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Mobile Data Network Performance Review – A Perspective of Zambia

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Abstract:- High speed mobile internet results in better user experience and satisfied subscriber. However factors that affect the download speed include transfer technology, number of subscribers sharing the connection, device capability and radio conditions at the subscriber location. This research was conducted to review the mobile internet performance in Zambia and determine its conformity to the regulator, ZICTA, QoS regulation. Two sets of empirical data were collected in the capital city, first in 2021 during the covid pandemic period and second in 2024. The data was compared to check for network operator developments. The results reveal that two MNOs acquired new 2600MHz spectrum, however only one MNO drew maximum benefit resulting in improved 4G download speeds. This improvement was despite an increase in market share over the same period. The second operator that deployed the 2600MHz LTE TDD mode spectrum recorded a degradation in overall downloads speeds when compared to the initial data set in spite of a reduction in market share over the same period. Thus the steps to improve the LTE network are to add more spectrum to at least reach the 3GPP Rel 10 standard of 5 carrier configuration (5CC) to reach a total 100MHz and configure network features like Carrier Aggregation (CA) to provide for higher throughputs for capable devices. Other ways to expand LTE network include add more antennas to allow for higher spectral efficiency using 8 x 8 MIMO or more and thirdly deploy Small cells solution to enhance coverage and capacity in both indoor and outdoor environment.

Keywords:- *LTE Download Throughput, LTE Cell Bandwidth, LTE Frequency Bands, LTE Carrier Aggregation, Latency.*

I. INTRODUCTION

The latest generation of mobile devices namely smartphones and routers have created an explosive growth of network data traffic. In sub Saharan Africa, smartphones contributed 50% of total connections in 2020 as cheaper devices are becoming available. The number of smartphones in sub Saharan Africa is projected to reach 65% of total connections by the end of 2025. During the Covid-19 pandemic between 2020 and 2022, mobile networks played a crucial role of connecting people and businesses thereby enabling some economic activities despite the restrictions on people gatherings.

Another contributor to the growth of the mobile internet usage is E-governance which refers to the use of ICT to facilitate Government (G2G), Government to Business (G2B) and Government to Citizens (G2C) services in a secure and robust environment. Examples include online tax payments, property registrations, businesses registration to mention a few services. [1][2][3]

In Zambia, between 2020 and 2021 the internet subscribers increased by 1.3% to reach 10.4 million subscribers with a reported internet penetration of 56.7. The telecommunication sites in the country increased by 8.5% to reach 11,478 sites for all MNOs across the country with 4G accounting for 28.4%, and 3G accounting for 31.9%. The regulator, ZICTA, has set throughput parameter targets for the licensees to be no less than 125Kbit/s for 2G, no less than 1.5Mbps for 3G and no less than 10Mbps for 4G Download throughput In Sept 2020 ZICTA conducted Quality of Service (QoS) tests and enforced its guidelines by fining the MNOs for QoS parameters not achieved. These parameters include HTTP Download rate, HTTP Successful Internet Log-ins, Call Setup Success rate and the Call drop rate. [4][5]

Motivation for this research: To gather information about the mobile internet performance in Zambia following the regulator enforcement of the QoS guidelines. To contribute to the knowledge base of mobile networks service provision of widespread high-speed mobile internet connectivity that enables work, business, education and thereby contribute to the economy.

This paper is organized as follows. Section II lists the references to similar work done and key literature review to back the research findings. Section III describes method used to collect data while section IV presents and analyses the collected raw data. Finally, Section V presents conclusion and recommendations for future work

II. RELATED WORK

Sridhar V et' al used crowdsourced data obtained through a mobile app deployed by the regulator in India. They analysed the collected data using panel data regression model to find the effect of supply side variables such as radio spectrum, the deployed network infrastructure and demand side variables such as the mobile subscriber base. They analysed that insufficient spectrum, poor coverage and deployed technology are factors the impact the user's download throughput. They also observed that subscriber

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base also has a moderate effect on the data download throughputs. They concluded by making policy recommendation on spectrum allocation and improvements in mobile access technologies to augment users' quality of experience. [6]

Putra et' al collected data by walk test measurement three times a day. The application used was a video streaming app, YouTube, with a duration of 10 minutes using varying resolution of either 144p, 240p, 360p, 480p, 720p or 1080p. They analysed that poor values of the RSRP, RSRQ and SINR obtained at a point are due to the propagation loss that occurs. The presence of buildings, trees, network density and weather cause changes in propagation known as reflection, diffraction and scattering. In addition the distance from the transmitter to the receiver is another factor that causes a decrease in the signal strength received from the user's device. The results of their evaluation serve as reference for further optimization actions to support the improvement of 4G network by service providers to ensure that the users experience satisfying 4G network services. [7]

Silalahi L.M et' al collected data by way of drive tests in Kuta city of Indonesia's Bali Province. The aim was to improve the coverage value and quality of the 4G network using parameters of RSRP and SINR. They collected the information using a mobile station (MS) then analysed it using Geographical Information System (GIS) tools like MapInfo to come up with optimisation actions to implement. Optimisation actions included changes to the antenna beam direction and increased transmitter power at the eNodeB. The post optimisation drive test resulted in improvement of the RSRP by 10.37% and SINR by 28.75%. [8]

Salo & Zacarias collected OSS measured performance data from a mobile operator. The network performance counters covered a period of two weeks for two cells serving a large number of smart-phone users. They analysed that the scheduled download throughput scales approximately inversely proportional to the average active UEs as predicted by theory. They further showed that the bigger the cell bandwidth the more active users and the higher the throughput recorded. Figure 1(a) below highlights that. [9].

Wannstrom reviewed the 3GPP Rel 10 standard and summarized that there are three CA configuration defined based on the type of CA and duplex type as follows: 1. intra-band contiguous FDD, 2. intra-band contiguous TDD and 3. Inter-band FDD. In the releases that follow additional CA configurations are defined. 3GPP TS 36.101 version 14.7.0 Release 14 lists the operating bands for CA configurations that include two bands, three band, four bands and five bands. Figure 1(b) shows the general CA concept. [10][11]

Ericsson's Synnergren & Dudda reviewed that data packet latency is a key performance metric in today's communication systems. In the HTTP/TCP transport layer protocol suite, the TCP slow start period is a significant part of the total transport period of the data packets. During the TCP slow start, the TCP congestion window increases exponentially which results in many segments brought in until the offered throughput is fully utilized. The incremental increases are based on the TCP ACK which are received after a round trip delay in the LTE system as shown in figure 1c. Therefore it turns out that during the TCP slow start the performance is latency limited in LTE, therefore an improved latency results in improved data throughput. This whole in turn free up radio resources quicker and potentially improving the improvement system capacity. [12]

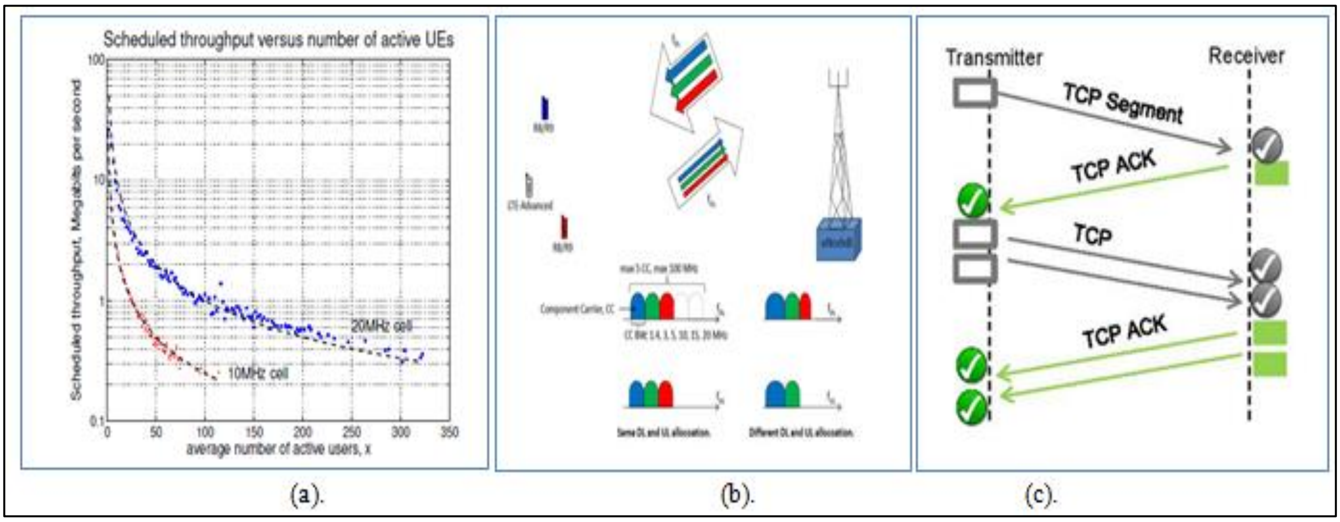

Fig 1: Literature Review (a) Scheduled Throughput vs Number of Active Users: [9] (b) Carrier Aggregation Concept for LTE Advanced UEs. [10] (c) The Initial TCP Slow Start Phase and Ramp Up of Bytes Dependent on Latency. [12]

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III. METHODOLOGY

The researcher followed ITU-T Rec. E.806 which states that measurement data can be collected from either indoor or outdoor environments and can further include stationary or mobile scenarios thus covering all environments in which typical subscribers make use of their mobile services.[13]

However this research was limited to outdoor scenario and includes both stationary and mobile scenarios. Two data sets were collected during this research. This first data set was collected during covid times in May 2021 while the second data set was collected in February 2024. The devices used to collect data during the two data collection were mostly Samsung devices, Samsung: SM-A6 and Samsung: SM-A53. In data set one the 3 operators were tested simultaneously using Samsung: SM-A6s while in data set two each operator was tested separately using Samsung: SM-A6 and Samsung: SM-A53 devices. The mobile phones were installed with an application for drive testing known as G-NetTrack Pro which is for Android devices. They were configured to conduct a periodic test sequence to obtain Upload, Download and Ping data test measurement data with phone setting set to auto connect (LTE, 3G or 2G) network settings. Figure 2 shows screenshots of the measuring application. The first screenshot has a plot showing the route driven and the second shows sample measurements of ping, download and upload among other measurements displayed.

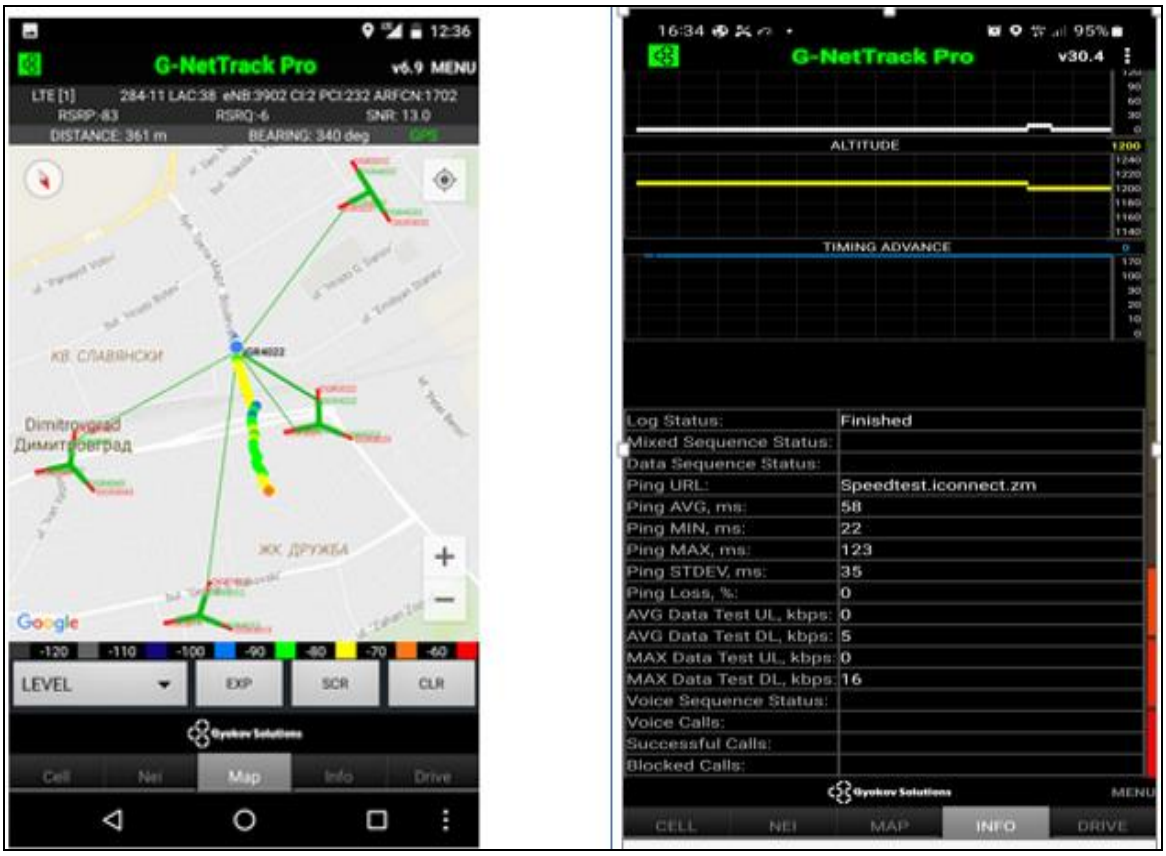

Fig 2: Screenshot of G-NetTrack Pro – the Network Monitoring App Installed on the Test Phone.

IV. MEASUREMENT RESULTS

The collected data was analysed using descriptive statistics and therefore presented in the form of tables and or graphical distributions. From the first data set we can conclude that all three operators provide 4G coverage across the city of Lusaka with varying measurement samples of 94%, 97% and 96% for MNO-A, MNO-B and MNO-C respectively.

The measured LTE download throughput for each operator is presented and analysed with the serving LTE frequency band and feature indication for carrier aggregation.

MNO-A was found to have improved its throughput in the second data set. SM-A6 measured an improvement from 4.38Mbps to 18.32Mbps while SM-A53 measured 24.89Mbps. Other observations include an increase in total LTE bandwidth from 25MHz to 90MHz with LTE TDD spectrum of 60MHz. The MNO has also deployed Carrier Aggregation (CA). SM-A6 measured 98% CA, of which 68% had band 41 as the PCC while SM-A53 also measured 97% CA of which 51% was with band 41 as PCC. In the first data set MNO-A's measured the lowest throughput of 4.38Mbps and at same time measured 40% samples on a 5MHz carrier on Band 8. Figure 3 shows the MNO-A's measurements.

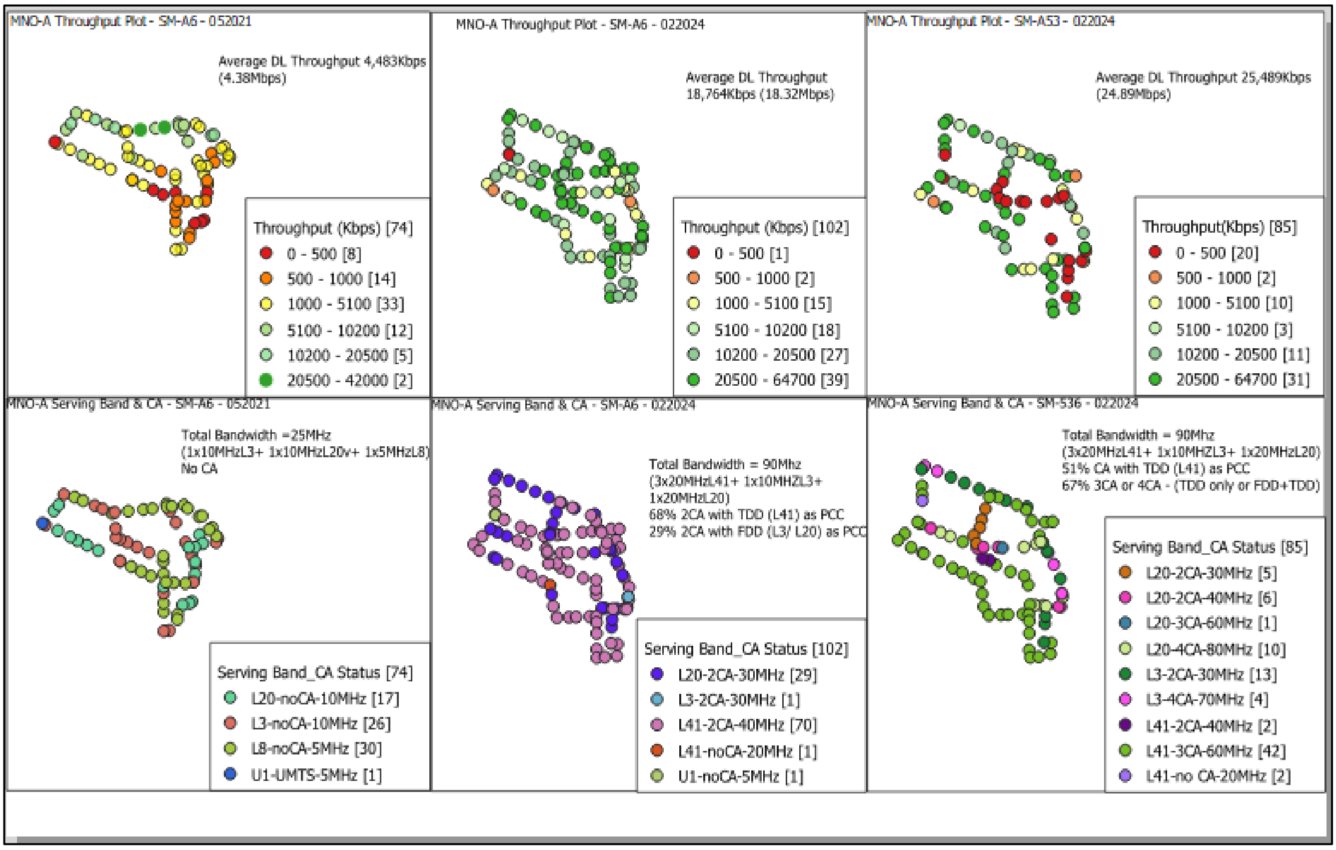

Fig 3: The MNO-A Data Sets' Throughput & Serving Frequency Bands Analysis

MNO-B was found to have degraded throughput in the second data set. SM-A6 measured a degradation from 11.82Mbps to 2.98Mbps while SM-A53 measured 4.81Mbps. Other observations include an increase in total LTE bandwidth from 35MHz to 60MHz with LTE TDD spectrum of 20MHz. The MNO has also deployed Carrier Aggregation (CA). SM-A6 measured 79% CA and none of it had band 41 as the PCC while SM-A53 also measured 90% CA and none of it band 41 as PCC. Both phones actually measured band 41 without CA configuration. Figure 4 shows the MNO-A's measurements.

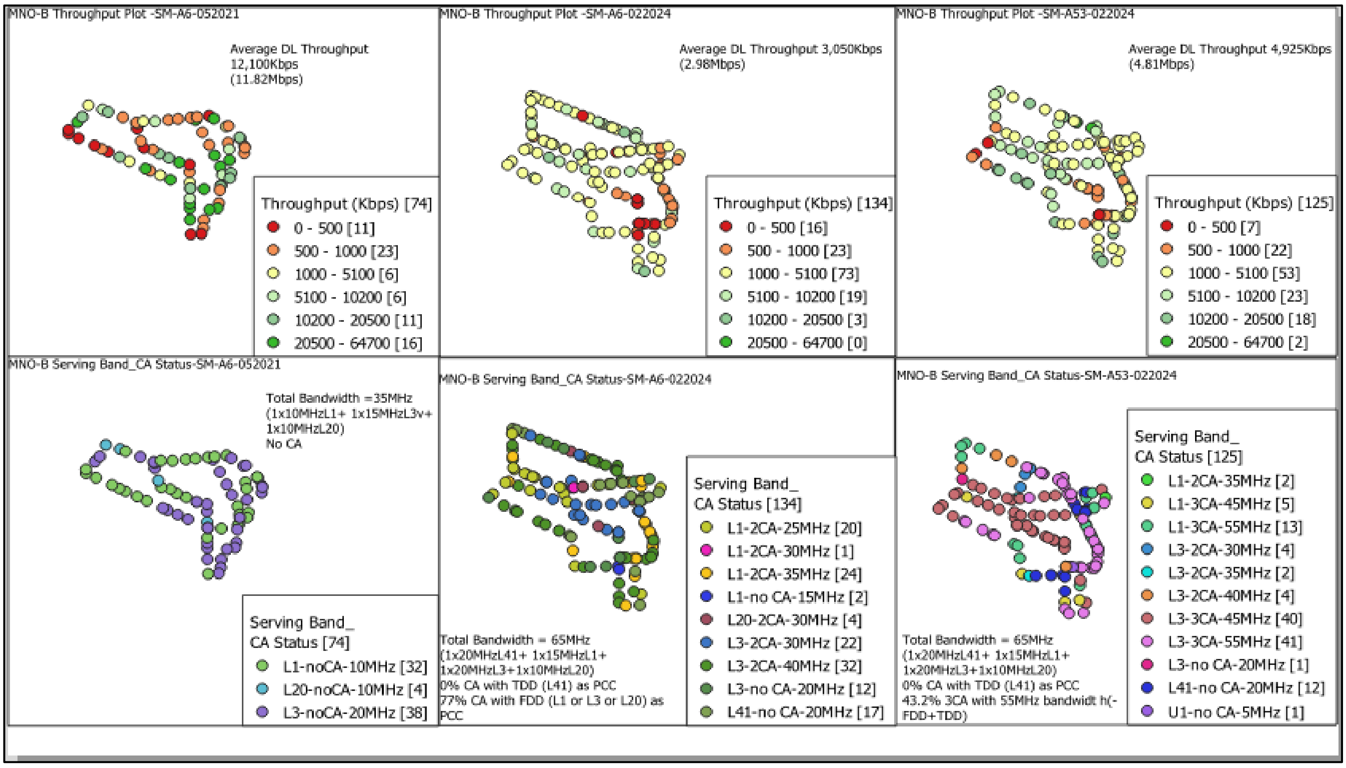

Fig 4: The MNO-B Data Sets' Throughput & Serving Frequency Bands Analysis

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MNO-C measured degraded throughput in the second data set. SM-A6 measured a degradation from 7.75Mbps to 1.47Mbps while SM-A53 measured 2.92Mbps. Other observations include a decrease in total LTE bandwidth from 55MHz to 35MHz and no Carrier Aggregation (CA) configuration. Figure 5 shows the MNO-A's measurements.

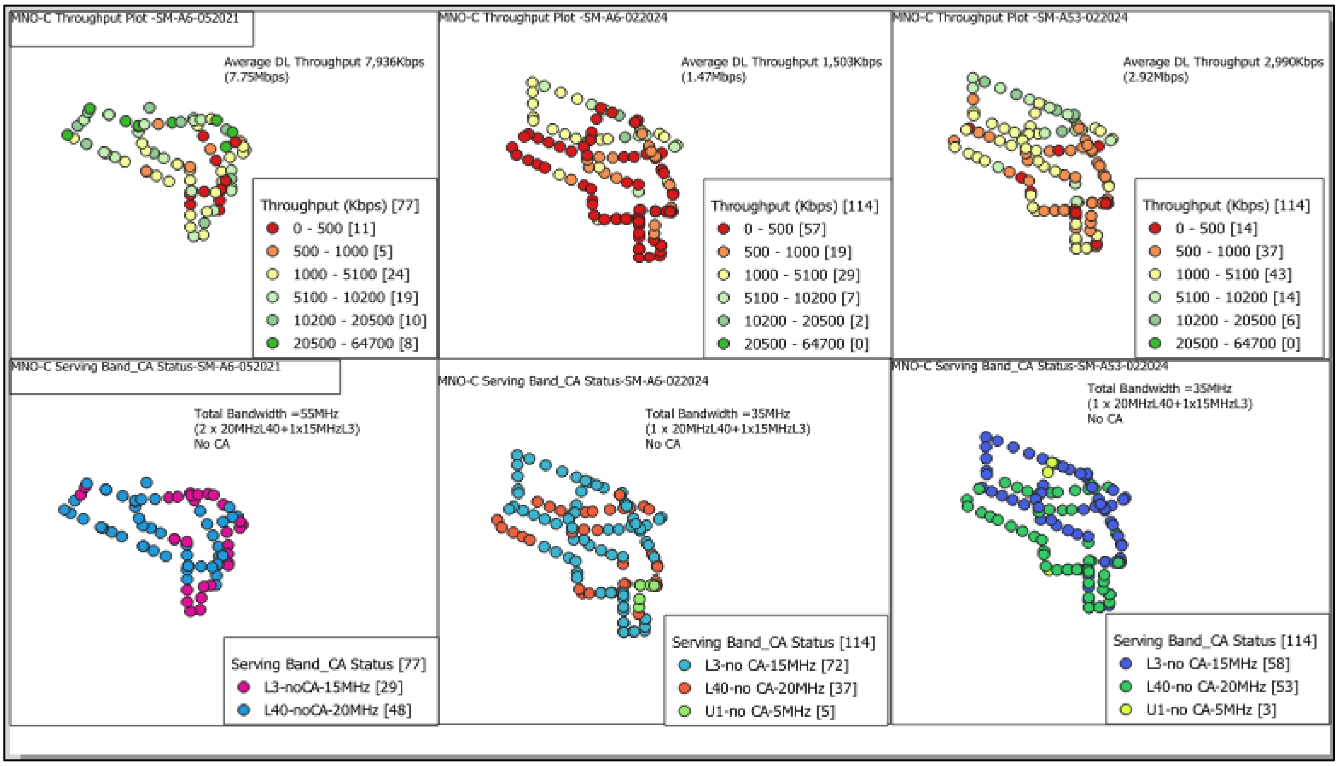

Fig 5: The MNO-C data sets' throughput & serving frequency bands analysis

The second data set latency is shown in figure 6 below. MNO-A has the least average at 77ms while the MNO-C has the longest average at 231ms. Long latency has the potential to impact application performance while short latency can positively impact the system capacity.

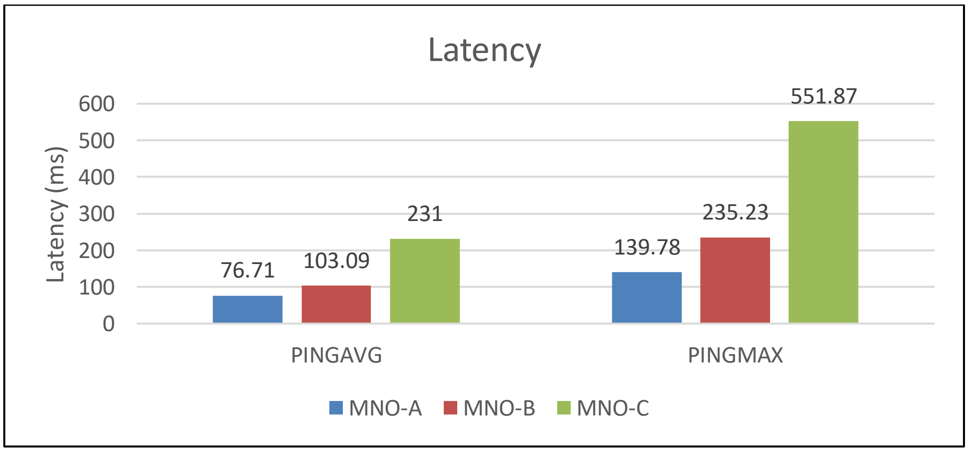

Fig 6: All MNOs' Latency Comparison

V. CONCLUSION

This research provided an insight into the performance of data services provided by the MNOs in Lusaka, Zambia. The configured LTE bandwidth per cell is a major factor and determinant of the download throughput. LTE cells configured with the maximum 20MHz bandwidth per carrier will give a higher throughput generally. In the first data set, MNO-B measured the highest throughput of 11.82Mbps with 51% samples on a 20MHz carrier on Band 3.

The second data set shows the positive impact of additional spectrum upgrade and the carrier aggregation feature. Both MNO-A and MNO-B acquired new LTE TDD band 41 spectrum of at least 50 MHz each, but MNO-A deployed multiple 20MHz carriers with intra band CA. With this configuration test phone SM-A6 measured the highest throughput of 18.32Mbps with 97% samples measuring 2CA and most of which had LTE TDD band 41 as the PCC. The higher capable test phone SM-A53 also measured highest

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throughput of 24.89Mbps with most 4CA samples using LTE TDD band 41 as PCC. On the other hand MNO-B measured lower throughputs and did not measure any samples with TDD band 41 as PCC, instead it measured more samples with FDD bands 1, 3 or 20 as PCC in its CA combinations for both types of test phones used. This implies that MNO-A managed to shift capable UEs from the FDD bands to the TDD band thereby efficiently using its resources. MNO-B on the other hand has most users in the FDD band and thus not efficiently using the TDD spectrum because no CA was measured with TDD as the PCC.

After the actions taken MNO-A has achieved the 4G download rate QoS target greater than 10Mbps, despite growing to have the largest market share from 39.7% to 47.4% over the same period. [4][24]

Secondly in the second data set the impact of the measured latency is inversely proportional to the measured download throughput. MNO-C measured the highest latency and at the same time measured the lowest throughput. Therefore in comparison to its competitors, it can be assumed that the main reason for its poor throughput is therefore due to it very high latency.

As the demand for data continues to soar MNOs will need to continuous expand their offered capacity. The three major options that exist for MNOs to deal with increasing demand are additional spectrum, additional antennas and additional small cells. In addition key technologies like MIMO and CA will result in improved spectral efficiency and user experience. [10] [22]

This research was limited to outdoor scenario only using a mobile phone based application. Future work can include indoor coverage scenarios as in ITU-T Rec E.806 and possibly include engagement with the mobile operators to get a deeper insight into the network deployment and performance KPIs. Crowdsourced data should also be considered to obtain huge samples of QoS measurement data. [13]

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