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EMPIRICAL INVESTIGATION OF CELL COVERAGE PARAMETERS' IMPACT ON RADIO FREQUENCY BROADBAND NETWORK INTEGRITY

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ABSTRACT
The need to provide superb user experience in terms of packet switch multimedia data communication was the key reason for evolving mobile broad cellular radio network technologies such as the universal mobile telecommunication systems (UMTS), High speed packet access (HSPA) and Long Term Evolution (LTE). Particularly, the LTE was developed to supports data transmission speed up to 300 Mbps and 75 Mbps in downlink and uplink, respectively, utilizing a robust multiplexing technique. The multiplexing technique is termed the Orthogonal Frequency Division Multiplexing (OFDM). For mobile radio networks operators to maintain high operability around the ever increasing and demanding subscribers, periodic evaluation, quantitative estimation and analysis of network performance integrity is pivotal. A key parameter to access the LTE network integrity is the throughput. In this work, with the help of Ascon based telephone mobile telephone mobile software tools, a realistic empirical based investigation technique has been engaged to investigate the impact of cell coverage and signal power on LTE user throughput performance over PDCP, RLC and PDSCH layers. The Ascon based telephone mobile software investigation tools provided us a good means of investigating and reporting an in-depth service quality performance around the studied operational cellular LTE broadband networks in typical urban microcells.

KEYWORDS: *Cell coverage, Signal Power, Throughput, LTE, Mobile Broadband network, Urban microcell*

INTRODUCTION

Establishing uninterrupted signal coverage and robust connectivity in cellular broadband networks remain one the core objectives that the operators aimed at in meeting the demand their customers One of first ever developed digital-based second generation (2G) wireless communications technology was the Global System for Mobile (GSM) communication. One of the leading purposes of evolving the GSM-based 2G cellular mobile technology was mainly for voice (speech) communication in the early 1980s. However, the need for packet switch multimedia communication such the voice over internet protocol or video telephony has triggered the introduction of more generations of wireless technologies like third generation (3G) and Fourth Generation (4G) cellular communication systems over the years. Long Term Evolution (LTE), as known as 4G LTE, belongs to the 3GPP technology groups of release 8. It was later extended to release 10 at the advanced phase (3GPP, 20011). It is a mobile broadband technology-based system networks standard that make use of internet protocol Multimedia Subsystem (IMS) to make provision for both voice, data and multimedia services (Clint and Collins, 2014). Its evolution combines the unique systems technology of GSM and UMTS, both which are second and third communication standards. The principal drive toward the introduction of the LTE communication technology is to meet growing high quality multimedia services demands like better user data communication speeds. LTE utilizes a of wide-ranging channel bandwidths of up to 20 MHz. Base on specifications of 3GPP's family, LTE system is designed to offer at least 100Mbits/s and 50Mbits/s of data rate in the downlink and uplink, respectively. The latest release of LTE known as LTE-Advanced is targeted to offer up to 1 Gbits/s downlink data rates and 500 Mbits/s on the uplink.

The multiplexing technique of LTE standard is the Orthogonal Frequency Division Multiple Access (OFDMA). In the OFDMA system structure or arrangement, multiple subcarriers are characterized into different resource blocks (RB) which can be allocated to individual users as displayed in table 1 and figure 1. Thus, LTE technology is so unique because it is the leading broadly-adopted cellular communication technology using the OFDMA technique (Cox, 2012). The multiplexing carrier technique was integrated into LTE to it enable it provide higher data transmission rates resourcefully while at the same time providing a better level of resilience to multipath fading and interference. The radio access in LTE air interface consists of a number of layers. Among the key layers are Radio Link Control (RLC), Physical Downlink Shared Channel (PDSCH) and Packet Data Convergence Protocol (PDCP). PDCP layer is made up of both the user plane, which deals with the internet protocol packet messages and the control plane, wherein RRC messages are processed. Other functions carried by PDCP throughput layer include integrity protection, Header recompression, ciphering, reordering and retransmission procedures for handover.

The RLC layer is designed to manage the sizes of upper layer packets transmission over the LTE air interface. RLC also recovers packet losses by transferring radio bearers again to avoid transmission errors. Packets reordering, packets losses recovering, and error protocol detection are other main function of RLC throughput layer. The PDSCH layer is utilize for user application data transfer via the downlink shared channel (DL-SCH) (Clint and Collins, 2014; Cox, 2012). In other words, it is the physical layer through which UE application data is transmitted over the LTE air interface. It the physical layer that contains the UEs' downlink data traffic or traffic.

LTE has been commercialized ever since 2009 and till date, it is the hottest mobile broadband communication technology being deployed by telecom network operators. Today in Nigeria, LTE/4G is undergoing rapid rollout by different network operators and as such, now plays a major role in cellular mobile communications most States, particularly within urban/built-up areas. The performance and practical value of an operational radio cellular network is usually measured in terms of available and accessible throughput by the end user (Isabona and Odion, 2015; Isabona, 2015). Therefore, for an operational radio cellular network, the mobile subscribers should be able to: access to the radio network with less effort, establish an active voice and data connection to the radio network and also achieve a certain desired throughput quality during radio network connection.

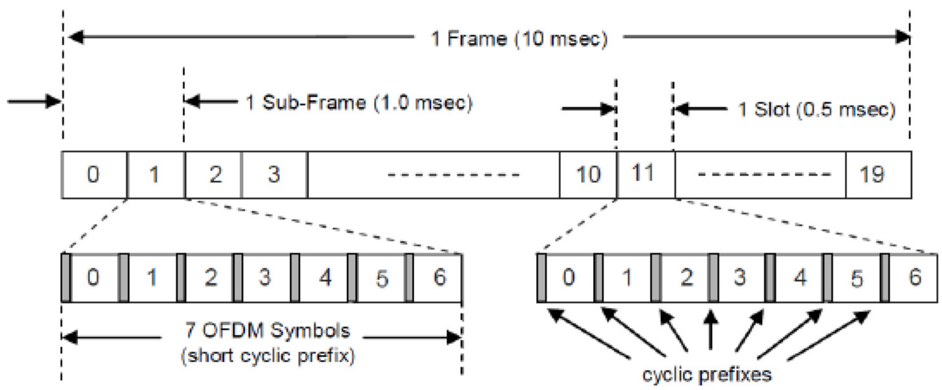

Fig. 1: LTE Generic Frame Structure (3GPP, 2011)

Table 1: Channel Bandwidth Arrangement in the Downlink of LTE Broadband System

	Channel Bandwidth Arrangement					
	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Frame Duration (ms)		10 ms				
Sampling Frequency (MS/s)	1.92	3.84	7.58	15.36	23.04	30.72
Resource Blocks	6	15	25	50	75	100
Subcarrier Spacing (kHz)	15	15	15	15	15	15
Sampling Frequency (MS/s)	1.92	3.84	7.58	15.36	23.04	30.72
Resource Blocks (RB)	6	15	25	50	75	100
FFT Size	128	256	512	1024	1526	2048

LITERATURE REVIEW

There exist a quantum of previous research works on LTE system network performance conducted both at spatial domain and temporal domain, but majority of the authors either concentrated their studies on only practical LTE radio coverage issues (Isabona and Ojuh, 2014; Isabona, 2019a; Isabona, 2019b; Merz *et al.*, 2014; Garcia, 2017; Lin *et al.*, 2014; Kora *et al.*, 2014; Elnashar and El-Saidny, 2013), or on general LTE network performance issues using analytical/simulation techniques (Isabona and Kehinde, 2019; Ebhota *et al.*, 2019a; Ebhota *et al.*, 2019b; Ebhota *et al.*, 2019c; Isabona, and Osaigbovo, 2019; Ball *et al.*, 2009; Lee *et al.*, 2008). For instance, in (Merz *et al.*, 2014; Garcia, 2017), studies on LTE radio system performance at different train velocities are presented. Specifically, the authors in (Merz *et al.*, 2014), reported that SNR was the most relevant parameter for reliable LTE network operation at high velocities. The application of dual radios-based access terminal as a means of improving drop-off and handover performance in LTE is clearly reported in (Lin *et al*., 2014).

By means of field drive test and computer simulations, effect of different metrics on LTE network performance is shown in (Elnashar and El-Saidny, 2013). The correlation between data interruption time and handover time with respect to LTE system channels is provided in details by the authors. The effect of path loss on data communication in LTE networks is also revealed by the authors.

A method for efficient radio coverage assessment over operational third/fourth generation broadband cellular networks using special drive test routes (SDTR) in considered in (Kora *et al*., 2016). The impact of the using SDTR technique over the random drive test method in open and clustered terrain is provided by the authors. Practical/simulation-based analysis of coverage metrics in terms of signal strength, noise and interference for multi-traffic users' distribution for the purpose of effective LTE networks planning using an urban area scenario is presented in (Ahamed *et al*., 2015). A number of research studies on accurate signal coverage loss analysis toward the effective LTE networks planning and deployment in built-up terrains are also presented in (Isabona, 2019a; Isabona, 2019b; Merz *et al*., 2014; Garcia, 2017; Lin *et al*., 2014; Kora *et al*., 2014).

A key parameter to access the LTE network integrity is the throughput. In this work, with the help of commercial user telephone mobile software tools, a realistic empirical based investigation technique has been engaged to investigate the impact of cell coverage and signal power on LTE user throughput performance over PDCP, RLC and PDSCH layers. The Ascon based telephone mobile software investigation tools provides a good means of conducting in-depth testing capabilities around any operational cellular broadband networks.

MATERIALS AND METHOD

This work adopts a four steps methodology to accomplish the central aim of this work. As clarified in the flowchart of figure 1, the steps include data collection through realistic field measurement. This is followed by data extraction and preprocessing as second step and third step, before data analysis and discussion is tracked.

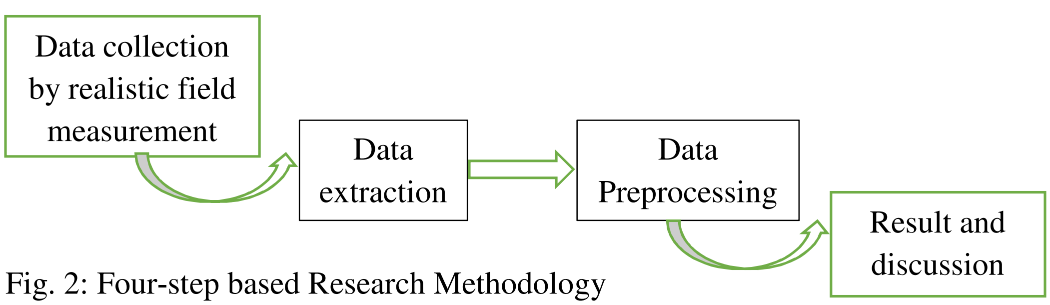

Fig. 2: Four-step based Research Methodology

Realistic empirical based investigation can either be performed by means of active measurements with commercial user equipment or using passive measurements with receive-only equipment. In this research work, the former method based on TEMS investigation tools was engaged to obtained Received Signal Reference Power (RSRP) and LTE network integrity Data. While RSRP was used to assess the LTE coverage Quality, the throughput which is an integrity indicator, as employed to investigate fast the user is able to sends data and receive same from the LTE mobile broadband network.

Field Measurement

With the aid of Ascom TEMS integrated drive test tools, housed in a salon car, RSRP and data throughput, were acquired from three operational LTE eNodeB sites in Waterline areas of Port Harcourt city. The three eNodeB site were empowered each with three sectored directional antennas. The eNodeB site locations were carefully chosen to reflect a good blend of various commercial and uneven residential structures that are permeate the study area. Thus, the area provides a distinctive terrain for measurement study of propagated LTE radio signals at 2600MHz. Candidly, to our best knowledge with regard to previous works and related literature, this is the first time this type of research work is being embarked upon in the study area.

The field signal measurement was conducted up to a distance of 1500m for site 1, 1300m for site 2 and 560m for site 3; the measured signal data consists of over 2000 data points, which are average to 600 readings. Shown in figure 1 is the snap shot of the drive test routes with TEMS tools. To ensure that the influence of small-scale fading on the propagation is catered for, all measured RSRP values were further post-processed to a single mean value, along the test routes and locations. The field test locations were kept track of using the GPS unit.

Data Processing

Poor data preprocessing negatively affects many realistic data mining and exploration efforts. Also, every measured data is always generally noisy. Thus, in this research work, we employed the MATLAB 2018a technical preprocessing environment to remove noise and outliers, wrong data, duplicate data and missing values proceeding to results analysis and discussion

RESULTS AND DISCUSSION

As mentioned earlier, establishing uninterrupted signal coverage and robust connectivity in cellular broadband networks remain one the core objectives that the operators aimed at in meeting the demand their customers. This section presents the results and analysis on impact of cell coverage and signal power on LTE user throughput performance over PDCP, RLC and PDSCH layers. For LTE networks, the minimum throughput quality level required for effective data communication at the user equipment terminal is about 24 Mbps (Isabona, 2021). To graphically present the results, we employ MATLAB R2018a technical software platform. Shown in figures 3 to 5 are the graphical results revealing how LTE cell coverage impact the user data throughput at various measurement distances from the three eNodeBs sites used as case study. First, the result show that the throughput qualities at the PDCP, RLC and PDSCH remained relatively stable at different level, until after a particular distance where the quality fluctuates and goes down abstrusely. The distance at which the throughput stays above or within the 24 Mbps desired quality level before go down of quality can be termed as the cell coverage radius of the LTE eNodeB. For example, at the PDCP, RLC and PDSCH layers, the attained cell radius stands at 0.42, 0.45 and 0.43km, respectively in site 1. For sites 2 and 3, the attained cell radius stands at 0.32, 0.75, 0.51km and 0.62, 0.55 0.51km, respectively. Such cell radius parameters of high importance to the cellular radio network engineers for planning, management and optimisation purposes

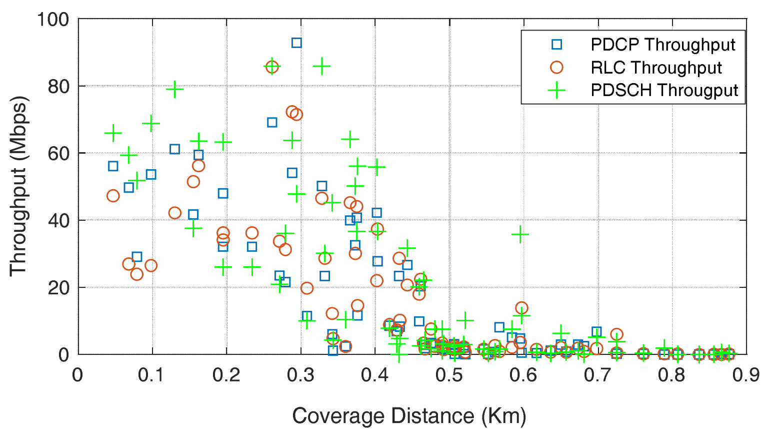

Fig. 3: Throughput as a function cell coverage distance for eNodeB site 1

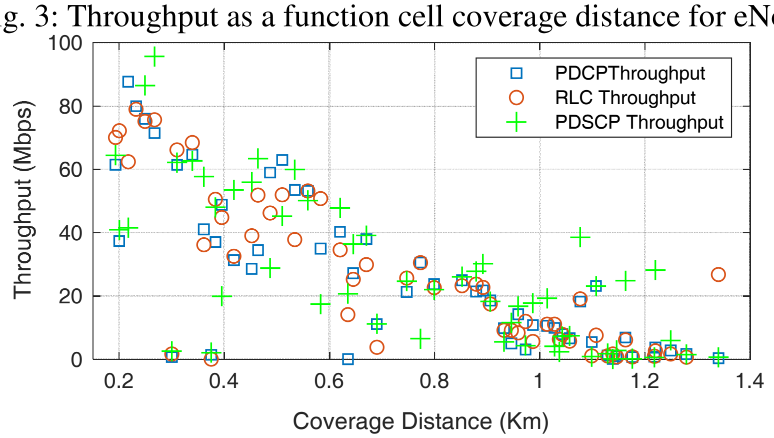

Fig. 4: Throughput as a function cell coverage distance for eNodeB site 2

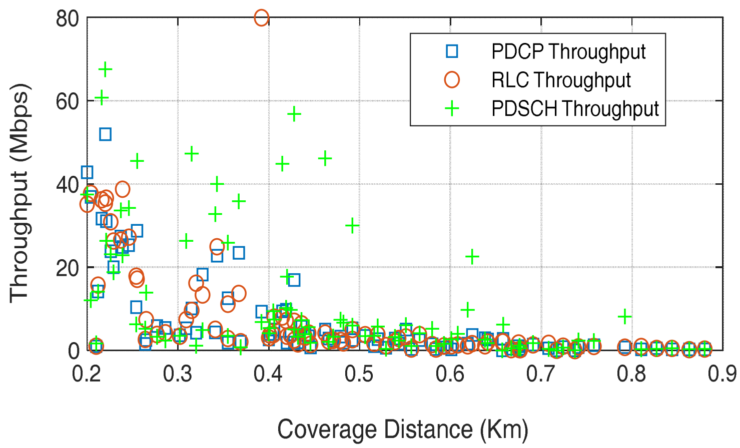

Fig. 5: Throughput as a function cell coverage distance for eNodeB site 3

Another parameter that impacts the user quality is the RSRP quality levels. It is an important performance indicator for measuring the LTE cell coverage on the forward link. During practical measurement, the UE will measure RRC which include RSRP values and send reports in a binned format. The mobile station continuously monitor RSRP measurement is to find out the best cell on the forward link of LTE radio interface and select the cell connection. Thus, for good communication over the LTE network channels, a minimum of -92dBm RSRP level is required at the user equipment (Isabona, 2021). Shown in figures 6 to 8 are the graphical plots revealing impact of the RSRP levels of user data throughput at various measurement distances from the three eNodeBs sites. First, the result show that the throughput qualities at the PDCP, RLC and PDSCH fluctuates and degrades in values at different distances as the user moves away from the eNodeBs. So, at the PDCP, RLC and PDSCH layers, the throughput quality attained the required RSRP threshold level stand at about 23, 28 and 30Mbps, respectively in site 1. For sites 2 and 3, the attained cell radius stands at 33, 53, 24Mbps and 24, 31 23Mbps, respectively. Such performance parameters are also of high importance to the cellular radio network engineers for planning, management and optimisation purposes.

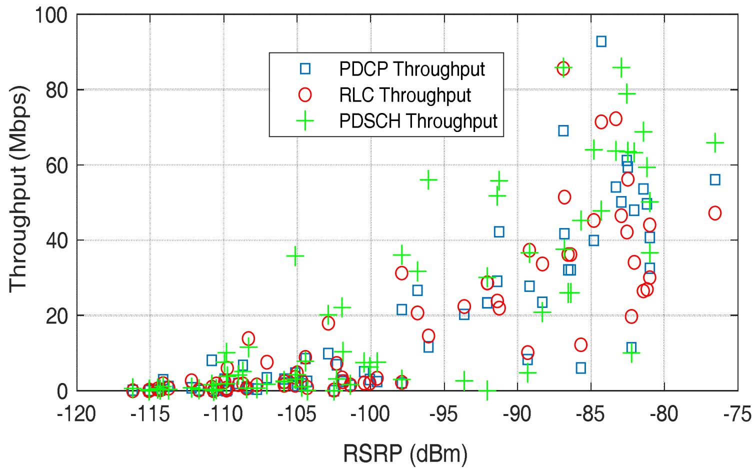

Fig. 6: Throughput as a function of RSRP for eNnodeB site 1

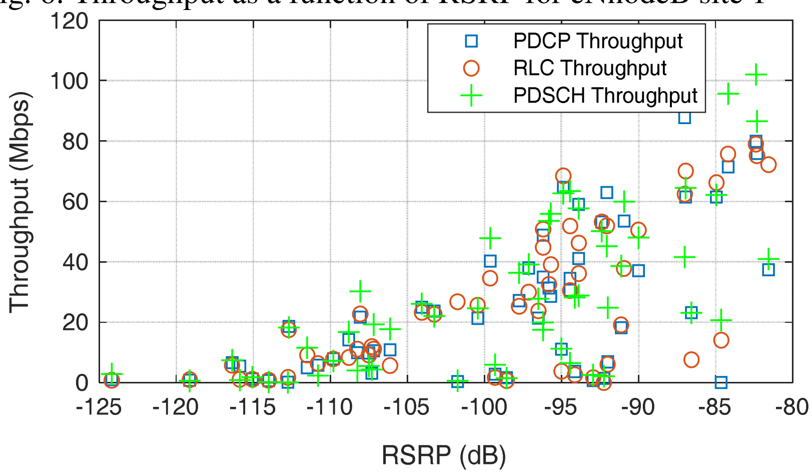

Fig. 7: Throughput as a function of RSRP for eNodeB site 2

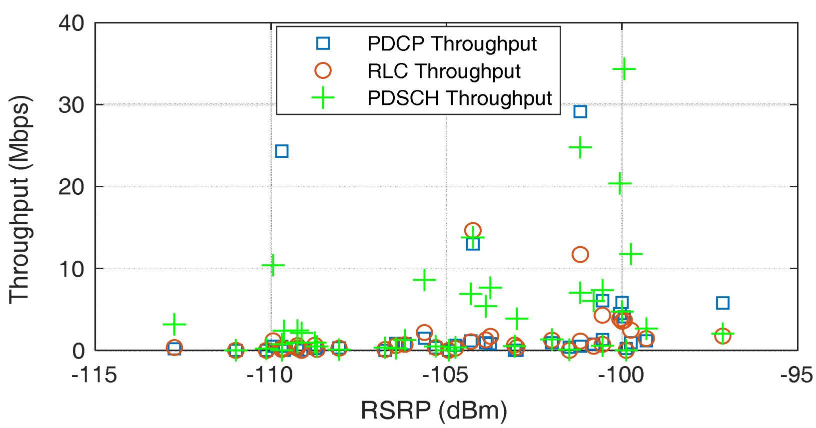

Fig. 8: Throughput as a function of RSRP for eNodeB site 3

CONCLUSION

Guaranteeing a resourceful and excellent service quality communication over operational cellular mobile broadband radio frequency network channel around teeming subscribers is always the heart desire of the cellular network providers, stakeholder and the mobile subscribers cannot be overemphasized. The evaluation of user throughput quality and its performance dependence on RF channel quality indicators is an important research topic for purpose of optimal cellular network planning and management.

In this work, by means of commercial user telephone mobile software tools, a realistic empirical based investigation technique was engaged to investigate the impact of cell coverage and signal power on LTE user throughput performance over PDCP, RLC and PDSCH layers. The Ascon based telephone mobile software investigation tools provides a good means of conducting in-depth testing capabilities around any operational cellular broadband networks.

In our future research, the focus shall be geared towards the used of both simulation and realistic field measurement approach for detailed based assessment more signal coverage and quality parameters on throughput quality in 4G-LTE cellular networks. We also intend to extend our study locations by considering urban and rural areas.

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