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Assessment of 4G Mobile Network Efficacy in Urban Terrain vis-a-vis the 3GPP and NCC Mobile Signal Threshold

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ABSTRACT

Evaluation of mobile signal efficacy in mobile user's terrain is a continuous process that provides firsthand information on the state of mobile services provided by the mobile vendor due to continuous development and population density. In this regards, a quantitative analysis of four major mobile service signals in the urban terrain of Ilorin metropolis was assessed. Majorly the interlinked routes that spanned the entire metropolis were selected and a RantCell mobile network app installed on Tecno Pouvrior 3 plus phone was used to measure each of the reference signal received power (dBm) for the four major signal services through a drive test. The analysis and results obtained show that no mobile signal services depicted an all-round percentage performance along all the measurement routes as far as the urban threshold of < -75 dBm is concerned. However, GLO mobile service gave 78% performance as least and a 98% performance as the highest value while MTN mobile gave 72% performance with a 99% percentage as the highest value. 9mobile and Airtel mobile services show the least of performance in all the measurement terrains respectively.

Keywords: Mobile Signal Criteria, Mobile Signal Threshold Value, Statistical Tools and 4G Mobile Networks

I. INTRODUCTION

Africa no doubt, offered huge market for mobile telecommunication services and Nigeria is by no small means the largest market for these mobile services in Africa, this follows through the successful auctioning of Digital Mobile License (DML) in 2001 by the Nigerian Communication Commission (NCC), being the regulatory body and the management of the radio spectrum. There are estimable 190 million subscribers and of which 130 million are provided with air interface accessed to the mobile telecommunication services [1]. This has prompted the drive for the emergence of electronic economy (e-economy) in Nigeria and offered platform for the idea of the e-Naira and if well sustained, has risen the hope and tendency of checkmating financial corruption and set the stage for the diversification of the Nigeria economy. However, the provision of quality signal coverage, low latency, high throughput and fast rate of data transmission becomes paramount for the sustainability of the e-economy and provision of acceptable mobile signal services for mobile subscribers [2]. Therefore, telecommunication researchers have deemed it necessary to provide a quantitative assessment of the mobile service's efficacy in urban terrain considering the mobile service's threshold values, specified in the Third Generation Partnership Project (3GPP) and NCC gazette for the rollout of the fourth generations (4G) network and the Long Term Evolution Network as depicted in the web layout of Table 1 and Figure 1 [3].

Table 1: Mobile Signal Coverage Threshold's Values

Mobile Terrain	Threshold (dBm)	Value
Urban	< - 75	
Sub Urban	< - 85	

Rural	< - 95

These specs as stated gave strong requirement for low latency, high end-to-end throughput, quality and security of services. For these standard, the Wideband Code Division Multiple Access (WCDMA) was employed as the air interface through the process of spread spectrum for high and fast data rate delivery [4].

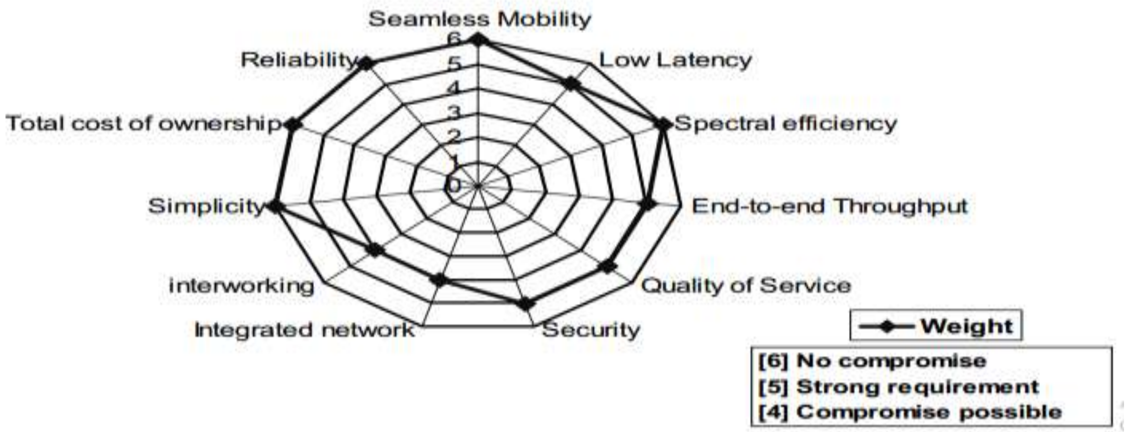

Figure 1: The Relative Priority of Mobile Characteristic Standard

Therefore, the spreading of the user's information bits was done over the wide bandwidth of the channel and the multiplication of the spread bits with the random quasi-numbers codes was done to help reduce the channel and receiver's noises and interference through the progressing gain method. The WCDMA has provided optimum spectral utilization, and the optimum spectral efficiency has been the front runner of development from one generation to generations of mobile services, although there are processes involved in designing any mobile network like the preplanning, planning and post planning stages of mobile network development [5]. Basically, each stage has their aim to fulfill in the designing process and to ensure a cost effective mobile system. The preplanning stage for instance, deals majorly with the placement, dimensioning, type of site (macro, micro, pico or femto) and propagation model deployment for the initial investigation of signal path losses considering the features of intending terrain of the site location [6]. The planning stage has to do with the implementation and rollout of the network system in line with the laid universal rules and regulations considering the proposed service criteria, while the post planning stage is the time to time assessment of the planned networks to ensure the deployed service continuously meets the targeted requirement of the users of the universal equipment [7]. This research work therefore presents a quantitative assessment of the 4G mobile network in relation to the 3GPP and NCC gazettes in Ilorin Metropolis.

II. REVIEW ON MOBILE SIGNAL CRITERIA

The analog telephone network system employed the wired system for its telephony service delivery, where the users are static and are connected to the regional offices as depicted in Figure 2. The major problems with this telephony system are limited numbers of subscribers, static users, noise; it is prone to disasters and also lacks the network roaming [8].

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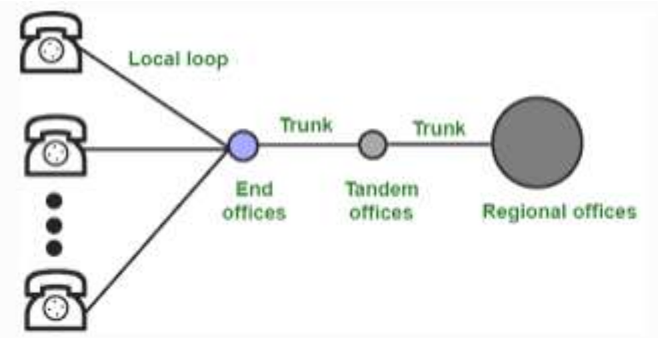

Figure 2: The Analog Telephony Network System

The above mentioned problems and most especially the static user's problem are the main drive as to why telecommunication engineers thought of a mobile network system where non static users (mobile users) can as well have better access to mobile telecommunication network. This is what birthed the First Generation (1G) network system where the designed architecture layout divided the geographical space into cells (cellular) with each cell hosting a Base Transceiver Station (BTS) as depicted in Figure 3 [9]. Examples of the 1G networks are the Nordic Mobile Telephony (NMT), Advanced Mobile Phone System (AMPS) and the Total Access Communication System (TACS) all operated in the 80s across Asia, Europe and United State respectively. However, one of the backdrop of these 1G network system is that they are not interconnected with each other. Presented in Table 2 are some of the criteria for the development of the mobile network system till date [10]. These criteria are the needs and wants of the service subscribers, and what the service vendors deem as optimum utilization of the spectrum resources, to ensure effective returns on investment and seamless access to the mobile services after rollout.

Table 2: Mobile Network Criteria over respective Generations

Network Generations	Network Acronyms	Bits Rate	Air Interface
2G	GSM	9.6 Kps	FDMA
2.5G	GPRS	115 Kps	FDMA
2.75G	EDGE	384 Kps	TDMA
3G	UMTS	2 Kps	CDMA
3.5G	HSDPA	2.1 Mbs	CDMA
4G	LTE	100 Mbs	WCDMA

GSM - Global System for Mobile Communication, GPRS - General Packet for Radio Service, EDGE - Enhance Data for Global Evolution, UMTS - Universal Mobile Telecommunication System, HSDPA - High Speed Downlink Packet Access and LTE - Long Term Evolution

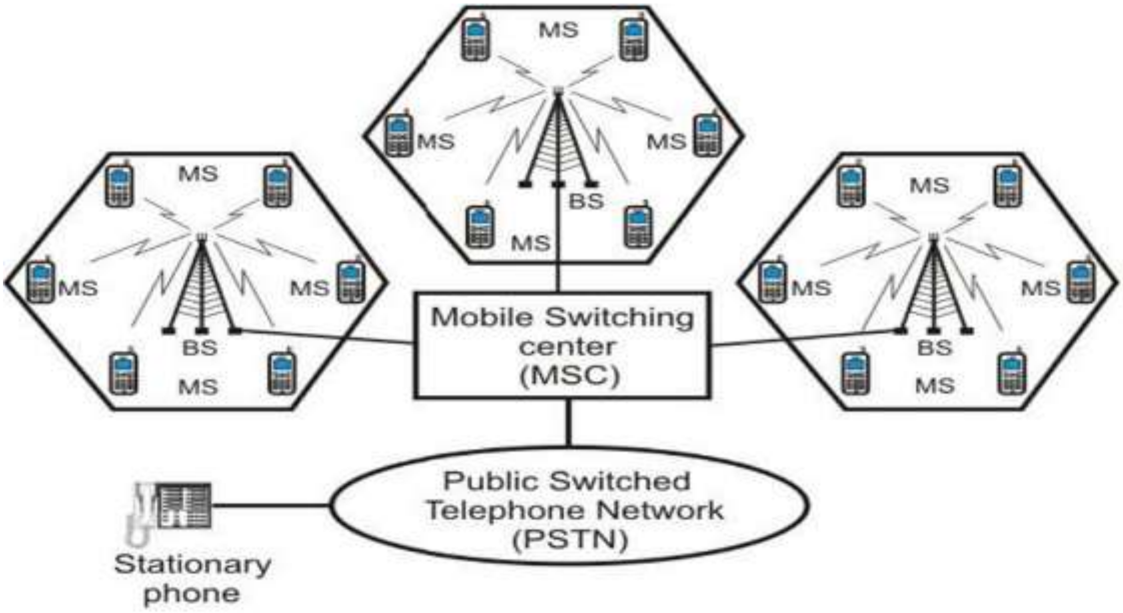

Figure 3: The Cellular Architecture System

The cellular mobile network system has evolved since conception and its evolutions seem not near end any time soon. This is because the provision of the mobile network system has brought the world in real time to a global village[11]. The situation where virtual attendance, browsing, chatting and amongst other information technology needs has put on more demand on the need of good quality mobile services and likewise researchers have continued their quest on the provision of high quality mobile services [12]. For instance, in 2013, Mohammadali et al., investigated the performance power consumption of a decentralized wireless network, rationalization of power was done amongst the Ad hoc multi hop and the multi branch system in a fading channel. Finally, results showed that optimum power allocation in an Ad hoc network helps improve on the performance of an Ad hoc wireless network [13]. In another study, Vishal Jain et al., in 2015 provided a paradigm of Radio over Fiber approach (ROF), the ideal is to modulate an optical signal with a radio wave and transmit through air interface for wireless access. This approach was chosen for the purpose of investigating the performance of radio coverage over fiber network [14]. Also in 2018, Anwesha et al., employed the cell breathing approach to investigate the performance of radio network. This approach focused on ameliorating of power consumption by BTSs due to high mobile traffic. The work employed adjacent cells to the traffic cell and sectored her antenna at 60 degrees, this approach offered a considerable reduction on power consumed by BTS [15], while the nature of mobile phone data traffic was investigated by John et al., In the work, the day and night time mobile call traffics were recorded and further employed for mobile traffic data management[16].

III. FIELD MEASUREMENT CAMPAIGN

The quantitative data for the efficacy assessment were recorded through drive test along major routes in the urban terrain of Ilorin metropolis as depicted in Figure 4.

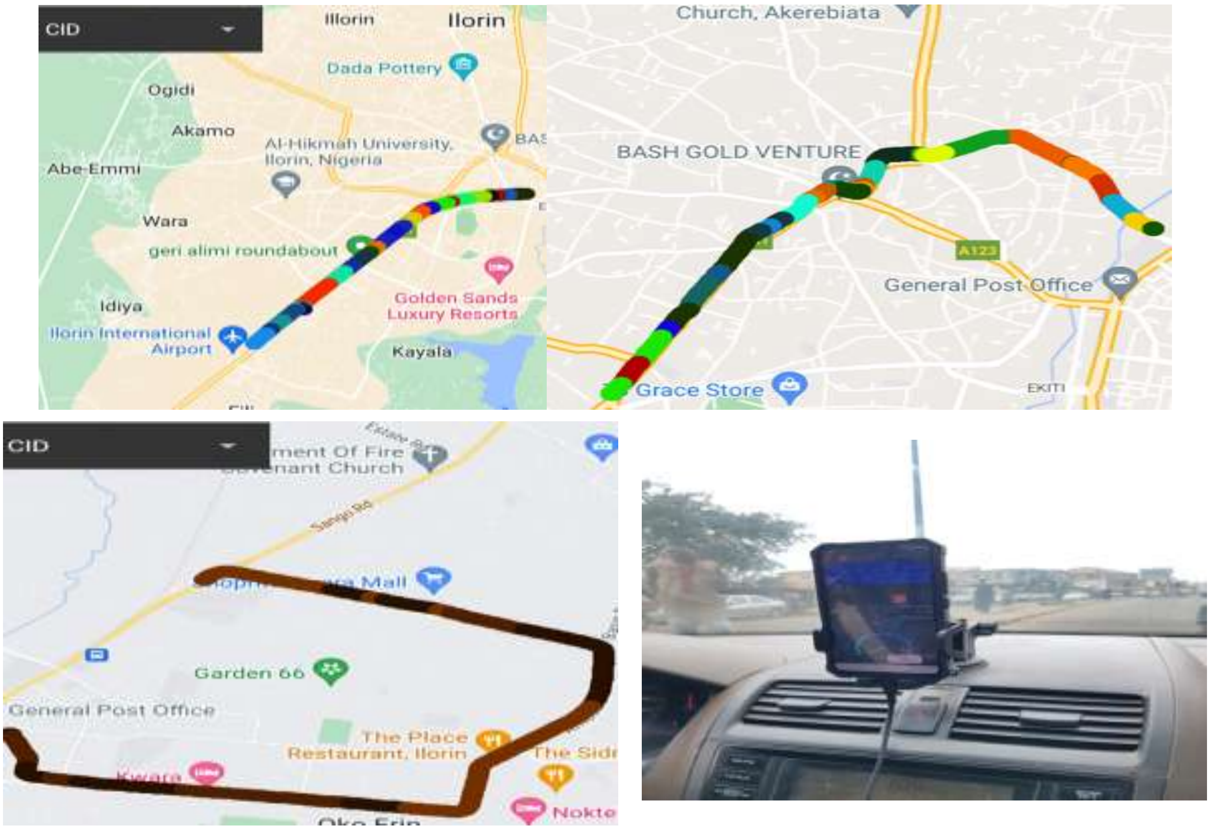

Figure 4: The Major Routes in the Urban Terrain of Ilorin Metropolis with the Drive Test Measurement set up.

All the measurement routes are approximately 4300 meters, dual carriage roads, dense population and consists of residential and office building. The entire roads span through Ilorin International Airport, Taiwo Road, Post Office, Offa Garage, GRA Road, Emir Palace, Ipata Marker and the Ilorin old Jebbba Road along Kulende Zango. These routes are interlinked and spanned the entire urban settlement of the ancient city of Ilorin. The signal measurement for the four major mobile service providers (MTN, Globalcom, Airtel and 9mobile) were all scanned and recorded over a period of one month considering the day and night time of the day respectively.

IV. FORMULATION OF THE PERFORMANCE METRICS

The difference in magnitude (dBm) between the mobile signal measured value (dBm) and mobile signal threshold values (dBm) for urban terrain termed Error Signal (dBm) is as mathematically stated in equation 1

$$Signal\,Error\,(E_s) = (M_s - Th_s) \quad (1)$$

Where M_S and Th_S are the mobile signal measured and threshold values respectively

$$Signal\,Mean\,Error\,(ME_s) = \frac{1}{n} x \sum_{1}^{n} (M_s - Th_s) \quad (2)$$

Where n denote the point of the signal measurement values along each route (frequency).

$$Absolute\,Signal\,Mean\,Error\,(AME_s) = \frac{1}{n} x \left| \sum_{1}^{n} (M_s - Th_s) \right| \quad (3)$$

Equation 3 can be further formulated to derive a quantity to give the amount of uncertainty in measured signal as compared to signal threshold value.

$$Relative\,Signal\,Mean\,Error\,(RME_s) = \frac{1}{n} x \sum_{1}^{n} \left(\frac{AME_S}{ME_S} \right) \quad (4)$$

To further gauge the efficiency of the mobile networks, the percentage error and percentage performance are as shown in equations (5) and (6):

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$$Percentage\ Error = \frac{1}{n} x \sum_{1}^{n} \left(\frac{AME_S}{ME_S} \right) * 100$$

(5)

$$Percentage\ Performanc\ e = 100 - \left(\frac{1}{n} x \sum_{1}^{n} \left(\frac{AME_S}{ME_S} \right) * 100 \right)$$

(6)

V. RESULTS AND DISCUSSIONS

The mean error presented in Table 3 gave the average deviation of the four mobile signal values from the mobile signal threshold value in the terrain of Ilorin settlement.

Table 3: Mean Error Rate (dBm) of the Four Mobile Service along the Measurement Routes

Routes/Mobile Services	MTN	AIRTEL	9MOBILE	GLO
GRA_FATE	-0.15385	-1.41026	6.92308	-0.41026
TAIWO_AIRPORT	-5.70732	-7.31707	4.51295	-0.36585
POST_OFFICE	-6.42105	-2.57895	6.28947	-6.65789
EMIR_PALACE	-9.48718	-9.25641	5.794871	0.41026

Mobile signal services with an average values of positive mean error values show that on average, the mobile signal has depicted values of signal above the threshold values, while mobile signal with negative mean error values indicate depiction of mobile signal services below the threshold value. However, the mean error is not enough to judge the performance of the mobile services, therefore the relative mean error was next computed. The relative mean error depicted the amount of deviation of the mobile signal services values from the threshold value of all the four major mobile services considered as depicted in Figure 6, along all the measurement routes.

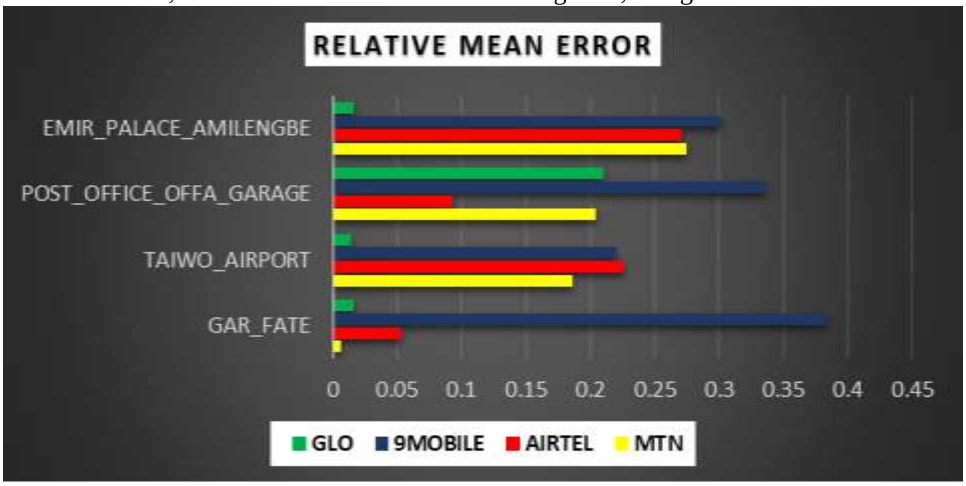

Figure 6: The Relative Mean Error for all the Four Major Mobile Services

MTN, GLO and Airtel all show little deviation from the threshold values along the GRA_Fate, Taiwo_Airport and Post_Office routes respectively while the 9mobile services did not at any time along all the route show minimum deviation from the threshold value. However, it was noticed that all the mobile services' signals show high deviation from the threshold value along the Post_Office Offa_Garage route. These two routes out of other routes has the high concentration of vehicular movement and dense buildings along its layby and these have the tendency to spark up multipath effect and fading on the mobile service signal along the routes, this is because vehicular screen is known to cause signal diffraction, scattering and reflection. Figure 7 on the other hand presented the percentage error rate against the signal threshold values.

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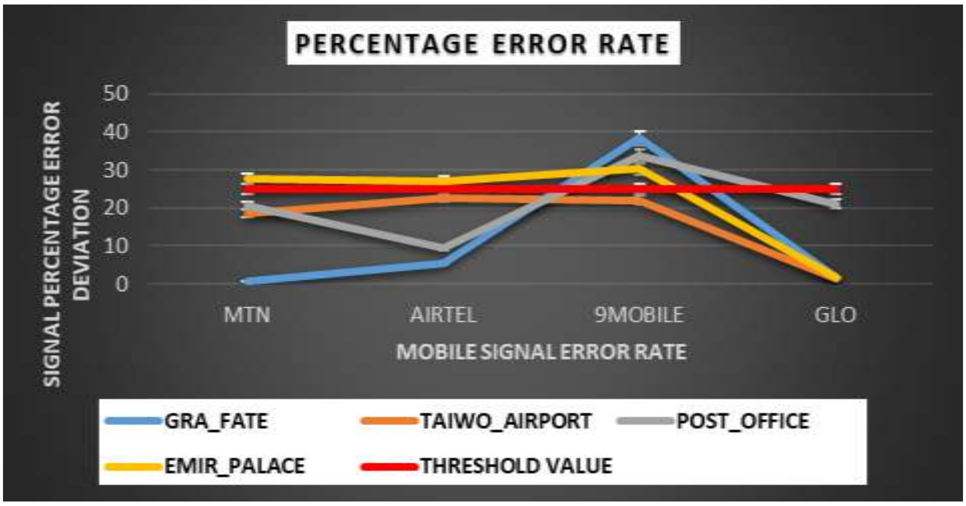

Figure 7: The Percentage Error Rate

The graph however, depicted 9mobile signal services to have average percentage error rate values above the percenatge error rate threshold values along GRA_FATE, POST_OFFICE and EMIR_PALACE routes, however, all the mobile signal services depicted average percentage error values below the signal error rate threshold value.

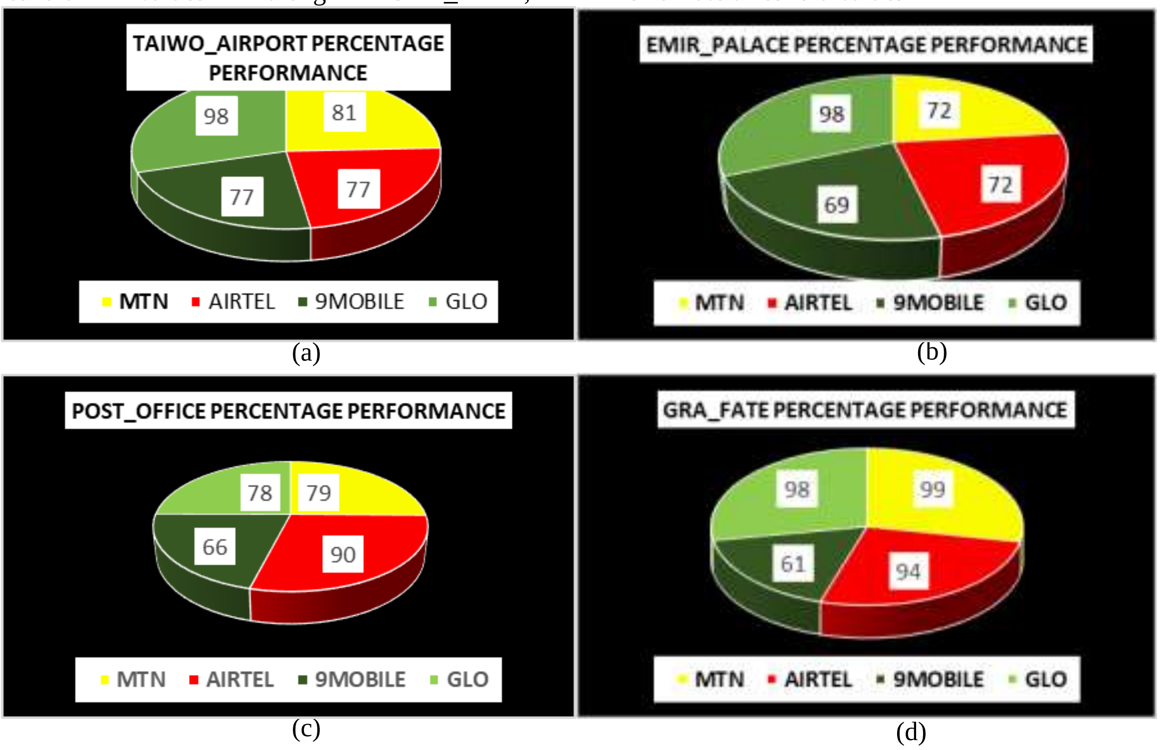

Figure 8: The Mobile Signal Percentage Performance along (a) Taiwo_Airport (b) Emir_Palace (c) Post_Office and (d) GRA_FATE Measurement Routes

The percentage performance of each of the four mobile signal services in the urban terrain of Ilorin is as depicted in Figure 8. From the pie chart of the performance depiction, the GLO network has shown good coverage of signal on her circuit switch channel majorly along all the measurement routes, with a percentage performance of 78% being the least along POST_OFFICE_OFFA_GARAGE route and a 98% percentage performance along other routes. Although it is worth mentioning that MTN gave percentage performance 99% along the GRA_FATE route.

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VI. CONCLUSION

The assessment of the four major mobile services available in the urban terrain of Ilorin metropolis has been done. More so, the assessment adopted the statistical tools of mean error rate, relative mean error, absolute mean error and percentage performance. Finally, the quantitative assessment shows that no signal service outperforms other networks in all the measurement routes considered, although, the GLO mobile service showed tremendous circuit switch signal coverage. This is followed by MTN mobile circuit switch service, Airtel mobile switch service and 9mobile switch service respectively.

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