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Performance Analysis and Evaluation of 4G Network Based on Handoff Process

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ABSTRACT

This Paper focuses on analyzing and evaluating the performance of an existing 4G network based on handoff process in the network since there is need for Network Providers to comply with the Quality of Service (QoS) standard in their network service delivery to the consumers. The regulatory authority in Nigeria being the Nigerian Communication Commission (NCC) sets up some key Performance Indications (KPIs) that the Network Providers need to adhere to in order to ascertain if the deployed model will enhance Mobility and Handoff Management and improve QoS delivery. This research work involved a Drive Test on Mobile Telecommunication Nigeria (MTN) network using Transverse Electromagnetic Simulator (TEMS) - 15.0. Based on the applied Mobile Assisted Handoff (MAHO) technique, and weeks of Drive Test, the Received Signal Strength Indicator (RSSI) in the characterized 4G Network showed evidence of strong signals in the range of -50dBm to -80dBm within the Base Station (BS) footprint for the one week of Drive Tests in which measurements were carried out within a range of 600m radii. MATLAB SIMULINK and mathematical calculations done on field experimental data gathered, confirms compliance with NCC benchmark. Finally, we still recommend an improved performance of the network, in terms of the measured and determined values of some of the key performance indicators.

1. Introduction

Wireless communication technology no doubt is one of the highest selling commodities in the world today, there is practically no aspect of life that is optimally driven outside wireless telecommunication system, from educational sector, to banking sector, to sports and games even the local market men/women in the village operates on wireless communication system [1]. For cellular systems particularly, there is a reflection of high interest for mobile broadband capacity systems, namely the universal mobile telecommunication systems (UMTS), known as a third generation (3G) technology [2]. However, it has its own limitations, which necessitated the introduction of long-term evolution (LTE) systems known as fourth generation (4G) [3]. LTE systems was introduced in order to handle the lapses in UMTS in terms of better spectrum efficiency, higher data rate, latency, capacity across the cell, better coverage, and better support for mobility [4]. A mobile node in a Fourth Generation (4G) environment will have several interfaces and be able to smoothly switch between heterogeneous networks to ensure the continuation of an active application session. In 4G, the majority of the traffic is data and multimedia as opposed to voice only and through a common wide-area radio access technology and flexible network architecture, LTE has enabled convergence of mobile and fixed broadband networks [5; 6]. Future network devices should be able to roam freely across different access technologies, including wireless local area networks (WLANs), WiMAX networks, cellular systems, etc., in order to enable seamless changeover [7]. The 4G network has been designed to provide Quality of Service (QoS) features while also offering transmission rates of up to 20 Mbps [8]. Customer satisfaction is a personal feeling of either pleasure or disappointment resulting from the evaluation of services rendered by an organization to an individual in relation to expectations [9; 10]. The aim of 4G is to replace the entire core of cellular networks with a single worldwide cellular network completely standardized based on the Internet Protocol (IP) for video, packet data utilizing Voice over IP (VoIP) and multimedia services. The newly standardized networks would offer uniform video, voice, and data services based solely on IP to the mobile phone or handheld Internet gadget.

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Software defined radios will be used in the deployment of 4G systems, enabling the equipment to be upgraded to new protocols and services via software updates. It is not an entirely new system, nor does it provide brand-new technical solutions. The main objectives of 4G are integration and convergence. Different wireless network types should be able to seamlessly communicate with the wired backbone thanks to the integration.

1.1 Mobility Management in 4G Network

In 4G Network, mobility management ensures prompt packet delivery to their destinations [11]. The fundamental prerequisite for this method is a routing protocol. Here, mobility management refers to both the location management and handoff management strategies. Networks can monitor the whereabouts of mobile nodes (MNs) thanks to location management. Location registration and call delivery or paging are the two main sub-tasks of location management. To keep the location database current during the location registration procedure, the MN periodically sends a set of signals to the network informing it of its location. After the location registration is finished, the call delivery operation is started.

The call delivery procedure asks the network for the precise position of the mobile device based on the data that was registered in the network during location registration in order for a call to be successfully delivered. The following concerns must be taken into account when designing a location management system [12], [13]:

(i) Minimizing signaling overhead and latency in the service delivery,
(ii) Ensuring applications receive the guaranteed quality of service (QoS), and
(iii) In a fully overlapping area where multiple wireless networks co-exist, an effective and reliable algorithm must be created to choose the network through which a mobile device should perform registration, decide where and how often the location information should be stored, and how to calculate the exactly where the location information should be stored.

Due to node mobility in ad-hoc networks, finding an efficient path for ad-hoc routing poses a challenge in research work. Node position and neighborhood information, both of which are important for communication, are affected by node mobility. Nevertheless, the discovery of multi-hop routing approach assists in settling this challenge. [14] have examined and assessed how node mobility affects the functionality of ad-hoc wireless networks. Additionally, they have merged this method with actual-world scenarios like pedestrian speed estimation [15]. It was determined that there are two ways to model the nodes' movement in a simulation.

The first is that node trajectories are calculated in a real network, for example, node positions can be determined using a GPS device, and are then utilized as input to power simulations. The realistic modeling of node mobility makes this method preferable. Utilizing a mobility model, which upholds a set of guidelines for node behavior, is the second option. These methods are insufficient to address these issues because the mobility model only partially captures node behavior. Instead, in order to describe node mobility in simulation, the aforementioned issues must be addressed.

1.2 Brief view of Handoff

Handoff (or Handover) is the process of transferring the point of attachment of a Mobile Station (MS) to the network from a Base Station (BS) to another BS as the MS moves from the region of coverage of the initial serving BS to the coverage region of the target BS. This is usually required to be seamless and continuous, so that the on-going communication is not dropped, and the user does not experience a poor QoS [16; 17].

In mobile networking, moving about is unavoidable with cellular deployment spanning many cells, as shown in Figure 1. The serving BS (SBS) changes as a result of mobility. In order to balance the network load, an SBS may alter depending on the load conditions and/or when a Mobile Station (MS) is involuntarily switched to another or a Target BS (TBS). A handoff decision process is therefore a crucial component of a cellular network. Signal strength, signal-to-interference ratio, distance to the BS, velocity, load, etc. could all be factors in the choice to hand off.

2. Literature Review

[18] presented a framework to inspect the performance of a network call handoff based on Nigerian Communications Commission (NCC) key performance indicators for 4G. The authors quantified the performance of a network handoff by analyzing the call setup success rate and handover success rate for the network. Their drawback is in existence of a defect in vertical handoff decisions.

[19] proposed an SDN-based centralized solution for handover management in LTE network. Based on their solution, the handover is being managed by SDN controller which keeps track of the overall network management and dictates the flow entries to the OpenFlow switches in the network.

[20] developed a study and evaluated the handoff process between WLAN and cellular networks using two algorithms. The algorithms were based on received signal strength, WLAN threshold value and lifetime estimation and their simulation model were developed to evaluate the performance of the vertical handoff algorithms using MatLab. They evaluated the performance based on the number of vertical handoffs, number of unnecessary handoff and handoff delay by varying the user mobility rate.

3. Methodology

This research work involves Drive Tests carried out on Mobile Telecommunication Nigeria (MTN) network using Transverse Electromagnetic Simulator (TEMS) - 15.0. A model of the 4G network was developed and a hybrid of Mobile Assisted Handoff (h-MAHO) used in handoff management. In this developed Method, the handoff is more decentralized such that both the Mobile Station (MS) and the Base Station (BS) supervise the quality of the link (that is, RSSI, channel availability). In the approach of decentralization of tasks in the network, the MS has a duty to measure the Received Signal Strength Indication (RSSI) of neighboring base stations and the network makes the handoff decision based on report from the MS which is transmitted twice in a second to the base station. The decision as to when and where to execute the handoff is still made in the network. From the developed model, a hybrid of MAHO based Handoff Technique was applied in the network and simulated using MATLAB Simulink/graphs.

Fig. 1: TEMS Measurement Tool used for Field gathering of RSSI Data

Although this research work focused primarily on Handoff and some significant Key Performance Indicators (KPIs) that improve Mobility Management and QoS delivery in 4G network, the Investigation page displays a variety of information about parameters like Network Frequency, Signal-to-Interference Ratio (SIR), Call Setup, Call Establishment, Call Drops, Uplink and Downlink Physical layer, Throughput, Handoff and Effect of Traffic/Load on Handoff.

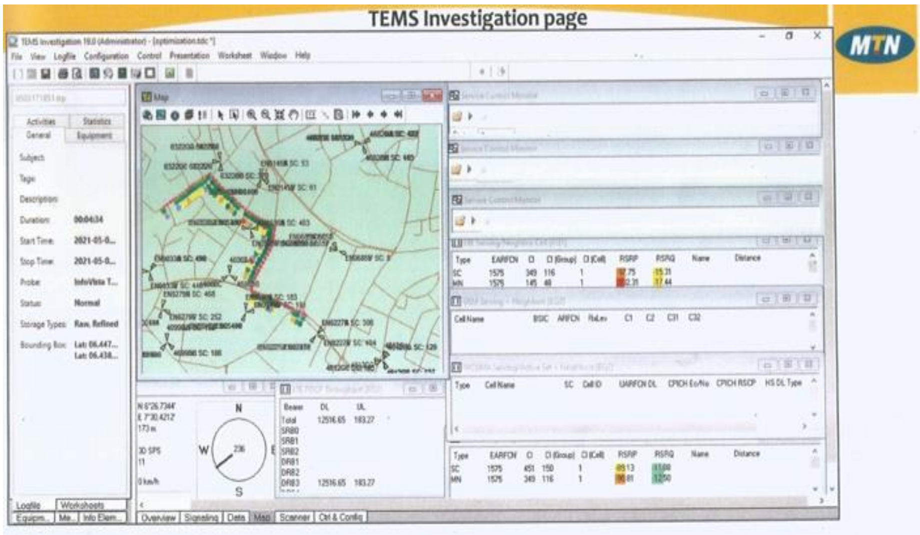

Fig. 2: TEMS Investigation Page

The overall scenario consists of a couple of GSM BTS sites, each of them with three sectors having different azimuths that are placed in order to cover the defined area but for Universal Mobile Telecommunication System (UMTS) sites, One Omni-directional antenna per BTS is deployed. The distance between the sites is approximately 600 meters which corresponds to typical Setup of commercial UMTS antennas. All sites are synchronized using a defined GPS-clock. The cell diameter is approximately 350 meters.

3.1 Characterization of the 4G Network and determination of KPIs.

The total number of calls made was calculated by adding Call Setups and Blocked Calls. The Call Setup Success Rate is one of the Key Performance Indicators (KPI) that Network Providers use to assess the usability and efficiency of their Networks. As the Call Setup Success Rate (CSSR) increases, the Blocked Call Rate (BCR) or Call Drop Rate (CDR) declines. It is conceivable that this will directly influence/have an impact on how Customers view and evaluate the Services offered by the Network and how it functions. CSSR benchmark set by Nigeria Communication Commission (NCC) is 80%.

Call Setup Success Rate Evaluation

$$\text{CSSR} = \frac{\textit{Number of successful calls Setup}}{\textit{Total number of call attempts}} \tag{1}$$

$$\text{HOSR} = \frac{\textit{Number of successful}\ \text{Handoff}}{\text{Number } \textit{of attempted}\ \text{Handoff}} \text{ x } 100\% \tag{2}$$

$$\text{GoS} = \frac{\textit{Number of}\ \text{lost or blocked}\ \textit{calls}}{\textit{Total number of}\ \text{offered}\ \textit{call}} \tag{3}$$

From measured data in the network:

Applying Equation 1: CSSR = $\frac{172602.8}{210165.03}$ = 82.127% or 82% (Round Figure)

Applying Equation 2: HOSR = $\frac{5772.7}{6329.9}$ * 100% = 91.2% or 91% (Round Figure)

Applying Equation 3: GoS = $\frac{3540}{240181}$ = 0.0147 ≈ 0.015 or 1.5%

4. Results and Discussions

This paper characterized the 4G network using TEMS devices and engaged MTN site Engineers during drive test so as to gather information on 4G network KPIs. The drive test was carried out within Fifteen (15) working days, and the received signal strength within the urban areas was good except for the week there was heavy rain fall, faulty generating sets in some of the thirty (30) BTSs of interest. The Call Setup Success Rate, Call Arrival Rate and number of Handoff performed by a cell in Base Stations were observed. Often Call Drop rises due to poor RSSI or network unavailability. To avert this scenario, a hybrid of MAHO technique was developed. This technique maintains information on the Small Base Station (SBS). The SBS contains the information relating to the Base Station's RSSI and load. During Handoff, the above two parameters were considered by the Mobile Station (Adaptive) before deciding on the BS to hand over to. This technique as implemented here helped in a great way to reduce Call Drops. This is because in the existing MAHO technique, the Handoff is performed based on RSSI, but the BTS may have high number of Handoffs and thereby drop the subsequent incoming ones. But where the system uses hybrid MAHO, the best available BTS is handed over to and the call transmission continues without call drop.

4.1. SIMULINK Simulation Plots of 4G KPI Characterized Network Parameters from 3 weeks conducted Measurements

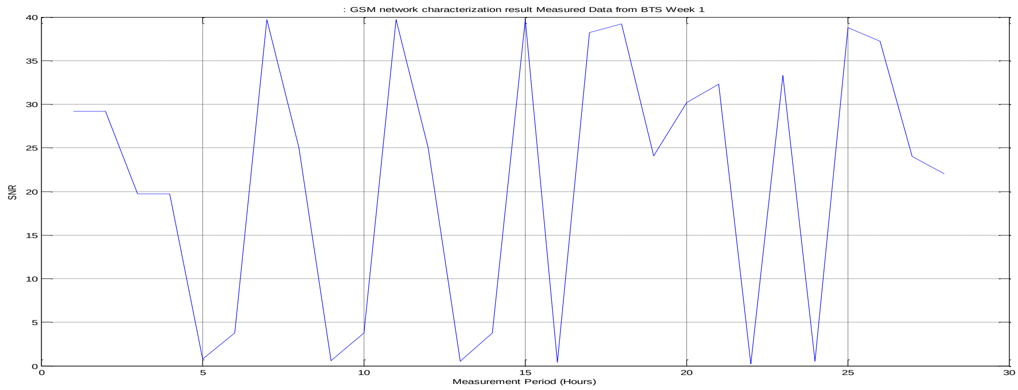

Fig. 3- Network Characterization – SNR (Week 1)

From Figure 3 and the measured data from the network, it can be seen that during the test, the entire tested area on the Network had a good Signal coverage transmitted by the radio/antenna, so there was very good signal quality received by MS. It was discovered that the Received Signal Strength can comfortably carry 4G facilities, that is, Voice and Data.

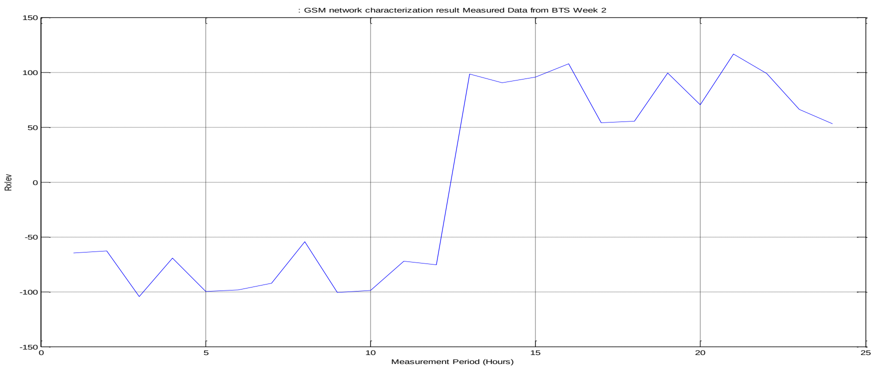

Fig. 4- Network Characterization – Rxlev (Week 2)

According to Figure 4 and the measured data from the network for the second week, the majority of the networked areas that were tested had inadequate radio/antenna signal coverage that was well outside the RSS-required Quality Signal of 80 dBm. Heavy rainfall that was seen during the second week of the test drive is to blame for the poor Signal Quality received by the MS. The Mobile Switching Center (MSC) Logbook also noted that the MSC Standby Generator was defective and required repairs for three days during the measuring period in the second week.

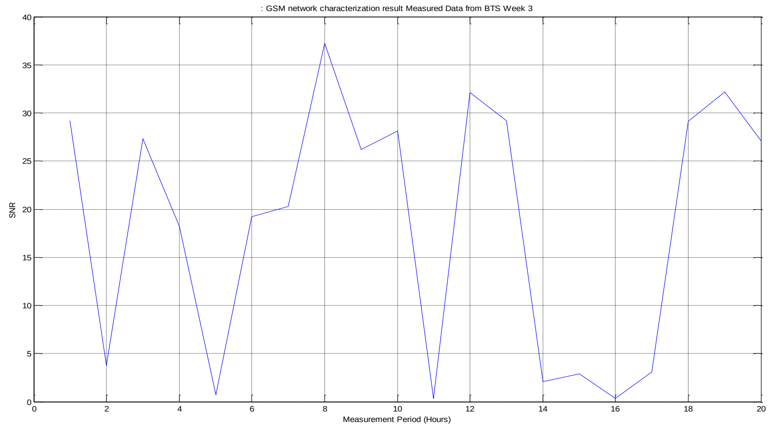

Fig. 5- Network Characterization – Rxlev (Week 3)

From Figure 5 and the measured data from the network in the 3rd week, the entire tested area on the Network had a good Signal coverage transmitted by the radio/antenna, so there was good Signal Quality received by the MS.

Table 1: Simulated Data of Offered Calls Probability of call blocking Using Hybrid of MAHO (RSSI and Load)

Offered calls	**Probability of call blocking % (Hybrid of MAHO)**
100	0.0000
200	0.0000
300	0.0003
400	0.0016
500	0.0055
600	0.0136
700	0.0270
800	0.0461
900	0.0700
1000	0.0978
1100	0.1281
1200	0.1597
1300	0.1916
1400	0.2232
1500	0.2539
1600	0.2834
1700	0.3116
1800	0.3383
1900	0.3636
2000	0.3874

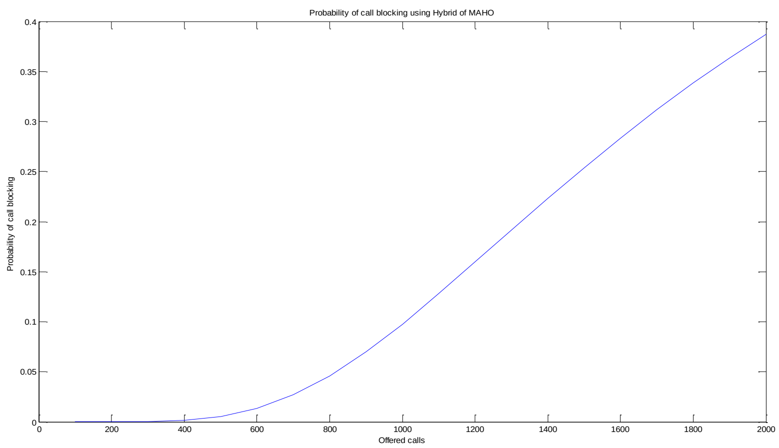

Fig. 6: Simulated Data of Offered Calls versus Blocked Callusing Hybrid of MAHO

Based only on the simulation results in Figure 6, the mobile station does not hand over to the base station. It also considers the quantity of handoffs on the BS (load). Based on the MAHO decision information - Adaptive, it continues to change at random within the range when choosing the BS to hand over to. For a traffic load of 100, the call blocking probability (P_b) is 0, but it rises as the traffic load does. The number of calls reduced to 0.3% when the traffic load reached 2000. When Hybrid of MAHO was introduced, the call drop rate was on average 0.1%.

Table 2: Comparison of call blocking probability

Offered calls	Probability of call blocking % (MAHO)	Probability of call blocking % (Hybrid of MAHO)
100	0.0136	0.0000
200	0.1597	0.0000
300	0.3383	0.0003
400	0.4695	0.0016
500	0.5611	0.0055
600	0.6270	0.0136
700	0.6762	0.0270
800	0.7141	0.0461
900	0.7442	0.0700
1000	0.7686	0.0978
1100	0.7888	0.1281
1200	0.8058	0.1597
1300	0.8203	0.1916
1400	0.8328	0.2232
1500	0.8436	0.2539
1600	0.8532	0.2834
1700	0.8616	0.3116
1800	0.8691	0.3383
1900	0.8759	0.3636
2000	0.8820	0.3874

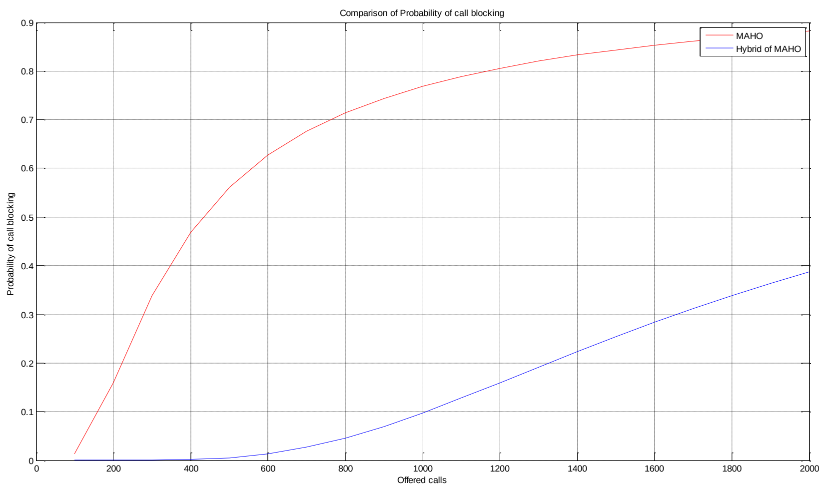

Fig. 7: Comparison of call blocking probability with MAHO and Hybrid of MAHO.

Based on Handover on the 4G Network, the algorithm's performance is evaluated. The blocking probability using MAHO and the hybrid MAHO handover technique is shown in Figure 7. According to the graph, the call blocking probability is lower with MAHO's hybrid than it is with MAHO. The graph demonstrates that, in comparison to MAHO handover technique with about 0.9% call blocking probability, the Hybrid of MAHO handover technique with about 0.3% suggested a reduced call blocking probability by 0.6%.

4.2. Handover Latency Simulation Result

The network delay experienced when switching from one base station to another base station is known as handover latency. For the network that does not use a handoff prediction table, the handoff latency is shown in Table 3 and Figure 8 to be high. The prediction Table is created using the results of the standard scans in the proposed scheme, and its contents are updated using the Handoff decisions from the Mobile Stations after each successful Handoff (HO) operation. The MAHO prediction Table is kept by the SBS in the suggested manner. With the implementation of the handoff prediction table, all of these requests from different MSs are combined into a single request, preventing network latency.

Table 3: Handover latency

Handover Latency (MAHO)	Handover Latency (Hybrid MAHO)
260 ms	180 ms

Table 3 shows that in terms of Handoff delay, the suggested approach outperforms the MAHO scheme. When hybrid MAHO was employed, it was found that the handoff latency was significantly reduced, going from 260msec to 180msec.

5. Conclusion

As described in this study, hybrid MAHO was used to improve seamless handoff management performance in 4G networks. This guarantees that it is possible to migrate data flows transparently across two access points that belong to different heterogeneous technologies and justifies the work done in this research. The design and implementation of an integration architecture that permits vertical handoffs across 4G wireless technologies were given in the research effort. The effort focused on minimizing roaming-related mobility disturbances and lowering latency. The study thus showed that employing a hybrid of the MAHO technique makes it possible to enable transparent mobility, track nodes during sessions, and decrease latency during heterogeneous handoffs. In comparison to the conventional MAHO technique, the proposed h-MAHO technique performs better, with a call setup success rate (CSSR) of 96.3% as opposed to the conventional MAHO model's 94.7%. The proposed model decreased the likelihood of blocking by 0.6%. In comparison to the conventional model's 0.3% call drop probability, simulation of the two models reveals that the suggested model achieves a better result of 0.1%. In terms of handoff latency, the proposed model decreased the time of the conventional model from 260msec to 180msec.

Therefore, it is feasible to implement an appropriate architecture that allows seamless mobility in a 4G network utilizing the techniques that were provided and assessed in this research.

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