User Experience Analysis on Real 3G/4G Wireless Networks

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Abstract—We conduct a set of measurements in real environment (a 2G/3G/4G commercial network is considered for this analysis), using as a measurement tool the user equipment (UE), in order to evaluate and analyze end user experience. In the complex equation of end user experience are involved several factors as: voice quality, call performance, data performance, web browsing, video performance, location accuracy, application performance and battery life. Analyzing all these parameters we estimate an important but also subjective parameter related to end user experience: user perception. We propose a solution for increasing Quality of Experience (QoE) that consists in network densification with Small Cells equipments customized for targeted building.

Keywords— user experience, Datum platform, 3G/4G networks, QoE, QoS

1. INTRODUCTION

Based on new 3G and 4G technologies wireless networks become more and more complex and due to advanced operating capabilities of smart phones, offer support for implementing complex multimedia applications besides the classical voice applications. These new services involve high bandwidth and have severe requirements for both network and user equipment.

From the network perspective, performance can be measured by collecting and investigating technical indicators known as Quality of Service (QoS) parameters. These relevant indicators collected at network layer are: bandwidth, delay, jitter, and packet loss rate and at UE level: signal level, noise and interference level, connection establishment time, drop rate, etc.

Quality of Experience is the overall performance of a system from the end-user point of view and is affected by various technical, business and contextual factors. QoE can be appreciated as a measure of the end-to-end performance level from the user perspective and as an indicator of how well this system meets the user needs.

Actually, QoE provides an assessment of human perceptions, feelings, emotions, and intentions with respect to a particular product, service and application [1], [2]. In this context it is critical to identify requirements for mobile multimedia applications that are associated to the wireless 3G/4G network QoS as well as to the UE context and UE feedback.

Today there are a variety of methods of network planning and optimization but these methods do not always provide results that express the real end-user experience [3].

The most important planning and optimization methods are presented below [4]:

- Path Loss Prediction, Automatic Frequency Planning (AFP) and Automatic Cell Planning (ACP)
- Field Drive Test using scanners and call placement equipment
- User device measurement collection
- Operation Support System (OSS) Key Performance Indicators (KPI) statistics
- Heuristic data analysis

The first method is used during the network planning phase, before the network to become operational, giving a first estimation of the network structure which needs to be improved later using more accurate methods.

Field drive testing is an essential part of the network deployment starting on the early stage of network operation and provides true real world measurements of the RF environment. On the other hand, drive testing is a time-consuming technique and requires very expensive equipments. For these reasons LTE release 10 and 11 propose the minimization of drive tests by introducing new UE measurements capabilities.

The third method collects measures made by the user equipment: these can be regular measurements (for power control, handover, timing advance) sent by the user to eNodeB (eNB) or measurements provided by special applications installed on UE. These applications are developed based on new capabilities offered by smart-phones.

Compared to drive test technique, the technique based on UE measurements is less expensive but the results can be less accurate and might depend on UE model. The fact that users are randomly distributed in the network can be an advantage by collecting measurements from a wider area than that covered by a field drive test. Since the UE processing capacity is still limited, techniques based on measurements taken by the UE and stored in a database and subsequently processed centrally have been developed.

OSS KPI statistics technique relies on statistics provided by eNB and OSS. But these statistics are not specified by 3GPP and are based on equipment vendor implementations. The performance averages afforded by KPIs give information about a specific cell, in general, and little information about the entire network.

Heuristic data analysis is based on algorithms developed to extract useful information regarding the network planning and management. Although based on large amounts of data collected by the techniques mentioned above heuristic algorithms provides information relating only to restricted areas and not on the entire network.

In our paper we use a technique in the third category based on DATUM application provided by SPIRENT Technologies [5]. Datum is an application that can be downloaded and installed on smart UE. This application connects to cloud-based servers including: the call server, used to initiate tests, the media server containing media files and the data base server where the UE measurement results are stored. Representative tests include: web browsing, file transfer, streaming data, multiservice (voice call and data) and latency. Centralized test scenarios are developed and tasks can be combined in any desired order of preference for tests purposes.

2. EXPERIMENT IMPLEMENTATION

For tests and analysis we configure the DATUM platform to work as a client-server application; the UE plays the client role and all processing effort is moved to the remote DATUM server. For the experiments we use a set of commercial UE having data and voice subscription with 2G, 3G and/or 4G capabilities. All the mobiles involved in experiments have Android Operation System (OS), but the mobile application for the client, DATUM, is available and can be installed on all mobile OS types.

The test scenarios are developed on the Datum server, available on the cloud. Once the test cases are created and the UE are registered to the test project, each test scenario can be run on any individual client. To avoid unwanted interactions between our test results and regular user traffic, each test case needs to be run by the end user, preferably when no other applications at UE level generate traffic (no ongoing video/voice calls or data traffic).

The aspects that we set out for our research are:

- Analysis the feasibility of commercial UE usage as a measurement tool.
- Evaluation of service quality ensured by two different service providers (in the analysis we considered 3G and 4G networks) inside a typical office building.
- Proposal of the network densification in the target area, based on the experimental measurements.

The measurements are performed in an office building with large rooms. The building dimensions are roughly 104 m x 24 m and it has three floors including an open floor plan with lots of office furniture and equipments. Particular to this building compared to other office buildings is the increased level of interference and multipath signal propagation resulted from high density concrete walls and multiple metallic equipment racks distributed throughout it. The measurements were performed on the middle floor of this building at an average pedestrian speed of 5 km/h and at an average UE height of 1.5 m while crossing the main hallway from West to East. The UE route is indicated in Fig. 1 from the starting point marked with a circle to the end point marked with a triangle. The measurement area is located in a congested area. In the building there are hundreds of employees that intensively use the phone. Nearby there are dense residential areas, a high school, business centers and a market. The base stations for the LTE and WCDMA network are located west of the building about 150 m from the start point. The tests are made at busy hours (11 and 16) when the network experiences relatively high load.

For all the tests our focus is the analysis of the LTE layer, but we also perform a limited set of 3G measurements to provide a baseline reference. We use UE provided by different vendors (Samsung, LG, and Sony) in order to mitigate the impact generated by the UE category, hardware platform and signal processor type to our final results.

The experimental results suggest that a network densification using small cell technology is highly recommended. We already analyze in different scenarios the benefits for network densification using small cell technologies for the same building in [6]–[8]. In these papers we analyze the UL, DL and handover (HO) performance in the context of Heterogeneous Networks configuration.

3. EXPERIMENTAL RESULTS

In order to have an accurate view of the end user experience for various services we develop and run the following test types:

- FTP transfer simultaneous on 2 LTE capable UE
- FTP downlink test comparison between 3G capable UE and LTE capable UE
- HTTP downlink test comparison between one 3G capable UE and one LTE capable UE
- Downlink + Uplink FTP test simultaneous on 2 LTE capable UEs

3.1. FTP transfer in parallel on 2 LTE capable UE

The scenario applied for FTP tests consists in transferring a 100 MB file on each UE. The file transfer is started simultaneous on both UE, the distance between UE is around 0.5 m and the UE are moved in parallel. Both UE have the same subscription type and have similar performance.

Fig. 1. Focus on measurements area.

The only difference was the fact that during the movement we keep the UE1 in the same position while we change the orientation during the movement for UE2. To increase the accuracy of results we perform four iterations. The results for FTP transfer in Downlink (DL) are exposed in Fig. 2.

We use the same test configuration for Uplink (UL) transfer keeping the same particularities as in DL but increasing the number of iterations for UL. The results are presented in Fig. 3. Analyzing the results we can conclude that in DL, due to the Multiple Input Multiple Output (MIMO) connection, we facilitate a MIMO dual-layer transition by modifying UE2 orientation. Consequently, we obtain a better average transfer throughput for UE2, even if the results for individual iterations are more fluctuating. For the UL this gain is not obtained because in UL the UE has only one transmit antenna. For UE1, the low throughput for the first two iterations is linked to additional traffic generated by other applications running during the tests. The values reported by DATUM are strictly related to tasks started by the application, and do not monitor all the data exchanged by the UE with the network.

3.2. FTP transfer in parallel on 2 UEs (one LTE capable and one WCDMA capable)

In the second set of experiments we analyze the DL FTP transfer running the test in parallel on two UE having different capabilities (one LTE and one WCDMA). For these experiments we transfer a 100 MB file and keep both UE in the same position, moving with the same speed, and having less than 20 cm distance between them.

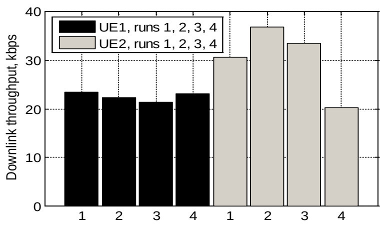

Fig. 2. FTP Downlink test simultaneous on 2 LTE capable UEs.

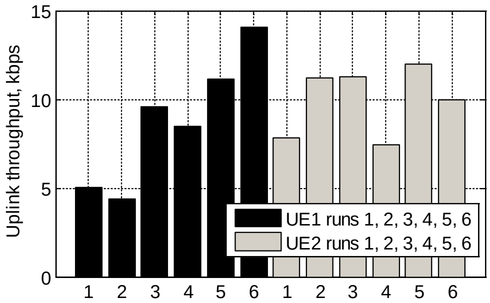

Fig. 3. FTP Uplink test simultaneous on 2 LTE capable UEs.

The results are presented in Fig. 4. We observe the significant difference between average transfer speeds obtained, in line with theoretical capacity for both systems.

Analyzing the obtained results for DL and UL throughput on LTE network, we observe a low average throughput compared with real eNB capabilities. The obtained values were 20-35 Kbps for DL and 5-15 Kbps for UL in the LTE network. In WCDMA network, the corresponding measured throughputs are smaller.

For LTE network, according to the standard specifications, considering a 10MHz bandwidth and MIMO 2X2 capabilities, the maximum value for DL throughput at application level is 61 Mbps in DL and 26 Mbps in UL per cell [9]. For WCDMA (HSDPA+) the maximum DL throughput at application level, for one carrier is 14 Mbps in DL and 5.7 Mbps in UL per cell [10].

These small differences between LTE and WCDMA reflect on one hand the maturity of WCDMA network that has a bigger base station density in comparison with the youngest LTE network and on the other hand the load balancing between technologies inside the same network provider.

Taking as reference for analyze the LTE with 61 Mbps DL maximum throughput, and considering 400 maximum number of simultaneous active users per cell, characteristic to a dense area, the resulted throughput per user is 152 Kbps. This value is typical for users in cell center proximity, experiencing good radio conditions and using 64QAM modulation and high coding rate. In reality the user's distribution in the cell is random, leading to a lower throughput for the users located at the cell edge due to lower modulation and coding schemes.

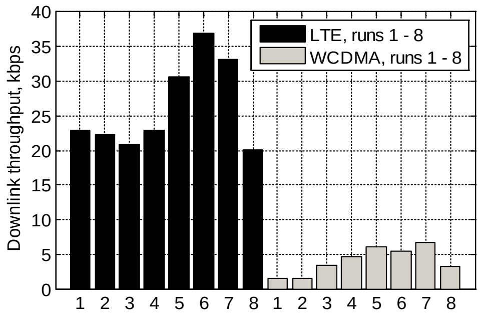

Fig. 4. FTP Downlink tests comparison between 3G capable UE and LTE capable UE.

3.3. HTTP Downlink test comparison between one 3G capable UE and one LTE capable UE

In order to evaluate the web browsing performance we chose to analyze the time needed to load an internet page comparing the LTE and WCDMA technologies. The experiment is repeated ten times in different part of the building for each UE. The results are taken in the same locations for both UE (LTE and WCDMA capable). The loading time for LTE is significantly short compared with WCDMA loading time. The obtained values are displayed in Fig. 5.

For Downlink and Uplink FTP test simultaneous on 2 LTE capable UE the results are consistent with the experimental result in previous sections and the related experiments are not included in our work.

For our experiments the user movement is performed from middle cell to cell edge. The area that includes the target building is a dense urban area with high apartment density and office buildings. Base on these observations the experimental values are in line with theoretical limits, but far from end-user expectation, which mostly are based on commercials campaigns made by network operators.

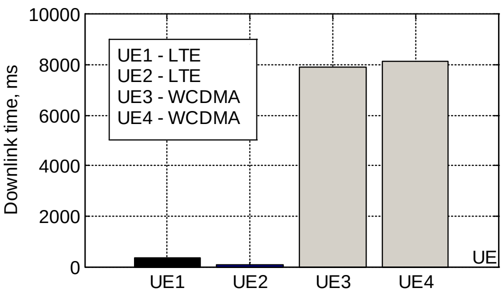

Fig. 5. HTTP Downlink test comparison between LTE and WCDMA capable UE.

Therefore, in order to meet the customer expectation, the network operators are required to increase the density of the network. In the considered environment the macro layer densification is hard to be performed due to interference and public safety norms. The recommended feasible solution remains the small cells implementation in a Heterogeneous Networks.

4. CONCLUSION

For a qualitative evaluation of a real network, analyzing a multi-technology network (3G and 4G capable), the UE is reliable to be use as measurement tool. Even if a regular commercial UE can't be compare as precision with a spectrum analyzer in terms of signal level measurement, when we discussed about end-user experience we need to consider subjective aspects as daily applications and types of interactions between peoples and there smart-phones. The results obtained consolidate our expectation: when we consider data transfer, independently of his type, the LTE performs much better than WCDMA. For FTP transfer we obtained a better throughput in case of UE with a variable position, due to the MIMO channel characteristics. In addition to the analyze presented above, we also investigate the service availability and Quality of voice service, but only in legacy technology WCDMA, because in the analyzed network the Voice over LTE VOLTE is not implemented.

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