

FOURTH GENERATION LONG TERM EVOLUTION (4G LTE) KEY PERFORMANCE INDICATOR ANALYSIS AND PERFORMANCE EVALUATION OF SPECTRANET

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Abstract

Long Term Evolution (LTE) is necessitated by the unceasing increase in demand for high speed connection on wireless mobile networks, notwithstanding the mammoth amount of investment into communication systems by Nigerian government through Nigeria Telecommunication (NITEL), Mobile Telecommunication (MTel), there is still need for improved Quality of Service (QoS) to enable efficient day to day businesses in the country. Proper cellular planning, adequate capacity provision and ability to sustain quality of service at all time, through means of generating and analysing key performance index of deployed radio cells at different locations, in order to detect, resolve and restore poor performing cells in shortest possible time, hence reducing downtime and enhancing Quality of Service (QoS). This paper analysed and evaluated the Key Performance Indicators (KPI) and empirical data of SPECTRANET LTD, Abuja, acquired through Huawei Imanager 2000 software tool, drive test and open Signal software. Analysing the obtained data, presented an accurate performance of the network and the performance of each cell sector. It was observed that less than or equal to 20% of online subscribers consumes about 80% of the provisioned radio resources per cell. From results obtained, it was discovered that cells with very poor throughput performance ($=0.8\text{Mbps}$) as well as low number users ($=15$) have island coverage, a footprint out of designed area. However, 70% the cells with average users >40 tends to have low throughput performance below $<1.5\text{Mbps}$, as well as poor Reference Signal Received Power (RSRP) of -95dBm , and Signal to Noise Ratio (SNR) of -10dB due to contention ratio amongst users. However, in contrast to conventional system of breakdown approach, this paper presented an evaluation technique based on preventive approach that reduces Mean Time to Repair (MTTR) and improves Mean Time before Failure (MTBF) by 50%, which are core maintenance metrics that drives network efficiency, reliability and availability.

Key Words: 4G LTE, KPI, MTBF, MTTR, PRB.

1.0 INTRODUCTION

Fourth Generation (4G) Long Term Evolution network, just like every other cellular network requires minute by minute monitoring of all deployed cells in the city in order to achieve 99% service availability and to guarantee Service Level Agreement (SLA) on quality of service. Hence, the need for remote information gathering based on performance conditions of Network Elements (NE). Huawei Imanager 2000 software tool is used in the case of SPECTRANET Ltd, Abuja for Key Performance Indicators (KPI) of the network element, as well as the Google Earth Pro. The Essence of KPI data is to detect the cells in a particular region that are performing well or

underperforming at every given time. The software tool captures all the cell locations and cell performance metrics. The KPI also shows the amount of the network Physical Resource Block (PRB) used per cell for a given period. It helps to observe when and where congestion triggers in the network etc. In-depth analysis of KPI data generated through Huawei Imanager 2000, drive test and Google Earth Pro gives operators due advantage to detect, resolve and restore poor performing cells within shortest possible time (Mean Time to Repair). Consequently, there are improved network availability, accessibility and reliability.

1.0 REVIEW OF RELATED RESEARCH WORKS

4G LTE is standardized by third generation partnership project 3GPP with major aim of providing high data rate for mobile device and data terminal, many authors have been working on implementable methods of achieving 99.9% LTE networks availability and network accessibility while guaranteeing Quality of service. The authors examined different efficient techniques of generating and analyzing key performance metrics determining quality service delivery of 4G networks Kamran [3], worked on LTE System Level Performance in the Presence of Channel Quality Indicator (CQI) Feedback for Uplink Delay and Mobility [3], the research presented the impact of CQI in uplink feedback delay on the overall network performance under different scheduling algorithms and mobility patterns. Researcher also investigated average user equipment (UE) throughput, the average throughput of UEs at cell-edge and the average cell throughput under UE mobility. The results concluded that for an efficient LTE-Advanced system on network reliability and accessibility, the scheduling algorithm is a solution to UE speed and CQI feedback delays. In the case of SPECTRANET, an intelligent scheduling algorithm that will do more of load balancing is required as well as efficient method of KPI data evaluation.

E.T Tchao [1] adopted simulation (Genex UNET) and field measurement to aid research evaluation on 4G network coverage and throughput performance of 2X2, 4X4 and 8X8 MIMO configurations of the deployed networks. The results showed that average simulated throughput (Mbps) per sector of 4X4 MIMO system configuration was better than 2X2 MIMO system configuration. Conversely, the percentage coverage for users under the 2x2 MIMO system simulation proved better than adaptive 4x4 MIMO System Configuration. This means that 2x2 MIMO system provides LTE network with more users (UE) accessibility. However, the author did not address the real circumstance or means that can improve the performances of Network elements of deployed 2x2, 4x4 or 8x8 MIMO

system when system fall short of desired performances.

[5] Presented an overview on 4G LTE system on its architecture, technologies and features. The paper reviewed the QoS concepts in LTE system, QoS parameters and QoS provisioning mechanism in LTE networks. The author stated that the reliability and effectiveness of Quality of service are dependent on network bearers of UEs. In LTE network, QoS bearer mechanism is provided through scheduling scheme which in turn helps in mitigating inter cell interference and uplifting cell throughput performance and ensuring network accessibility for numerous users. The author did not state the scheduling schemes that best suits network peculiarities, as observed in the case of SPECTRANET where less than or equal to 20% of online subscribers (Ues) consumes about 80% of the provisioned radio resources per cell.

T. Dikamba [9], did research on downlink scheduling in 3GPP Long Term Evolution (LTE). He proposed a scheduling strategy that assigns resource blocks to the users with unsurpassed radio link environment using advanced CQI values to accurately detect channel condition. This method improves throughput of users with good radio conditions but the number of users accessing the network and getting bearers are limited. SPECTRANET eNodeBs in most locations has a coverage radius above 400Meters and requires good number of UEs requesting radio access.

1.0 LTE ARCHITECTURE AND KEY FEATURES

LTE is enhanced radio and core technology from 3G, 4G simplified its architecture while most of the advanced changes occurred in three aspects of the architecture thus; the Mobile stations/user equipment (UE), the Evolved Universal Terrestrial Area Network (E-UTRAN) and the Evolve packet core (EPC) however, the radio interface of LTE employed Orthogonal Frequency Division Multiplexing (OFDM) for downlink while Single Carrier Frequency Division Multiple Access (SC-FDMA) is built for uplink channel. Figure 1 presents 4G LTE network Architecture.

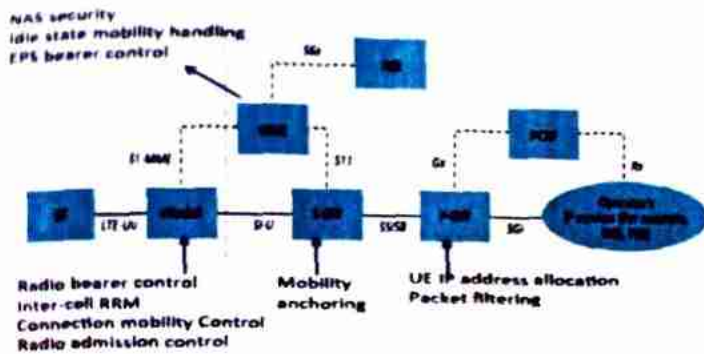


Figure 1: Long Term Evolution Network Architecture [8]

One of the key elements of the architecture is the eNodeB which is in charge of Radio bearer control and procedures of scheduling, eNodeB handles Inter-cell radio resource management, and it also controls UE connection mobility as well as radio admission control. Mobility Management Entity (MME) handles Non Stratum Access (NAS) connection security, manages UE's idle state mobility, also oversees Evolved packet System (EPS) bearer control while Serving Gateway (SGW) anchors mobility and finally, Packet Gateway (P-GW) handles UE IP address allocation and packet filtering.

1.0 KEY PERFORMANCE INDICATOR (KPI) METRICS

The following KPI metrics were generated on daily basis using Huawei Imanger 2000 for the purposes of identifying, resolving and timely optimization of cells with poor Quality of Service.

- I. Average and maximum throughput (Mbps) in downlink (DL).
- Ii. Average and maximum throughput (Mbps) in uplink (UL).
- Iii. Average and maximum number of active user on the network and per cell.
- Iv. Average Number of Physical Resource Block (PRB) used Rate (%)
- V. Congestion traffic rate
- Vi. Bit error rate (BER) i. Signal to Noise Ratio (SNR)
- Vii. Reference Signal Received Quality (RSRQ)
- Viii. Reference Signal Received Power (RSRP)
- Ix. Number and height of antennas (Backhaul receiver and transmitter)

X. Downlink and downlink Transport Block for QPSK, 16QAM, and 64 QAM i.

Average Downlink and uplink MCS

Xii. Average downlink and uplink Packet loss rate

Xiii. Average DL and UL Transmission Block Retransmission Rate

Xiv. Average Intra-eNB Handover Out Success Rate

Xv. Average Downlink CQI

Average of the data is determined before employing it over various analysis in the study:

$$\text{Average}(\bar{x}) = \frac{\sum x}{n} \quad (1)$$

Where x = collected data of various parameters, n = Number of collected data

$$\text{Date Rate (bps)} = [1 - \text{Bler}] * \text{TBS (bits)/TTI (secs)} \quad (2)$$

Where Bler = Block Error rate, TBS = Transport Block Size (bits), Transmission Ttime Interval (TTI).

The throughput performance (P) of the network is calculated as [1]

$$P_T = \frac{T_e}{T_{QCI}} \quad (3)$$

Where: T_e = Experimental throughput, T_{QCI} = Expected throughput by QCI standard

However, Spectral efficiency (E) of the network is determined using modified Alpha-Shannon Formula and is given as:

$$\epsilon_s = a \log_2 \left(1 + 10^{\frac{SNR}{10}} \right) \quad (4)$$

Where: a = Bandwidth efficiency factor, G_f = Geometry distribution factor in (dB)

The average signal-to-noise ratio (SNR) in decibel is the measure of the ratio of average of received signal power and average of noise power [3].

$$SNR = \frac{P_s}{P_n} \quad (5)$$

Where: P_s = Received Signal Power (dB), P_n = Noise power (dB)

Mean Time to Repair (MTTR) [6] = Total maintenance time/total No of Repairs (6)

Mean Time before Failure (MTBF) = Total Operational Time/total No of failure (7)

1.0 DATACOLLECTIONAPPROACH

The filed measurements were carried out in Federal Capital Territory (FCT), Abuja in the central Northern Nigeria. It is the administrative hub of Nigeria. For the purpose of this research, collection of data lasted from November, 2018 through February, 2019 and April to June, 2019. In order to cover the extreme weathers of Abuja City. KPI data were permitted by the Network operators to be collected five times (days) in a week (Monday Friday) for a period of seven Months. All the 403 cells of SPECTRANET were monitored and studied on daily basis. The average performances of each cell for the period under study were computed, combined, and evaluated. Figure 2 presents an overview of SPECTRANET eNodeB Sites in Abuja Metropolis.



Figure 2: Overview of SPECTRANET eNodeB Sites in Abuja Metropolis

Huawei Imanager 2000 helped in generating KPI data for active cells across Abuja metropolis. Table 1 and Table 2 presents the sample of the KPI data logs as generated per day (24Hrs) and the Key performances are organized per Site, Sector (eNodeB), Busy Hour (BH), Evening Hour (EH), Congestion Hours, and Network Traffic. Table-1 depicts Abuja KPI Data Log sample for 24Hrs performance per Sector for a particular day. It

shows the measured average Downlink and uplink throughput performance (Mbps), average and maximum users per cell. Other Measured parameters shown are the Maximum Downlink and Uplink Physical Resource Block (PRB) Used Rate (%), Downlink and Uplink PRB utilization rate above eighty percent (> 80%) etc. However, Table 2 shows sub data sheet for the measured average Downlink throughput performance (Mbps), average Throughput Uplink (Mbps), Maximum Throughput Downlink (Mbps) etc. per network site (eNodeB). Recall that a network site has

Table 1: SPECTRANET Cells KPI DATA sample for 24Hrs-Sector Record

Table 3: Abuja Coverage KPI DATA LOG sample for 24Hrs Site Record

Table 1 and 2 shows each eNodeB Function name: AB001, Cell name (e.g: AB_12001_2), Local Cell ID = 2, ENodeB ID = 12001 as well as Cell FDD TDD indication: Cell_TDD. Another important column in the log is the PRBs for Uplink and downlink, it presents them in percentage when the PRBs are almost consumed (> 80% usage) for each cell. Once it gets to 90%, there will be congestion and packet data will start to drop after number of HARQ sequence. This causes increase in delay of delivering packets successfully.

SPECTRANET operates 20MHz bandwidth, thus 100 PRBs and one PRB has 12 sub-carriers, and each sub-carrier corresponds to one User (UE- user equipment) allotment. Theoretically, the maximum number of user each cell can have or contain at every given point in time is 1200 subscribers.

Other Sub sheets or Tab shows the average performances at EH (Evening hours (6PM to 9PM)) and BH (Busy Hours) (9AM to 12PM) in each site. The Congestion Tab shows the performance as at the set Busy Hour. Good to monitor and observe changes during this period.

6.0 DRIVE TEST

Drive test helps identify cell's Physical Cell Identifier (PCI) number, RSRP performance of each cell which gives the detail of the total received power towards a particular area, RSRQ which gives details of quality of received signal at every given location and SINR value which presents the ratio of signal strength against noise at every given location. Figure 4 depicts drive test kits configuration.

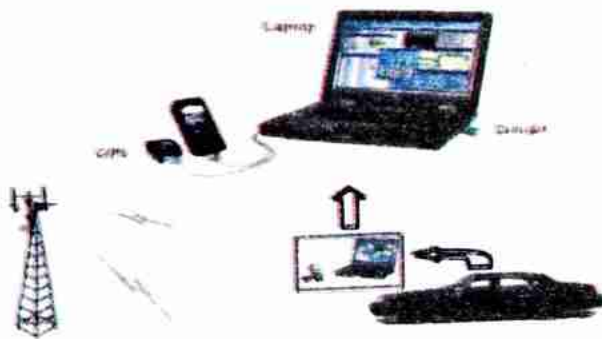


Figure 3: Drive Test kits and illustration [4]

Figure 3 presents tools used for single and cluster cells experiment (Drive-Test). HP Laptop, GPS device, SPECTRANET Modem, Car, Google Earth, MA-INFO, Transmission Evaluation and Monitoring System (TEMS) 15.3.4, Power Inverter etc. Figure 4 presents a screen grab of sectors routes driven.



Figure 4: Drive Test for Optimization over MAITAMA District eNodeB Sites, Abuja

Figure 4 is a screen shot of events during drive test using TEMS Investigation 15.3.4 at Maitama District Abuja. All serving sectors (Cells) and sites in the route are monitored; PCI numbers of serving are displayed. The Signal Quality indication is identified by colours (Red= Poor, Yellow= Good, Green = Excellent), observe some sites are two sectored sites but Majorly 98% of the sites in Maitama district are three sectored site, the handover symbols with the hand sign, frequent and successive handover within a short distance is a sign of degraded service or wrong configuration.

The monitoring cells to each serving cell are listed on the right hand side of the tab. The monitoring cells observes the connectivity and performance of each cell and UE and ever ready to accept UEs with poor RSRP or that those UEs making request for handover etc. The generated data log was further analysed using MapInfo software. Summary of empirical data from Drive test is given in table 3.

Table 3: SPECTRANET LTE Empirical Values

S/N	Performance Remark	SINR (dB)	RSRQ (dB)	RSRP (dBm)
1	Excellent	30 ~ 40	20 ~ 30	30 ~ 40
2	Very Good	20 ~ 30	15 ~ 20	20 ~ 30
3	Good	10 ~ 20	10 ~ 15	10 ~ 20
4	Fair	5 ~ 10	5 ~ 10	5 ~ 10
5	Very Bad	0 ~ 5	0 ~ 5	0 ~ 5

7.0 RESULT AND DATA ANALYSIS

From 403 deployed active cells in the network of SPECTRANET LTD, Abuja, empirical data were obtained through different means and for different purposes. Key Performance Indicator (KPI), Drive test, Google Earth Professional, and OpenSignal are some of means for data collection. Figures (6 - 9) present sample cells

performance analysis. Figure 6 presents the corresponding average throughput (Mbps) performance for various Cells (AB0012 to AB0017) during the period of investigation.

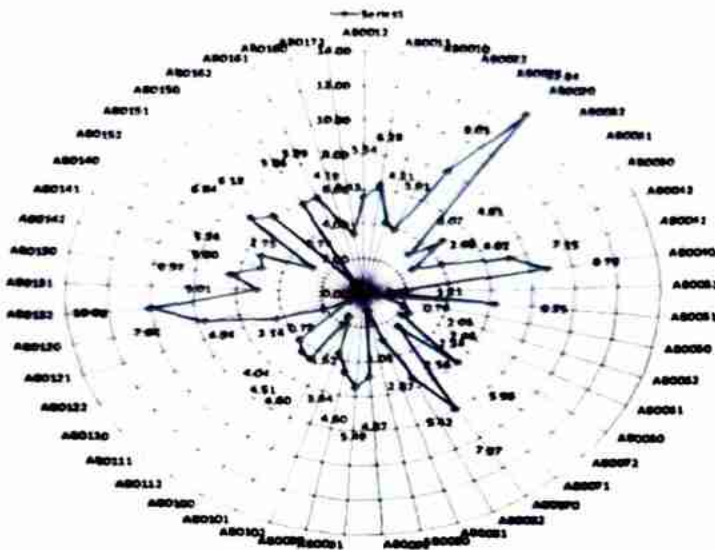


Figure 5: Average Throughput (Mbps) Performance per Active Cell (AB0012 Ab0171)

Figure 5 presented the corresponding average throughput performance for each Cell under study. They are part of the actively deployed cells around Abuja metropolis. The cells are serialized in order of deployment, just like the PCI numbers are given in order of commissioning of sectors. Cells with average throughput of ≥ 0.8 Mbps are considered to be underperforming while cells with throughput < 0.8 Mbps are in the cadre of good performance.

The underperforming sectors (Mbps) are: AB0121 (0.78), AB0050 (0.76), AB0150 (0.74) Sector with great performance (Mbps): AB0020 (12.84), AB0132 (10.08). AB0070 (7.97) Percentage of good performing to underperforming: $> 80\%$ Great Possible causes and actions for improvement: Number of users and contention ratio, and lack of dominant cell.

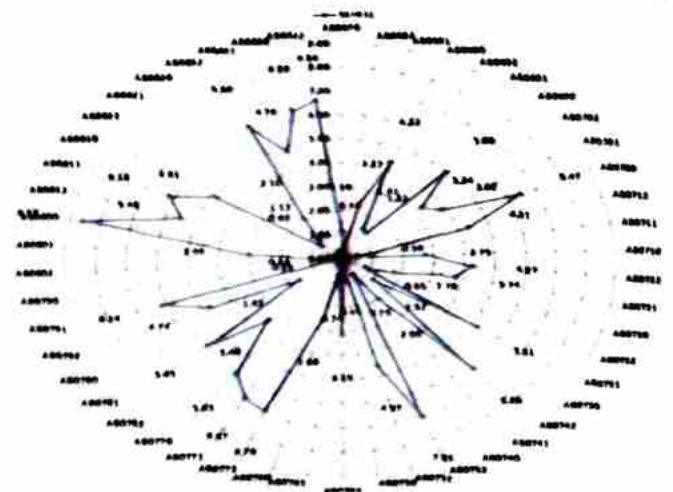


Figure 6: Average Throughput (Mbps) Performance per Cell for (AB0670 AB0842)

Figure 6 presents the corresponding average throughput performance per Cell under study. This helps in identifying cells that are underperforming (Mbps). From figure 6, sectors such as AB0790 (0.15), AB0802 (0.23), AB0750 (0.45) etc. are found to be underperforming.

Sector with good and great performance: AB0752 (7.01), AB0800 (8.57), AB0700 (6.47)

Percentage of good performing to underperforming: $> 80\%$ Great Causes and Actions for improvement:

Number of users and contention ratio, Monitoring cells, weak coverage and lack of dominant cell.

7.1 Average Throughput Performance against Average number of UEs.

This analysis shows the impact of average number of users on throughput performance; average number of users on each cell is calculated and plotted against average throughput performance. Theoretically, stable network should be able to admit high number of users and still have average throughput above 3 Mbps, while the underperforming cells have low number of users as well as low throughput performance, figure 7 and 8 presented cells of SPECTRANET network performances with respect to average number of user.

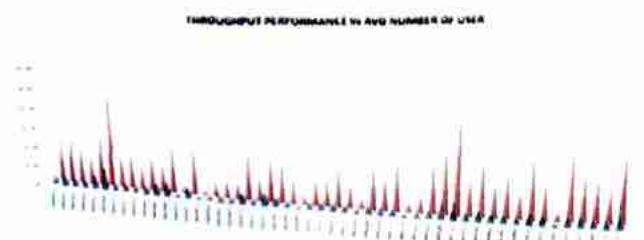


Figure 7: Average Throughput (Mbps) Performance against Average number of UEs sample 50 sectors (AB0012 Ab0171)

Figure 8 presents Stable and good performing cells: AB0700, AB0742, AB0752, AB0771, AB0770, AB0800 etc. The listed cells have an average user above 30 and throughput > 3Mbps. Underperforming cells: AB0711, AB0790, AB0802, AB0750, AB0740 etc. they have very low average number of user < 10 and poor throughput < 0.8mbps.

7.2 Relationship Effect between Average Number of Users and PRB Utilization

The sampled cells in figure 9 showed the number of times the cell's PRB utilization went above over 80% and its corresponding average number of users. Theoretically, the higher the number of UEs that latch into an eNodeB, there will be high utilization of the Physical Resource Blocks (PRB). From the graph in figure 9, observe that most of the times when a cell's number of users is high, the PRB utilization count for 80% utilization and above is also high.

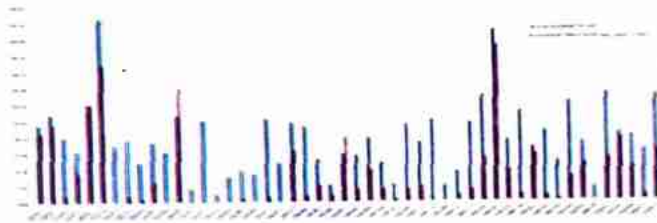


Figure 9: Average Number of UEs Vs Average PRB UTILIZATION >80% Count (24Hrs) Sampled sectors [AB0012-AB0171]

The graph figure 9 shows the sampled 50 sectors (AB0012-AB0171) performance as regards PRB utilization greater than 80% count (Number of times) and its corresponding average number of users. Cell AB0020 and AB0132 proved to be have most robust service, they both recorded over the period of research an average of 57 users with an average of 42 times reaching the PRB utilization above 80%. They also have shown at the previous analysis to have average throughput of 10Mbps. However, AB0032, AB0052, AB0051, AB0062, AB0060, AB0111, AB0110, AB0150 sectors showed to have at an average, very little number of times utilizing their PRBs above 80%. The cells whose average number of times the PRB utilization went above 80% is greater than its average number of users are likely to

have low average throughput performance, as can be observed for AB0140 with an average of 17 times hitting PRB utilization above 80% but have an average number of user set at 12, going back to earlier analysis, cell AB0140 recorded an average throughput of 2Mbps, usually in this case, RF engineers suspects high data Rate users occupying the cell and pulling down the throughput performance. Finally, cells with very low number of users are always a concern, especially if the cells are located in populated area of the town. Over time, such cells will tend to be underperforming just in the cases of AB0050 and AB0150 with 2.5 and 4.5 average number of users respectively. Notice also from the earlier analysis that their average throughput performance are below 0.7 Mbps.

7.0 CONCLUSION

4G LTE network performance is efficient in delivering high speed data rate to subscriber, however, daily monitoring and analysis of all cell performances is a definitive and first method of enhancing sustainable Quality of services (QoS) to subscribers. Nonetheless, when compared to normal system of breakdown approach, this technique reduces MTTR and improves MTBF by 50% [6], which are core maintenance metrics that drives network efficiency, reliability and availability. Preventive maintenance is assured by obtaining and analyzing with right and accurate network performance data. This gives due advantage against breakdown maintenance. This paper presented steps of empirical data and remote data acquisition of key performance indicators using Huawei Imanager tool and drive test. Analysis of obtained data proved to be able to detect the underperforming cells and the root causes of poor service delivery. First, it was observed that small percentage =20% of subscribers consumes about 80% of the provisioned radio resources per cell. Secondly, it was discovered that cells with very poor throughput performance as well as low number users have island coverage, a footprint out of target area. Thirdly, it was disclosed that 70% cells with users >40 tend to have low throughput performance due to contention ratio amongst users. Finally it was observed that

cells configured with more neighbouring cells achieved better average throughput performance of 5Mbps while cells deployed in less populated area and fewer neighboring cells achieved average throughput of 1Mbps.

7.0 RECOMMENDATION

The following recommendations are made;

1. Network operator to deploy more robust system of essential and accurate cell performance data gathering, by incorporating a threshold alert system to improve MTTR
2. SPECTRANET to deploy more radio cell in the areas with fewer neighbouring cells.
3. Need to develop resource scheduler algorithm to differentiate Quality of service of high data rate UEs (20%) in order keep balance and fairness to all subscribers.

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