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Analysis and Evaluation of Intercell Vertical Handoff for 4G Networks using NCC Key Performance Indicators

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Abstract

This work presents a cogent framework to inspect the performance of a network call handoff based on Nigerian Communications Commission (NCC) key performance indicators for 4G. To quantify the performance of a network handoff, the call setup success rate and handover success rate were used to analyze the network performance. The ever-increasing demand for handoff decisions on mobile communication network especially as the volume of the network users increase leads to this work. The traditional means where the handoff is performed on the basis of the evaluation of signal strength are not enough. They do not take into consideration various mobile users attachment options such as the current context or the attachment of the user option. The mathematical model for the mean Call Setup Success Rate (CSSR) and mean Handover Success Rate (HOSR) were adopted to evaluate the network handoff performance. The probability threshold interval medium is assigned to characterize the defect in vertical handoff decisions that is made under uncertain information conditions. The accuracy of vertical handoff decisions which is based totally on the CSSR and HOSR were evaluated. These was done by benchmarking with NCC key performance indicators for 4G network and the evaluation was carried out using Microsoft Excel. These analytical results are applied to examine the performance of the vertical handoff model between any two base transceiver stations. Finally, we recommend an improved performance of the HOSR and CSSR in order to enhance the call handoff of a network.

Keywords: Base station, Heterogeneous network, Horizontal handoff, Vertical handoff

1. Introduction

In future generation wireless networks, one of the challenging areas is continuous service for the mobile moving in an area where there is overlapping of networks (Ukoima *et al*., 2019). The aim of any future generation cellular network is ubiquitous connectivity to every user at anytime and anywhere. In the recent past, some research work has been focused on the issue of mobility management process in heterogeneous wireless systems (Cavalcanti *et al*., 2005; Imad *et* al., 2016; Adnan and Hilles, 2017; Akpiri *et al*., 2019). When a mobile user equipment is in continuous motion, there is a need for handoff to be performed from one network to the other network, keeping in view, the requirement of the user in future. Handoff mechanism is concerned with the idea of changing over the channels linked with the current connection when a call advance. Vertical handoff is most conspicuously used approach to guide continuing call between several networks possessing different air interconnection method during internetwork movements (Paul, 2013). Handover is a procedure and manner of diverging the mobile device services in a network to a new network with a higher signal strength. The Mechanism of handoff assist in choosing the most suitable network to by which the user is connected after the initiation of handoff (Sen, 2010; Amit and Sujata, 2014). This work is focused on designing and implementing many new algorithms with the aim of providing the required quality of service (QOS) required over a wide and extensive range of applications. The heterogeneous networks are exploited by many users by reason of proclivity given to several QoS parameter acting as real time bit error rate (BER). Vertical handoff is imperative for better execution and high availability bases. The main parameter like potential of the network, latency of handover, price of the network, and prevailing conditions in the network, user proclivity and power utilization are to be examined during vertical handoff (Galadima, 2014).

The handoff mechanism is made up of four different stages: handoff initiation, handoff decision making, network selection, and implementation of handoff process (Udo *et al*., 2021). Handoff mechanism could be classified into horizontal handoff and vertical handoff which are shown diagrammatically in Figure 1. Horizontal handoff is a system where the handoff is executed between two networks with the same technology, while vertical handoff is the handoff between networks having non-identical technology and different architecture which are mostly used handoff mechanism (Avinash *et al*., 2010; Amitav, 2014). This work however stressed on the phase of handoff decision making, where the emphasis is laid on the decision by which the best network amongst all the available networks is been selected. TOPSIS algorithm based on the concept of Multiple Attribute Decision Making (MADM) will be adapted to select the best network and redirect the connection to the mobile terminal.

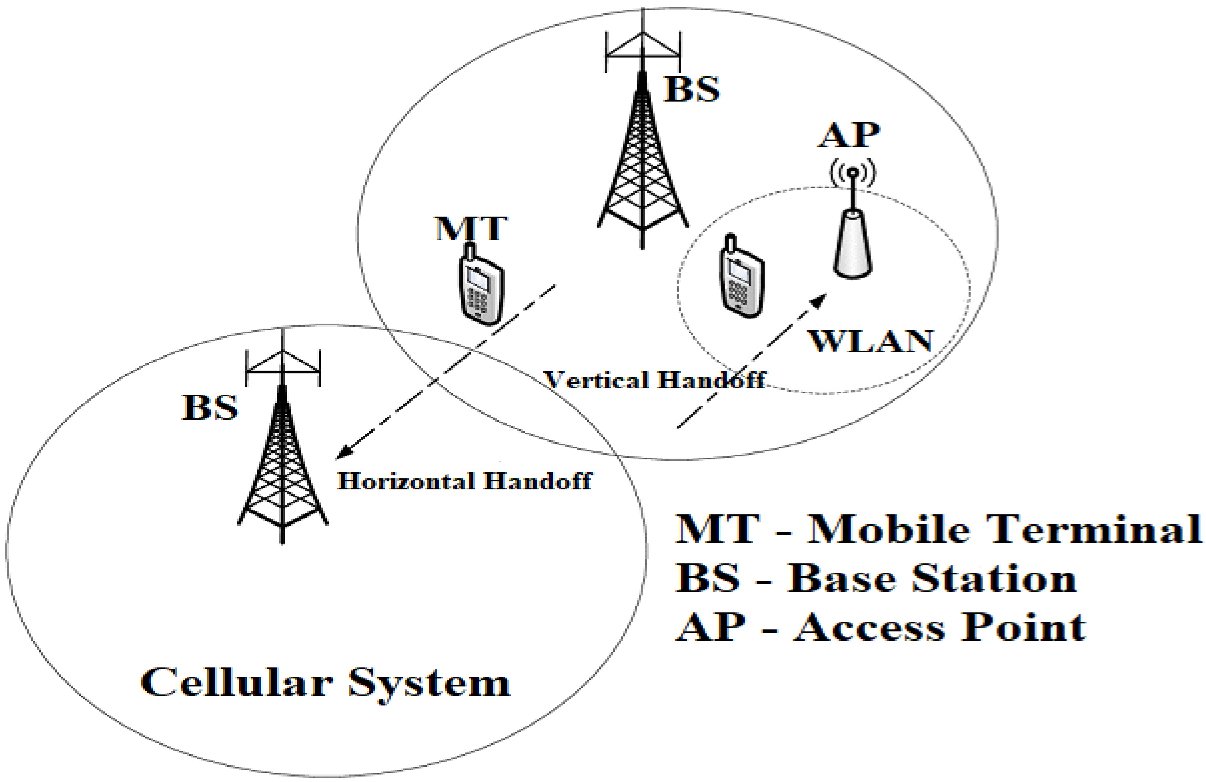


Figure 1: Horizontal and Vertical Handoff (Avinash *et al*., 2010)

Furthermore, vertical handoff could be categorized into two types such as upward handoff and downward handoff; as well as soft and hard handoffs. Based on the area of coverage, target and home networks; vertical handoff is categorized as downward and upward vertical handoffs. If the switching of the mobile is from a small coverage area to a large coverage area network, it is termed as upward handoff. On the other hand, if switching is in the reverse direction, *i.e.*, from a larger coverage area to a smaller coverage area network it is termed as downward handoff. Likewise, the vertical handoff procedure where a mobile intersection connects with the new base station after getting disconnected from the preceding base station is known as hard handoff. Additionally, in soft handover a mobile intersection keeps the connection with the antecedent base station until its connection with the new base station is rounded off. This approach is also known as make before break and the mobile intersection keeps simultaneous connections with both the base stations during the short-term period. Soft handoffs are preferable when compared to hard handoffs as they usually terminate the issue of service interruption (Mandeep and Sanjay, 2011).

Many algorithms on handoff decision have been proposed by different scholars in the past. According to Navarro and Wong, (2006), a comparison carried out among several algorithms such as Grey Relational Analysis (GRA) and Multiplicative Exponent Weighting (MEW), Simple Additive Weight (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for determining when to carry out a vertical handoff. A fuzzy Multiple Attribute Decision Making (MADM) applied in vertical handover decision is formulated by Attaullah *et al*., (2008). Savitha and Chandrasekar, (2010) discussed vertical handover decision strategy to avoid the processing delay which uses the MADM method. Liu *et al*., (2010) worked on an algorithm to cause a trust handover decision and to decrease processing delay period in a heterogeneous wireless environment using simple additive weight method with a Distributed Vertical Handoff Decision (T-DVHD). Onyishi *et al.*, (2013) carried out the performance assessment of handover medium exchange plan in GSM network. The results as exhibited show increase in the probability of handover failure which was obtained through the use of medium exchange as against that of no medium exchange gotten from the GSM network. Galadima *et al*. (2014) presented analysis and enhancement of inter cell handover methods in a GSM network. The result displayed that handover failure rate was decreased by an average of ninety percent (90%) for changing loads. All these scholarly works mainly lay their emphasis on the handoff decision making and computing the criteria for handoff decision making on the mobile terminal, the proposed algorithms are focused on reducing the delay due to processing by doing the required computations using MADM in a distributed manner. Keeping view to all these methods, this work thereby presents an algorithm to examine and select the best network amongst respective visitor networks for the vertical decision schemes.

2.0 Material and methods

Some of the materials deployed are edge router, webserver, laptop, while the equipment utilized are a Base Transceiver Station (BTS), General Packet Radio Service (GPRS), Transmission Control Protocol (TCP). The method applied is as described in the experimental set up in Figure 2.

2.1 Experimental Setup

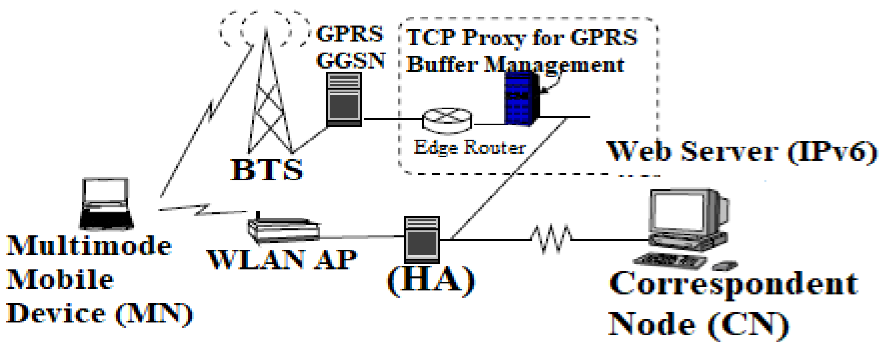


Figure 2: Experimental Test bed using TCP proxy

This section, describes a setup of experimental test bed. In Figure 2, a Mobile-IPv6 based LAN-WLAN-GPRS test-bed was setup. In this test bed, the cellular GPRS network infrastructure currently in use is a Nigerian network provider (NP) GPRS network. The WLAN access points (APs) are IEEE 802.11b APs located at different locations of the NP Computer Laboratory, for Communication Engineering. The GPRS infrastructure is made up of base stations (BSs) which are channeled to the Serving GPRS Support Node (SGSN) and then connected to a Gateway GPRS Support Node (GGSN). In the current network configuration, both SGSN and GGSN node is co-located in a single Combined GPRS Support Node (CGSN). A well fitted Virtual Private Network (VPN) links the lab network to that of the NP backbone through an IPSec tunnel over the public Internet. A separate operator-type. RADIUS server is equipped to authenticate GPRS mobile users/terminals which is also assign IP addresses. For access to the wireless test bed, mobile nodes (e.g. laptops) link to the local WLAN network and also concurrently to GPRS via a personal computer card modem. The mobile node's MIPv6 execution is built on that established by the MediaPoli project, chosen for its comprehensiveness and open source nature.

The user equipment switched on; it should detect the available network. The network is screened and the appropriate signal is detected. If the signal detected is strong it should be boasted. If not, it should continue to search for the targeted network from the current network. Moving from a cell to another it should executed handoff or reject it.

2.2 Handoff Key Performance Indicators

Call setup failure rate: This refers to the amount of the blocked call attempts divided by the total amount of call attempts. It can equally be referred to as the Blocking Probability and expressed in percentage. (Shoewu & Edeko, 2011):

$$\text{Call setup Failure Rate} = \frac{\text{Number of Blocked calls}}{\text{Number of call attempt}} \times 100 \quad (1)$$

$$\text{Call Setup Failure Rate} = 1 - \text{Call Setup Success Rate} \quad (2)$$

Call drop rate: The Call Drop Rate (CDR) is the amount of dropped calls divided by the total amount of call attempts:

$$\text{CDR} = \frac{\text{Number of Dropped calls}}{\text{Number of Call Attempts}} \text{ x } 100 \quad (3)$$

CDR = 1 - Call Completion Ratio (4)

A dropped call is a call that is precipitately stopped before being released typically by either the caller or called party.

Traffic channel availability (TCH): The traffic channel is that channel used by mobile station for communication. Traffic channel availability is a measure of congestion of the traffic channel measured at the busy hour (Tawil *et al.*, 2008):

$$\text{Traffic Channel Availability} = \frac{\text{Busy Hour TCH Traffic (Erlang)} - \text{Average TCH Traffic (Erlang)}}{\text{Busy Hour TCH Traffic (Erlang)}} \times 100 \quad (5)$$

Therefore, Handover Failure Rate = 1 – Handover Success Rate (6)

Also, in a Base Station Controller (BSC) and Base Transceiver Station (BTS) handover rates can be expressed as:

$$\text{HSR}_{\text{BSC}} = \frac{\text{HO}_{-\text{succBSC}}}{\text{HO}_{\text{succBSC}} + \text{HO}_{\text{unsucc\_R}} + \text{HO}_{\text{\_unsucc\_L}}} \quad (7)$$

Where;

HSRBSC is handover success rate

HOsuccBSC is successful intercell handover in a BSC

HOunsucc-R_ is unsuccessful intercell handover with reconnection per BSC

HO_unsucc_L is unsuccessful intercell handover with loss of connection per BSC

$$\text{HSRCELL} = \frac{\text{HO}_{-\text{succeout}}}{\text{HO}_{-\text{total}}} \quad (8)$$

Where;

HSRCELL is successful intercell handover per cell

$HO_{succout}$ is successful outgoing handover per cell

HO_{total} is total outgoing handover per cell.

2.3 Analysis of Handover Algorithm

To analyze handover algorithm based on signal strength, a two base station model shown in Figure 3 is assumed for simplicity. The model has two base stations, BTS1 and BTS2, separated by D meters. Mobile station (MS) is moving from BTS1 to BTS2 with constant speed. The signal level received from two BTSs (in dB) at a distance, d from BTS1 can be expressed mathematically as follows (Sanjay, 2009):

$$P_{rx1(d)} = K_1 - K_2 log_{10}(d) + y_1(d)\,) \quad (9)$$

$$P_{rx2(d)} = K_1 - K_2 log_{10}(D - d) + y_2(d) \quad (10)$$

Prx1(d) and Prx2(d) are received signal from BTS1 and BTS2 respectively at a distance d meters from BTS1. Rayleigh fading is neglected since it has shorter correlation distance compared to shadow fading. K1 and K2 are due to path losses. K2 is actually 10n, where n is path loss component. If K1 = 0 and K2 =30. x1(d) and x2(d) are two independent zero mean stationary Gaussian processes. Hence received power from BTSs can also be considered to be Gaussian processes with mean, μ1= K1 – K2 log(d) and μ2= K1 – K2 log(D-d) respectively. x1(d) and x2(d) are assumed to have exponential correlation proposed by Gudmundson (1991) based on experimental results.

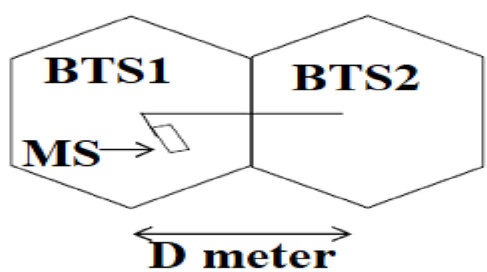


Figure 3: Inter BTS system model

When received signal from BTS1 is less than a specified value and at the same time received signal from BTS2 is more than minimum value of received signal for continuation of a call, then handover (HO) will take place from BTS1 to BTS2. Similarly condition for handover from BTS2 to BTS1 can be stated as follows.

Prx1(d) <Prho and Prx2(d) >Prmin: HO: BTS1 TO BTS2
Prx2(d) <Prho and Prx1(d) >Prmin: HO: BTS2 TO BTS1
Where Prho = Absolute value of received power from any BTS after which handover should take place. Prmin = Minimum value of received power for which call is possible. If signal strength becomes less than Prmin then there will be call drop for ongoing call and new call will not be possible.

$$Call\ Blocking = \frac{Total\ number\ of\ new\ calls\ rejected}{Total\ number\ of\ calls\ processed} \quad (11)$$

$$Handover\ Failures = \frac{Total\ number\ of\ handover\ calls\ not\ admitted}{Total\ number\ of\ calls\ processed} \quad (12)$$

$$Throughput = \frac{Handover\ calls\ admitted + New\ calls\ admitted}{Total\ number\ of\ calls\ processed}\ x\ 100 \quad (13)$$

Traffic load is determined from the number of or volume of calls intensity (λ) and Service time, but here the throughput as a rate is used as load since is the actual work done by the computer system and is also a function of time and number.

3.0 Results and Discussions

The data obtained from NCC is shown in Table 1, while the statistical mean of relevant parameters was computed and tabulated as shown in Table 2.

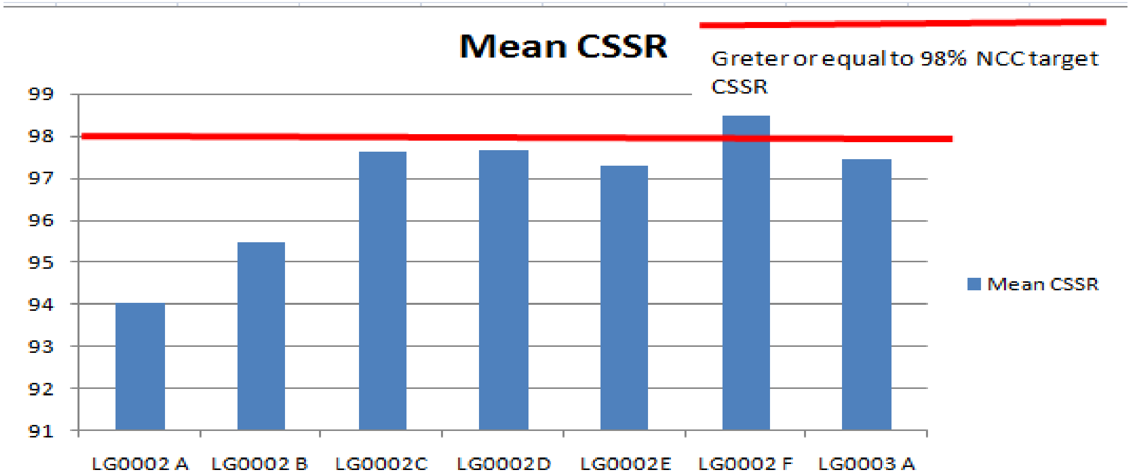
Table 1: NCC Benchmarks (www.ncc.gov)

S/NO	KEY PERFORMANCE INDICATOR	NCC TARGET
1	Call setup success rate (CSSR)	≥98%
2	Drop Call Rate (DCR)	≤2%
3	Handover success Rate HoSR	≥98%
4	Standalone Dedicated Control Channel Congestion (SDCCH Cong)	≤0.2%
5	Call Completion Rate (CCR)	≥96%
6	Traffic Channel Congestion (TCH Cong)	≤2%
7	Blocking Probability	≤0.02%

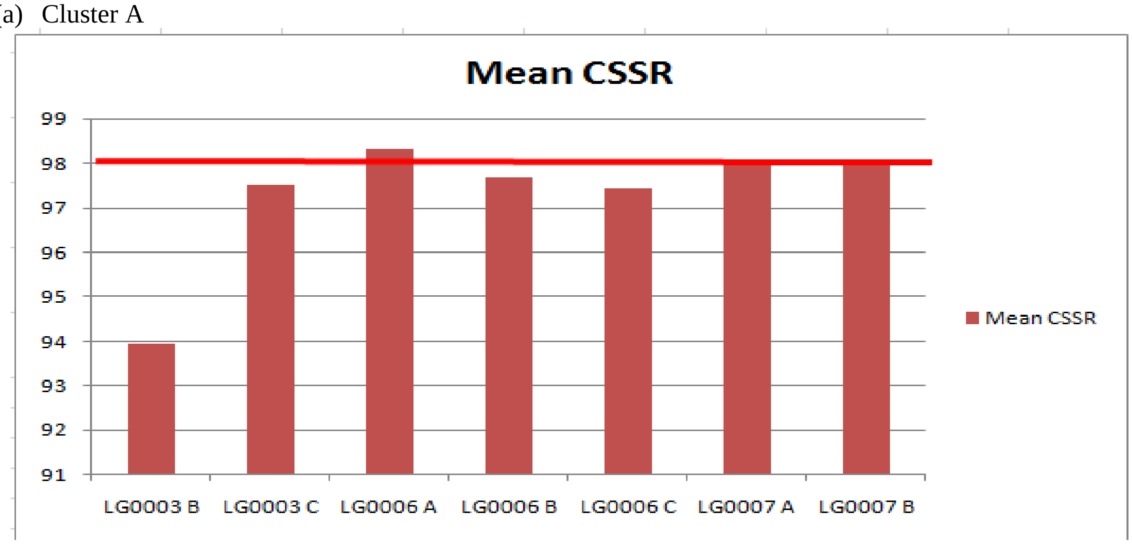
Table 2: Statistical mean for all the needed parameters

Cell	Mean CSSR	Mean Handover Success Rate (%)	Mean TCH Cell Drop Rate (%)	Mean RCH Congestion Rate (%)	Mean SDCCH Blocking Rate (%)	Mean Traffic Load (Exl)	Calls per Day	Prob. Blocking	Handover Failure Rate (%)
LG0002 A	94.024	95.057	0.917	2.204	0.977	110.443	53012.400	0.0598	4.943
LG0002 B	95.468	93.603	0.795	2.292	0.254	51.283	24616.070	0.0453	6.397
LG0002 C	97.621	97.277	0.999	1.166	0.223	41.407	19875.548	0.0238	2.723
LG0002 D	97.682	98.428	0.456	1.419	0.486	148.017	71048.191	0.232	1.572
LG0002 E	97.308	98.595	0.407	2.157	0.153	60.660	29116.643	0.269	1.405
LG0002 F	98.464	99.005	0.330	1.121	0.142	65.989	31674.730	0.0154	0.995
LG0003 A	97.444	97.376	0.306	0.452	0.043	9.957	4779.287	0.0256	2.624
LG0003 B	93.955	98.185	0.597	0.435	0.096	12.788	6138.157	0.0604	1.815
LG0003 C	97.510	97.252	0.579	0.602	0.087	71.533	34335.965	0.0249	2.748
LG0006 A	98.326	98.212	0.361	0.547	0.341	83.020	39849.496	0.0167	1.788
LG0006 B	97.694	94.817	0.568	1.102	0.369	168.382	80823.496	0.0231	5.183
LG0006 C	97.445	95.551	0.511	0.683	0.968	182.319	87512.922	0.0255	4.449
LG0007 A	98.031	94.477	0.437	0.766	0.495	85.839	41202.835	0.0197	5.523
LG0007 B	980.190	96.654	0.465	0.423	0.590	123.114	59094.887	0.0181	3.346

Call setup success rate (CSSR) is a critical parameter in evaluating the network accessibility and retain ability perceived by subscribers. From Table 2 where we presented mean call setup success rate values for all the cells in cluster ‘A’ in Figure 4 when compared with NCC targets for CSSR, only LG0002F was able to accomplish NCC point minimum of ninety eight percent (98%). This means that an average of eighty five percent (85%) did not meet the NCC target. Taking into account the fact that all call setup success rate failures are either drops or unsuccessful call set-ups, it means that drop calls are directly tied to handover dynamics. Judging from the respective cell performances, it is significant to note that retain ability of this network is highly hampered. And improvement in inter cell handover dynamics can greatly improve on these performances. On the graph, a horizontal thick red line was drawn to specify NCC minimum CSSR suggested target (98%). In the second category of seven cells (cluster B) the cells call setup success rate representation enhanced a little bit with cells LG0006A, 7A and 7B achieving the NCC minimum CSSR set target. Note that 57% of the cells in this category did not meet up. These percentages are significantly high. Improving the call setup rate will in turn improve the call handover. According to international best practices and standards it is recommended that only 5% to 10% is acceptable.



(a) Cluster A



(b) Cluster B

Figure 4: Mean CSSR of two clusters with NCC Target Indication

Handover success rate (HOSR) indicates the success of handovers. As earlier indicated the system will normally initiate handover when the signal strength is 102 dB below which the call is handed over or dropped. In Table 2 computed statistical mean of cell handover success rates was introduced among the first category of seven cells, cells LG0002D, 2E, and 2F achieved a bit above the NCC suggested minimum target of ninety eight percent (98%). It is not so remarkable due to 57% of the cells in a category of (7) performed beneath NCC suggested minimum targets. This have an adverse impact on inter cell/inter BTS handover dynamics. To qualitatively reinforce the computed results of mean handover success rates for cells as seen in Table 2, a bar chart is drawn with Microsoft Excel 2010 version. The bar chart graph is displayed in Figure 5 with a horizontal red line drawn across the bars to indicate the NCC suggested minimum handover target. In the second category of seven cells, there are only two cells (LG0003B & LG0006A) achieving the NCC suggested minimum target of 98%. This implies that 71% of the cells drop below the target. This clearly displays that a compelling number of cells are not performing as desired hence there is a compelling need for optimization.

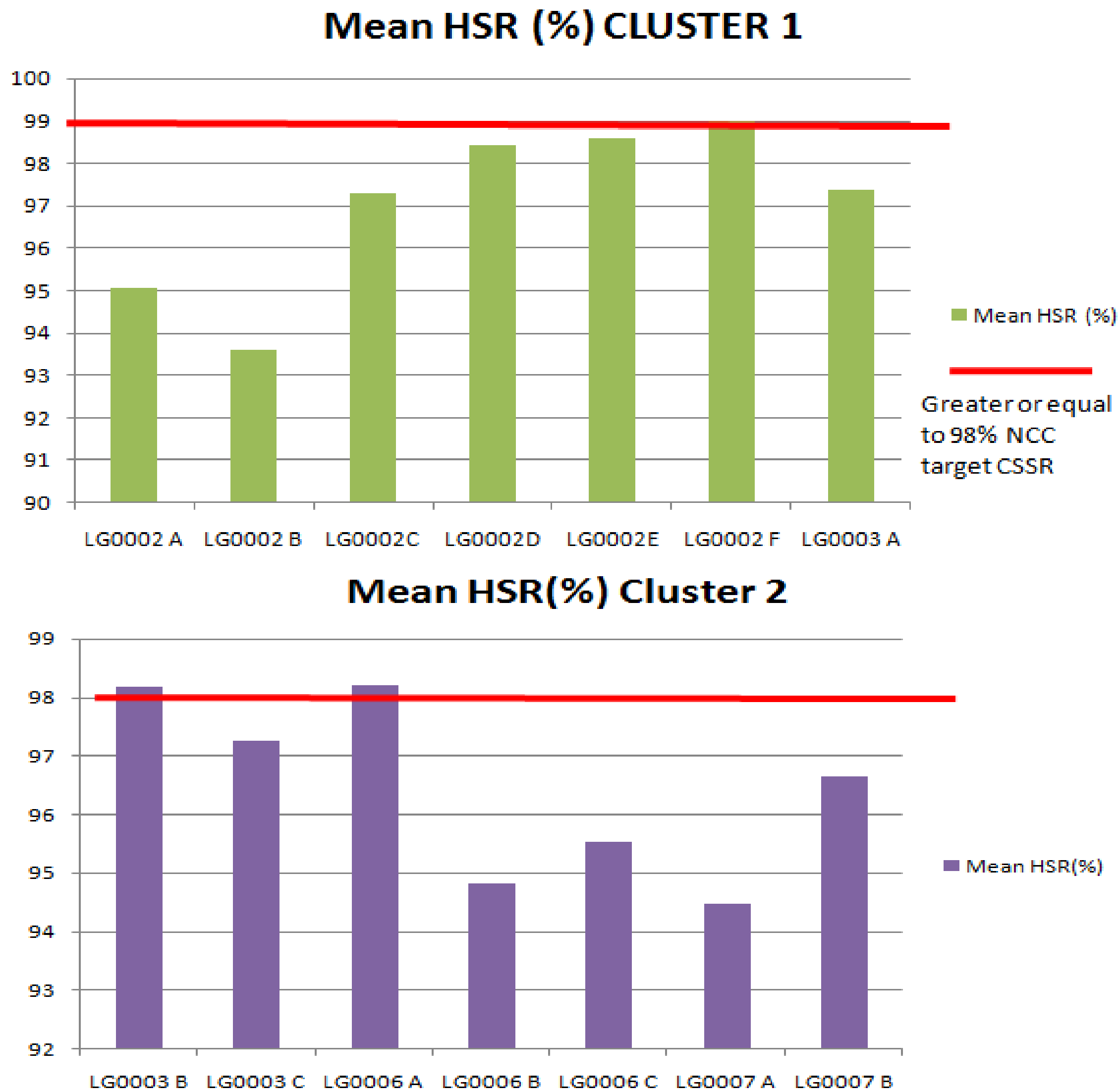


Figure 5: Mean HSR of Groups 1and 2 with NCC Target Indication

4.0. Conclusion

The research analyzed the intercell handover dynamics by profiling the performance of cells. Quality of service (QoS) key performance indicators parameters of HOSR and CSSR, were extracted, computed and analyzed using Microsoft Excel as our main tool. Evaluation by way of benchmarking with NCC suggested standards was carried out. The evaluation disclosed that seventy two percent (72%) of cells examined performed beneath NCC targets of 98% for Call Setup Success Rate (CSSR), Sixty-four (64%) failed to attain Handover Success Rate (HOSR). Improving the Call Success Rate (CSSR) and the Handover Success Rate (HOSR), will positively impact on the QoS and hence enhance the call handoff of the user equipment.

5.0 Recommendation

Further work may focus on the deployment of the simulated program in an existing network. This will necessitate development of architecture to execute this and similar program. The dynamics of intra cell handover maybe analyzed with the view of analyzing its impacts on QoS.

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