Analysis of key performance indicators of a 4G LTE network based on experimental data obtained from a densely populated smart city

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Abstract

Key performance indicator (KPI) data provide candidate information required for effective network planning, performance analysis and optimization. However, inadequate KPI data could limit efficient network planning leading to escalating operational cost, and this could adversely affect the subscribers of the network. To this end, this article presents radio frequency (RF) measurements and evaluation of KPIs taken at 1876.6MHz with a bandwidth of 10MHz, for an operational 4G LTE network in Nigeria. The measurements campaign specifically examine the behaviour of the RSRP, RSRQ, RSSI, SINR, PCC PHY DL Throughput, and the PDCP DL Throughput. Huawei Technologies Modem E392 was used for the propagation measurements, and RF measurements cover three evolved node base stations (eNodeBs) with average heights of 25 m. The geographical coordinates of the sites are as follows: Site 1 (Latitude 6.43543333; Longitude 3.44539667), Site 2 (Latitude 6.55639500; Longitude 3.36693333), and Site 3 (Latitude 6.51879500; Longitude 3.39911000). The E392 4G (LTE) Modem is capable of propagation measurements at the various LTE frequency bands, enables LTE download Speed of 100 Mbit/s, supports LTE upload Speed of 50 Mbit/s, utilizes LTE 2x2 MIMO (Multiple Input Multiple Output), and supports 64QAM (Quadrature Amplitude Modulation). The Drive Test (DT) Software version-Genex prove V16,
and Genex Assistance V16 were deployed, and the test car carried a test terminal station, a GPS, a Windows supported Computer, and the accompanying drive test system. The test vehicle was driven such that it considered the actual road traffic conditions at a relatively medium speed of up to 30km/h with uniformity thereby reducing possible Doppler effects. Terminal connection was established, and data download services was started (using file transfer protocol - ftp, a drive test software, which has the function to download a large file of around 20GB). Thereafter, the download simultaneous file downloading limit was set to 5 files (such that 5 files can be downloaded simultaneously with quality download speed). When connection drops, simultaneous connection was re-established using the ftp software, and drive test was carried out within a planned cluster on a bright and sunny day. Statistical descriptions and probability distribution functions of the KPI data is reported and interdependence amongst the KPIs are presented to ease understanding of the interrelationships among the tested KPIs. The data reported would find useful applications in RF planning, radio channel measurements and modelling, feasibility studies and formulation of appropriate regulatory policies for wireless communication systems. Network operators could leverage on the data for appropriate KPI analyses, radio resources management, and research and development.

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### Specifications Table

| Subject                          | Engineering and Technology |
|----------------------------------|---------------------------|
| Specific subject area            | Wireless Communications Engineering |
| Type of data                     | Tables, Graphs, Charts, Figures |
| How data were acquired           | The experimental data presented in this article were acquired through extensive drive test in and around Lagos, an emerging smart city in Nigeria. The DT equipment comprising of a test terminal station- Huawei Modem E392 (4G LTE Modem), Global Positioning System (GPS) equipment and the associated drive test system were carefully assembled in test car. The car was driven at a near constant speed of 30km/h to avoid or minimize Doppler effects, and the KPIs were measured and automatically recorded for further processing. |
| Data format                      | Raw and Analysed |
| Parameters for data collection   | The parameters measured and tested comprise of the key performance indicators such as the Reference Signal Received Power (RSRP), Signal-to-Interference-plus-Noise Ratio (SINR), Received Signal Strength Indicator (RSSI), Reference Signal Received Quality (RSRQ), Packet Data Convergence Protocol Downlink Throughput (PDCP DL Throughput), and the Primary Component Carrier Physical Downlink Throughput (PCC PHY DL Throughput) [1]. |
| Description of data collection  | The KPI data were collected from fixed transmitters referred to as the 4G LTE base station (BS) or evolved node base station (eNodeB) with average heights of 25 m, commercial equipment belonging to one of the network operators in Nigeria. The Drive Test (DT) equipment captured the SINR, RSRP, RSSI, RSRQ, and other KPI information from the active sectors of the eNodeBs. The specifications and network design parameters were given due consideration following the manufacturers’ directives and instructions. |
| Data source location             | The key performance indicator (KPI) data reported in this article were collected in and around three eNodeB sites with the following coordinates; Site 1 (Latitude 6.43543333; Longitude 3.44539667), Site 2 (Latitude 6.55639500; Longitude 3.36693333), and Site 3 (Latitude 6.51879500; Longitude 3.39911000), located in one of Africa’s fastest growing smart city, Lagos, Nigeria. |
| Data accessibility               | A detailed datasets on the measured KPIs taken at 1876.6MHz with a 10MHz bandwidth, of a functional 4G LTE network is provided as a supplementary file attached to this article in a spreadsheet format for easy accessibility and data reusability. |
1. Data

Wireless communication data provide useful information pertinent to the development of communication equipment, standards and specifications, conducting high-level feasibility studies during initial deployment of telecommunication infrastructure, and providing accurate evaluation of the quality of service (QoS) in order to enhance the quality of user experience (QoE). Generally, wireless communication systems are designed to transfer data from a source to a destination (from the transmitter to the receiver). As wireless systems continue to grow and evolve to accommodate upward scaling traffic requirements following the rapid deployment of 4G LTE networks and the evolving 5G and beyond wireless systems, analysis of the key performance indicators increasingly becomes a concern. Toward this end, the need to critically examine and evaluate the KPIs of an operational 4G LTE network becomes imperative. This is considered highly important due to the enormous benefits such data provide: useful information about the performance of the network in real time, and present a suitable platform to furnish improvement initiatives on the existing network structure in terms of coverage and capacity. Finally, the data could aid the development of advanced modulation techniques, and foster the development of energy efficient wireless communications systems.

In this article, analysis of some selected KPIs of an operational 4G LTE network is presented. The tested KPIs include the RSRP, RSRQ, RSSI, SINR, PCC PHY DL Throughput, and the PDCP DL Throughput. These KPIs were measured at a 4G LTE frequency of 1876.6MHz with 10MHz bandwidth. The extensive RF measurements span a propagation distance of up to 2km, and measured KPIs were extracted and analysed in IBM SPSS Statistics and MATLAB.

The KPIs derived from the experimental data are briefly described as follows. First, the aerial view and the geographical coordinates of the measurements environment are as shown in Figs. 1–2, respectively. The trajectories of 4G LTE RSRP, RSRQ, SINR, and PCC PHY Throughput performance distributions are as shown in Figs. 3–6, respectively. The specific KPI information are presented in Figs. 7–12. Specifically, the RSRP measured at Sites 1–3 is given in Fig. 7, and Fig. 8 shows the RSRQ measured at Sites 1–3. Fig. 9 represents the RSSI measured at Sites 1–3, Fig. 10 gives the SINR measured at Sites 1–3, and Fig. 11 presents the PCC PHY DL Throughput measured at Sites 1–3. Finally, Fig. 12 shows the PDCP DL Throughput measured at Sites 1–3.

The statistics of the measured KPIs are given in Tables 1–9. More specifically, Table 1 presents statistics of measured RSRP, RSRQ, and the RSSI at Site 1. Table 2 gives the statistics of measured SINR, PCC PHY DL Throughput, and the PDCP DL Throughput at Site 1. Table 3 represents the statistics of measured RSRP, RSRQ, and the RSSI at Site 2. Table 4 depicts the statistics of measured SINR, PCC PHY...
DL Throughput, and the PDCP DL Throughput at Site 2. In addition, Table 5 presents the statistics of measured RSRP, RSRQ, and the RSSI at Site 3, whereas, Table 6 gives the statistical analysis of the measured SINR, PCC PHY DL Throughput, and the PDCP DL Throughput at Site 3. Furthermore, Table 7 gives a comparison of the measured RSRP and the RSRQ at Sites 1–3, and a comparison of the measured...
The probability distribution of the KPIs observed are given in Figs. 13–18. Notably, Fig. 13 illustrates the probability density of the measured RSRP at Sites 1–3. Fig. 14 gives the probability density of the measured RSRQ at Sites 1–3, and Fig. 15 provides the probability density of the measured RSSI at Sites 1–3. In the same vein, Fig. 16 reports the probability density of the measured SINR at Sites 1–3, whereas, Fig. 17 represents the probability density of the measured PCC PHY DL Throughput at Sites 1–3. Finally, Fig. 18 presents the probability density of the measured PDCP DL Throughput at Sites 1–3.
2. Experimental design, materials, and methods

The equipment used for measurements is the Huawei Modem E392. The E392 4G (LTE) Modem offers flexibility in RF measurements and post processing of measurements data. The equipment can be used for propagation measurements at various LTE frequency bands, and supports a LTE download Speed of 100 Mbit/s, while the LTE upload Speed supported is up to 50 Mbit/s. Furthermore, the device supports LTE 2x2 MIMO and 64QAM (Quadrature Amplitude Modulation). The Drive Test (DT) Software version-Genex prove V16, and Genex Assistance V16 were selected and carefully connected and assembled in the DT car for seamless propagation measurements. The drive test car carried the test terminal station, the GPS equipment, and a personal computer (PC), and the associated drive test system.

Fig. 5. Trajectories of 4G LTE SINR performance distribution.

Fig. 6. Trajectories of 4G LTE PCC PHY Throughput performance distribution.
Fig. 7. Measurements of RSRP at sites 1–3.

Fig. 8. Measurements of RSRQ at sites 1–3.
Fig. 9. Measurements of RSSI at sites 1–3.

Fig. 10. Measurements of SINR at sites 1–3.
Fig. 11. Measurements of PCC PHY DL Throughput at sites 1–3.

Fig. 12. Measurements of PDCP DL Throughput at sites 1–3.
| Table 1 | Statistical description of measured RSRP, RSRQ, and RSSI at site 1. |
|---------|---------------------------------------------------------------|
| Statistics | RSRP (dBm) | RSRQ (dBm) | RSSI (dBm) |
| N | 428.000 | 428.000 | 428.000 |
| Range | 42.140 | 6.300 | 40.680 |
| Minimum | -103.380 | -12.400 | -78.010 |
| Maximum | -61.240 | -6.000 | -37.330 |
| Mean | -82.508 | -9.247 | -59.056 |
| Std. Deviation | 10.308 | .768 | 10.158 |
| Variance | 106.257 | .589 | 103.194 |
| Skewness | .130 | -.912 | .182 |
| Kurtosis | -1.083 | 2.706 | -1.127 |

| Table 2 | Statistical description of measured PCC SINR, PCC PHY DL Throughput, and PDCP DL Throughput at site 1. |
|---------|---------------------------------------------------------------|
| Statistics | PCC SINR (dB) | PCC PHY DL Throughput (bps) | PDCP DL Throughput (bps) |
| N | 428.000 | 428.000 | 428.000 |
| Range | 26.590 | 23885.700 | 19223.970 |
| Minimum | -1.800 | .000 | .000 |
| Maximum | 24.790 | 23885.700 | 19223.970 |
| Mean | 10.085 | 7557.274 | 5653.074 |
| Std. Deviation | 5.545 | 3888.595 | 3423.003 |
| Variance | 30.749 | 15121167.752 | 11716951.633 |
| Skewness | .364 | .721 | .978 |
| Kurtosis | -.318 | .672 | .804 |

| Table 3 | Statistical description of measured RSRP, RSRQ, and RSSI at site 2. |
|---------|---------------------------------------------------------------|
| Statistics | RSRP (dBm) | RSRQ (dBm) | RSSI (dBm) |
| N | 523.000 | 523.000 | 523.000 |
| Range | 30.590 | 16.500 | 21.790 |
| Minimum | -112.270 | -20.180 | -81.020 |
| Maximum | -81.680 | -3.680 | -59.230 |
| Mean | -94.810 | -9.069 | -71.625 |
| Std. Deviation | 4.315 | 1.356 | 3.845 |
| Variance | 18.619 | 1.839 | 14.783 |
| Skewness | .107 | .107 | .107 |
| Kurtosis | .213 | .213 | .213 |

| Table 4 | Statistical description of measured SINR, PCC PHY DL Throughput, and PDCP DL Throughput at site 2. |
|---------|---------------------------------------------------------------|
| Statistics | PCC SINR (dB) | PCC PHY DL Throughput (bps) | PDCP DL Throughput (bps) |
| N | 523.000 | 523.000 | 523.000 |
| Range | 28.420 | 14129.570 | 12084.160 |
| Minimum | -8.980 | .000 | .000 |
| Maximum | 19.440 | 14129.570 | 12084.160 |
| Mean | 7.456 | 6031.110 | 4825.821 |
| Std. Deviation | 3.838 | 2583.239 | 2488.209 |
| Variance | 14.734 | 6673125.510 | 6191182.572 |
| Skewness | .107 | .107 | .107 |
| Kurtosis | .213 | .213 | .213 |
### Table 5
Statistics of measured RSRP, RSRQ, and RSSI at site 3.

| Statistics | RSRP (dBm) | RSRQ (dBm) | RSSI (dBm) |
|------------|------------|------------|------------|
| N          | 411.000    | 411.000    | 411.000    |
| Range      | 62.740     | 21.940     | 51.050     |
| Minimum    | –117.990   | –22.380    | –85.050    |
| Maximum    | –55.250    | –34.000    | –51.050    |
| Mean       | –93.444    | –10.412    | –68.474    |
| Std. Deviation | 13.701    | 3.926      | 11.636     |
| Variance   | 187.706    | 15.412     | 135.403    |
| Skewness   | .727       | –.728      | 1.110      |
| Kurtosis   | .466       | .217       | .771       |

### Table 6
Statistical description of measured SINR, PCC PHY DL Throughput, and PDCP DL Throughput at site 3.

| Statistics | PCC SINR (dB) | PCC PHY DL Throughput (bps) | PDCP DL Throughput (bps) |
|------------|---------------|-----------------------------|---------------------------|
| N          | 411.000       | 415.000                     | 414.000                   |
| Range      | 41.760        | 17347.690                   | 14309.480                 |
| Minimum    | –11.760       | .000                        | .000                      |
| Maximum    | 30.000        | 17347.690                   | 14309.480                 |
| Mean       | 5.905         | 4309.303                    | 3568.004                  |
| Std. Deviation | 9.157       | 4244.998                    | 3746.405                  |
| Variance   | 83.842        | 1802006.824                 | 1403549.722               |
| Skewness   | .072          | .656                        | .706                      |
| Kurtosis   | –321          | –.690                       | –.671                     |

### Table 7
Comparison of the statistics of measured RSRP and RSRQ at sites 1–3.

| Statistics | RSRP (dBm) | RSRQ (dBm) |
|------------|------------|------------|
|            | SITE 1     | SITE 2     | SITE 3     |
| N          | 428.000    | 523.000    | 411.000    |
| Mean       | –82.508    | –94.810    | –93.444    |
| Std. Deviation | 10.308     | 4.315      | 13.701     |
| Variance   | 106.257    | 18.619     | 187.706    |
| Skewness   | 0.130      | –0.025     | 0.727      |
| Kurtosis   | –1.083     | 1.677      | 0.466      |
|            | –0.235     | 0.121      | 0.240      |
| Range      | 42.140     | 30.590     | 62.740     |
| Minimum    | –103.380   | –112.270   | –117.990   |
| Maximum    | –61.240    | –81.680    | –55.250    |

### Table 8
Comparison of the statistics of measured RSSI and SINR at sites 1–3.

| Statistics | RSSI (dBm) | SINR (dB) |
|------------|------------|-----------|
|            | SITE 1     | SITE 2     | SITE 3     |
| N          | 428.000    | 523.000    | 411.000    |
| Mean       | –59.056    | –71.625    | –68.474    |
| Std. Deviation | 10.158     | 3.845      | 11.636     |
| Variance   | 103.194    | 14.783     | 135.403    |
| Skewness   | 0.182      | 0.456      | 1.110      |
| Kurtosis   | –1.127     | 0.111      | 0.771      |
|            | –0.235     | 0.213      | 0.240      |
| Range      | 40.680     | 21.790     | 51.050     |
| Minimum    | –78.010    | –81.020    | –85.050    |
| Maximum    | –37.330    | –59.230    | –34.000    |
Table 9
Comparison of the statistics of measured PCC PHY DL Throughput and PDCP DL Throughput at sites 1–3.

| Statistics            | PCC PHY DL Throughput (bps) | PDCP DL Throughput (bps) |
|-----------------------|-----------------------------|--------------------------|
|                       | SITE 1 | SITE 2 | SITE 3 | SITE 1 | SITE 2 | SITE 3 |
| N                     | 428.000 | 523.000 | 415.000 | 428.000 | 523.000 | 414.000 |
| Mean                  | 7557.274 | 6031.110 | 4309.303 | 5653.074 | 4825.821 | 3568.004 |
| Std. Deviation        | 3888.595 | 2583.239 | 4244.998 | 3423.003 | 2488.209 | 3746.405 |
| Variance              | 15121167.752 | 6673125.510 | 18020006.824 | 11716951.633 | 6191152.572 | 14035549.722 |
| Skewness              | 0.721 | 0.324 | 0.656 | 0.978 | 0.428 | 0.706 |
| Std. Error of Skewness| 0.118 | 0.107 | 0.120 | 0.118 | 0.107 | 0.120 |
| Kurtosis              | 0.672 | 0.811 | -0.690 | 0.804 | 0.212 | -0.671 |
| Std. Error of Kurtosis | 0.235 | 0.213 | 0.239 | 0.235 | 0.213 | 0.239 |
| Range                 | 23885.700 | 14129.570 | 17347.690 | 19223.970 | 12084.160 | 14309.480 |
| Minimum               | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Maximum               | 23885.700 | 14129.570 | 17347.690 | 19223.970 | 12084.160 | 14309.480 |
Fig. 13. Probability density of the measured RSRP at sites 1–3.

Fig. 14. Statistics showing probability density of the measured RSRQ at sites 1–3.
Fig. 15. Statistics showing probability density of the measured RSSI at sites 1–3.

Fig. 16. Statistics showing probability density of the measured SINR at sites 1–3.
Fig. 17. Statistics showing probability density of the measured PCC PHY DL Throughput at sites 1–3.

Fig. 18. Statistics showing probability density of the measured PDCP DL Throughput at sites 1–3.
In order to achieve quality results, the test vehicle was driven such that it considered the actual road traffic conditions at medium speed of up to 30 km/h with uniformity. This helps to reduce the possible impacts of Doppler effects. Afterwards, the terminal connection was established, and data download services started using file transfer protocol - ftp, a drive test software, which has the function to download a large file around or up to 20 giga bytes (GB). Thereafter, the download simultaneous file downloading limit was set to 5 files (such that 5 files can be downloaded simultaneously without significant computational cost especially on the baseband processing unit). When connection drops, simultaneous connection was re-established using the ftp software, and drive test was carried out within a planned cluster located in the geographical coordinates of the measurements environment. For data post processing, MATLAB 2018a, a product of Mathworks Incorporated, and the IBM Statistical tool (SPSS) version 24 were used.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Transparency document. Supporting information

Transparency data associated with this article can be found in the online version at https://doi.org/10.1016/j.dib.2020.105304.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2020.105304.

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