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Achievable Throughput over Mobile Broadband Network Protocol Layers: Practical Measurements and Performance Analysis

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ABSTRACT

Having cognizant practical knowledge of the achievable throughput quality that can be attained at the user equipment communication device over deployed mobile broad cellular networks radio interface under different protocol layers has manifold gains for both subscriber and the radio network service operators. The benefits range from root-cause analysis of results, the network status exposure, triggering of performance optimisation, to path and server selection. However, most radio network service operators usually hide this information regarding practical performance status their networks. To tackle this problem, a practical–based measurement assessment and in-depth analysis of cellular network performance status is proposed. To actualize this, firstly, radio frequency eNodeB site survey was conducted to identify accessible field drive test routes and obtained the relevant eNodeB transmitting engineering parameters, Secondly, an in depth radio channel and achievable throughput quality and radio channel has been conducted under PDCP, RLC and PDSCH LTE protocol layers. Thirdly, the impact user communication distance, signal quality and signal coverage levels on the achievable throughput quality is reported across for three different eNodeB transceivers. The results at PDCP, RLC and PDSCH layers indicate that the achievable throughput degrades proportionally with user location transmission distance and radio network signal coverage and signal quality conditions

Keywords - **Practical Measurements, Achievable throughput, RSRP, RSRQ, Transmission distance**.

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I. INTRODUCTION

The Recent time has witnessed awe-inspiring upsurge in data communication rather than just voice calls, thus leading to internet services subscription and traffic globally. Ubiquitous mobile data access is gradually becoming a reality for almost anyone, anytime and anywhere. This may be ascribed to explosive evolution of diverse smart phones (e.g., Andriod, iPhone phones) and advancement in cellular broadband communication technology in recent times. Cellular broadband communication technology can either be mobile or fixed. The cellular Mobile Broadband technology, which is most common nowadays, defines the broadband internet access operated by means of mobile cellular networks infrastructure [1] [2]. One of such internet protocol (IP) based mobile broadband cellular communication technology is the Long Term Evolution (LTE). The flat LTE system architecture provide high CAPEX and OPEX saving through the introduction of IP multimedia subsystem (IMS) [3] [4].

One of the prevalent disruptive challenges these cellular broadband networks face is the loss of data and signaling channels owing to various harsh radio propagation conditions and base station infrastructure limitation. These challenges call for constant assessment of deployed operational cellular broadband networks status and conditions for the purpose of their timely service management and optimisation.

Research on achievable throughput assessment analysis has been broadly studied in the past, particularly for wired networks [5-12]. The techniques employed in the assessment and analysis can be generally classified into two, namely passive and active methods. With passive methods, data throughput quality are monitored reflexively for evaluations along communication network paths. But by means of active methods, live throughput data quality probing techniques are engaged to assess the reveal the network performance quality and user quality of experience survey.

This paper focuses on active achievable throughput methods, which can be employed for proactive and realistic network performance status monitoring and optimisation.

II. LITERATURE REVIEW

In literature [5]-[8], frustration regarding Quality of Experience (QoE) has been identified as foremost factor responsible why about 82% of telecom network subscribers constantly change from one network operator to one operator. One unique indicator for assessing subscribers' service quality experience is the achievable throughput. From an active subscriber's point of view, the achievable throughput during a connection in cellular networks is an important performance indicator on application level. The achievable throughput reveals the maximum data quantity that can be reliably conveyed through the network at a particular time. The achievable throughput performance of an active communication link over a cellular network infrastructure is hinge upon the performance of the key different components involved in the communication: the radio frequency link, the mobile device, the cell user capacity, the propagation environment and even the core network design infrastructure.

To enhance the performance and ensure high user quality experience for on mobile broadband networks such as 3G and 4G, there is need to periodically assess and evaluate the networks in a specific area by measuring relevant performance parameter such as network coverage and throughput, that of vital importance to the user. There exist four main protocol layers in LTE radio access architecture [13] [14]. They are: Mac action control layer (MAC), Physical layer (PHY), Packet Data Convergence Protocol (PDCP) and the Radio Link Control (RLC) layer. While the MAC and PHY layers are utilize for transporting blocks to enable information exchange over the LTE radio system interface, the RLC layer is designed to organize the sizes of upper layer packets, recover packet losses and also record received packets during data transmission. The PHY consists of many sub-layers, all which are mainly for allocating and controlling data communication. One such sub-layers is Physical Downlink Share Channel (PDSCH). The PDSCH is specifically used for user data transmission, paging messages and system information broadcasting in the physical later of the LTE radio air network interface [4]. The PDCP layer is designed to process RLC and IP packet messages both in the control plane and user plane, and as well organize integrity protection and Header recompression during data transmission over the LTE radio interface.

The work is designed in order to provide a better insight and understanding into the communication link performance of the Long Term Evolution (LTE) in terms of data throughput quality and stability at the user equipment terminals at different distances from the transmitting Base Station (BS), by taking three different key layers (PDCP, RLC, PDSCH) into consideration.

III. METHODOLOGY

This section contains the practical–based measurement assessment and in-depth analysis of cellular network performance status is proposed in this study. To actualize this, we adopt a three-step method, which include detailed radio frequency (RF) site survey for drive test routes and eNode B location documentation, practical measurement campaign for in-depth relevant data collection and lastly, the decision step. The decision step comprises of measurement results presentation and the analysis of the results. In this step, the overall acquired achievable throughput qualities at different measurement eNodeB locations in correspondence with the minimum performance thresholds and other radio channel quality parameters are discussed.

1.1 RF Site Survey

Radio frequency site survey was conducted to identify available eNodeB sites, their locations and their engineering configuration parameters. Conducting site survey also enable us to identified the possible and accessible drive test routes around the eNodeB sites.

1.2 Measurement Campaign

This work employs TEMS Investigation tools to collect the throughput data round three eNode sites in outdoor urban environment. The TEMS Investigation tools includes two TEMS pocket phones, one TEMS empowered HP laptop and MapInfo software for real time data collection processing. Other tools include a GPS and a magnetic compass for location mapping, time information and antenna direction checking. All these tools were connected to together inside a rover car for field drive test round the three eNodeBs. With the aid of integrated TEMS Investigation tools in the drive test car, a file size 100 Mbits was periodically downloaded at different distances along the every accessible driving routes round the three eNodeBs. The file download was only initiated during the test when the cellular network was on LTE technology operating on a 10 MHz bandwidth and a frequency of 2.6 GHz. The throughput data was obtained by dividing downloaded fize by the download time at every measurement point under PDCP, RLC and PDSCH LTE protocol layers. The key radio channel parameters also acquired during the measurement process are RSRQ (Reference Signal Received Quality) and RSRP (Reference Signal Received Power).

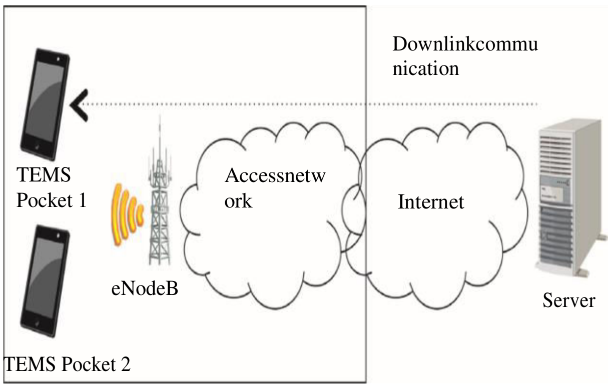

Figure 1: Throughput Measurement flow Architecture

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IV. RESULTS AND DISCUSSION

This section provides and discusses the practical results of the achievable throughput measurement campaigns conducted on three protocol layers, namely PDCP, RLC and PDSCH, over the LTE radio access mobile broadband networks.

We commence by displaying, in Figure 1 to 3, graphical presentation of the achievable throughput results attained at PDCP, RLC and PDSCH layers versus user transmission location with respect to distance for eNodeB 1 to 3.The figures indicate that the achievable throughput quality in Mbps degrades proportionally with user location transmission distance. The throughput fluctuates and degrades gradually as the Tr-Tx transmission distance grows because of the data packet collisions, transmission loss, bit errors, and radio frequency propagation issues. Low signal level could results to intermittent connectivity, high packet loss and variable propagation delay

To examine the reliance of achievable throughput on signal coverage level and coverage quality, using RSRP and RSRQ as indicators, many practical throughput measurements were also conducted along different routes and the results are revealed in Figs. 4 to 9. Some levels of achievable throughput quality variations can been observed in correspondence with Tx-Tr connection distances in the PDCP, RLC and PDSCH layers of eNode 1 to 3. This performance variations may ascribed to changes in the radio conditions and multipath propagation characteristics effects.

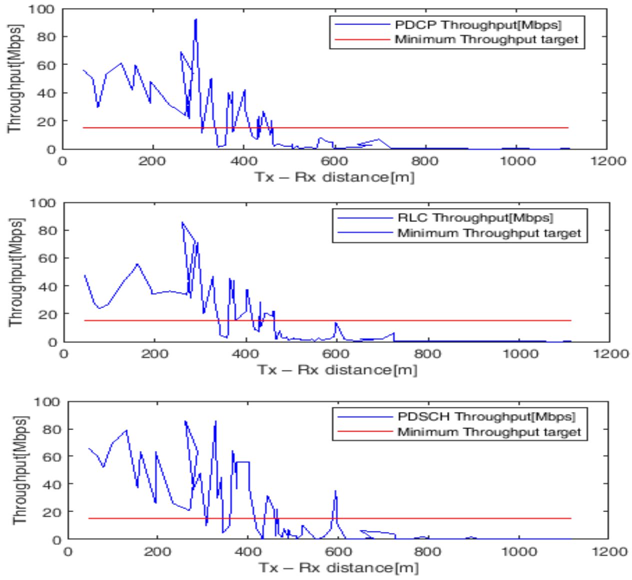

Figure 1: Achievable throughput performance trend with user transmission distance at eNodeB 1

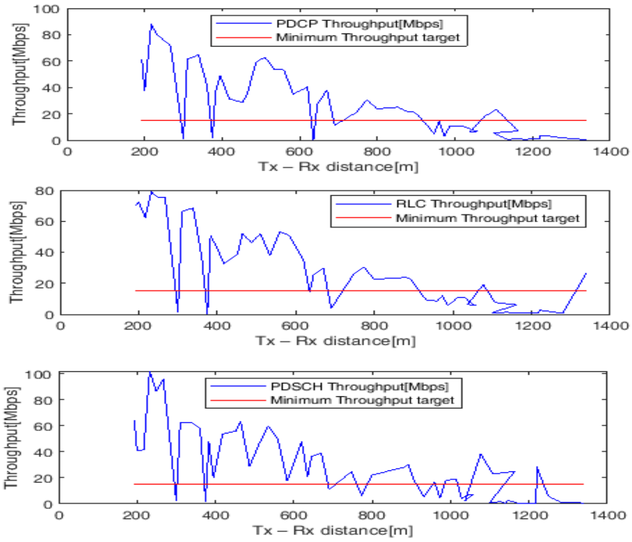

Figure 2: Achievable throughput performance trend with user transmission distance at eNodeB 2

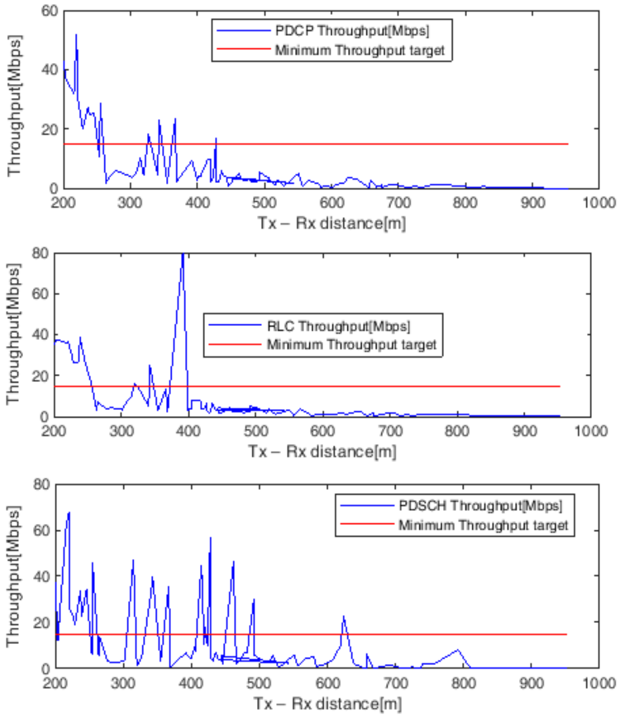

Figure 3: Achievable throughput performance trend with user transmission distance at eNodeB 3

As defined in [15], the minimum functional throughput target should 15Mbps for 10MHz transmission bandwidth in the FDD mode. The graphical results in Figs. 8, 9 and 10 are provided to reveal and observe the performance stance between user transmission location and achievable throughput quality. In each graph, while the blue line indicate the measured throughput quality, the red line indicate the minimum throughput target that is expected to be achieved at user communication device. From the graphs, minimum throughput target value of 15Mbps is attained 308, 342 and 343m, respectively, in PDCP, RLC and PDSCH layers for eNodeB 1. For eNode B 2 and 3, the minimum throughput target value of 15Mbps were achieved at 300, 645, 670m and 255m communication distance, in PDCP, RLC and PDSCH layers, respectively.

Figures 4 to 6 demonstrates the achievable throughput at the user equipment terminals at different RSRP and RSRQ values. The throughput quality also degrades due to various data packet loss and connection encounter at the communication links during transmission as the as the signal coverage and signal quality suffer due to factors such as multipath, free space loss, diffraction los, and multipath, vegetation and the general atmosphere turbulence.

Again, by employing the minimum throughput target value of 15Mbps as indicated by the red line in Figures 4 to 6, it found the attained 308, 342 and 343m, respectively, in PDCP, RLC and PDSCH layers for eNodeB 1. For eNode B 2 and 3, the minimum throughput target value of 15Mbps were achieved at 300, 645, 670m and 255m communication distance, in PDCP, RLC and PDSCH layers, respectively.

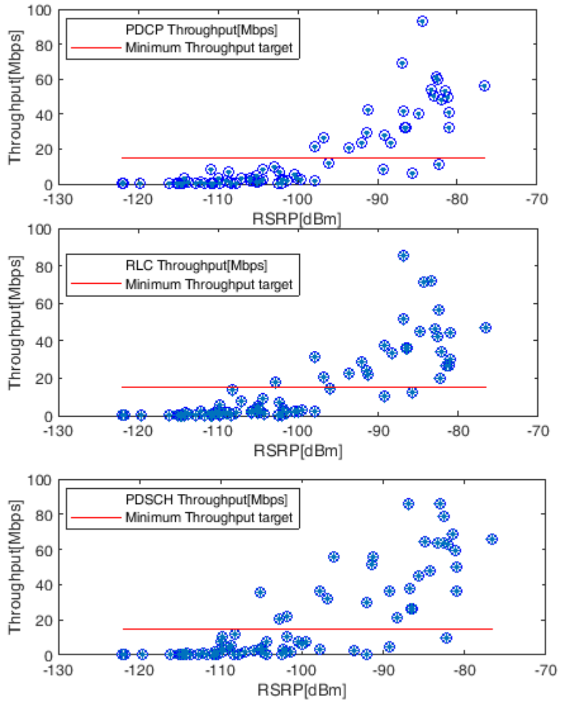

Figure 4: Achievable throughput performance trend with RSRP coverage condition for eNodeB 1

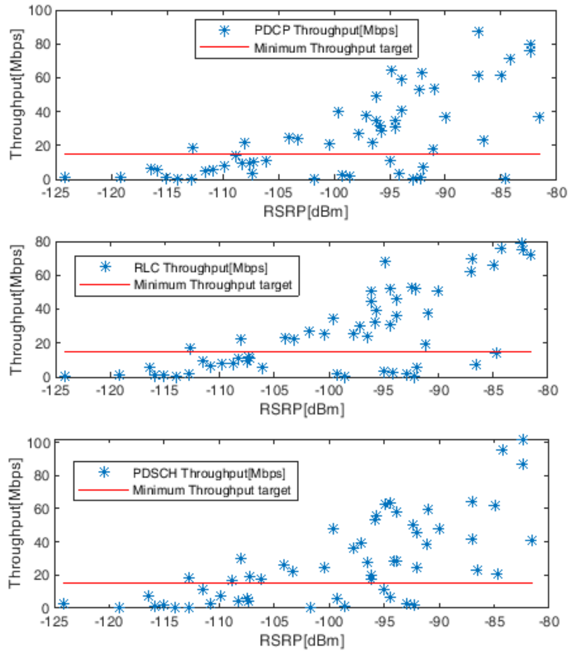

Figure 5: Achievable throughput performance trend with RSRP coverage condition for eNodeB 2

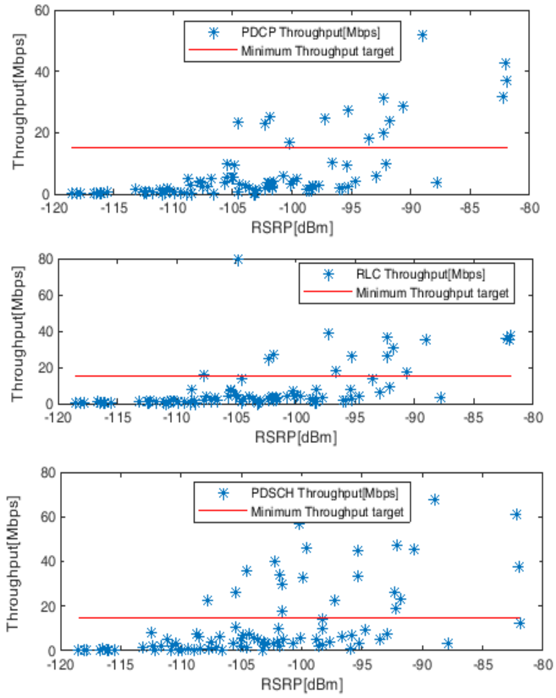

Figure 6: Achievable throughput performance trend with RSRP coverage condition for eNodeB 3

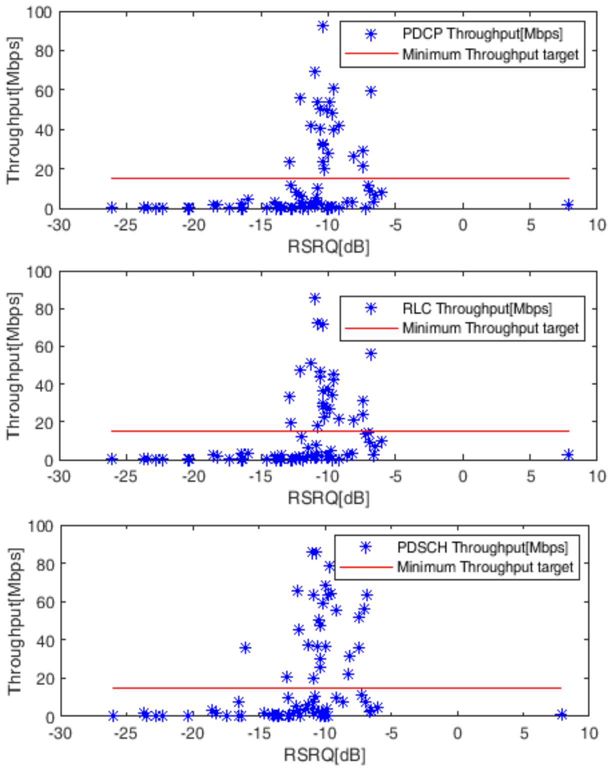

Figure 7: Achievable throughput performance trend with RSRQ condition for eNodeB 1

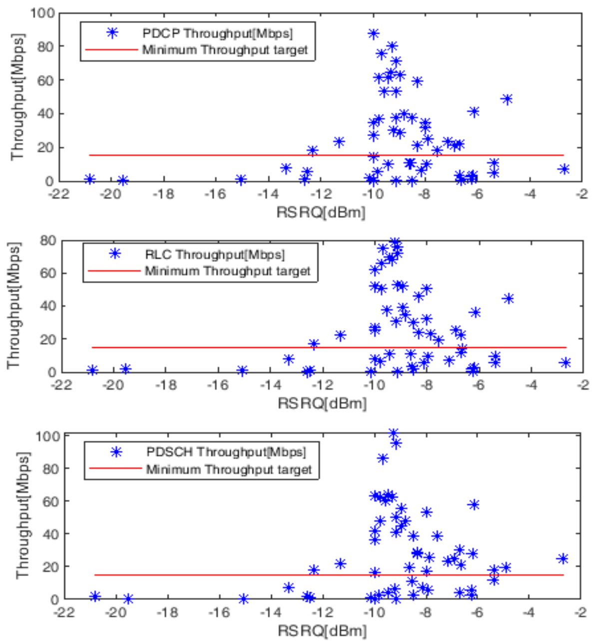

Figure 8: Achievable throughput performance trend with RSRQ condition for eNodeB 2

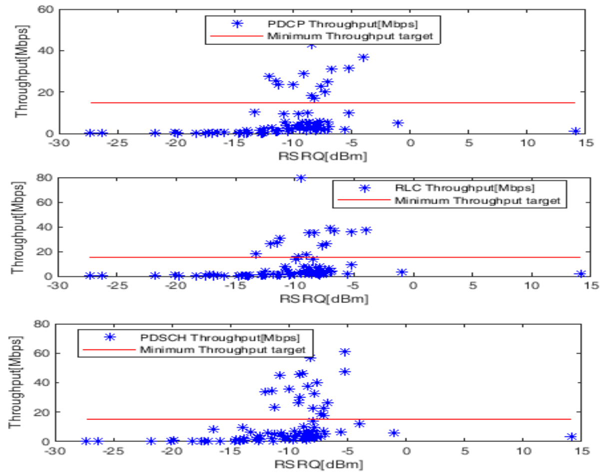

Figure 9: Achievable throughput performance trend with RSRQ condition for eNodeB 3

By means of three 3D plots, the various graphs in Figs. 9-15 are presented to examine the combined effect of signal coverage quality and signal coverage level on the achievable throughput at the three LTE protocol layers across the three eNodeB sites. In these figures, whereas RSRP expresses signal coverage level, the RSRQ expresses the quality signal coverage level.

A clear correspondence connection can observed in the graphs as both increment in RSCP and RSRQ values also results to improved achievable throughput performance and vice versa, across the PDCP, RLC and PDSCH layers in the three study sites. These practical results also clearly reveals that both signal coverage quality and signal coverage level performance places high and one-to-one impact on the throughput qualities attainable at the user equipment terminals. However, the shifting of the graphs to the right positions in almost all the figures indicate that the achieved throughput qualities in PDCP, RLC and PDSCH layers were more impacted by RSRP coverage levels compared to RSRQ. At mean -12.16dB and -100.5dBm values of RSRQ and RPRS, 23.2, 33.1, and 42.5Mbps throughput qualities were achieved in PDCP, RLC and PDSCH layers for eNodeB 1. For eNodeB 2 and 3, the achieved throughput quality stood at 20.2, 23.9, 45.8 Mbps and 33.3, 34.6, 42.5Mbps in PDCP, RLC and PDSCH layers with -11.16dB, -101.5dBm and -13.10dB, -103.9dBm mean values of RSRQ and RPRS, respectively.

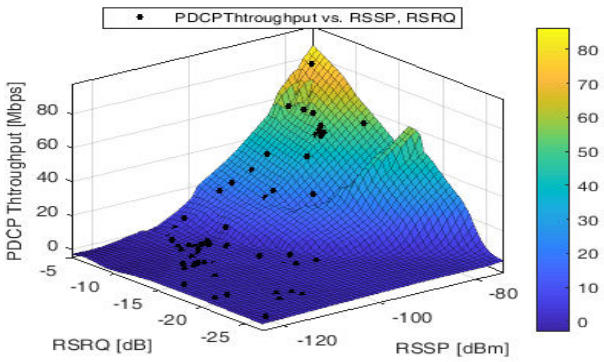

Figure 10: PDCP Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 1

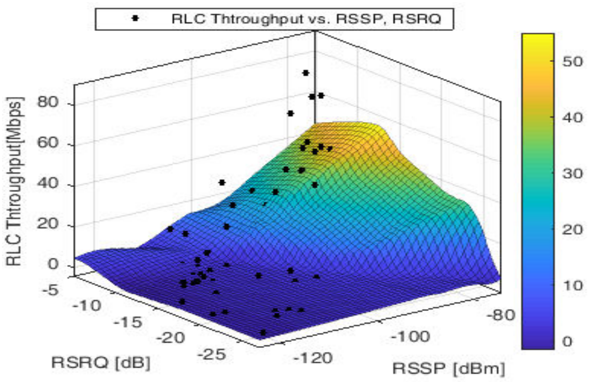

Figure 11: RLC Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 1

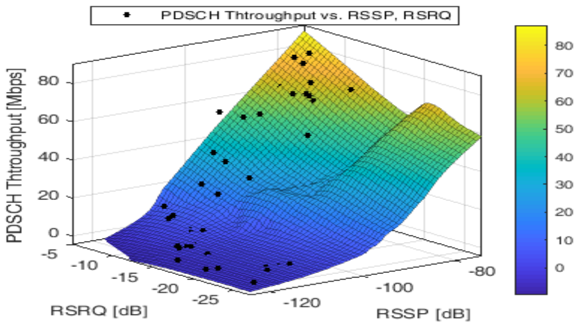

Figure 12: PDSCH Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 1

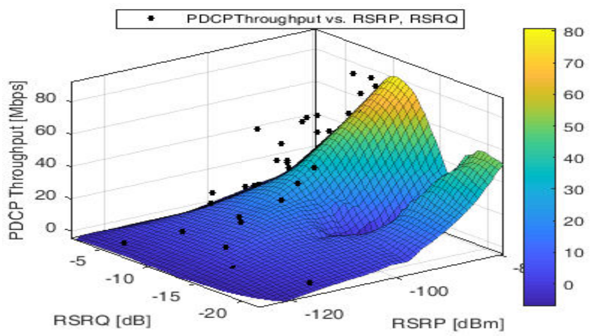

Figure 13: RLC Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 2

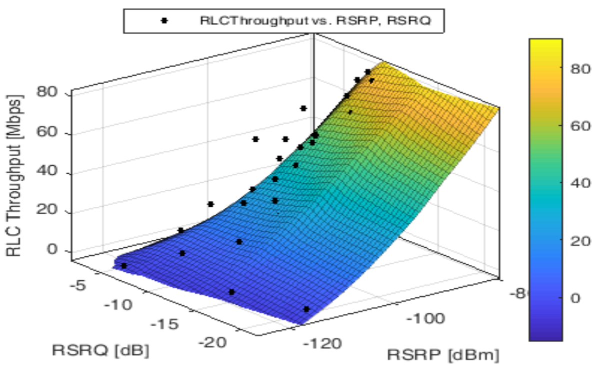

Figure 14: PDSCH Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 2

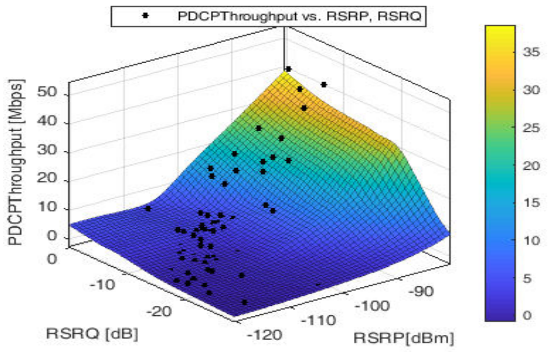

Figure 15: PDCP Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 3

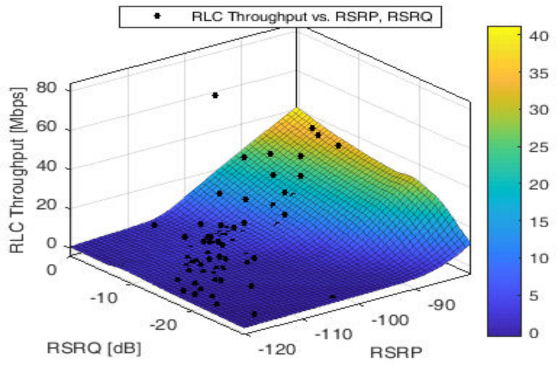

Figure 16: RLC Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 3

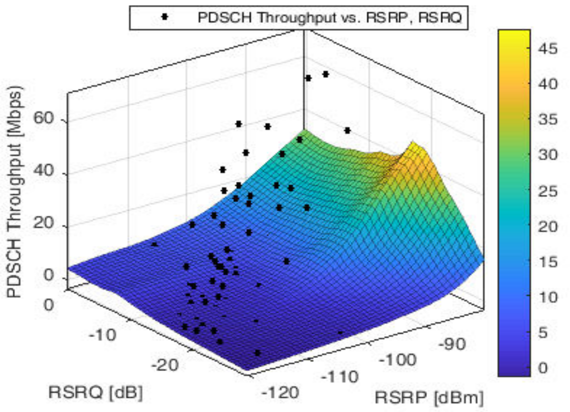

Figure 17: PDSCH Achievable throughput performance trend with RSRP and RSRQ radio condition for eNodeB 3

V. CONCLUSION

Resourceful deployment and operation of a cellular mobile broadband network is dependent on the networks ability to provide the needed reliable and steady services to its teeming subscribers. To guarantee such reliable and steady services during active communication in the network, it is imperative to constantly conduct detailed accurate measurement based assessments of the relevant network metrics like signal coverage quality, link quality and achievable throughput, all which impacts on users experience during the network usage. Measurement based assessments such key network characteristics metrics aid in network usage performance monitoring, user quality of experience monitoring, error diagnosis, resource allocation and management.

In this research effort, we have presented an in-depth practical measurement and findings for operational LTE mobile broadband network in terms of achievable throughput performance at PDCP, RLC and PDSCH layers. Specifically, findings on the impact of user transmission location, signal coverage quality and coverage level on the achievable throughput over the PDCP, RLC and PDSCH layers have been reported for three eNodeBs.

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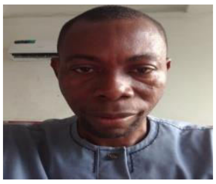

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