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Analysis and Computer Simulation of Handoff Decision in 4G Networks

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Abstract

This paper focuses on the analysis and computer simulation of handoff decision in 4G networks. Everyone around the world would like to be connected seamlessly anytime anywhere through the best network. The 4G wireless system must have the capacity to provide high data transfer rates, quality of services and seamless mobility. In 4G, there are a large variety of heterogeneous networks. Vertical handoffs pose a great challenge in communication channels thereby making life unbearable for subscribers in 4G wireless networks. The key performance indicators were used to determine the call setup rate, drop call rate, handover success rate and traffic channel congestion of the characterized networks. The experimental test bed technique using TCP proxy method was employed in this paper. The test-bed was operated using network discovery for the mobile node, which was performed based on router advertisements. The data was collected from MTN Nigeria, Ikeja-Lagos Network control office which covers cluster A and B. The results obtained shows that when the real loads was 60.606, 83.789 and 75.294, the simulated loads was 62.252, 81.841 and 76.343. Again, when the real handover failure rate was 1.405, 1.788 and 5.439, the simulated handover failure rate was 0.020, 0.009 and 0.012 respectively. It is concluded that when the mean call setup success rate values for all the cells in the two clusters were compared most of the cells were able to achieve NCC recommendation.

1. Introduction

When mobile users migrate from the coverage of one network access point to another, they are said to perform a handoff. Most handoffs occur in between access points of the same network technology and are termed horizontal handoffs. Handoffs between different access points belonging to different networks (e.g. WLAN to GPRS) are referred to as vertical handoffs, and pose a great challenge in communications [1]. Transparent mobility has enabled mobile users to seamlessly move across networks, wired as well as wireless, with minimal disruption to packet flows. A mechanism that can enable this has to exhibit a low handoff latency, incur little or no data loss, scale to large inter-networks, adapt different applications to the networks environments, and finally act as a conjuncture between heterogeneous environments and technologies without compromising on key issues related to security and reliability [2]. The process of handoff within any cellular system is of great importance, if performed incorrectly it will lead to the process of loss of calls and this makes it a very critical process. One of the key elements of a mobile cellular telecommunications system is the split of the coverage area into many small cells providing good spectrum utilization and coverage. Mobility is a very important feature of a 4G wireless networks system. Mobile terminals should be able to choose the best network among the available networks including WLAN, WiMAX, and satellite systems and then make handover. However, as the mobile users move from one cell to another, it must be possible to retain the connection without having a drop call [3].

Dropped calls are particularly annoying to users and if the number of incidences of dropped calls rises, dissatisfaction increases that can make a subscriber to change network provider. Again, GSM handover is an area to which particular attention was paid when developing the GSM European Telecommunications Standards (ETS) [4].

Wireless and wired technologies offer links that have widely varying link characteristics. Current generation cellular networks such as 4G and 3G offer bandwidths that are much higher than those of their predecessors. However, they are still significantly lower than WLANs [5].

Fourth Generation networks (4G) mainly visualizes the concept of vertical handoff. The concept of being Always Best Connected (ABC) and have highlighted different aspects of ABC criterion that will expand the technology and business platform of next generation communication. A survey based on various issues like research, future challenges, and various approaches are possible to tackle the challenges of ABC for handoff over heterogeneous wireless networks [6].

The wireless telephony system has changed with advancement of the technology according to the demand of end users. The first such impact was voice telephony system in 1G. The need of the end user was shifted to avail the voice communication mobility. After this, the wireless technology evolved as GSM and 2G in which the data service was embedded with mobility. Due to increase in demand of data services, the evolution of wireless technologies from 3G to 4G and 5G was developed [6]. Global System for Mobile Communications (GSM) is a wireless digital network standard that is designed by standardization committees and manufacturers in telecommunications. The 4G network provides compatible services and capabilities to all its several million mobile user across the world [7]. Handover process in cellular network automatically transfers a call from one radio channel to another radio channel while maintaining good Quality of Services (QoS) of the call. The number of cell boundaries increases because smaller cells are deployed in order to meet the demand of increased capacity. Each handover requires network resources to route the call to the next base station [8].

The statement of problem is that there is an increasing demand for handoff decisions on mobile communication networks as the volume of network users increases. Therefore, the traditional methods where handoff was performed on the basis of the evaluation of signal strength did not take into account various mobile user attachment options such as the current context of the user options. The objective is to analyze and simulate the performance improvement of handoff decision in 4G Network.

2. Methodology

The materials used in this paper are Laptops, web server, LAN network cable and network cable connectors, JPERGY software, Base Transceiver Station (BTS), Microsoft excel software (version 2010), Multimode Mobile Device, WLAN Module and TCP PROXY Module for GPRS.

The cellular GPRS network infrastructure was used in MTN Nigeria's GPRS network.

The WLAN Access Points was located at different locations of the MTN Computer Laboratory for Communication Engineering. The GPRS infrastructure comprises Base Stations that was linked to the Serving GPRS Support Node (SGSN) and connected to a Gateway GPRS Support Node (GGSN). However, both SGSN and GGSN nodes were co-located in a single Combined GPRS Support Node. Again, well provisioned Virtual Private Network (VPN) was connected to the Lab network of the MTN's backbone via an IPSec tunnel over the public Internet. The RADIUS server was provisioned to authenticate GPRS mobile users and also assigned IP addresses. For

access to the wireless test bed, mobile nodes were connected to the local WLAN network and this was carried out simultaneously to GPRS through a PC Card modem.
The router in the lab acted as a IPV6/IPV4 tunnel end point to the BT-Exact's IPV6 network. This router was also an IPV6 access router for the lab's fixed internal IPV6 enabled network and for WLANs.
Routing in the lab has been configured such that all GPRS/WLAN user traffic going to and from mobile clients was allowed to pass through the internal router, enabling the users to perform traffic monitoring. The arrangement assisted users in analyzing traffic traces to accurately repay the TCP connection timeliness during vertical handoffs.
For testing handovers, file downloads were initiated by the multimode mobile device over WLAN from an internal web-server and then forced handoff to GPRS and back again to WLAN.

3. Results and Discussion

The data obtained from a base station controller was collected and analyzed. The statistical mean for relevant parameters such as Call Setup Success Rate, Handover Success Rate, TCH call drop rate, TCH congestion rate, SDCCH blocking rate, Traffic Load, calls per day, probability blocking and Handover Failure Rate (%) were used. A handover can fail due to insufficient bandwidth in the target cell when the connection was dropped. The Call Dropping Probability (CDP) represents the probability that a call was dropped due to a handover failure. The Handover Dropping Probability (HDP) represents the probability of a handover failure due to insufficient available resources in the target cell. The values for handover dropping probability was fixed for individual cells and only the minimum number of handover was considered by subscribers between two points when the call begins and when the call ends.
The simulation was carried out in a number of channels and it was discovered that when a high handover failure rate was experienced, the number of guard channels determined were either decreased or increased. Again, when the system does not use a significant portion of the guard channels, it gradually decreased until most of the guard channels were used frequently.
Table 1 shows the statistical mean of handoff parameters. Table 2 showed the weekly mean of call data for cell LG0002A. Table 3 shows the computed call and handover dropping probabilities. Table 4 showed the average simulated values.
Table 5 shows the comparison between real and simulated handover failure rates. When the handover failure rate from data and simulated handover failure values was compared the simulated values were better than those obtained from data when evaluated. Also, by comparing simulated handover failure rate and real handover failure rate of some cells, their percentage difference represent improvement. The percentage improvement on handover failure rate averages were over ninety (90%) in most cases. When the load increases, handover failure rate reduces, this is as a result of making the guard channel flexible thereby improving on channel resource utilization.

Table 1: Statistical mean of handoff parameters

`Cell	Mean CSSR	Mean Handover Success Rate (%)	Mean TCH Cell Drop Rate (%)	Mean TCH Congestion Rate (%)	Mean SDCCH Blocking Rate (%)	Mean Traffic Load (Exl)	Calls per Day	Prob. Blocking	Handover Failure Rate (%)
LG 000 2 A	94.024	95.057	0.917	2.204	0.977	110.443	53012.400	0.0598	4.943
LG 000 2 B	95.468	93.603	0.795	2.292	0.254	51.283	24616.070	0.0453	6.397

LG 000 2C	97.621	97.277	0.999	1.166	0.223	41.407	19875.548	0.0238	2.723
LG 000 2D	97.682	98.428	0.456	1.419	0.486	148.017	71048.191	0.232	1.572
LG 000 2E	97.308	98.595	0.407	2.157	0.153	60.660	29116.643	0.269	1.405
LG 000 2 F	98.464	99.005	0.330	1.121	0.142	65.989	31674.730	0.0154	0.995
LG 000 3 A	97.444	97.376	0.306	0.452	0.043	9.957	47792.870	0.0256	2.624
LG 000 3 B	93.955	98.185	0.597	0.435	0.096	12.788	61381.570	0.0604	1.815
LG 000 3 C	97.510	97.252	0.579	0.602	0.087	71.533	34335.965	0.0249	2.748
LG 000 6 A	98.326	98.212	0.361	0.547	0.341	83.020	39849.496	0.0167	1.788
LG 000 6 B	97.694	94.817	0.568	1.102	0.369	168.382	80823.496	0.0231	5.183
LG 000 6 C	97.445	95.551	0.511	0.683	0.968	182.319	87512.922	0.0255	4.449
LG 000 7 A	98.031	94.477	0.437	0.766	0.495	85.839	41202.835	0.0197	5.523
LG 000 7 B	98.019	96.654	0.465	0.423	0.590	123.114	59094.887	0.0181	3.346

Table 2: Weekly mean of call data for cell LG0002A

CELL ID	Handover Failure Rate (HFR) (%)	Handover Dropping Probability (HDP)	Predicted Call Dropping Probability (CDP)
LG0002A	4.943	0.049	0.096
LG0002B	6.397	0.064	0.124
LG0002C	2.723	0.027	0.054
LG0002D	1.572	0.016	0.031
LG0002E	1.405	0.014	0.028
LG0002F	0.995	0.010	0.020
LG0003A	2.624	0.026	0.052
LG0003B	1.815	0.018	0.036
LG0003C	2.748	0.027	0.054
LG0006A	1.788	0.018	0.035

LG0006B	5.183	0.052	0.101
LG0006C	4.449	0.044	0.087
LG0007A	5.523	0.033	0.107
LG0007B	3.346	0.033	0.066

Table 3: Computed Call and Handover Dropping Probabilities

CELL ID	Handover Failure Rate (HFR) (%)	Handover Dropping Probability (HDP)	Predicted Call Dropping Probability (CDP)
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LG0002F	0.995	0.010	0.020
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LG0003B	1.815	00.18	0.036
LG0003C	2.748	0.027	0.054
LG0006A	1.788	0.018	0.035
LG0006B	5.183	0.052	0.101
LG0006C	4.449	0.044	0.087
LG0007A	5.523	0.033	0.107
LG0007B	3.346	0.033	0.066

Table 4: Average Simulated Values

Time (Sec)	Average Load (Erl)	Average HFR	Average Call Blocking Probability
1000	76.343	0.0268	0.210
2000	63.707	0.0255	0.335
3000	62.252	0.0230	0.355
4000	63.550	0.0205	0.344
5000	64.182	0.0143	0.344
6000	65.378	0.0250	0.325
7000	66.856	0.0140	0.318
8000	65.419	0.0130	0.329
9000	66.121	0.0191	0.320

Table 5: Comparison between real and simulated handover failure rate

Load (Erl) (Real)	Load (Erl) (Simulated)	HFR (Real)	HFR (Simulated)
60.606	62.252	1.405	0.020
65.789	65.373	0.995	0.026
83.789	81.841	1.788	0.009
72.927	66.856	7.281	0.010
75.294	76.343	5.439	0.012

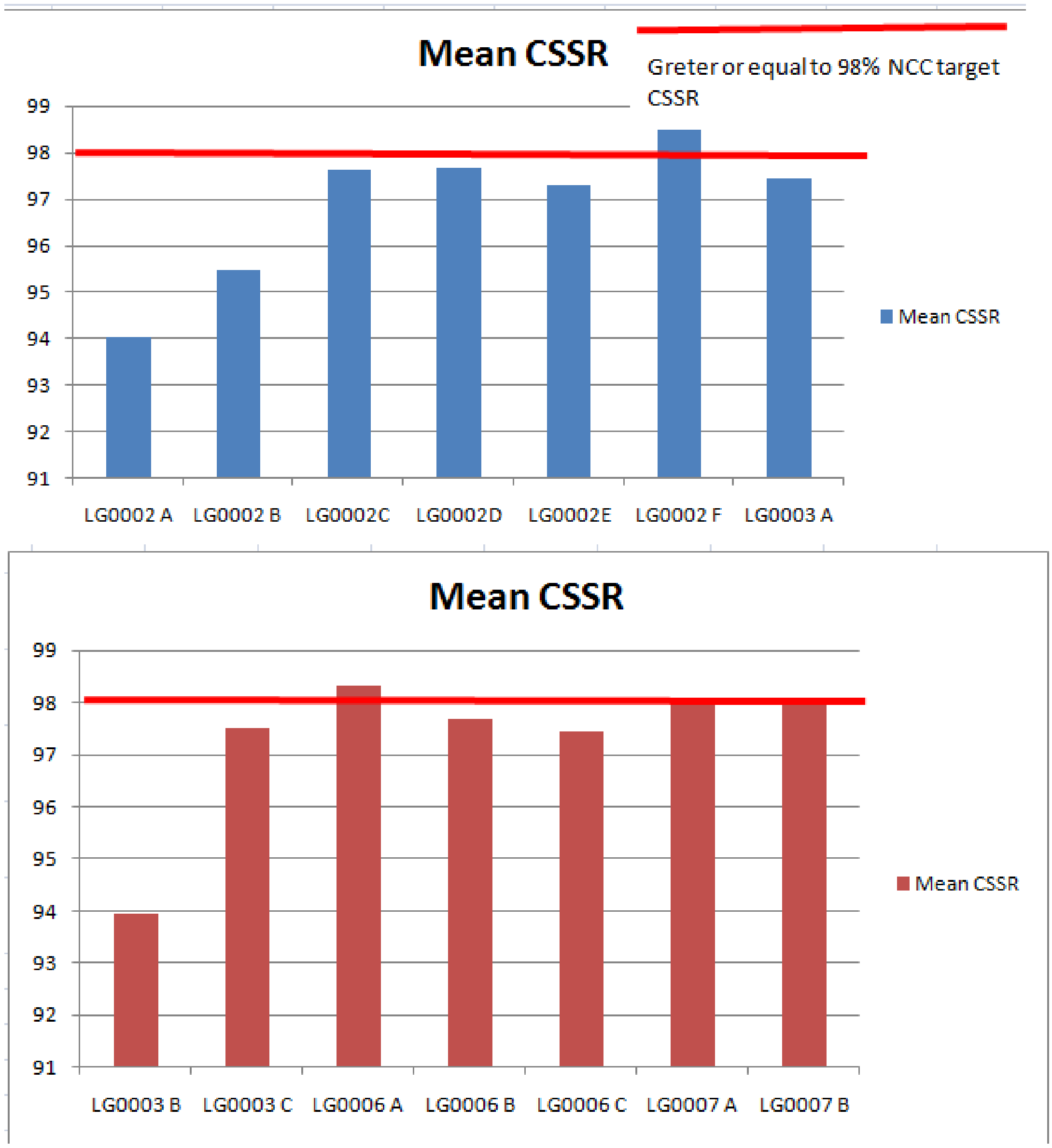

Figure 1: Mean CSSR of two clusters with NCC target indication

In Figure 1, a bar chart was plotted for clusters A and B. Again, a horizontal thick red line was drawn to indicate the NCC minimum CSSR recommended target of 98%.

In cluster B, the Call Setup Success Rate performance was improved with a reasonable bit. However, the cells of LG0006A, LG0007A and LG0007B also achieved the NCC minimum CSSR set target (NCC, 2009).

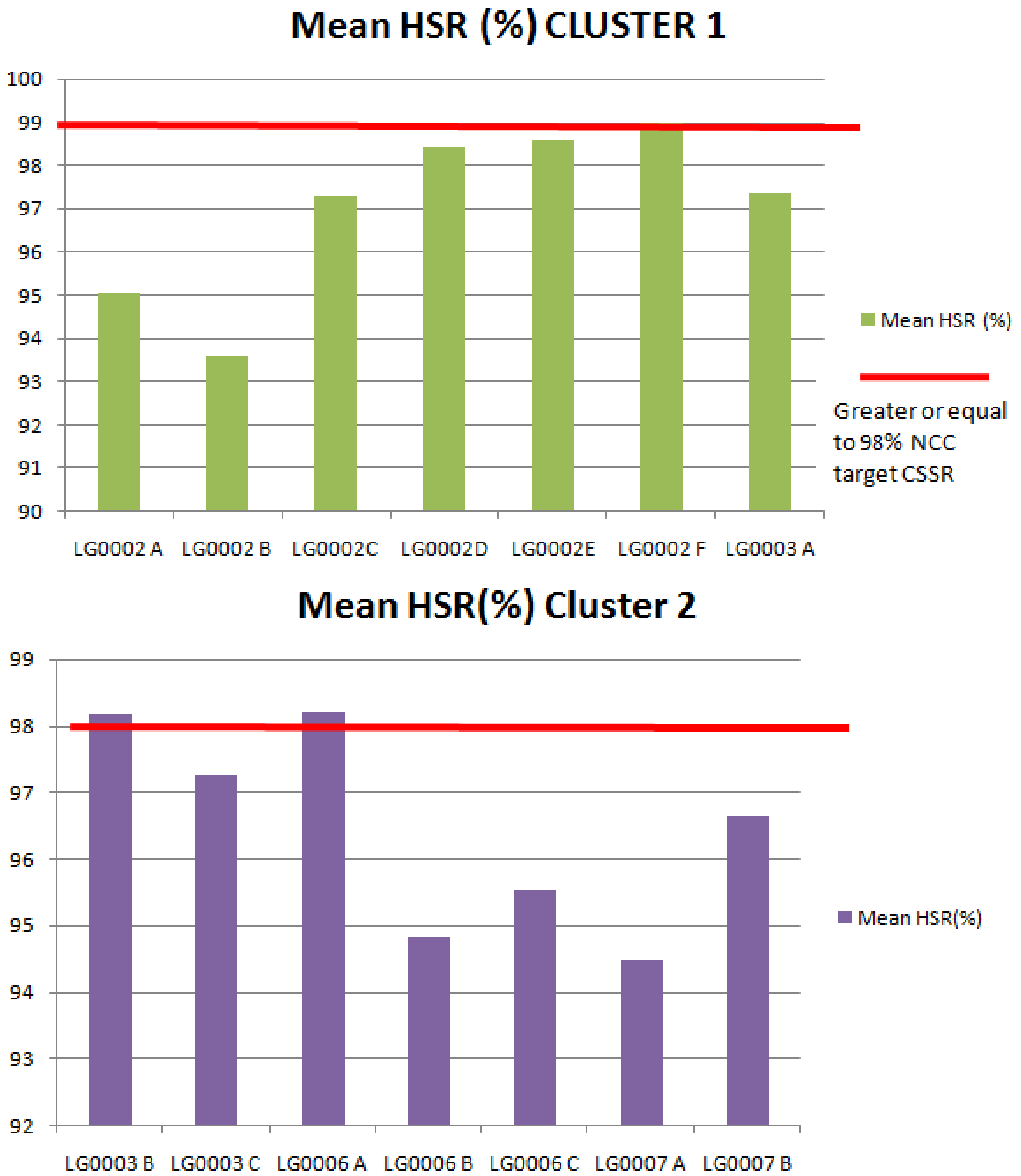

Figure 2: Mean HSR of groups 1and 2 with NCC target indication

In Figure 2, a bar chart was plotted for clusters A and B. Also, a horizontal red line was drawn across the bars to indicate the NCC recommended minimum handover target. In cluster B, only two cells of LG0003B and LG0006A were able to achieve the required minimum target of 98% (Nawaz *et al*, 2013).

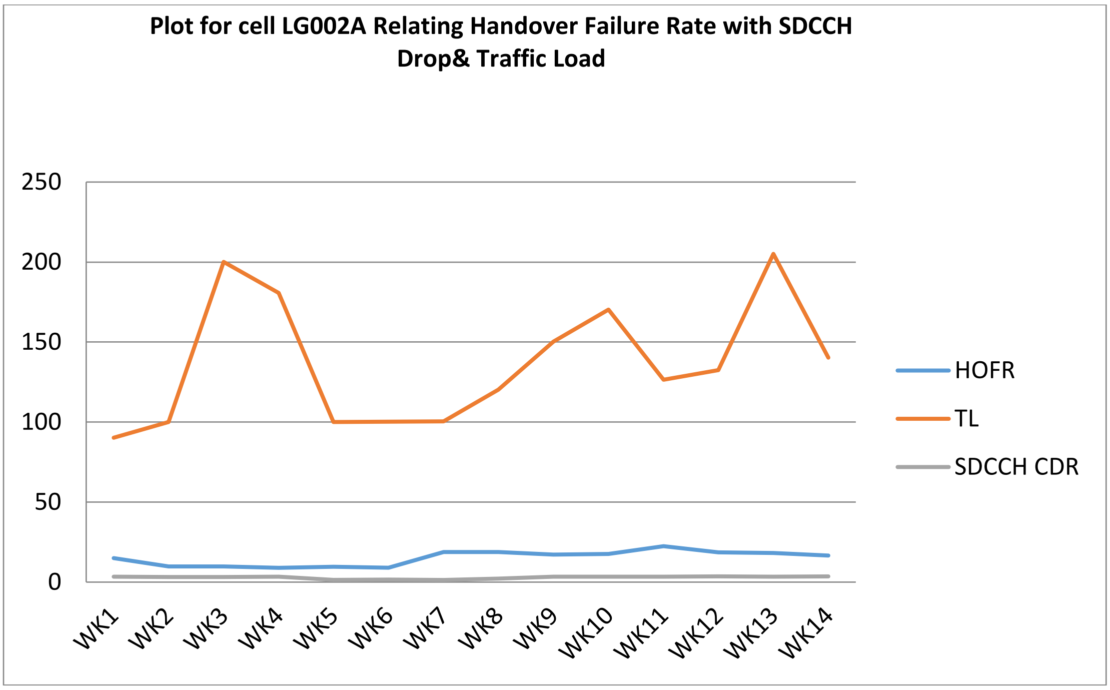

Figure 3: Graph of traffic load, SDCCH call drop and handover failure rate for LG0002A

Figure 3 shows the graph of weekly pattern of behavior for traffic load, standalone dedicated control channel call drop and handover failure rate. The graph has indicated a high standalone dedicated control drops which translated into a substantial revenue loss by the operator. The situation gave rise to congestion which lead to degradation of handover performance and also affected the quality of service negatively. This indicated that the weekly mean traffic load was high and the handover failure rate was proportionally high.

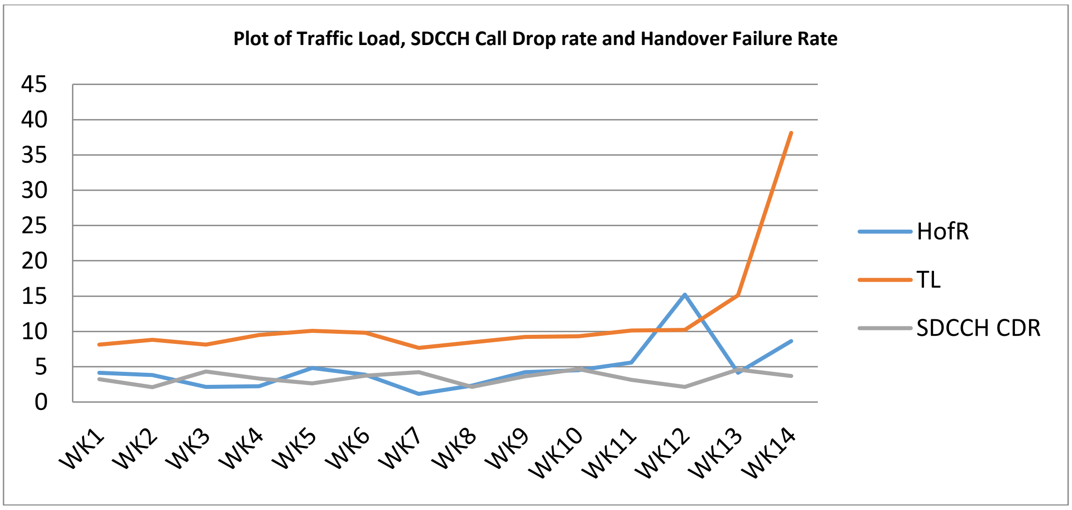

Figure 4: A Graph of traffic load, SDCCH call drop rate and handover failure rate for LG0003A

Figure 4 shows the graph of behavioral pattern of traffic load, standalone dedicated control channel call drop rate and handover failure rate. It was observed that there was an increase in traffic load which produces a corresponding increase in handover failure rates at the same time. This indicated that the mean standalone dedicated control channel blocking probability was poor with a high failure rate [12].

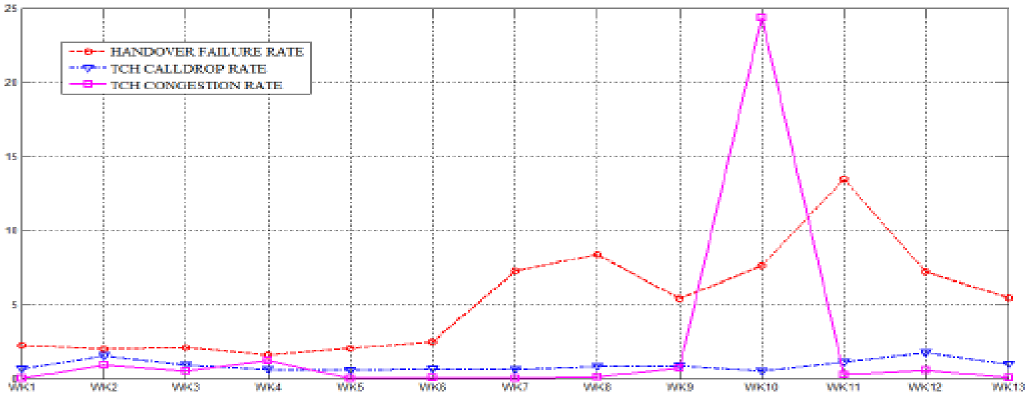

Figure 5: Weekly Behavioral Pattern of Traffic Channel Drop, Congestion and Handover Failure

In Figure 5, the traffic channel call drop and Congestion are presented graphically alongside handover failure rate. With zero congestion, call drop on traffic channel was minimal until congestion begins to build up and call drop in traffic channel increased. It was observed that increase in traffic channel call drop produced a corresponding increase in handover failure rate most of the time. In week nine the system suffered from unusually high congestion in the system and handover failure rate was observed to be equally high and rising between week 9 and week 12.
This indicates that poorly performed handover procedures can lead to congestion which degrades Quality of Service (QoS). Again, traffic channel call drops are large due to inter-cell handover failures [13].

Figure 6 presents computed traffic channel call drop, traffic channel congestion and handover failure rate for weekly behavioral patterns. It was observed that in week eleven there was steady sharp rise in handover failure while in week 12 there was a steep decline which led to a fault condition in week eleven. It was also observed that during week 11 handover problems which could have been due to hardware fault corresponds to increase in traffic channel congestion and traffic channel call drop was recorded showing the negative effect of handover failure. It was also observed that traffic channel call drop and handover failure rates are directly proportional. Hence, increase in handover failure rates produces a corresponding increase in traffic channel call drop rate.

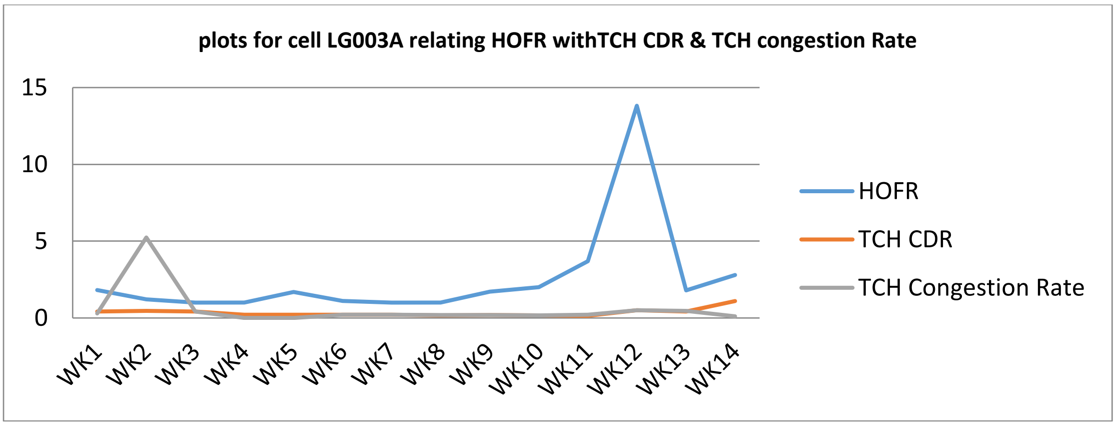

Figure 6: Plot for Cell LG0003A Relating Handover Failure Rate, TCH Call Drop and TCH Congestion

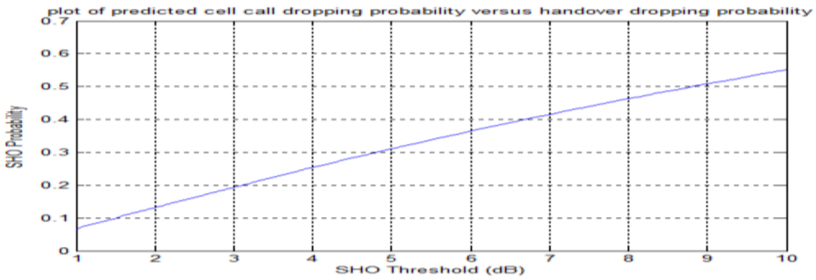

Figure 7: Predicted cell call dropping probability versus handover dropping probability

Figure 7 shows the graph of predicted cell call dropping probability versus handover dropping probability. The graph presents a linear relationship between handover dropping probability and call dropping probability. It was observed that the average call drop rate per cell was more than 6% which means that at least six out of every hundred calls were dropped due to handover rate.

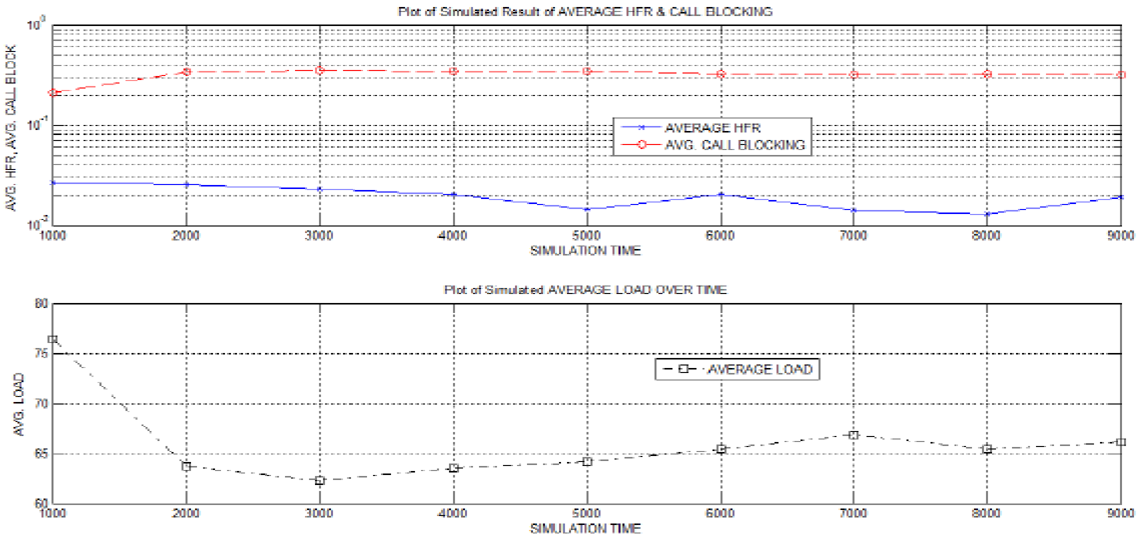

Figure 8 (a and b): Graph of simulated results for average handover failure rate, call blocking and load

Figure 8 (a and b) shows the graph of simulated results for average handover failure rate, call blocking and load. It was observed that data load and simulated loads are non-uniform. It was also observed that average handover failure rates were less than those analyzed data obtained from the system.

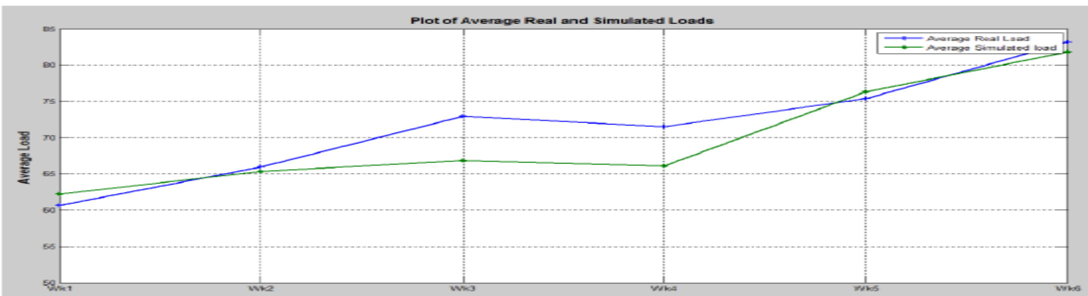

Figure 9: Plot of average real and simulated loads.

Figure 9 shows the graph of real average loads against simulated loads. It was observed that the graph shows a lot of similarities at various points and their dynamic nature. A correlation coefficient of 0.9122 was calculated using MATLAB which is quite significant and indicates that the two loads are virtually the same except for minor errors.

4. Conclusion

System validation was achieved by comparing the real and simulated load characteristics which have similarities. The evaluation revealed that seventy-two percent (72%) of cells considered performed below NCC targets for Call Setup Success Rate (CSSR), Sixty-four percent (64%) failed to achieve Handover Success Rate (HSR), Sixty-four percent (64%) failed to achieve Standalone Dedicated Control Channel blocking rates targets, twenty-one percent (21%) failed to achieve congestion targets and the average call drop rate per cell was predicted to be six percent (6%). The algorithm initially gave priority to handover by reserving some channels exclusively for handover and dynamically alters it with a view of getting minimum handover failures. However, an average of ninety percent (90%) performance improvement was realized after comparing the real handover failure rates per cell from the simulation. This is a better result taking into consideration the obtained data. Seventy-two percent (72%) of the cells did not achieve the NCC recommended standard for handover success rate (>=98%), while the simulation results showed only an average of twenty percent (20%). Simulation system validation was achieved by comparing properties and values of simulated load and load obtained from data.
Call Setup Success Rate (CSSR) is a critical parameter in evaluating the network accessibility and retain ability perceived by subscribers. Handover Success Rate (HSR) indicates the success of handovers. Again, the system will normally initiate handover when the signal strength is 102dB below which the call is handover or dropped.

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