mentioning that is necessary to install an application in the SIM card of the cellular phone. This application is related to a voice quality algorithm to determine an MOS index. For real applications this algorithm need to be performed in real time and use as an input the voice signal received in the UE, without any speech reference. ITU-T Recommendation P.563 [12] is an objective voice quality methodology that accomplishes these two requirements.

V. Results

Figure 4 and Figure 5 present the results of quality voice calls assessment on a GSM cellular network, which can be extended to 3G and 4G networks, because the voice quality measurement is performed on the user's terminal. The purpose of these tests is to demonstrate that although parameters, power level of receiving signal in Figure 4 and the Interference Channel parameter in Figure 5 have a similar behavior as the MOS obtained, in some cases they are different. This fact highlights the importance of assessing the speech signal quality directly using the MOS index.

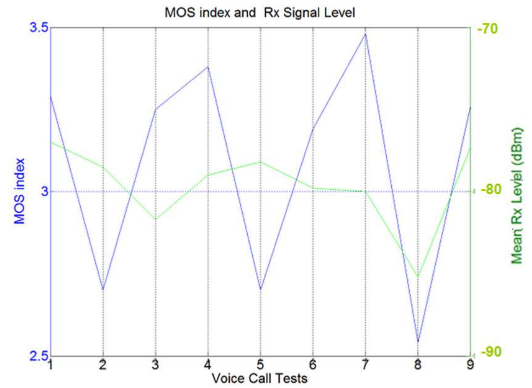

Fig. 4. MOS index vs. Rx. Level.

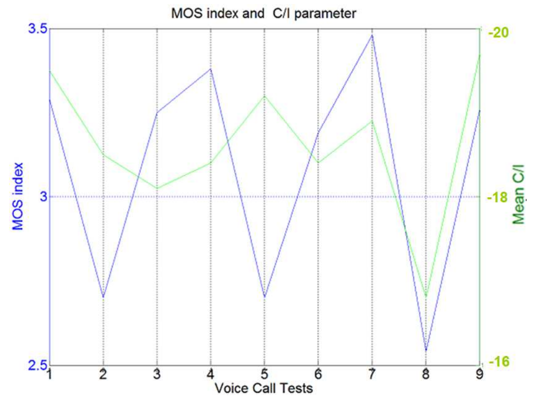

Fig. 5. MOS index vs. C/I.

Figure 6 shows different MOS values corresponding to five different geographical regions, in which a service provider offers its services. The goal of this figure is to demonstrate that there are areas where the voice call quality is lower than others (i.e., region 2 of Figure 6).

VI. Conclusions

This paper shows the twelve SMP indicators used by ANATEL for supervise the performance of cellular operators. These indicators do not consider the voice quality after the call was established. As a consequence, these parameters do not reflex the real users' QoE, because in some cases the call is established properly but phone call quality is not acceptable.

Results of measurements tests of voice quality in a cellular network showed the relevance of considering the MOS index as a new parameter in the MDT project. This paper stressed the reasons why the voice quality should be included in

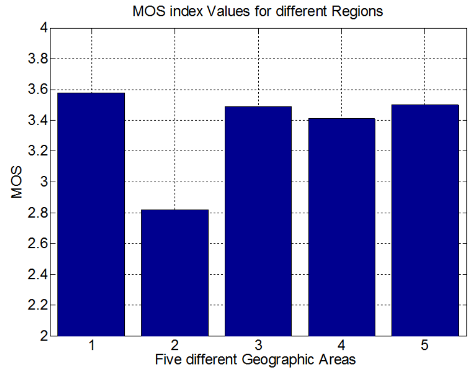

Fig. 6. MOS index Values for different Geographical Regions.

MDT solution, due the RF parameters in some cases are not correlated with the MOS index.

Network architecture of the proposed solution is presented, in which an application inside of the UE is considered to assess the voice quality. As showed in the tests performed, the MOS of a call phone is possible to be calculated. Therefore the implementation of the solution proposed is technically feasible, mainly because it is based on the MDT project.

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