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An Efficient Approach for Evaluating Performance of LTE Network Using Android Application in the Smart-phones

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ABSTRACT
Long Term Evolution (LTE) Like other cellular technologies requires measurement collection which is called "drive testing" in the earliest phases of deployment as well as during the network's life cycle. The main benefit of drive testing is to Obtain Key Performance Indicators (KPIs) such as Signal Strength, Signal Quality and all needed data related to the coverage. These measurements are usually obtained by a professional tool with special software and license. Introducing the smart phones which are the new generations of mobile devices, enable to run applications that can obtain the KPIs that reflect the real end-users experience and network performance, at a low-cost while being user friendly.

Keywords - Application Programming Interface (APIs), Drive test, LTE, RSRP

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I. INTRODUCTION

In daily practice, RF engineers utilize drive-test frameworks as essential tools for obtaining the performance of cellular networks. There are types of drive-test tools including the scanning receiver tools which are only network-based, and the user-deployed applications that can keep running on commercial smartphones [1].

Nowadays, Long Term Evolution (LTE), a 4G high speed data connection for mobile devices, has divergent merits to ensure customer satisfaction. For instance, the LTE aims at extending capacity, getting peak data rates, and reducing latency to ensure the quality of service (QoS) [2].

When making a call, the UE moves from one base station to another. To maintain a steady connection between the base station and the UE, the user equipment has to perform handover for cell selection or re-selection. This task can be achieved through measuring the Key Performance Indicators (KPIs) such as Reference Signal Received Power (RSRP), Receiver Signal Strength Indicator (RSSI), and the Reference Signal Received Quality (RSRQ). These indicators are ranked and referred to as the coverage parameters [3]. RSRP, also known as, received power by receiver (UE) from reference signal resource elements over desired bandwidth and it is essentially used for making a selection, reselection and reliable handover for a cell when a user equipment moves from a cell to another cell. Reference Signal Received Power (RSRP) can be calculated using the following formal [4]:

$$RSRP[dBm] = RSSI\ [dBm] - 10 \log(12*N) \qquad (1)$$

Where, N is the number of Resource Blocks, for 10 MHz, N is equal to 50

As specified early, the Key Performance Indicators can be determined by developing running application on any smart phones. It is an effective method to find key performance indicators with end-user experience and network performance which help the researchers to develop solution for network issues and Mobile Network Operators for improving their network arrangement and to abstain from using costly, tedious devices to achieve the required parameters [5].

The outline of the paper is as follows: Section-2 Background work which focus on how the application can get the required KPIs such as RSRP; Section-3 the verification of drive test methodology such as tools, scenarios, and data collection; Section-4 presents the data analyses and results of drive testing. Section-5 Observation and Conclusion with extend work of future use of the application.

II. BACKGROUND

The Android application can be designed and implemented in order to determine the Key Performance parameters such as Reference Signal Received Power (RSRP) from any commercial smart phone that support LET technology.

2.1 SMARTPHONE ARCHITECTURE

Smartphones have two processors which are application processor and baseband processor. The application processor accommodates the OS and is integrated with a system on a chip (SOC) as well as other built-in working parts. A baseband radio processor (modem) supports communication access to cellular networks. The combination of these two processors is an essential component in current Smartphone design when used in conjunction with other secondary aspects, including the touch screen interface, GPS, and a keyboard [6].

The modem and the application processor is handled by the telephony stack. The stack is composed of all the aspects and interfaces necessary for application creation, via modem, by developers. Figure 1 below illustrates the layers of the Smartphone in which are used to send and receive the required data [6].

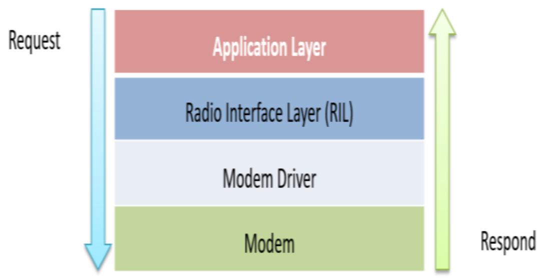

Figure 1: Layers of smartphone

The RIL principle changes Android requests into AT commands which are instructions to control a modem. By providing a RIL among radio hardware and Android Telephony functions API "android.telephony", these Android bundles aid in the monitoring of elemental phone information, including the type of network and the connection state [7].

2.2 ANDROID APPLICATION

The purpose of the Android application's design is to access LTE network performance data via the application layer as well as to find the Radio Access Technology (RAT) distinct criteria that influence the end-user experience. Contingent upon the RAT it differs how the received power is figured and which Application Programming Interface (API) must be utilized. Varying forms of Android Operating Systems support different API levels. Latest releases of the APIs are useful in supporting the various LTE measurements such as RSRP, RSSI, and RSRQ, as mentioned above. Such current API releases include Signal Strength and Cell Info and this has subclass called Cell Info Lte which is utilized to acquire the necessary data [8][9].

In light of the past works seen by [10], [11], along with measurements taken from development applications, indicate that the RSRP values changes from the Cell Info API from phone to phone from various brands in terms of update frequency and availability. This shows that different manufacturers implement the received power to the Radio Interface Layer from the network modem differently.

III. METHODOLOGY

The aim of this paper is to verify that the LTE RSRP can determine from the android application using the Android APIs on a commercial smartphone. The methodology is to verify the application measurements from two different phones in two different scenarios.

3.1 EQUIPMENT SETUP

The list phones and their key Parameters that used to obtain the network performance parameters are given in the below table 1 [12].

Device type	Phone (A) LG K20	Phone (B) Kyocera Hydro Shore
OS	Android (7.0)	Android (5.1)
System chip	Qualcomm Snapdragon 425 8917	Qualcomm Snapdragon 210 8909
Processor	Quad-core, 1400 MHz, ARM Cortex-A53, 64-bit, 28 nm	Quad-core, 1100 MHz, ARM Cortex-A7
System memory	2 GB RAM	1 GB RAM
Built-in storage	16 GB	8 GB
Operator and Band	Operator (X) and Bands 2, 4, 5, 13	Operator (X) and Bands 2, 4, 5, 7, 12

Table 1: Key parameters for the phones

Both phones were connected to the same Mobile Network Operators (X). As mentioned above, the measurements obtain from the application that run on two different phones are expected to be different due to different manufacturers in terms of update frequency and availability, but the results will be comparable and reflect the real network performance. Also, to minimize the different gains that could be experienced due to hand grip, the phones were placed in a measurements-based apparatus that was designed specifically for this experiment [5].

3.2 Data Collection and Drive Test Methodology

Data collection from survey areas helps in analyzing and evaluating network performances. The RSRP measurements were taken in west Melbourne of Brevard County, Florida Which is considered as a suburban environment with a flat terrain. This sort of drive test encourages the RF designers to see the real performance of the network. In such an experiment, weather conditions and time are kept constant to minimize the fast fading variation effects, which aid in increasing the loss of the signal path.

The methodology is to compare the application measurements from two different phones made in two different scenarios indoor and outdoor at the same time and coordinates which help to see how the received power changes from indoor scenario to outdoor scenario and also to see how the received power change from phone to phone in the same scenario which help to reflect the real end user experience. Figure 2 shows the process of how the measurements can be obtained by the application from smart phones.

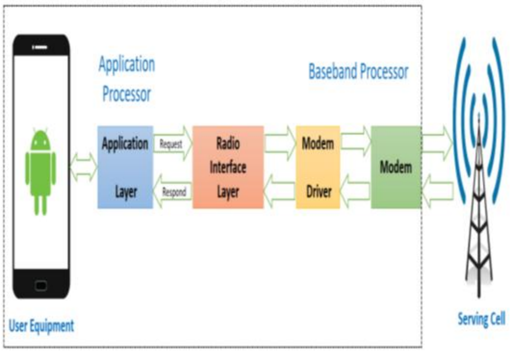

Figure 2: Application processes

The application can capture and record the received power at rate of 1 Hz per measurement which mean 60 measurements per minute.

IV. DATA ANALYSIS AND RESULTS

It is one of the most important parts of evaluation of Radio Frequency is to use statistical analysis of measurement and this is achieved by post processing the measurement in Matlab in order to find how well the application measurements match from two different smart phones using the same network operator and connected to the same Physical Cell Identifier and running simultaneously. The application's measurement from Phone A is compared with measurement pf phone B and both phones are connected to the same Operator, but there will be small difference as mentioned earlier due to radio frequency front end and antenna gains [5].

The results presented below are sorted according to each scenario. For each of the scenario, the results obtained from two different phones at the same time of the day and the same weather condition in order to reduce the variation of the fast fading effect.

4.1 INDOOR SCENARIO

The measurement in this scenario obtained in a suburban environment with a flat terrain. Figure 3 shows a portion of the measurements that reflects the performance of the network in term of received power. Expectantly, the received power between two phones are different due to being produced by different manufacturers in terms of updated frequency and availability.

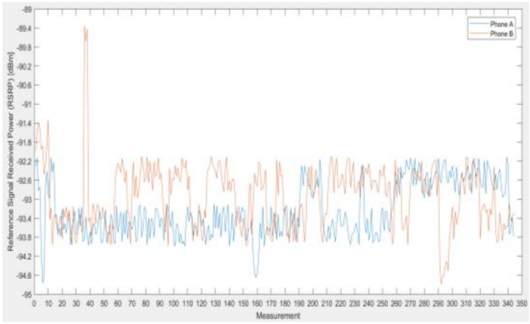

Figure 3: RSRP for LTE indoor scenario

The results for this scenario are summarized in the table 2 below.

Devices	Mean (dBm)	Median (dBm)	Standard Deviation (dB)
Phone A	**-93.2442**	**-93.3400**	**0.5707**
Phone B	**-92.9311**	**-92.8650**	**0.7026**
A – B (dB)	**-0.3131**	**-0.3100**	**0.9564**

Table 2: Performance summary of indoor scenario

As can be seen, Phone B has better received signal power than Phone A which is about 0.31 dB, but the Phone A has better standard Deviation than Phone B which mean Phone A is more stable than Phone B and this is also due to the same reason that mentioned above.

Figure 4 shows the Histogram difference between the two Phones in term of the received power. As can be seen, statistical properties of the difference between the two phones are close to the normal distribution.

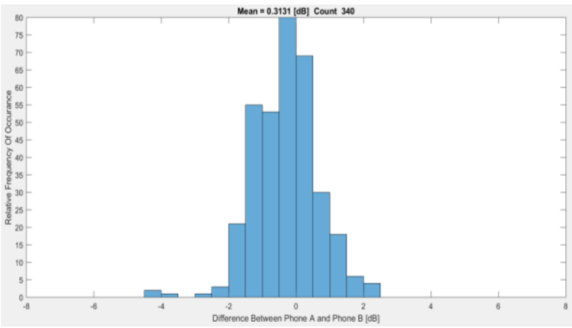

Figure 4: Histogram of difference between phones for indoor scenario

The differences between two phones in term of Standard Deviation and Root Mean Squared Error are defined by the following formals respectively [13]:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2} \quad (2)$$

Where x_i is the interest value of the sample signal, $\overline{x}$ is the mean value of the interest signal and N is the length of the signal.

$$\mathrm{RMSE}(x,y) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2} \quad (3)$$

where x and y are the interest signals of Phone A and Phone B respectively, and N is the length of the signals.

Standard Deviation = 0.9564 dB
Root Mean Squared Error = 1.0050 dB

4.2 OUTDOOR SCENARIO

The measurement in this scenario obtained in same environment that mentioned above. Figure 5 shows a portion of the measurements that reflect the performance of the network in term of received power.

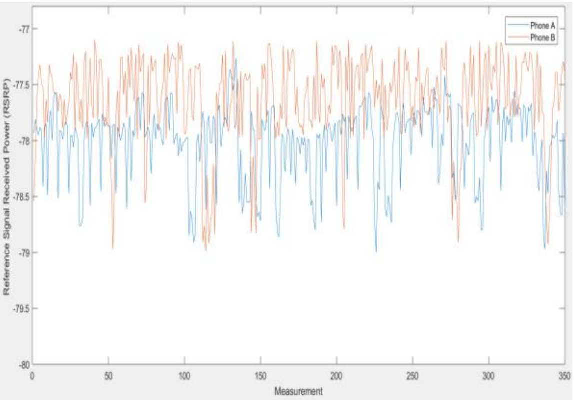

Figure 5: RSRP for LTE outdoor scenario

The results for this scenario are summarized in the table 3 below.

Devices	Mean (dBm)	Median (dBm)	Standard Deviation (dB)
Phone A	-77.9800	-77.9100	0.3532
Phone B	-77.6279	-77.5550	0.4067
A – B (dB)	-0.3521	-0.4300	0.5044

Table 3: Performance summary of outdoor scenario

As can be seen, Phone B has better received signal power than Phone A which is about 0.35 dB, but the Phone A has better standard Deviation than Phone B which mean Phone A is more stable than Phone B.

Figure 6 shows the Histogram difference between the two Phones in term of the received power. As can be seen, statistical properties of the difference between the two phones are close to the normal distribution.

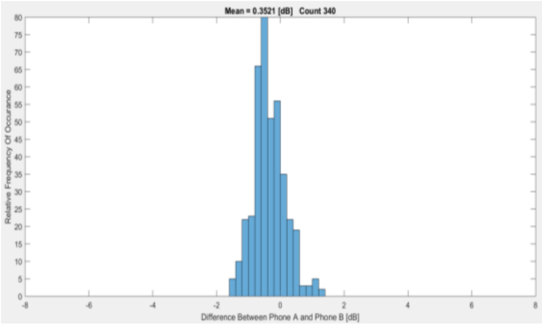

Figure 6: Histogram of difference between phones for outdoor scenario

The differences between two phones in term of Standard Deviation and Root Mean Squared Error are defined as:
Standard Deviation = 0.5044 dB
Root Mean Squared Error = 0.6146 dB

V. OBSERVATION AND CONCLUSION

Results recorded in the previous section, verified that the application running on a commercial smart phone can get the Key Performance Indicators such as RSRP for LTE network. It acts as an economical replacement to the professional radio system scanner.

Conformation of the application's received power is a critical accomplishment, since it empowers the further examination of measurements, for example, signal quality. Additionally, the received power measurements can be utilized to study and analyze the scope of different Mobile Network Operators.

The received power measurements were performed by using the application on two different commercial phones. The phones used the same network and are connected with the same Physical Cell Identifier simultaneously. The measurements are conducted both indoors and outdoors, with constant weather conditions to minimize the fast fading effect variation.

After the experiment, the results indicate that the application is able to obtain the required data with root mean squared error of 1 dB from the two phones A and B and this is because different producers execute the received power reported to the Radio Interface Layer from the system modem in diverse ways.

Future work incorporates comparing the application measurements of received power utilizing similar scenarios above with radio network scanner to check how precise the application measurements which help to supplant utilizing the expert tools and influence the drive test process to become more productive, generally cheap, and easy.

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