EVALUATING THE EFFECT OF FIFO QUEUING SYSTEM ON ORIGINATING AND HANDOFF CALLS

by

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DECLARATION

I hereby declare that this submission is my own work towards the M.Sc. Telecommunication Engineering and, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

I would like to dedicate this thesis to my parents, Mr Y. Sayawu and Hajia M. Sayawu, my late friend Muhammad Noordeen Muhammad Lawal and the entire family for their love, support, and sacrifice along the path of my academic pursuits.

ABSTRACT

In cellular networks, there exist fixed and dedicated channel for the entire duration of a set up call. The signal strength and interference at various locations differs within a cell and this affects the quality of the on-going call including handoff calls. This may require the transfer of the on-going call to another cell with a better signal strength. Given a fixed channel at a cell site, and assuming the arrivals of originating calls and handoff requests to be Poissonian, either process could result in queuing. This thesis by using Matlab seeks to evaluate in terms of probability of blocking, which queuing system is more suitable when either or both priority are given and when no priority is given. It is observed that, for cell sites with traffic intensity to channel ratio of 0 – 0.75 which is considered as not congested, a system of either queuing the originating calls or the handoff calls can be employed. For a congested system in which the traffic intensity to channel ratio is 0.76 – 1 there should be separate queuing of both the originating calls and the handoff calls. When the cell site is very congested that is, having a traffic intensity to channel ratio of greater than 1, queuing of handoff calls provides the best network optimization.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

The exponential growth of mobile communications has led the exploitation to achieve an efficient use of the scarce spectrum allocated for cellular communications. In the cellular system, a geographical area is divided into cells, a cell is defined as the geographic area within which mobile subscribers (MS) can communicate with a particular base station (BS). Each of these cells has a base station, these base stations provides radio reception for a closely defined area and also provides access for the mobile station to a backbone wired network. When MS moves across a cell boundary while maintaining it call, the channel in the old base station (BS) is released and an idle channel is required in the new base station (BS) [1] to keep the call. The process of transferring control of MS from one BS to another BS without interruption of service is known as *Handoff* or *Handover* [2], [3], [9],[15], [24], [34], [36], [44], [46], [49],[51], [56]. Handoff or handover is primarily of two types, namely, the hard handoff and the soft handoff [4], [24],[37],[47]. Hard handoff is referred to as “Break before Make connection”. The MS is connected to only one BS at a time. Soft handoff refers to as “Make before Break connection”. It is possible that, an MS may be in connection with more than one BS at a time [34], [41], [47].

With the hard handoff, channel transfer is between two frequencies. In transition from cell to cell, the frequency connections from the old station are dropped gradually before connections are established in a new cell, this occurs within a short duration. For the soft handoff, the transfer is between two code words. Two secure code channels are needed for the handoff process. This reduces the call capacity; however, the call drop rate is reduced due to this switching method. Primarily, there are two types of calls in a mobile communication; new calls or originating calls and handoff calls or ongoing calls. New calls are defined as calls that the mobile user springs up to enter the network and start a call, whilst handoff calls are referred to as the ongoing calls that are transferred from one cell to another in order to prevent the termination of those calls (e.g. a mobile user in a moving car) [5], [9], [15].The latter is critical in cellular communication systems because neighbouring cells are incessantly using a disjoint subset of frequency bands, so negotiations must take place between the mobile station (MS), i.e. the current serving base station (BS) and the next potential BS [24] which could be the targeted cell or the adjacent cell.

Handoff is regarded a very vital prospect in wireless cellular communication due to the mobility it grants to users by allowing MS to move around while keeping an ongoing call or session on a terminal [7]. The changes of channels on account of handoff may be through a time slot, frequency band, codeword, or combination of these for time-division multiple access (TDMA), frequency-division multiple access (FDMA), code-division multiple access (CDMA), or a hybrid scheme, respectively [2].

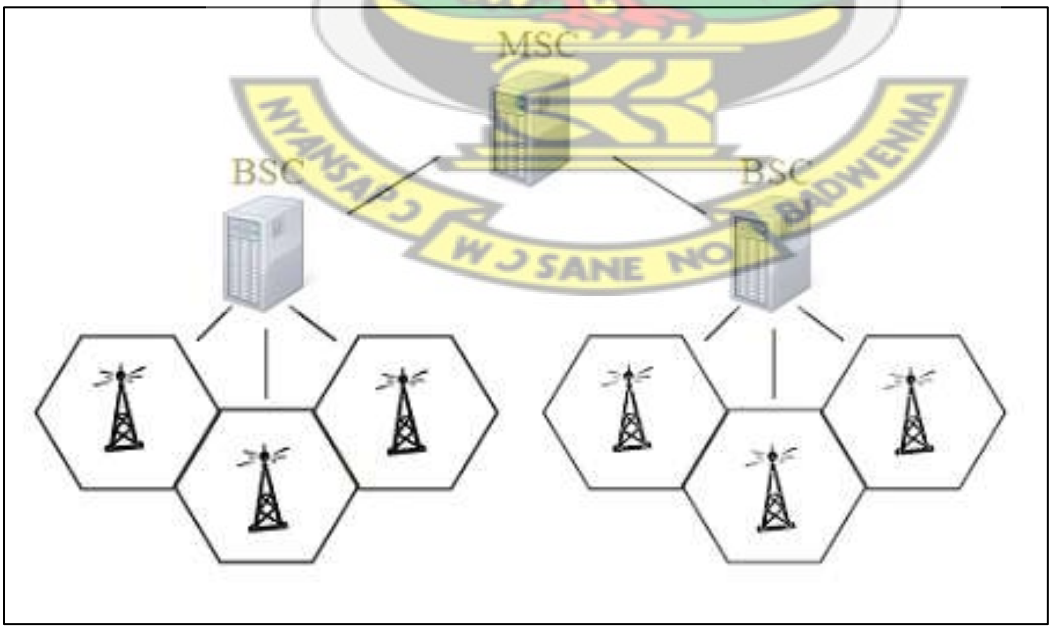

Fig 1.1: Basic concept of handoff

Handoff could as well be classified into horizontal handoff and vertical handoff. Horizontal handoff is linked with the movement of MS from one cell to another of the same system e.g., global system for mobile communication (GSM). Vertical handoff [8] refers to the movement of MS from one cell of a system to another cell of a different system e.g., GSM and wireless local area network (WLAN). Handover procedure can be carved up into *Initiation* and *Execution* phases. The initiation phase is based on various criteria's such as signal to interference ratio (SIR), received signal strength (RSS), bit error rate (BER), distance, and velocity. It is assured if MS receives signal from BS other than it serving BS then quality of service (QoS) will be better or not. In the best case, handover should rely upon path loss and to some level on shadow fading [34].*Bandwidth Utilization*, *Call Blocking Probability*, and *Call Dropping Probability* are the three fundamental metric for measuring quality of service (QoS).

Originating calls are blocked if the root cell cannot provide sufficient bandwidth .The call blocking probability (CBP) refers to the probability of a new call to be refused a channel by the root cell. But then, a handoff request is put forward to the target cell or the adjacent cell for an on-going call, if the root cell no longer has enough bandwidth to maintain the call or when the signal strength of the targeted or adjacent cell is stronger than that of the root cell. However, if the target cell also has deficient bandwidth for continually providing service, the on-going call is dropped. The probability of freezing off a handoff request due to the insufficient bandwidth is called call dropping probability (CDP). Dropping of an on-going call is unbearable to the users than blocking a call that is yet to be established [17], [42],[43].

This thesis attempts to compare in terms of probability of blocking, which queuing system is more suitable for the various telecommunication networks cell sites in Ghana by separately analysing queuing of originating calls and queuing of handoff calls.

1.2 Research Problem

The bottleneck at the base station controller (BSC) in allocating channels amongst originating calls and handoff calls remains vital and must be resolve in cellular communication, an allocated channel remains to a mobile user until, either its call is completed in the cell or it crosses the cell boundary, requiring a new channel frequency to continue. An originating call in a cell and likewise a handoff call seeking for channel may be blocked and cleared up from the system, if all the channels portioned to the related base station are all in use. This means, both the originating calls and the handoff calls are blocked/dropped once the target cell and the adjacent cell does not have resource to serve the call connection. In order to reduce such forced call termination, call arrivals (new calls and handoff calls) have to be treated differently, which leads to the call admission control (CAC) and resource management in wireless cellular networks [45]. The new calls are those ones, which are just starting, and handoffs calls are those calls already ongoing but have moved onto a new cell and need to connect to a new base station [33].

Though many researches' has been carried out in this area, they are largely conducted in advanced countries where the weather conditions , the terrain, the contour of the earth and so on are totally different from that in Africa particularly West Africa and in Ghana as well. However, the competition for channel access by handoff requests and originating calls results in call drops, this is undesirable to a subscriber. Nevertheless, there is no any perfect system so far available in tackling this bottleneck. Appropriate systems which are suitable in managing this bottleneck are made available in this thesis, thus the need for this research.

1.3 Motivation

The queuing of the blocked handover attempts, along with the use of guard channels, has been proved to be an efficient technique for the optimization of the call forced termination probability. However, there are several drawbacks in using guard channels. One is the waste of channels in a typical residential area where the handover traffic load is low [14].

According to this technique, if a handover attempt finds all channels in the target and adjacent cell occupied, then it can be queued. When a channel is released in the cell, it is assigned to the next handover call waiting in the queue, if any. If more than one handover calls are in the queue, the first-in- first-out (FIFO) queuing discipline is used. Assuming that the queue size is finite, a handover call attempt that finds the queue fully occupied, will fail and drop by the system [25], It has been found that due to varying speed of different mobile units, the received signal strength (RSS) at the base station changes at different rates, so FIFO queues are unsuitable for managing handoff calls [28]. This brands the analyses of the queuing methods in cellular communication networks very important.

1.4 Objectives

The main objective of this thesis is to evaluate the probability of blocking, by analysing queuing of originating calls and also queuing of handoff calls to determine the best queuing system which provides effective and efficient system performance under varying network conditions.

1.4.1 Specific Objectives

The specific objectives of this thesis are to analyse the following scenarios;

a. Handoff performance when there is queuing system of the handoff calls.

b. Handoff performance when there is a queuing system of the origination calls.

c. Originating call performance when there is a queuing system of the origination calls.

d. Originating call performance when there is a queuing system of the handoff calls.

1.5 Project Scope

This thesis only considers the GSM system in Ghana. According to the author of [50], queuing of handoff is more effect than two-threshold-level handoff. The MSC will queue the handoff call requests instead of rejecting them when the available channels on the new cell site are busy. This is effective only when requests come in batches. However, this thesis seeks to analyse the performance of the various telecommunication networks cell sites in Ghana in terms of the best queuing method to be employed.

1.6 Outline of the Thesis

This final section of the first chapter presents the layout of the rest of the thesis, organized into four further chapters as follows:

Chapter 2 will be the literature review, where will focus on the related works in this field, particularly with regards to queue in cellular networks to put into perspective current developments and future outlooks.

Chapter 3 will describe the considered system model and the methodology.

Chapter 4, here the assessments of the methods described in chapter three are presented and demonstrated by means of simulation.

Chapter 5, in this chapter, conclusions will be drawn and the necessary recommendations which could lead to future research work will be presented.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Wireless cellular networks go through the handoff phenomenon, in which a call already in progress in a cell due to user mobility is handed over into another cell [27]. The recent scarcity of bandwidth over the air and the rapid widespread of wireless cellular networks in recent years and has seen substantial attention in the literature. In these dimensioning models it is a common assumption that calls arrival processes are Poisson. Where call service time distributions and cell residence times are typically permitted to follow arbitrary distributions due to the well-known insensitivity property of loss queuing systems. However, an important proportion of cellular system operation models also are the handoff call strategy, or how the new and handoff calls are treated in terms of channel assignment [3].

Due to the varied nature of factors such as cell population, cell residency times, cell overlap areas, call holding times, handoff arrival rates and distribution systems; much research is being done to improve handoff performance.

This chapter briefly reviews some concepts of handoff in cellular networks and takes up the literature related to handoff. The intent is to spotlight the overall methods and future trends in how cellular networks deal with handoff

2.2 State-of-the-Art

V. H. Mac Donald showed in 1979 shows how cellular systems operating within a limited block of frequency spectrum can meet the objectives of a large scale mobile telephone service designed with attention to cost restraint. The paper explored the key rudiments of the cellular concept frequency reuse and cell splitting and draws certain mathematical properties of hexagonal cellular geometry. A description of the basic structure and features of the advanced mobile phone system (AMPS) shows the cellular concept can be put into practice. In [4], focus was mainly on CDMA systems unlike this research which is focused mainly on the GSM system in Ghana. The paper shows the positive effects of the soft handoff on the uplink direction of IS-95 CDMA networks, showing an optimized soft handoff for capacity under perfect power control approach. Practically, a nonzero handoff completion delay and soft handoff provides the required robustness to delays, yet, it writes down to additional network resources. Hence, there is a trade-off between the extent of soft handoff required and the handoff execution delay. The work in [9] devised a scheme known as “A Novel Adaptive Channel Allocation Scheme (ACAS), where, based on the average handoff blocking rate measured in the past certain period of time the number of guard channels are automatically adjusted. The handoff blocking rate is controlled under the designated threshold and the new call blocking rate is minimized. The main methodology for the paper was simulation of nodes which was really used to determine the performance of the ACAS. The result showed that the ACAS outperforms the Static Channel Allocation Scheme by controlling a hard constraint on the handoff rejection probability. The proposed scheme executes best by maximizing the resource utilization and adapting itself to changing the traffic circumstances automatically. A new model was proposed in [13] with a devoted queue for every single transceiver in the cell. Fixed assignment was considered in both models and performance characteristic was based on blocking probability. Mean waiting time on queue and cost functions were derived in order to compare the two methods. The methodology for the research paper was mathematical analysis and computer simulations. According to [29] handoff schemes based on hysteresis margin and time-to-trigger are used in the GSM Standard, the PCS standard and the LTE standard to make more accurate handoff decision and avoid ping-pong effect. Unfortunately, it is not efficient to reduce the handoff failure rate when UEs are moving with high speed.

Two schemes with queuing of both Handoff Calls (HC) and Originating Calls (OC) were proposed by the authors of [39], where priority in the channel assignment favours the former. The strategies, referred to as Buffer Rigid Partitioning (BRP) and Buffer with Handover Control (BHC), are both studied by means of an accurate analytical model, that fits in with simulation results.

The authors of [54] in January 2008, proposed a new handoff technique by blending the Mobile Assisted Handoff (MAHO) and Guard Channel (GC) techniques using mathematical analysis. With the technique, the Mobile Terminal (MT) reports back the Received Signal Strength (RSS),the Bit Error Rate (BER) and the number of free channels that are available for the handoff traffic as well. This is to ensure that a handed-off call has acceptable signal quality as well as a free available channel. Nasif Ekiz et al proposed in [58] using logical analysis, different handoff approaches which when applied to achieve better handoff service by considering impacts on forced termination probability and call blocking probability as well as using guard channels and or queuing handoff.

In [18], queuing system with two arrival streams was considered. A numeral scheme assigning different priorities to each of the two arrival streams was modelled. One of the streams is considered to require a high priority to access the server than the other stream. Jain and Gupta focused on the problem of congestion control in wireless ATM network based on new Hybrid Scheme [19] the propose work solved the handoff problem in ATM-based PCN by given handover calls high priority over new calls.

Kashish Parwani and G.N. Purohit in [12] proposed a Markov model and analyse the effect of queuing handoff and also no queuing of handoff in sub-layers of a hierarchical cellular network at femto and picocell layers using mathematical analysis. The cell size is considered, cell dwelling time and the mobility of the users to calculate the queue times of users. They proved that by having a queue of the handoff, the call blocking probability is reduced. In comparison to this report, it must be noted that their analysis was on the premise of Markov nature of handoff arrivals, rather than Poissonian as this paper does. The paper does not investigate the performance of a method of queuing originating calls. The research in [4] analysed the effect of handoff on a cell which employs the use of guard band as well as queuing and finally determined optimal guard channels by considering Quality of Service (QoS). In [10], the authors proposed a new scheme to deal with seamless roaming and reduce failed handoffs using Qualnet software and the results justify the benefits of the scheme. Their analysis showed a 66.66% improvement in QoS. They realized that using WAP techniques to provide handoff and connectivity in urban areas is a feasible alternative.

Romano Fantacci, Senior Member IEEE in March 2000 published in[26]. The paper carried out analysis of two prioritized handoff schemes, with regards to the fixed channel assignment, where handoff requests are queued for a maximum time when all channels are busy. The attempts are queued according to the FIFO policy. It was also demonstrated there that the FIFO policy allows performance very close to that of the ideal prioritized handoff scheme and, hence, that it was a solution suitable for applications in mobile cellular networks where a high service quality is required.

Yum and Lawrence [53], developed an analyticalpattern for evaluating the call blocking probability of a cellular system with Directed Retry (DR), which gave precisesolutions for systems with both uniform and non-uniform traffic distributions. The paper then formulated a second model based on the first one to evaluate the probability of additional handoff on account of DR. They realized that since the probability of additional handoff due to DR is more sensitive to cell overlap percentage than to the mean path length a mobile unit ttravels, the probability of additional handoff is minimal. In the work, for an example of a 30% cell overlap, the probability was as low as 0.022%. The conclusion was that, the use of handoff gave rise to only a minimal amount of additional load in handoff processing, therefore, a minimal effect on handoff failure.

Yunguang Fang [45] applied an approach to the analysis of call connection performance and mobility management under the assumptions that many time variables such as call holding time, cell residence time, channel holding time, registration area (RA) residence time, and inter-service time are assumed to be generally distributed and showed how to obtain more general analytical results. Trivedi et al. In [36], focused on a performance model of a cell for handoff arrivals with guard channels included is developed. Algorithms were developed to find out the optimum number of guard channels and channels allocated. Mathematical analysis was used to develop expressions for loss probabilities, optimal number of channels and guard channels in the system. In conclusion, an analytic model for wireless systems with hard handoff as well as hard handoff with channel failures was developed.

Authors of [7] discussed and equated handoff algorithms intended for WLAN, GSM, UMTS, etc. in terms of their usability in 60 GHz networks and made good word for handoff algorithms in such networks. They used simulations to determine the coverage of the 60GHz as compared to the 2.4 GHz frequency in the same building. The work gave an overview of the handoff algorithms in cellular and wireless networks, studied the characteristics of the 60GHz band, showing that it was the obvious choice to support high speed multimedia applications in indoor environments. It is also seen that it is difficult to implement this due to its steep signal degradation and small cell size which gave rise to more handoffs in lesser time for carrying out the handoff. Conventional handoff schemes were shown to perform poorly in 60 GHz. With the use of additional information and intelligent handoff algorithms, more successful handoffs occur in 60GHz systems. Designing appropriate network architecture, they also presented some recommendations and discussions may help in choosing the right handoff algorithm for 60 GHz networks.

Researchers from [11] proposed a channel assignment algorithm in which handoff requests are prioritized and serviced based on upon measurements of received power of the current base station and the effect of adjacent overlap cells using simulations. They compared this method to a more standard Measurement Based Priority Scheme (MBPS) which showed the proposed one had similar blocking probability but lower forced termination probability as well as the realization there was no need for new measurements as power measurements which should be performed by mobile stations could be sent to base stations. The paper [38] studied the performance of different channel assignment strategies for handoff and initial access, and observed that, giving a priority to handoff seeks over initial access attempts would dramatically improve the probability of forced termination of the system without seriously degrading the number of failed initial access attempts

Beraldi and co[21] compared the queuing of both handoff and originating calls, using three MBPSs namely, Push Out (POC), Threshold Push Out (T_POC) and Partitioned Push Out (P_POC) in addition to the FIFO policy for the comparisons, all done by means of simulations for selected percentages of handoff calls according to the radii of the cells. The conclusion was that, out of the three schemes; with queuing of both originating and handover calls and on the push-out Strategies, The P-POC scheme seems to provide the best performance but it is more complex to implement.

Hybrid cut-off priority scheme for wireless networks carrying multimedia traffic and capable of handling buffering for both new calls and hand off calls was proposed in [40].Simulation was done to achieve some graphs for analysing and evaluating of various call blocking probabilities. They finally proposed a new handoff model based on the cut-off priority scheme used in traditional macro-cellular networks for handling multiple classes of traffic in the multimedia wireless environment.

In [41], two new parameters are considered for the betterment of handoff algorithm, namely, signalling delay and angle of motion. Broad simulation analysis was used to validate the proposed technique and the results showed that fuzzy are a viable option for handoff.

2.3 Cellular Handoff Fundamentals

Handoff is the key operation in cellular mobile communication systems. It is the means through which a call is enable to proceed uninterrupted when MS moves from one cell area to another. Handoff can be defined as the process of transferring a mobile station from one base station or channel to another. The channel change due to handoff occurs through a change in time slot, frequency band, codeword or a combination of these. In time division multiple access (TDMA) the time slot is changed. Where as in frequency division multiple access (FDMA) the frequency is changed and code division multiple access (CDMA) the code is changed.

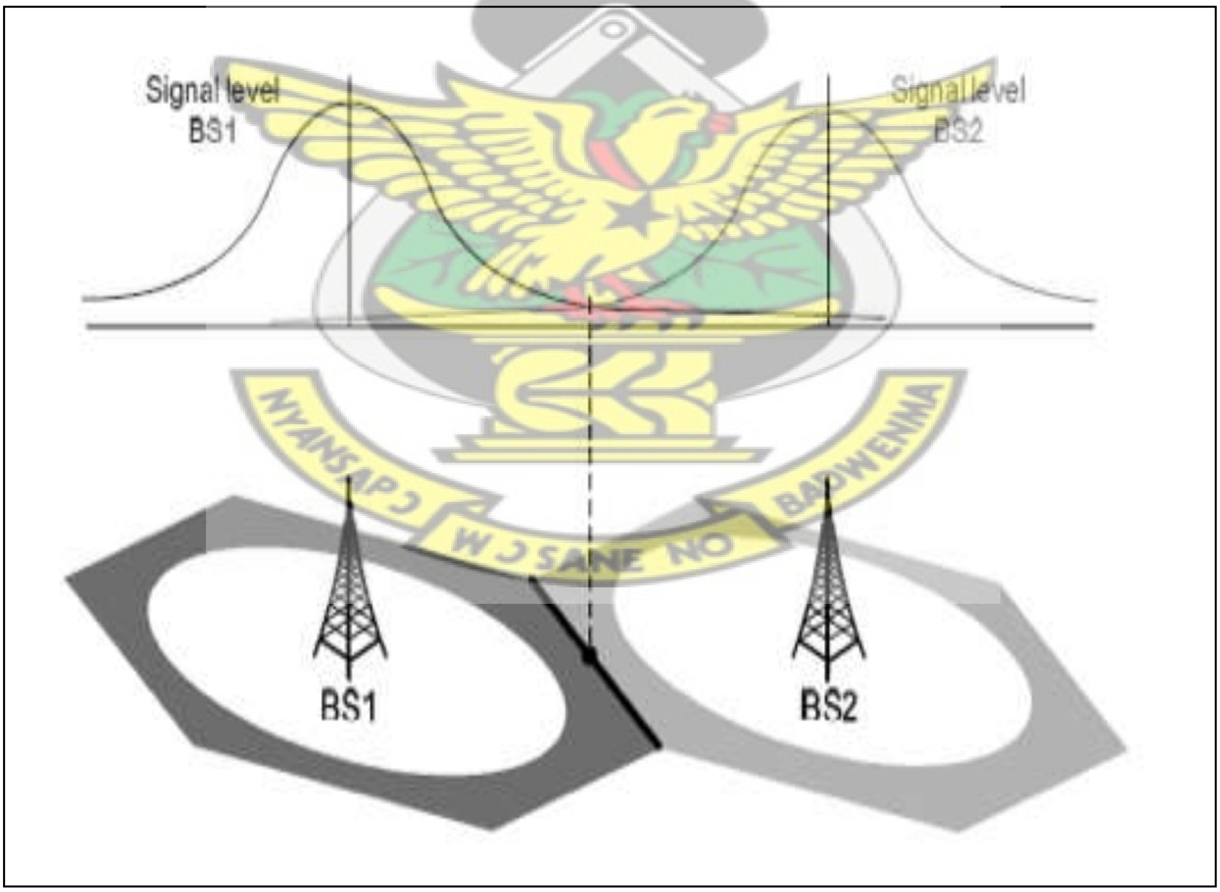

Fig 2:1:Handoff Scenario in Cellular Communication System.

Figure 2:1 shows a mere handoff scenario in which a MS who loves to talk while travelling is travelling from BS 1 to BS 2. Before the MS starts travelling it was connected to the home based base station i.e. BS 1. At a certain time during the travel like the overlap region, where the signal strength from BS 2 exceeds the signal strength of BS 1, the mobile is handed off from BS 1 to BS 2. When the MS is close to BS 2, it remains connected to BS 2. The process of handoff has to be completed in the overlap region for a successful handoff.

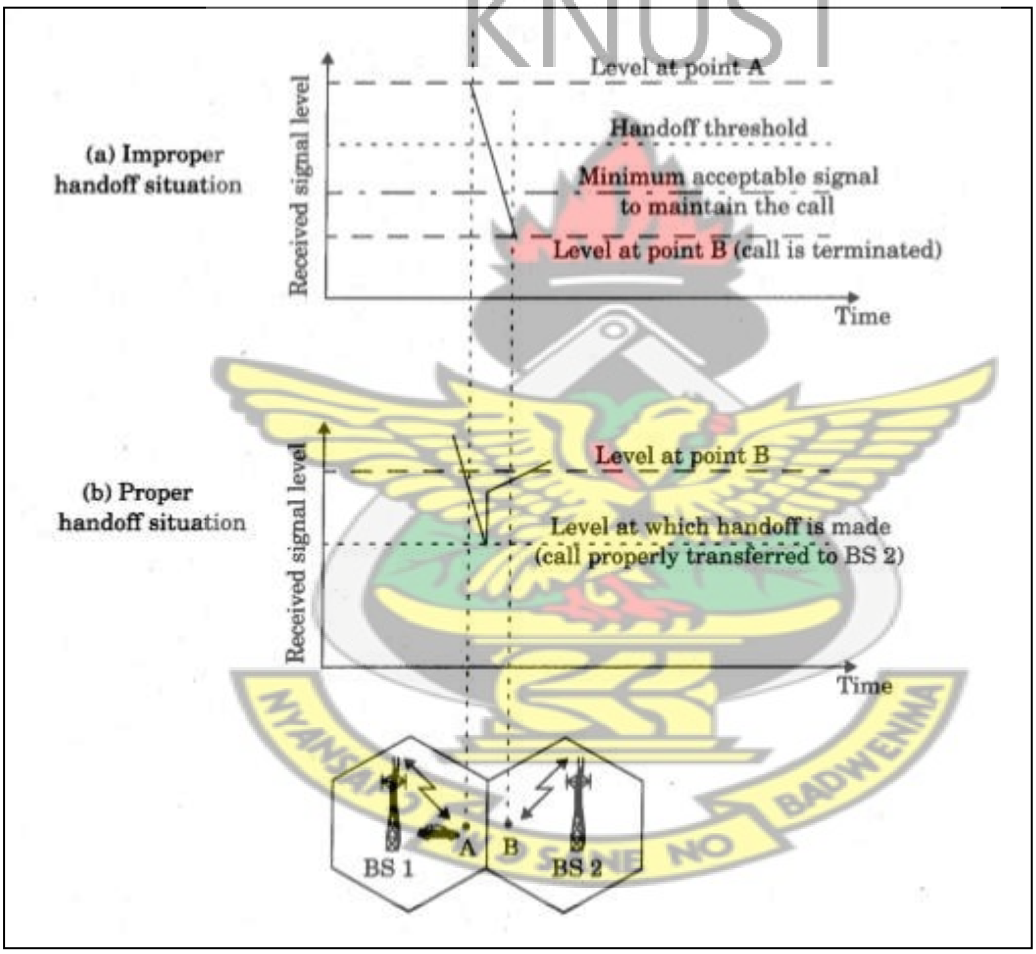

Fig 2.2: Illustration of improper and proper handoffs.

2.4 Handoff Priority Schemes (no priority employed)

An ideal handoff is one in which forced probability decreases while maintaining blocking probability, yet, for instance where no priority strategy is employed, the new call requests and handoff call request are treated in the same way and the probability of blocking handoff is equal to the blocking probability of new call.

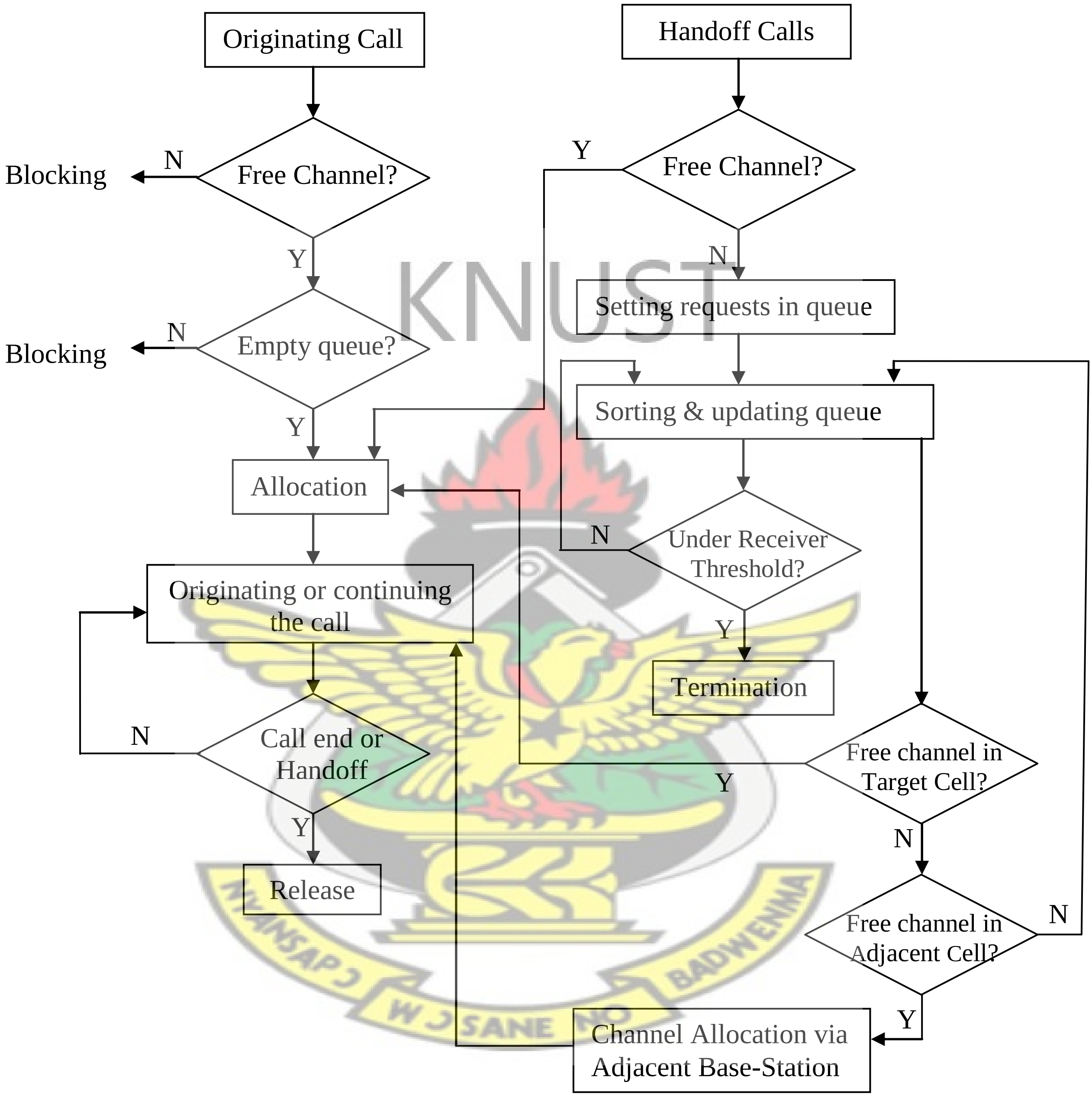

Fig 2.3: Flow Chart of Priority Scheme [11].

In such situations, a significant handoff performance improvement can be obtained by prioritizing handoff calls to ensure a reduction in the handoff failure rate [41], [42].

Markov process with an s+1 states where s is the number of channels present in the cell is used to model the no priority scheme.

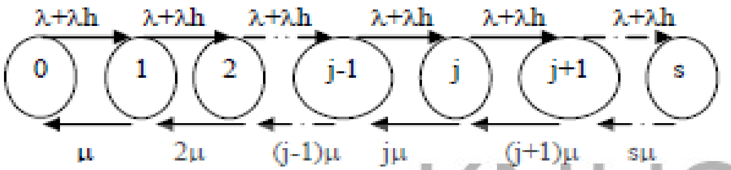

Fig 2.4: State Transition Diagram [42].

New calls and handover calls use the s channel as they are free. For $0 \leq j \leq s$, the new call or handover call uses one channel. If a requet arrives and all the s channels are occupied the request will be blocked. The NPS is modeled by a queue M / M /s/ s. P_j is the probability ofstate j.

It shows that:

$$P_j = \frac{\dfrac{\left(\dfrac{\lambda + \lambda h}{\mu}\right)^j}{j!}}{\displaystyle\sum_{k=1}^{s} \dfrac{\left(\dfrac{\lambda + \lambda h}{\mu}\right)^k}{k!}} \tag{2.1}$$

We get:

$$P_b = P_h = P_s = \frac{\dfrac{\left(\dfrac{\lambda + \lambda h}{\mu}\right)^s}{s!}}{\displaystyle\sum_{k=0}^{s} \dfrac{\left(\dfrac{\lambda + \lambda h}{\mu}\right)^k}{k!}} \tag{2.2}$$

This equation is known as Erlang-B formulae.

2.5 Handoff Prioritization Scheme

Dropping of on-going call is undesirable to subscriber than blocking of a new call and therefore, worth implementing schemes that mitigates call drops. A keyway to reduce handoff failure rate is to prioritize handoff. Prioritization scheme reduce the forced termination probability by assigning more channel to handoff calls. The two known prioritization schemes are: Guard channels and Queuing of handoff calls.

2.5.1 Guard Channels

This scheme prioritizes handoff calls by reserving some of the total channels available in a cell for handoff calls only. N channels out of C total channels are reserved for handoff calls. The rest of the channels are used by new and handoff calls, therefore, handoff calls are better served and a new call is blocked if the number of channels available is less than (C – N).Hence, less number of channels are available for originating call. This process increases the call blocking probability and decreases the call dropping probability [2], [41], [42], [58].

2.5.2 Queuing Handoff

The process of delaying handoff call when the available channels allocated to the target BS are occupied is called queuing of handoff. The MSC queues the handoff requests instead of denying access if the candidate BS is busy. Queuing is possible due to time interval between handoff initiation and receiver threshold. The probability of a successful handoff can be improved by queuing handoff requests when the channels are used up. When a channel is released, it is assigned to the handoff calls in the queue. It is worth noting that, queuing does not guarantee zero forced termination probability [2], [41], [42], [58].

2.6 Conclusion

Based on the literature review imparted above, it is obvious there is a lot to consider when studying the concept of handoff in wireless systems. Certain trends have emerged such as the disputing of handoff arrivals to be Poissonian (Poisson Distribution Process) and the proofs that they are Markovian (Markov Regenerative Process), the realization that handoff needs to be queued, need to improve vertical handoff systems to reduce dropping, etc. More research is needed to develop a prime balance that reduces call dropping without increasing call blocking, improve seamless handoff occurrence whilst being able to provide reliable and cost effective priority schemes since these seems to have little attention in literature.

This thesis focuses on determining the impact of having no queuing, queuing of originating calls and queuing of handoff requests in the Ghanaian cellular communication networks. It is also worth noting that these systems are mainly GSM based, and their characteristics may not apply to other systems.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In this chapter we introduce the research methodology used for the study; we also present the theoretical description of the problem being studied, the considered system model for the problem and the solution approach. A mathematical synthesis supporting the background theory and the solution adopted is presented in this chapter. The principal aspects being considered are the call blocking probability variations of originating and handoff calls in the various network locations under the impact of queuing only handoff calls and also impact of queuing only originating calls.

Data for simulation was secured from a leading telecom operator, a major telecom operator in Ghana, which will be referred to as “DIA” in the remaining part of the thesis for the purpose of anonymity. Similar MATLAB simulations are carried out for each of the GSM networks for specific locations in Ghana. Simulations are carried out based on algorithms for the three methods under analysis which were published in [50].

3.2 System Model

Consider a geographical area divided into cluster of cells, each cell has a base station which is allocated a set of channels C, and the channels are given to subscriber on demand for both handoff calls and originating calls.

Consider a geographical area divided into cells, each cell has a base station which is allocated a set of channels C, and the channels are given to subscriber on demand for both handoff calls and originating calls. When a subscriber requests service, a channel is allocated and remains dedicated for the entire duration (holding time) of the call, H. The service rate, μ, which is the frequency of the allocation of C to a subscriber, is the reciprocal of H. Therefore, the average calling time or holding time per subscriber is given by H=1/μ.

We consider subscribers requesting for C for either originating calls or handoff calls. The frequency at which these requests arrive at the MSC is known as call arrival rate, λ. For originating calls it is denoted λ_1 and λ_2 for handoff calls. Assuming the number of call request at the mobile switching centre comes in batches and all the available channels are occupied, any call request is blocked or access to the system is denied. A queue is employed to hold the requesting user until a channel become available. M_1 refer to the size of queue for originating calls and M_2 refer to the size of queue for handoff calls. Therefore, at a particular cell site, the total traffic intensity due to originating calls and handoff call is given by: $a = (\lambda_1 + \lambda_2) / \mu$ As a result, the traffic intensity due originating call is given by: $b_1 = \lambda_1 / \mu$. The traffic intensity due handoff calls is also given by: $b_2 = \lambda_2 / \mu$.

Queuing spring up when the short term demand for service exceeds the available capacity. Queuing is possible due to the overlap region between the adjacent cells in which MS can communicate with more than one BS. If handoff requests occur uniformly, queuing is not needed; queuing is effective only when handoff requests arrive in batches. Successful handoff probability can be improved by queuing handoff requests at the cost of increased new call blocking probability and a decrease in the ratio of carried to admitted traffic since new calls are not assigned a channel until all the handoff requests in the queue are served. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available BS could take the call. The probability of a call not having immediate access to a channel and the call getting delayed for any period of time greater than zero is determined by the Erlang C formula given in [51] as:

$$\Pr = [delay > 0] = \frac{A^C}{A^C + C!\left(1 - \frac{A}{C}\right)\sum_{k=0}^{C-1}\frac{A^k}{k!}} \qquad (3.1)$$

Assuming all the channels are occupied the call is delayed, and the probability that the delayed call is forced to wait more than *t* seconds is given by the probability that a call is delayed, multiplied by the conditional probability that the delay is greater than *t* seconds. The grade of service of a trunked system where blocked calls are delayed is hence given in [51] as:

$$\begin{aligned} \Pr[\text{delay} > \text{t}] &= \Pr[\text{delay} > 0]\Pr[\text{delay} > \text{t} \mid \text{delay} > 0 \\ &= \Pr[\text{delay} > 0]e^{\frac{-t(C-A)}{H}}\left(-\left(C-A\right)t / H\right) \end{aligned} \qquad (3.2)$$

The average delay D for all calls in a queue system is given by

$$D = \Pr[delay > 0]\frac{H}{C-A} \qquad (3.3)$$

Where the average delay for those calls which are queued is given by H/(C-A).

3.3 New Call and Handoff Call Blocking Probability

When a mobile station wants to communicate with a base station, it must first obtain a channel from one of the base stations that hears it the best. When a new call (NC) is attempted and a channel is available, it is granted to the user. In the case that all the channels are occupied, the NC is blocked. This kind of blocking is called new call blocking. Similarly, if an idle channel exists in the target cell, the handoff call (HC) continues nearly transparently to the MS, otherwise, the HC is dropped [1]. The performance of the probability of blocking when there is no queue employed, when there is queuing of originating calls only and when there is queue for handoff calls only are considered in each case below.

Case I: **Probability of Blocking (no queue)**

The Erlang B formula which determines the probability that a call is blocked, is the assess of the GoS for a trunk system which provides no queuing for blocked, these Erlang B model call is based on the following staple assumptions:

There are memoryless arrivals of call requests, implying that all users, including blocked users, may request a channel at any time.

- All free channels are fully available for servicing calls until all channels are occupied.
- The probability of a user occupying a channel (called the service time) is exponentially distributed. Longer calls are not or are less likely to happen as described by an exponential distribution.
- The trunking pool has finite number of available channels.
- Traffic requests are described by a Poisson distribution which implies exponentially distributed call inter-arrival times.
- Inter-arrival times of call requests are independent of each other.
- The number of busy channels is equal to the number of busy users.

The Erlang B formulais the probability of blocking either the originating calls or handoff calls when there is no queuingof neither calls is given by:

$$P_b = \frac{A^C}{C!} P(0) \tag{3.4}$$

Where,

$$P(0) = \left(\sum_{k=0}^{C} \frac{A^k}{k!} \right)^{-1} \tag{3.5}$$

C is the number of channels, **A** is the offered traffic.

Therefore, from 3.4 and 3.5 we obtain;

$$P_b = \frac{\frac{A^c}{C!}}{\sum_{k=0}^{c} \frac{A^k}{k!}} \tag{3.6}$$

The vice versa of this instance is where excess calls are not blocked but queued based on the assumption that;

- Callers never hang off whilst in queue.
- All calls start and end in the same time period being estimated for.
- Callers never try to call back after having hanged up while in queue.

The probability of blocking with queuing is written in [50];

$$P_{bq}(0) = \left[C! \sum_{C=0}^{C-1} \frac{A^{c-C}}{c!} + \frac{1 - \left(\frac{b_1}{C}\right)^{M_1+1}}{1 - \left(\frac{b_1}{C}\right)} \right]^{-1} \tag{3.7}$$

Where, M_1 is the originating calls queue size, b_1 is the traffic offered by the originating calls.

Case II: **Probability of Blocking (when Originating Call is Queued)**

In case when only the originating calls but not the handoff calls are queued, the blocking probability for originating calls is written as:

$$B_{oq} = \left(\frac{b_1}{C}\right)^{M_1} P_{bq}(0) \tag{3.8}$$

The resulting blocking probability for handoff calls is given by:

$$B_{hq} = \frac{1 - \left(\frac{b_1}{C}\right)^{M_1+1}}{1 - \left(\frac{b_1}{C}\right)} P_{bq}(0) \tag{3.9}$$

Case III: **Probability of Blocking (when Handoff Call is Queued)**

When the handoff calls are queued but not the originating calls, the blocking probability for handoff calls is given as:

$$B_{hq} = \left(\frac{b_2}{C}\right)^{M_2} P_{bq}(0) \tag{3.10}$$

And the blocking probability for origination calls is also given:

$$B_{oq} = \frac{1-\left(\frac{b_2}{C}\right)^{M_2+1}}{1-\left(\frac{b_2}{C}\right)} P_{bq}(0) \tag{3.11}$$

3.4 Proposed Queuing Scheme for Queuing both OC and HC in a Single Queue.

In [50], a system of queuing both originating calls and handoff calls together in a single queue was not considered in [50]. However, the study from this thesis proved that, for cell sites with very low traffic intensity per channel ratio and approximately equal arrival rates for originating and handoff calls, there is the need to queue both originating and handoff call. This fits the conditions for nano and picocells which will be implemented in the future and where there will be generally less disparity between originating call and handoff call arrival rates. When this is implemented in sites with generally large disparity between originating and handoff calls, we noticed higher blocking rates for handoff calls.

The delay probability can be written as;

$$P_{bq}(0) = \left[C! \sum_{c=0}^{c-1} \frac{A^{c-C}}{c!} + \frac{1-\left(\frac{b_1+b_2}{C}\right)^{M_1+M_2}}{1-\left(\frac{b_1+b_2}{C}\right)} \right]^{-1} \tag{3.12}$$

The blocking probability for originating calls for this system is given as;

$$B_{oq} = \left(\frac{b_1 + b_2}{C}\right)^{M_1+M_2} P_{bq}(0) \qquad (3.13)$$

And finally the blocking probability of handoff calls is given by:

$$B_{hq} = \frac{1-\left(\frac{b_1 + b_2}{C}\right)^{M_1+M_2}}{1-\left(\frac{b_1 + b_2}{C}\right)} P_{bq}(0) \qquad (3.14)$$

3.5 Conclusion

The concept of handoff raises a lot of issues such as system performance in relation to call blocking and the probability of force termination, queuing of handoff in wireless and specifically cellular systems, handoff implementation schemes such as prioritization or non-prioritization of handoff and many more. Some researchers even go as far as to mix up some of these methods, or design newer ones altogether. In this chapter, the theoretical description of the problem being examined is presented and in the next chapter, analyses is done using base data, induction, mathematical analyses, simulations and patents.

CHAPTER FOUR

EXPERIMENTS AND RESULTS

4.1 Introduction

The previous chapter discussed the system model with mathematical synthesis to exhibit a theoretical description of blocking probability in cellular mobile networks. This section renders a detailed analysis of collected results and thus identifying various observed phenomena and highlighting the importance of made observations. The results of the analysis performed are also posed here; deductions and interpretations are also discussed.

4.2 Simulation Results and Discussion

In this section, by means of numerical analysis, we show the probability of blocking OC and HC when OC is given priority, also, the probability of blocking OC and HC when priority is given to HC. Simulations in this work are implemented using MATLAB[2] version R2012a.System levels simulations are perform using Monte-Carlo simulation based on data. The Monte Carlo simulation is a software program that calculates multiple scenarios of a model by repeatedly sampling values from the probability distributions for the uncertain variables. The Monte Carlo simulation in our view is appropriate because it models the real life situation; it is able to generate several results under various conditions.

The simulation focuses on six randomly selected cell sites of a leading GSM cellular communication operator.Each cell site have different traffic to channel intensity, we classify the six cell sites into three categories according their channel occupancy; sites with traffic intensity per channels ratio range of 0 – 0.75 channel occupancy, sites with traffic intensity per channels ratio ranging from 0.76 -1 channel occupancy and sites with traffic intensity per channels ratio greater than 1 channel occupancy.This eases the study of the various scenarios of interest. The next section explores the results for the named scenarios.

4.2.1 Result for Valley View (DIA)

Case I

The analysis of sites with traffic intensity to channel ratio of 0 – 0.75 is considered next. Here, the originating call arrival rate, $\lambda_1 = 0.0172$ per sec, the handoff call request arrival rate, $\lambda_2 = 0.08$ per sec. The mean holding time is 49.85 sec, the number of channels allocated to the cell site is 13.The traffic intensity generated from the stated data is 4.8454 Erlang while the blocking probability at 0 queue size is 0.001.From the figure 4.1, it is deduced that the blocking probability decrease as the queue size increases, yet, it does not conform to the general concept of blocking probability.

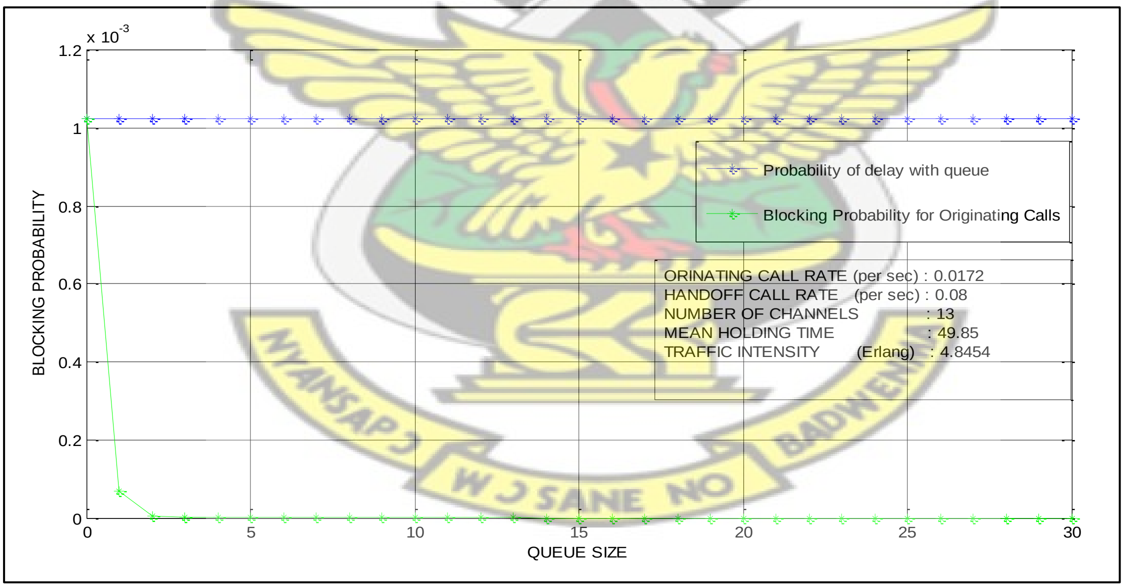

Fig 4.1: Queuing of OC Blocking Probability of OC (Valley View-DIA)

Blocking probability of handoff calls when originating calls are queued is explored next. The parameters used in analyzing the blocking probability of originating calls when originating calls are queued are same used here. From Figure 4.2, it is observed that, queuing originating calls have an effect on the blocking probability of handoff calls; this effect is insignificant since it does not really make any difference due to the initial probability of blocking.

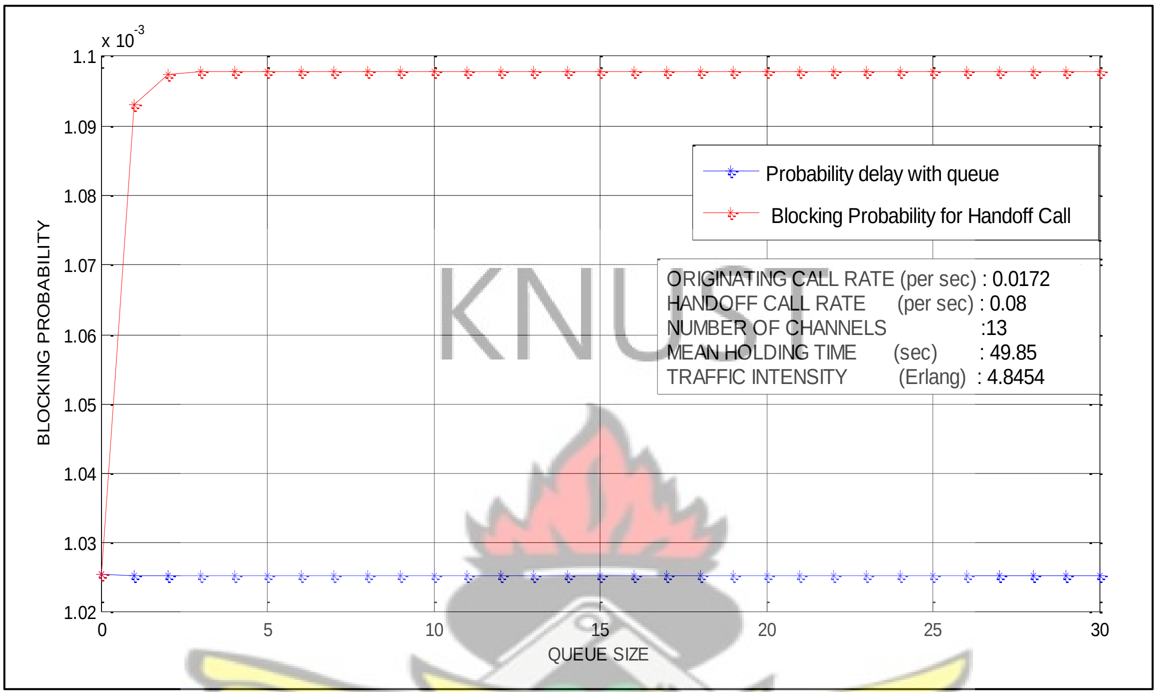

Fig 4.2: Queuing of OC Blocking Probability of HC (Valley View-DIA)

Case II

Here, we consider the opposite of the *case I* where priority is given to the handoff calls. It is seen from the figure even at queue size of 0 the probability of blocking is approximately 0 and it further decreased to 0 at queue size of 5.

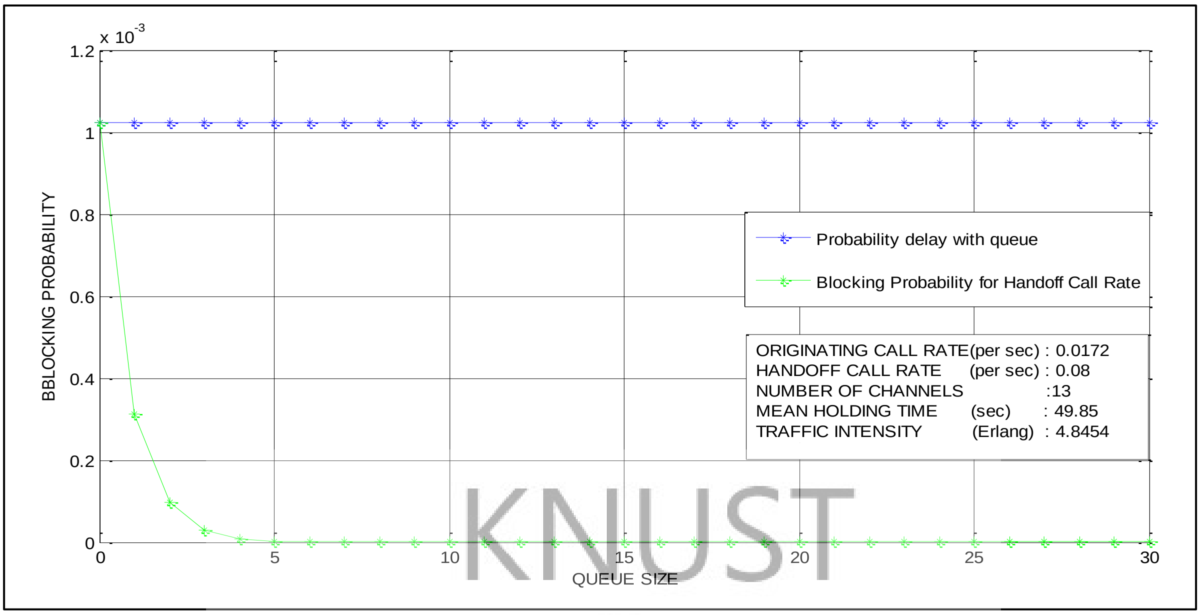

Fig 4.3: Queuing of HC Blocking Probability of HC (Valley View-DIA)

For this cell site, we finally consider the effect queuing handoff calls would have on originating call. It is observed from the figure that, queuing of handoff calls at this cell site does not have any impact on the originating.

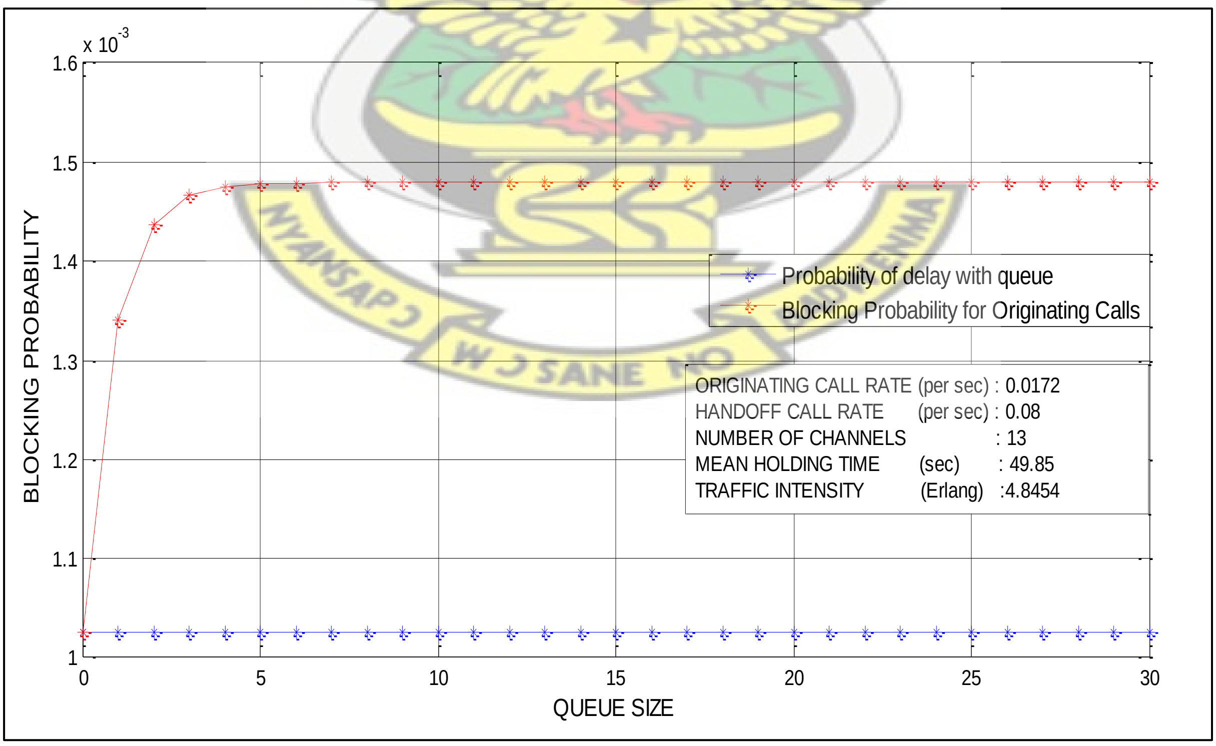

Fig 4.4: Queuing of HC Blocking Probability of OC (Valley View-DIA)

We noticed from the figure above a significant decrement in the blocking probability of the originating calls, since the originating calls are given the priority, the calls are queued when there is no available channel and they are granted channel as soon as an idle channel exists. 0.06 blocking probability at 0 queue size reduced to 0 at 28 queue size.

Now, we consider the impact queuing originating calls has on handoff calls. Since priority is given to originating calls, handoff requests are dropped when available channels are occupied. The blocking probability of the handoff increases as the queue size of the originating calls increases.

4.2.2 Results and Analysis for Ebony (DIA)

Case I

In order to substantiate the previous claims, we further analyse Ebony cell sites which also have traffic intensity to channel ratio of 0 – 0.75 (0% – 75%).The originating call arrival rate λ_1 = 5.219 per seconds, handoff arrival rate λ_2 = 0.314 per seconds and a mean holding time of 16.43 seconds. Number of allocated channels, N= 121 and thus, the generated total traffic intensity of 90.91 Erlang. From the figure it is observed that the blocking probability at queue size 0 is 0.00040165 (4.0165 x10^{-4}) which is very low, therefore, it's very uncommon for this cell site to cause blockage of originating calls when originating calls are queued.

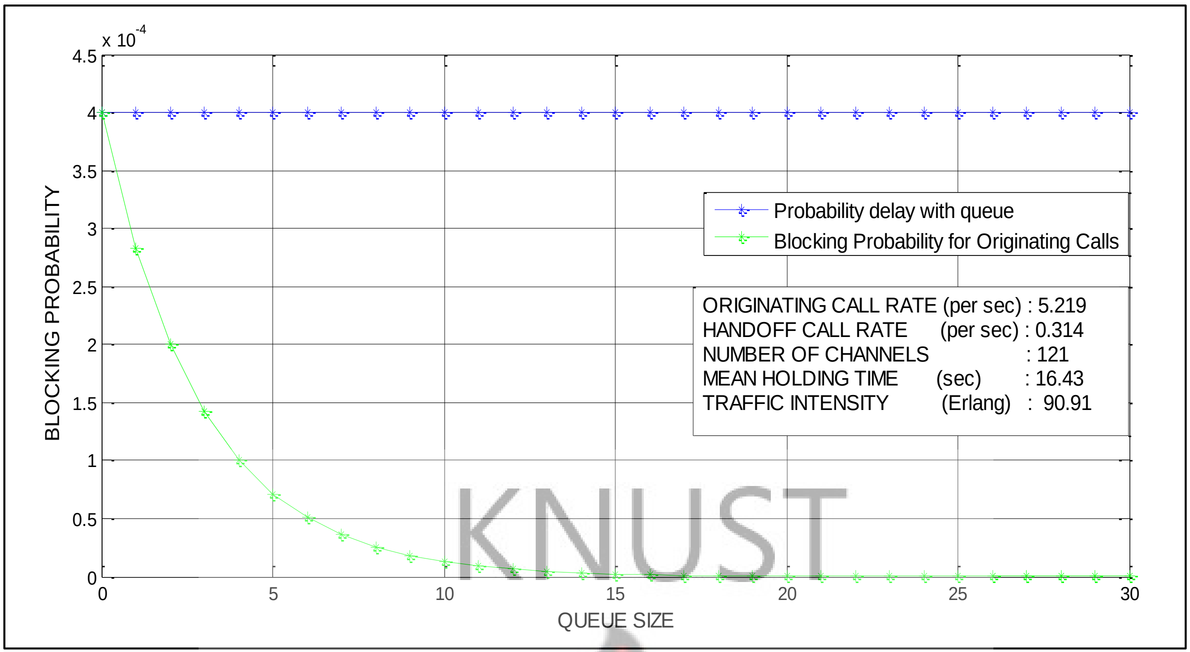

Fig 4.5: Queuing of OC: Blocking Probability of OC(Ebony-DIA).

However, it is seen from the figure that, queuing originating calls only does have an effect on handoff calls, which is the handoff blocking probability increases as compared to the delay probability. However, this effect is quite insignificant because the maximum blocking probability, queuing originating calls have on handoff calls is approximately 0.0014 (14×10^{-4}) which can still be approximated to 0. This cell site at Ebony will hardly offer resistance to any handoff when all things are equal

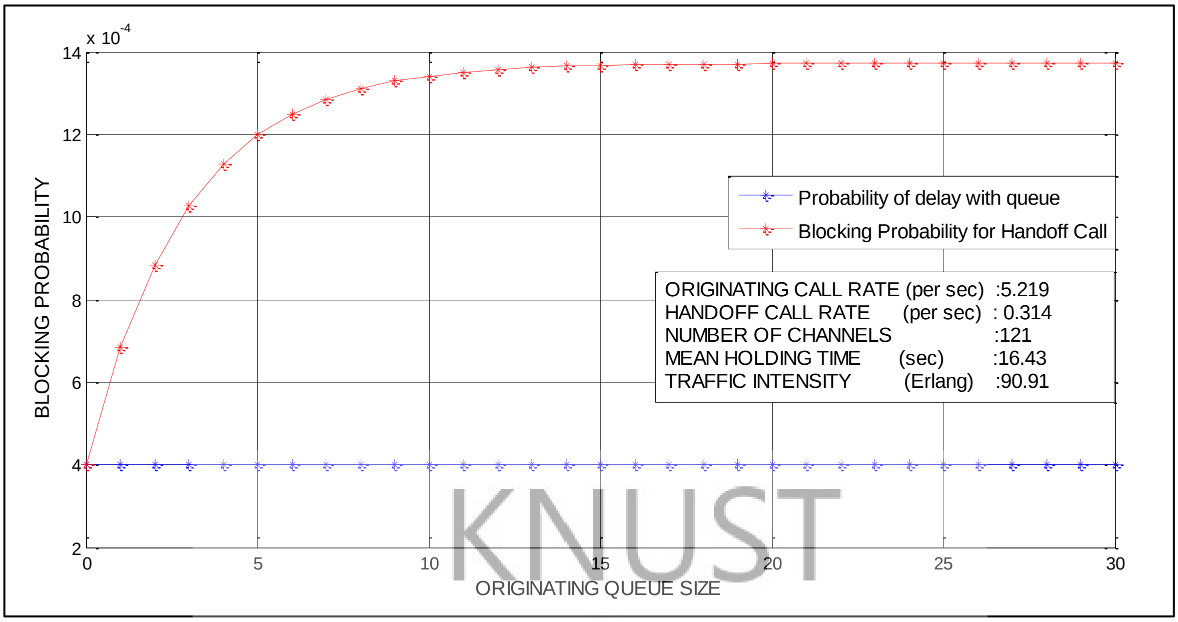

Fig 4.6: Queuing OCBlocking Probability for HC (Ebony -DIA).

Case II

This case considers the vice versa of *case I* that is, queuing the handoff calls and not the originating calls. It seen that the blocking probability of handoff calls reduces as compared to the delay probability with queuing. Figure 4.27 shows that even at queue size of 0, the blocking probability of hand off calls is 0.0004 (4×10^{-4}) which is very small. This can be attributed to the low handoff arrival and the high number of channels available. After a handoff calls queue size of 2, the blocking probability of handoff calls falls abruptly to 0 which implies that for the cell site at Ebony, a total of 5 queue size for handoff request is more than enough to prevent any blockage at the cell site.

As expected of a very efficient system like the site at Ebony, it is seen from the figure that, the maximum blocking probability that can ever be offered to an originating call when handoff calls are queued is 0.000419 (4.19×10^{-4}). This probability is very small; which means queuing handoff calls will hardly have any effect on the originating calls as the blocking probability of the originating calls rises only by a very small margin.

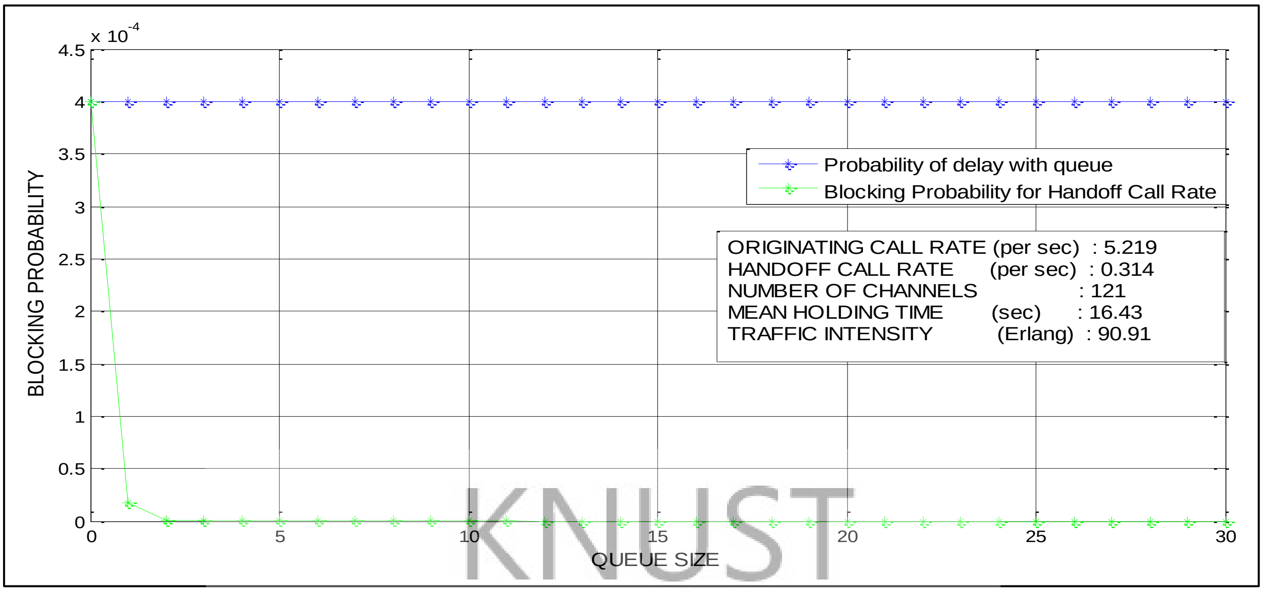

Fig 4.7: Queuing of HC Blocking Probability for HC (Ebony-DIA).

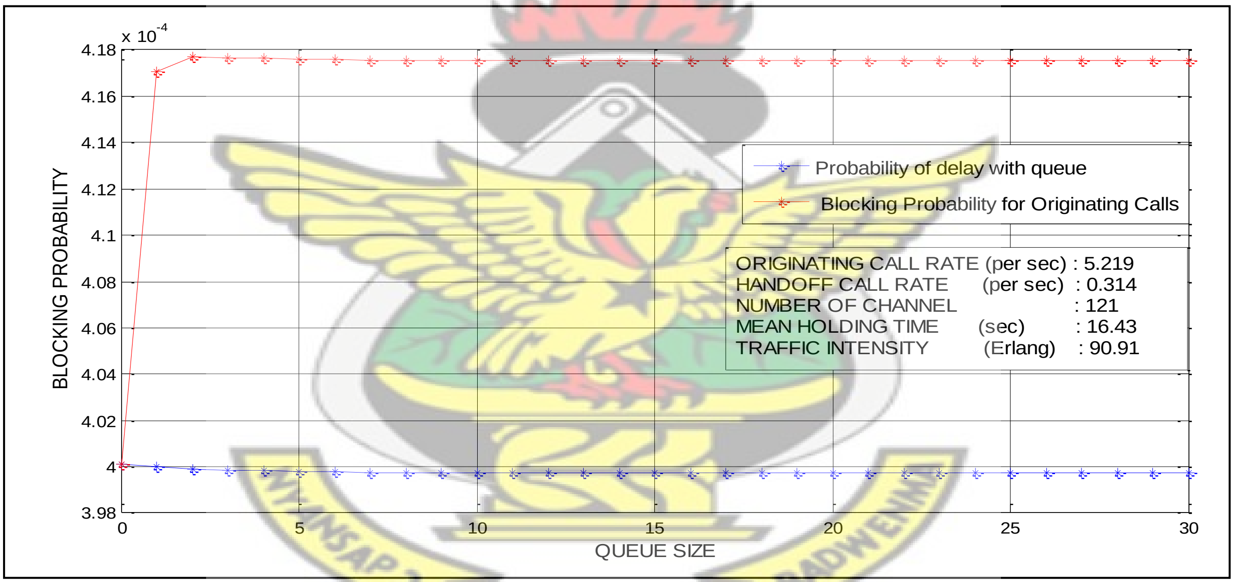

Fig 4.8: Queuing of HC Blocking Probability for OC (Ebony-DIA).

4.2.3 Results and Analysis for Achimota (DIA)

Case I

The analysis of sites with traffic intensity to channel ratio of 0.76 – 1 (0.76% – 100%) is considered next. here, the originating call arrival rate, λ_1 = 4.2030 per sec, the handoff call request arrival rate, λ_2 = 0.5018per sec. The mean holding time is 21.57 sec, the number of channels allocated to the cell site is 114. The traffic intensity generated from the above stated data is 101.48Erlang while the blocking probability at 0 queue size is 0.02.From the figure, it is deduced that blocking probability decrease as the queue size increases; it reduced from the initial probability of blocking of 0.02 at 0 queue size to 0 at 22 queue size, a gradual reduction though, but does conform to the general concept of blocking probability as in the [50].

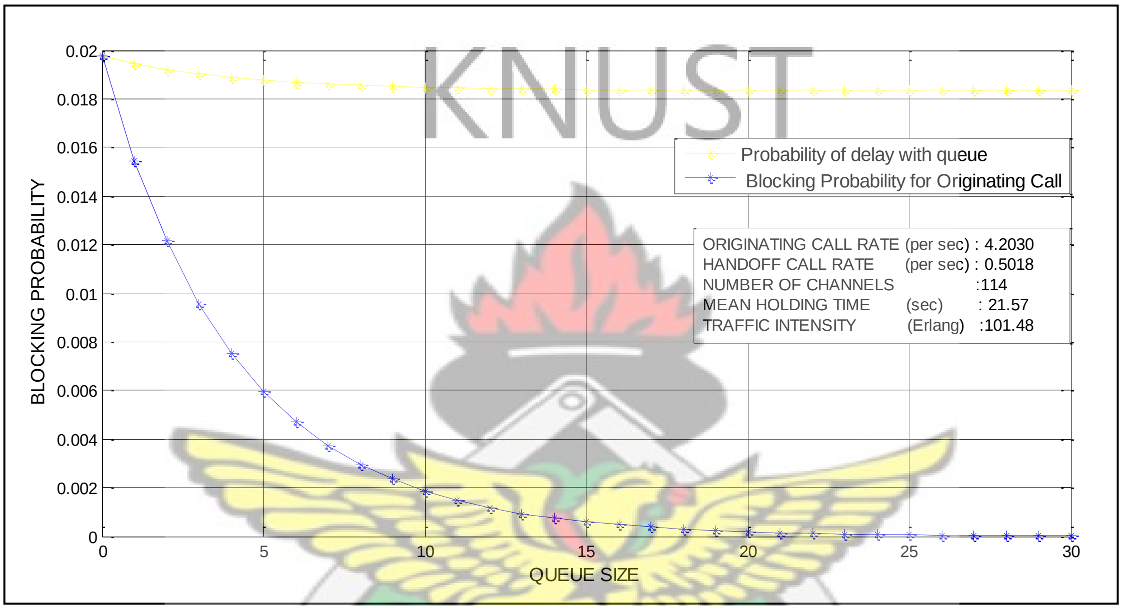

Fig 4.9: Queuing of OC blocking probability of OC (Achimota- DIA)

Since originating calls are given priority, there exists no room to accommodate handoff requests. This implies that any handoff request at Achimota cell site is dropped as soon as it comes. These results in the increase in blocking probability for handoff calls from a little above 0.02 to almost 0.09 as the queue sizes for the originating calls increased.

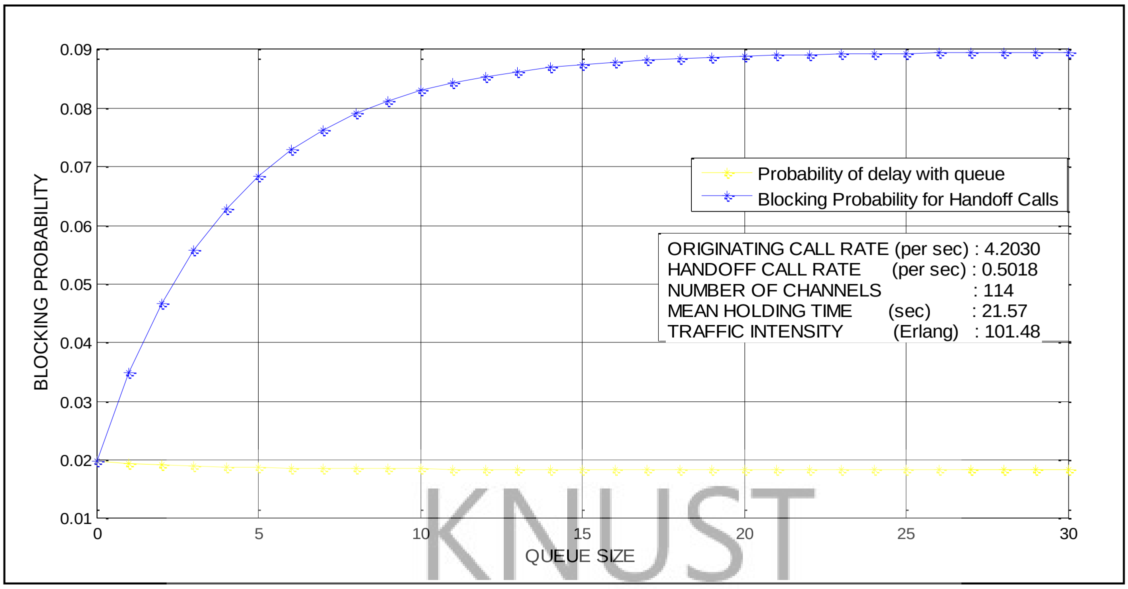

Fig 4.10: Queuing of OC blocking probability of HC (Achimota- DIA)

Case II

In this case, we consider the opposite of *case I* that is, queuing the handoff calls and not the originating calls. The parameters used; the originating call arrival rate, λ_1 = 4.2030 per sec, the handoff call request arrival rate, λ_2 = 0.5018 per sec. The mean holding time is 21.57 sec, the number of channels allocated to the cell site is 114. The traffic intensity generated from the above stated data is 101.48 Erlang.

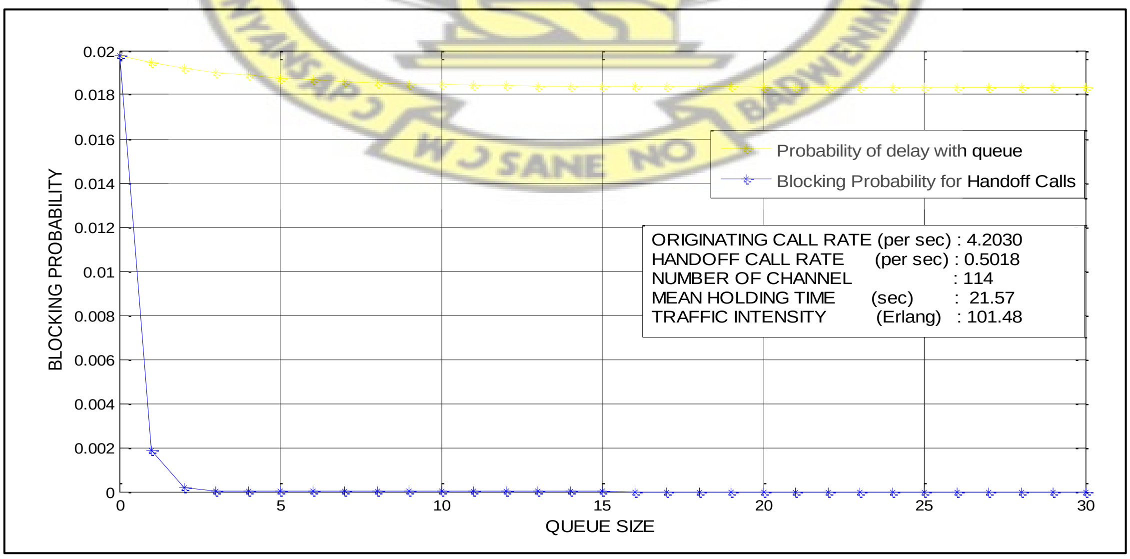

Fig 4.11: Queuing of HC blocking probability of HC (Achimota - DIA)

It is observed from the plot that blocking probability of handoff calls drops sharply to 0 just at queue size of 3. This is due to the fact that, there are small number of handoff calls and a relatively large number of channels and therefore, the handoff calls get the channels as soon as the requests are put in.

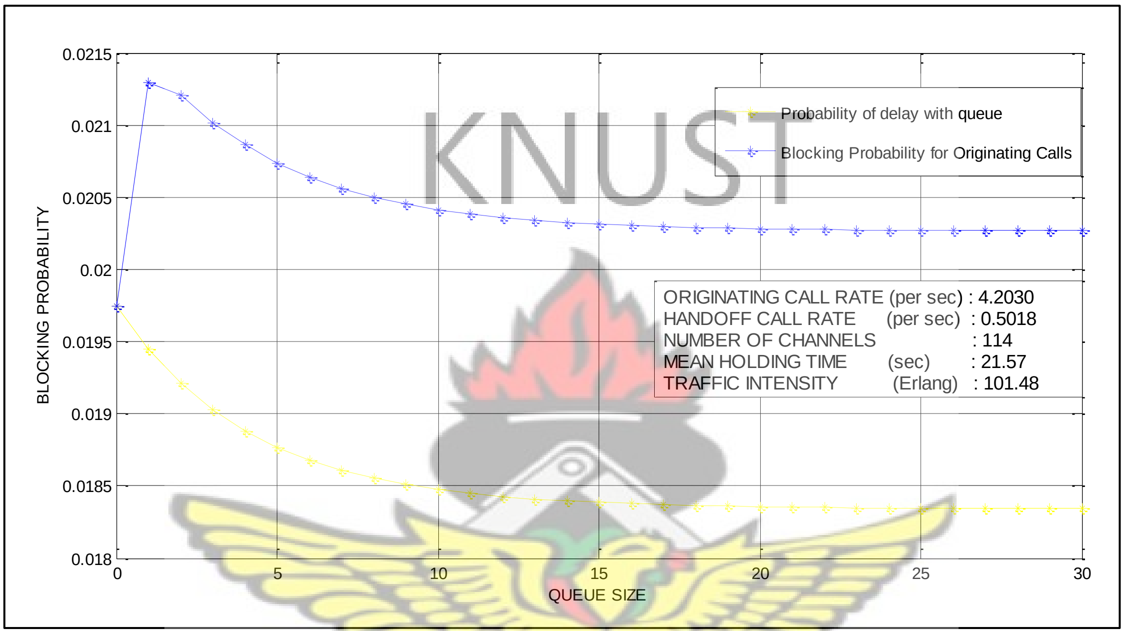

Fig 4.12: Queuing of HC Blocking Probability of OC (Achimota - DIA)

From the graph the blocking probability of originating call increased by a value of 0.0015 at queue size of 1, as a result of the huge originating call arrival rate. It then decreased gradually and finally to a little above 0.02 with queue size of 30.

4.2.4 Results and Analysis for Adenta (DIA)

Case I

Adenta cell site is with traffic intensity to channel ratio of 0.76 – 1 (0.76% – 100%) is considered next. here, the originating call arrival rate, λ_1 = 6.8102 per sec, the handoff call request arrival rate, λ_2 = 1.0141 per sec. The mean holding time is 12.17 sec, the number of channels allocated to the cell site is 98. This information generates traffic intensity of

95.22Erlang. 0.06is the blocking probability at 0 queue size.From the figure, it is deduced that blocking probability decrease as the queue size increases; it reduced from the initial probability of blocking of 0.02 at 0 queue size to 0 at 22 queue size, a gradual reduction though, but does conform to the general concept of blocking probability as in the [50].

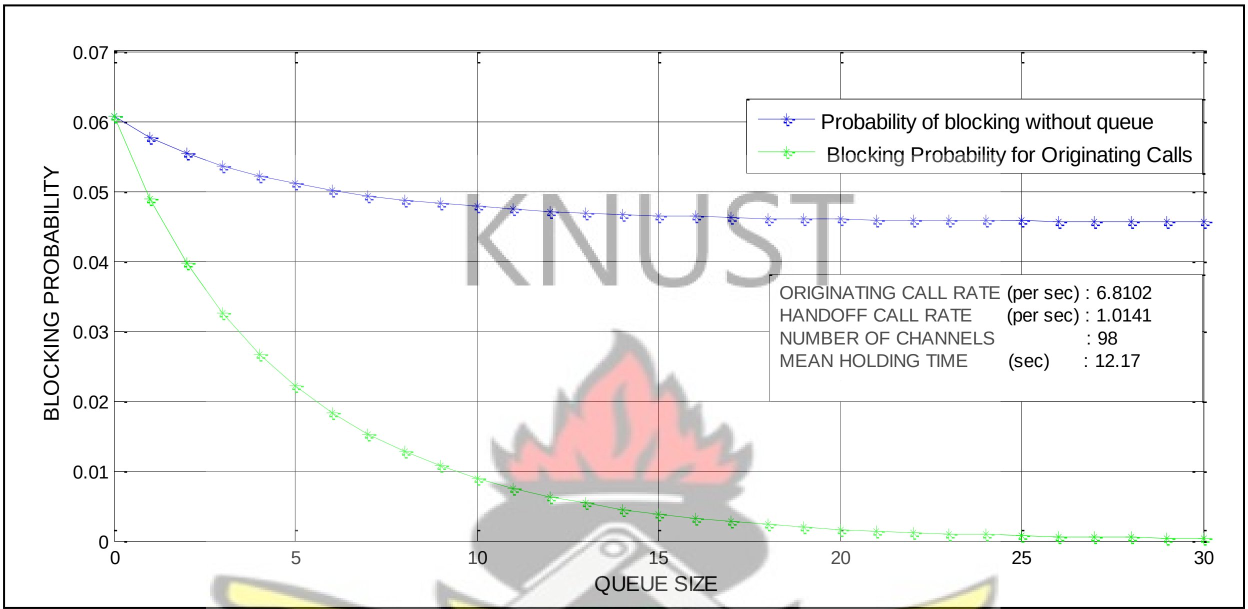

Fig 4.13: Queuing of OC Blocking Probability of OC (Adenta - DIA)

We noticed from the figure above a significant decrement in the blocking probability of the originating calls, since the originating calls are given the priority, the calls are queued when there is no available channel and they are granted channel as soon as an idle channel exists. 0.06 blocking probability at 0 queue size reduced to 0 at 28 queue size.

Now, we consider the impact queuing originating calls has on handoff calls. Since priority is given to originating calls, handoff requests are dropped when available channels are occupied. The blocking probability of the handoff increases as the queue size of the originating calls increases.

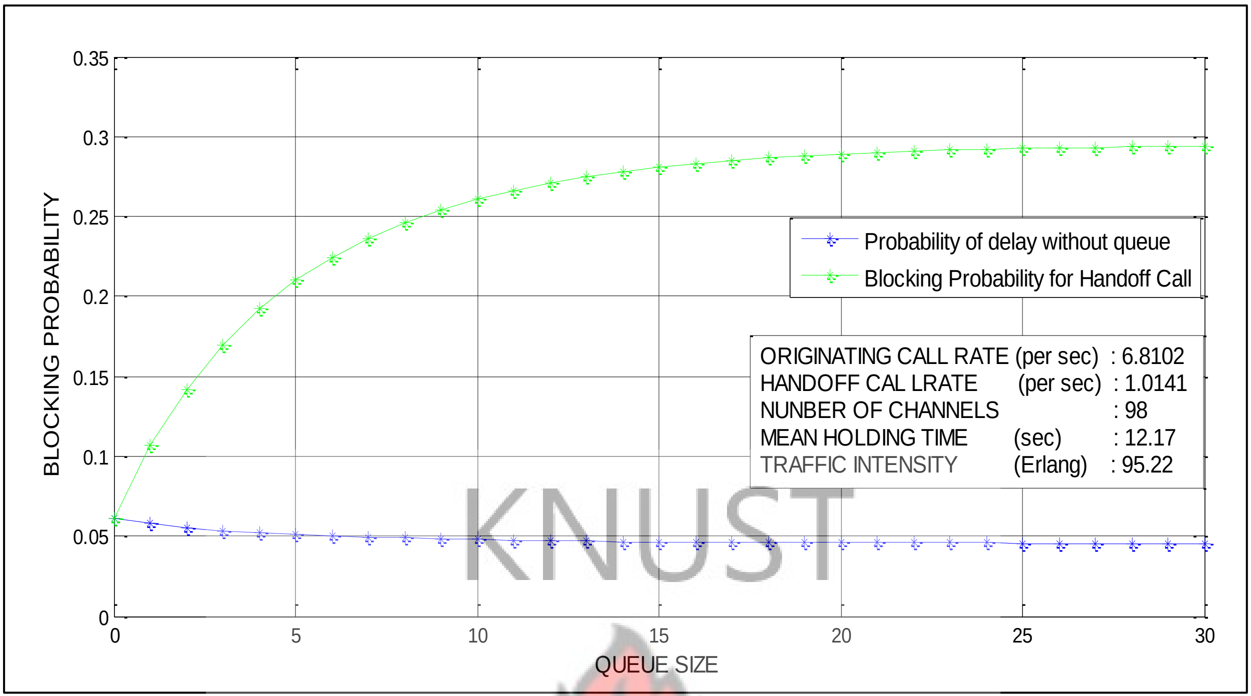

Fig 4.14: Queuing OC blocking probability of HC (Adenta –DIA)

The probability of blocking handoff calls increased from 0.06 at 0 queue size to a little below 0.3 at 30 queue size. This very high probability of blocking occurs due to the high originating calls arrival rate. Since the originating calls rate is very high, all the available channels are used by it and the handoff calls are dropped once the available channels are used up.

Case II

This case considers the opposite of *case I* where priority is given to handoff calls and not the originating calls. The parameters used; the originating call arrival rate, λ_1 = 6.8102 per sec, the handoff call request arrival rate, λ_2 = 1.0141 per sec. The mean holding time is 12.17 sec, the number of channels allocated to the cell site is 98. The traffic intensity generated from the above stated data is 95.22 Erlang.

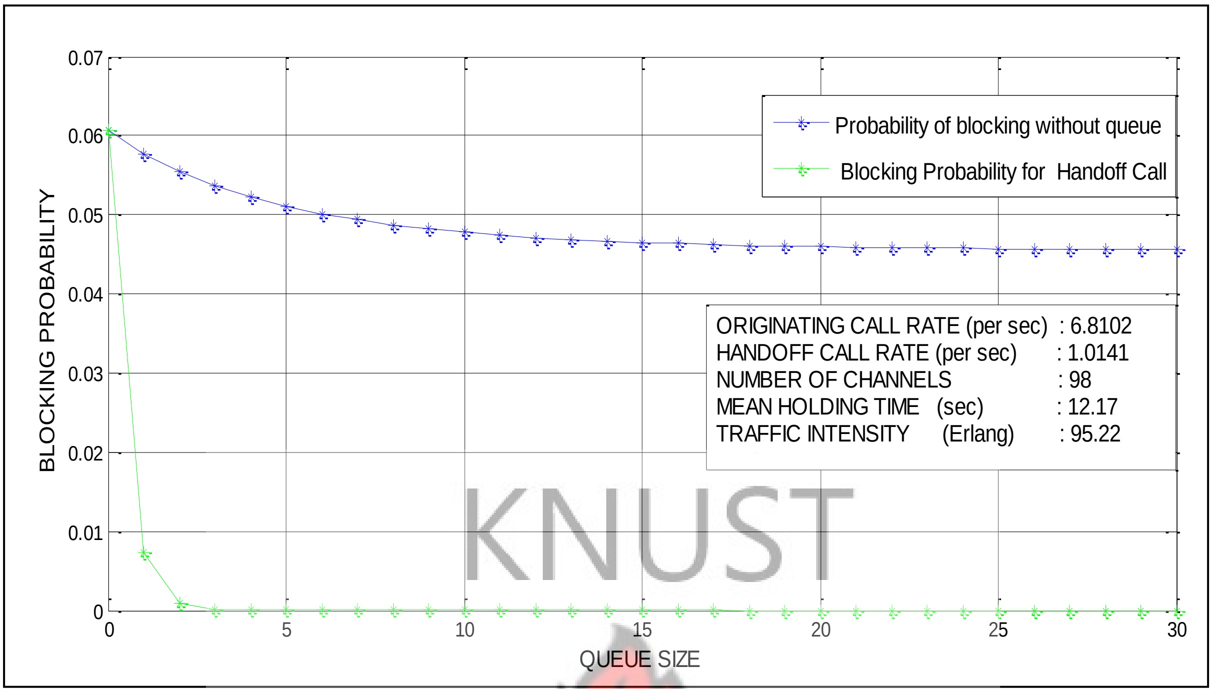

Fig 4.15: Queuing HC Blocking Probability of HC (Adenta –DIA)

It is deduced from the graph that, the blocking probability of handoff calls dropped massively from 0.06 at 0 queue size to 0 at just 3 queue size. This means at Adenta cell site a total queue size of 3 is enough to perfectly handle handoff calls when handoff calls are queued. Next, we consider the impact queuing handoff calls has on originating calls.

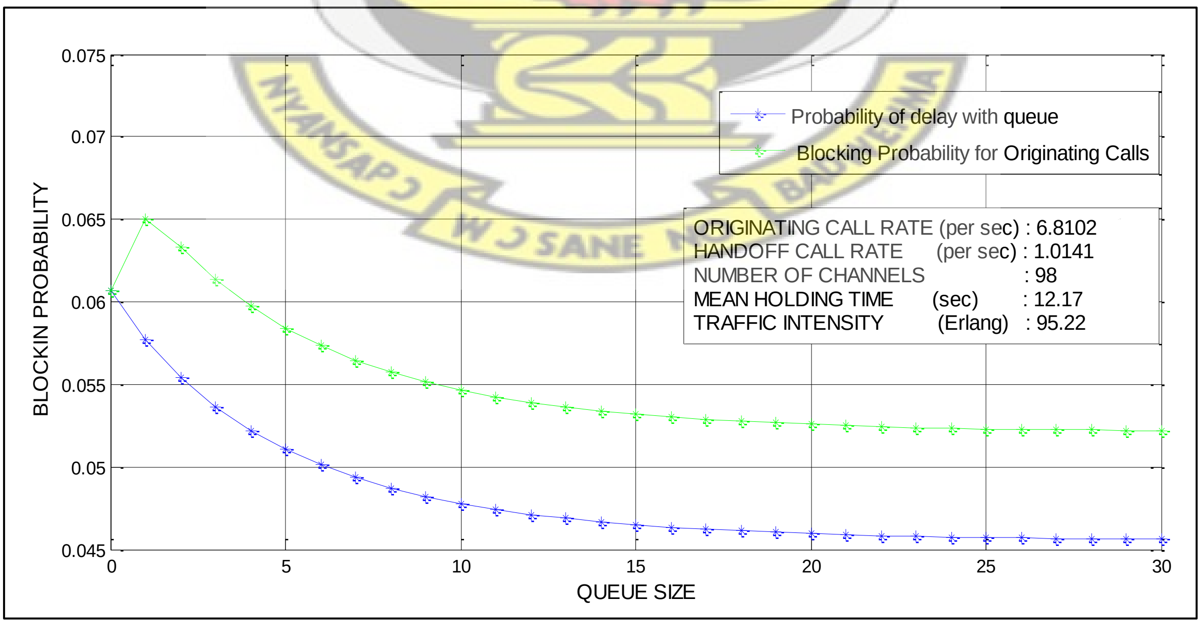

Fig 4.16: Queuing HC Blocking Probability of OC (Adenta –DIA)

From Figure 4.15 it is seen that the blocking probability of handoff calls increased to 0.065 at queue size of 1 and then decreased gradually to 0.052 at queue size of 30. The initial increase in the originating call is as a result of the high arrival rate of the handoff calls and the gradual decrement is due to the availability of the channels after serving the handoff calls. Because the handoff calls rate is relative low compared to the originating calls, they are allocated channel just on demand and the rest of the channels are used in serving the originating calls.

4.2.5 Results and Analysis for Kotobabi (DIA)

Case I

Cell sites having traffic intensity to channel ratio greater than 1 or greater 100%, are considered next.

The following parameters are used for the analysis;

- Originating calls arrival rate, $\lambda_1 = 7$ per sec,
- Handoff calls arrival rate, $\lambda_2 = 1$ per sec.
- The mean holding time = 23.37 sec,
- The number of available channels =135.
- The traffic intensity generated = 186.96Erlang.

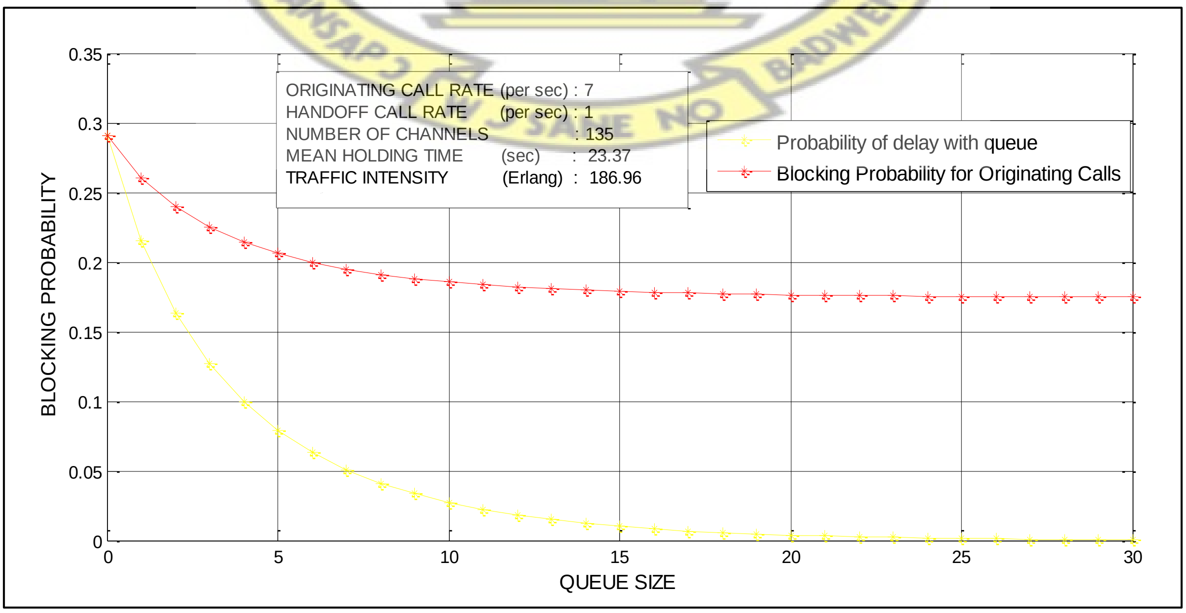

Fig 4.17: Queuing of OC Blocking Probability of OC (Kotobabi DIA)

From Figure 4.17 it is deduced that the probability of blocking originating calls decreased from the initial probability of blocking from 0.29 at 0 queue size to 0.17 at queue size of 30. In comparison with the blocking probability with queue, we realised, it's an increment instead. As the probability of delay with queue dropped to 0 at queue size of 20, the probability of blocking originating calls was about 0.17 at the same queue size. This is not in conformance to the general concept as in [50].

Once originating calls are given priority, there exists no room to accommodate handoff requests. This implies that any handoff request at Kotobabi cell site is dropped as soon as it comes. This results in the increase in blocking probability for handoff calls from a little below 0.3 at 0 queue size to 1at 21 queue sizes. This is because of the relatively high call arrival rate of originating calls as compared to the handoff requests.

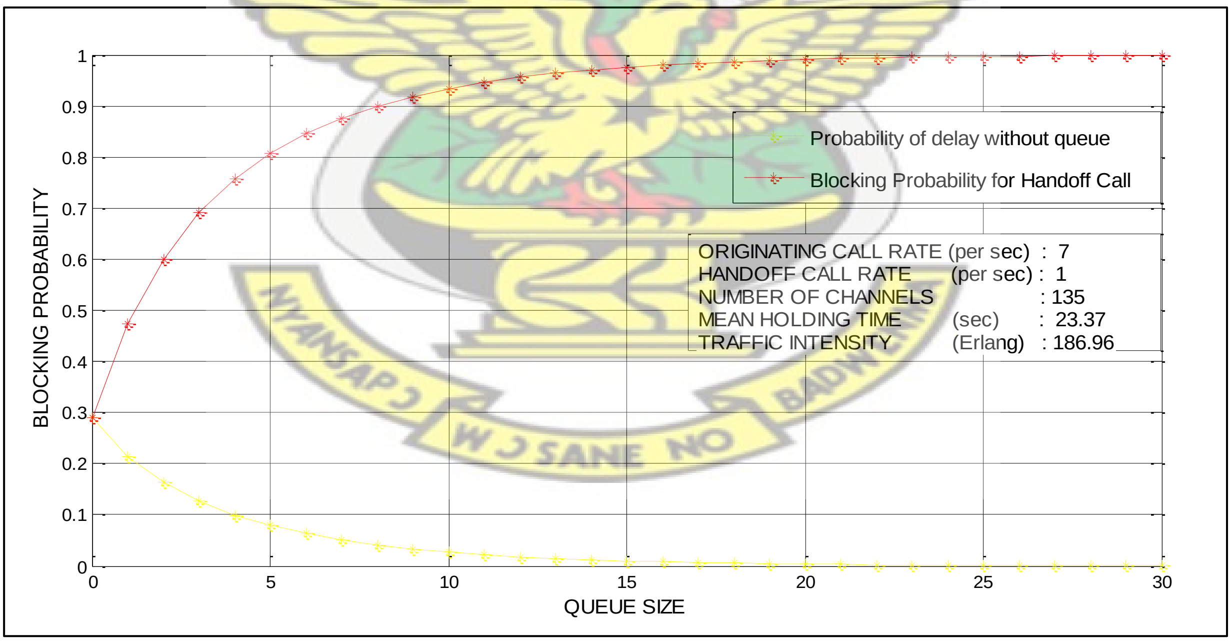

Fig 4.18: Queuing of OC Blocking Probability of HC (Kotobabi DIA)

Case II

This case considers the opposite of *case I* where priority is given to the handoff calls and not the originating calls. The following parameters are used for the analysis;

- Originating calls arrival rate, $\lambda_1 = 4.2030$ per sec,
- Handoff calls arrival rate, $\lambda_2 = 0.5018$ per sec.
- The mean holding time = 21.57 sec,
- The number of available channels =114.
- The traffic intensity generated = 101.48 Erlang.

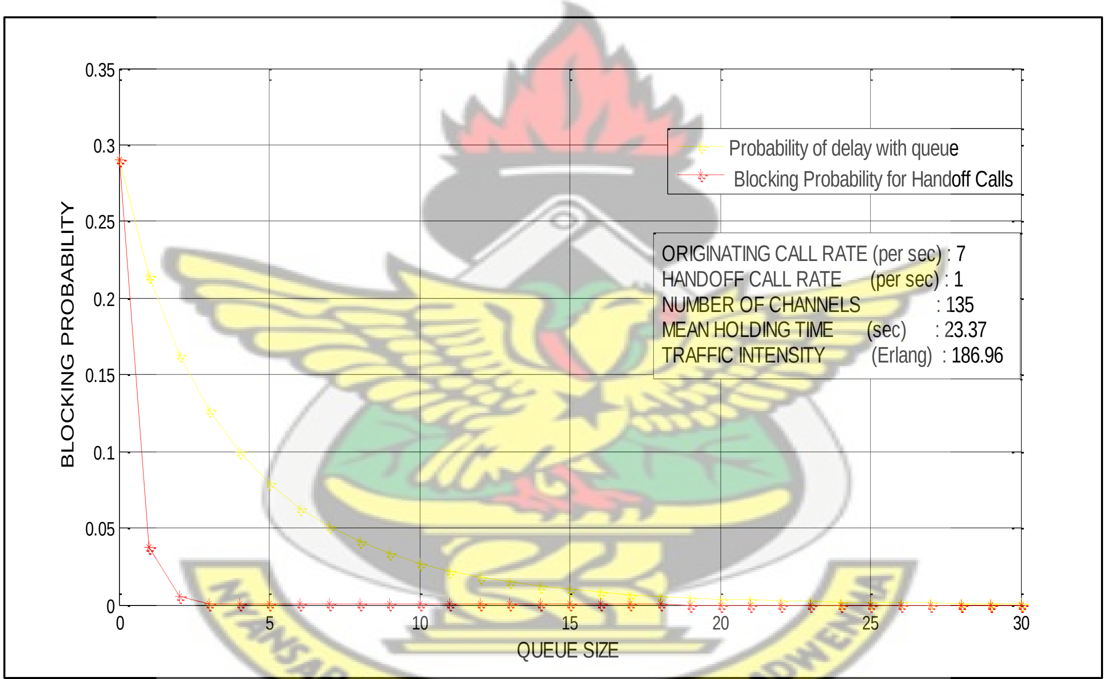

Fig 4.19: Queuing of HC Blocking Probability of HC (Kotobabi DIA)

When handoff calls were given priority, the blocking probability of the handoff calls as shown in the figure above dropped quickly to 0 when the queue size employed is only 3. This is because of the very small handoff calls arrival rate and also due to the large number of channels available.

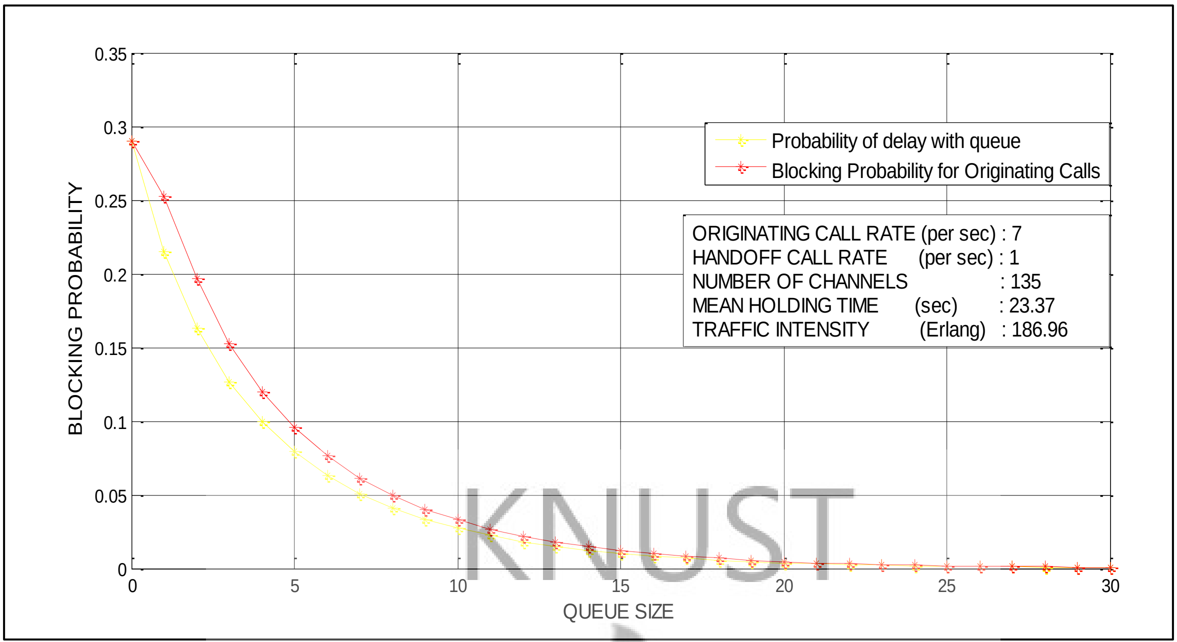

Fig 4.20: Queuing of HC Blocking Probability of OC (Kotobabi DIA)

In the figure above, it is observed that, the blocking probability of originating calls when queuing handoff calls are queue only changed somewhat as the queue size increases This is because the relatively very few handoff requests which come into the system are allocated a queue and serviced straight away, freeing the channels to serve the larger number of originating calls. Hence, the less probability of blocking the originating calls.

4.2.6 Results and Analysis for Osu (DIA)

Case I

Here, we Cell siteshaving traffic intensity to channel ratio greater than 1 or 100%, are considered next.

The following parameters are used for the analysis;

- Originating calls arrival rate, λ_1 = 3.1414 per sec,
- Handoff calls arrival rate, λ_2 = 0.0844 per sec.
- The mean holding time = 16.47 sec,
- The number of available channels = 32.
- The traffic intensity generated = 53.13Erlang.

- Traffic intensity to channel ratio= 1.66.

A substantial rise occur in the blocking probability of the originating calls when originating calls are queued which is not in consistence to the general concept in the reference model. This is as a result of the small number of channels available. The relatively high λ_1 generate much more of the traffic at this site, fills up the queue allocation, and hence more blocking occurs.

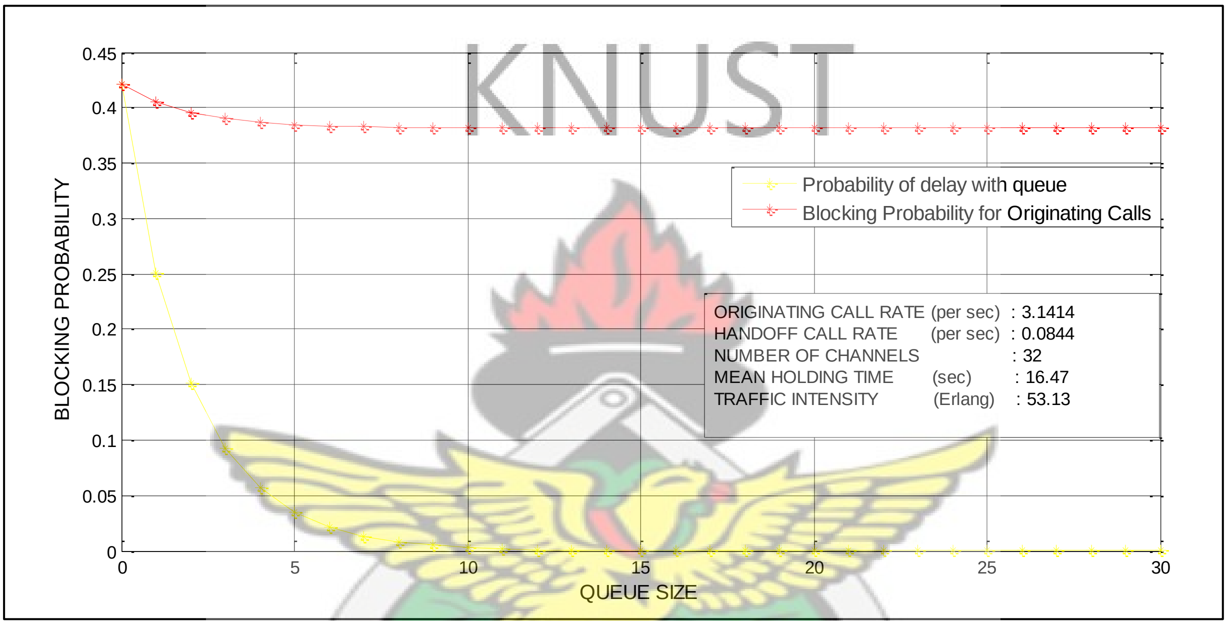

Fig 4.21: Queuing of OC Blocking Probability of OC (Osu- DIA)

Since the handoff calls arrival rate is high and the allocated number of channels is low, there are no spare channels to serve handoff calls. Hence, the uttermost increase in the blocking probability of handoff calls as shown in Fig 4.22 below. It is observed that, the blocking probability increase from 0.42 at 0 queue size to 1 at queue size of 10. This means any handoff call request after the 10 queue size will be dropped.

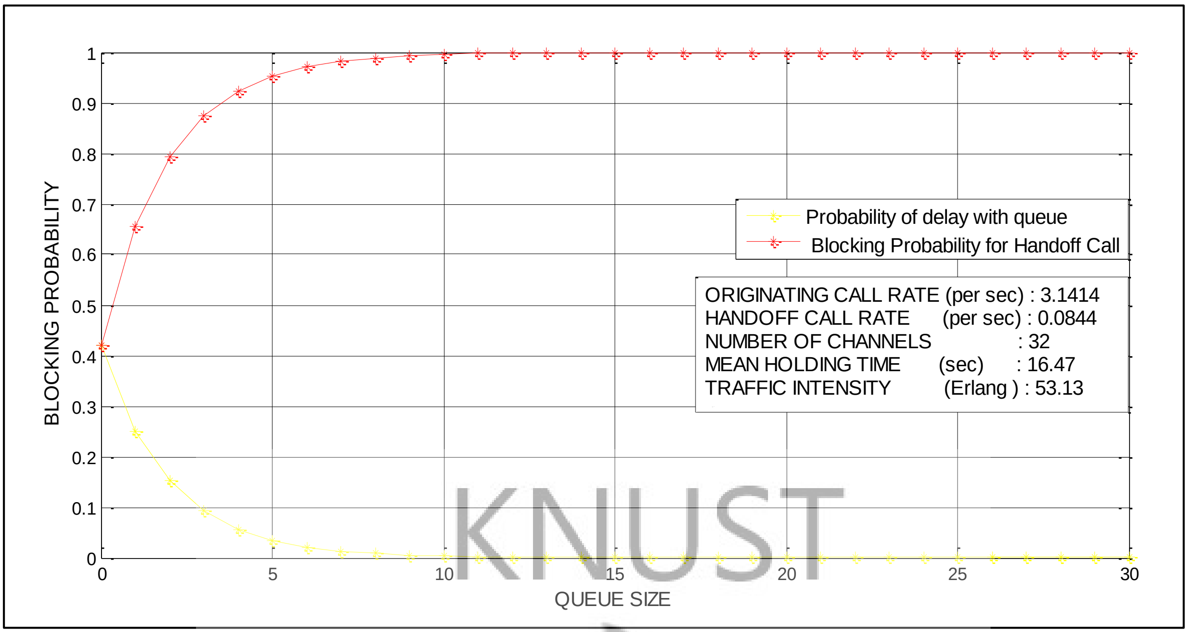

Fig 4.22: Queuing of OC Blocking Probability of HC (Osu- DIA)

Now, we consider instance where handoff calls are queue for a period of time when the available channels are ran through. It is deduced from Figure 4.23 a speedy drop from the initial probability of blocking to 0 just at queue size of 2. Such a cell site will perform perfectly with as little queue size as 2.

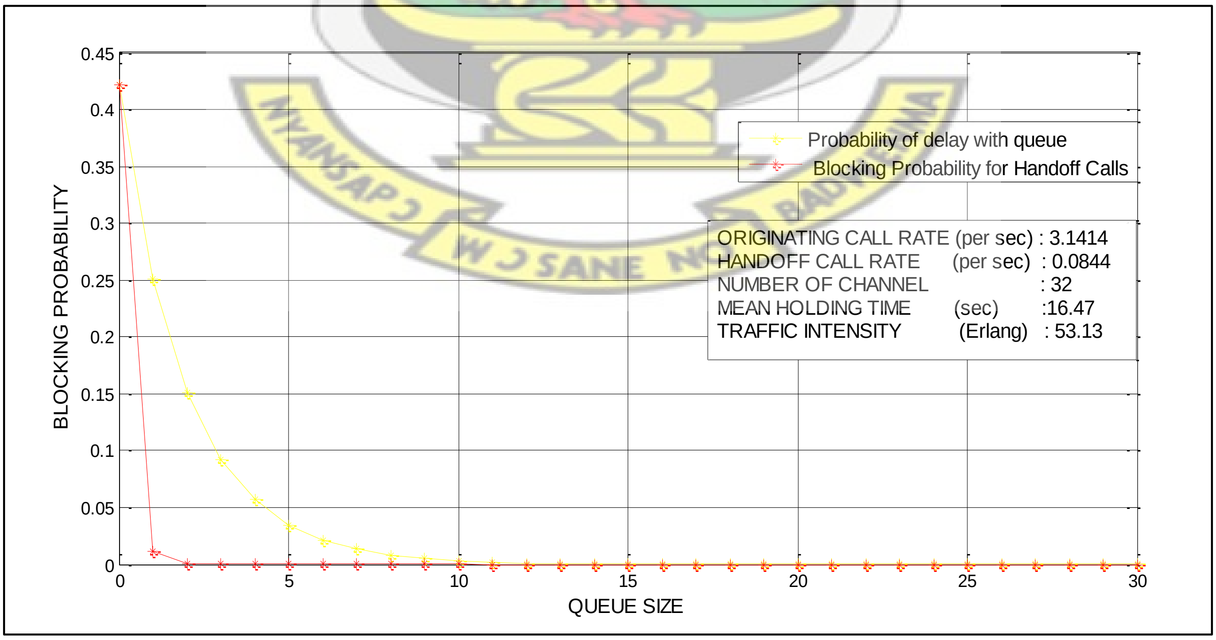

Fig 4.23: Queuing of HC Blocking Probability of HC (Osu- DIA)

Finally, we analyse corresponding effect of queuing handoff calls on the blocking probability of originating calls. It is seen that there is a fringy rise in blocking of originating calls from the delay probability when handoff calls are queued. The blocking probability of originating calls then reduces as the queue size increases. It is best to queue handoff call at this cell site because it yields maximum performance.

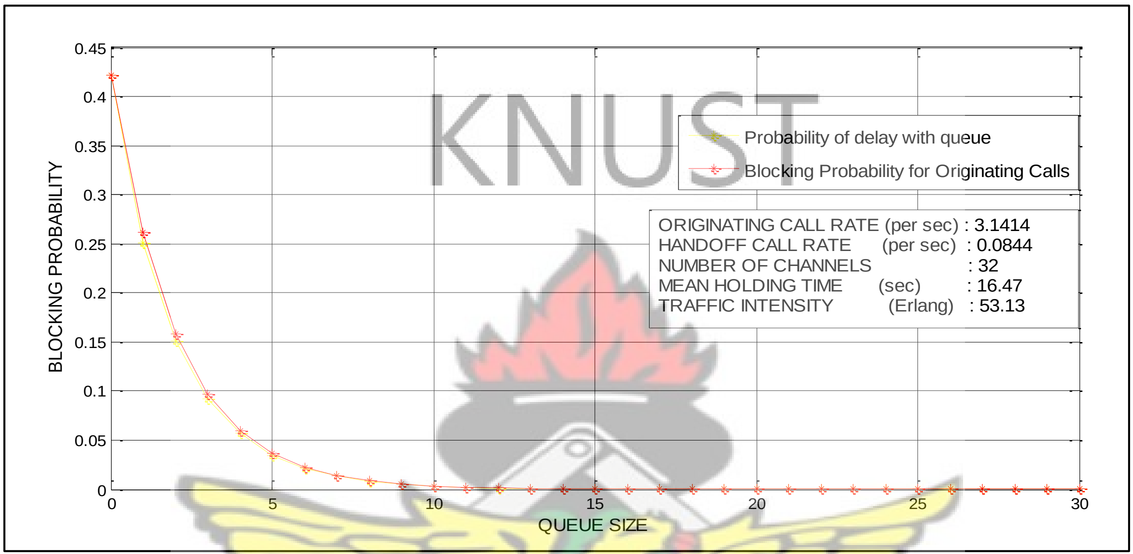

Fig 4.24: Queuing of HC Blocking Probability of OC (Osu- DIA)

4.3 Results and Analysis for (Accra Mall -DIA)

The simulation results below are based on the new proposed queuing scheme. It is worth noting that, queuing both the originating calls and handoff calls at cell sites with very low traffic intensity per channel ratio and approximately equal rates for originating and handoff calls yields optimum performance.

The following parameters are used for the analysis;

- Originating calls arrival rate, λ_1 = 0.373 per sec,
- Handoff calls arrival rate, λ_2 = 0.012 per sec.
- The mean holding time = 44.23sec,

- The number of available channels = 27.
- The traffic intensity generated = 16.99Erlang.

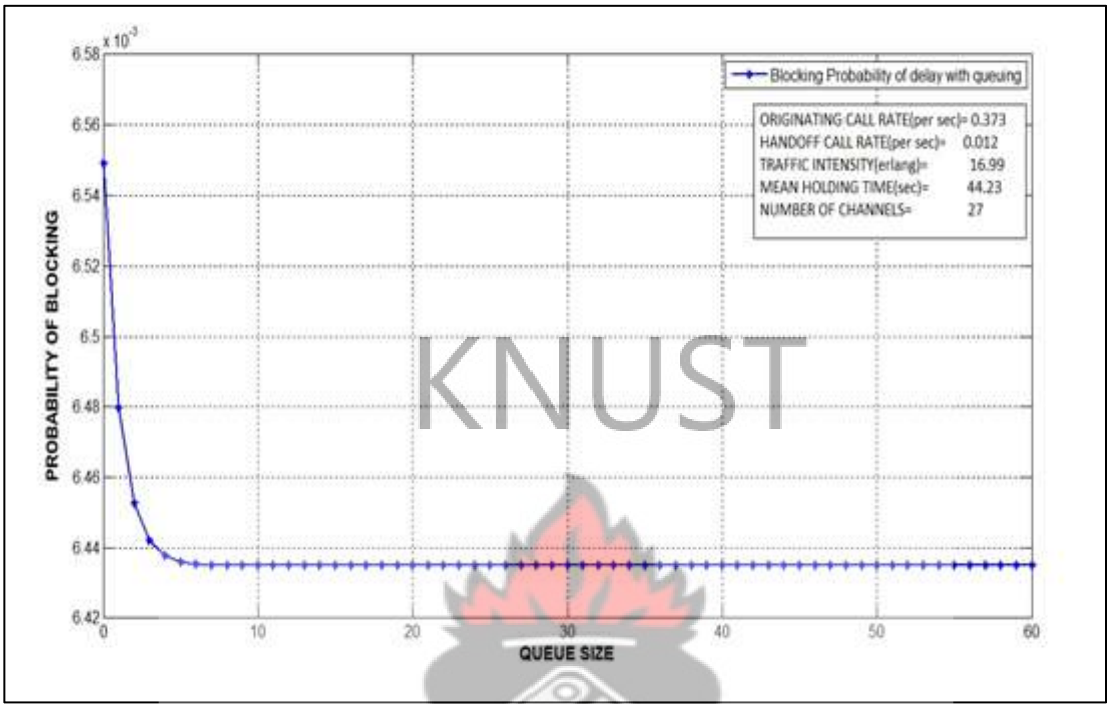

Fig 4.25: Queuing HC and OC Blocking Probability of Delay with Queuing. (Accra Mall- DIA).

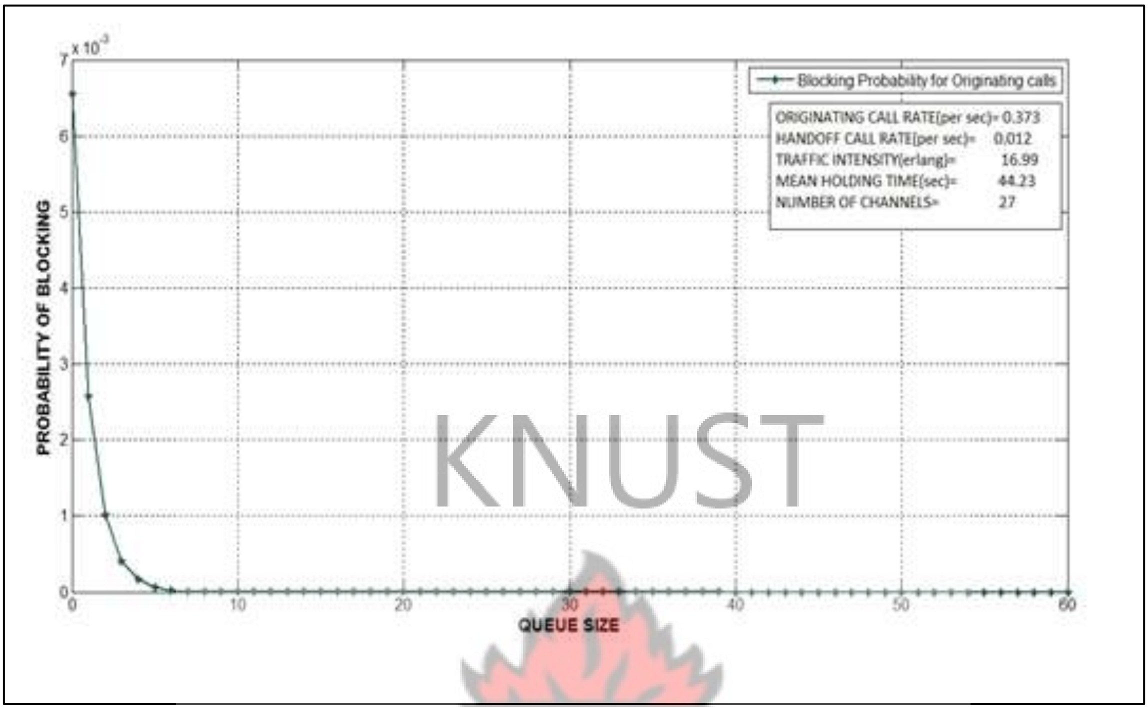

Fig 4.26: Queuing OC and HC Blocking Probability for OC (Accra Mall-DIA)

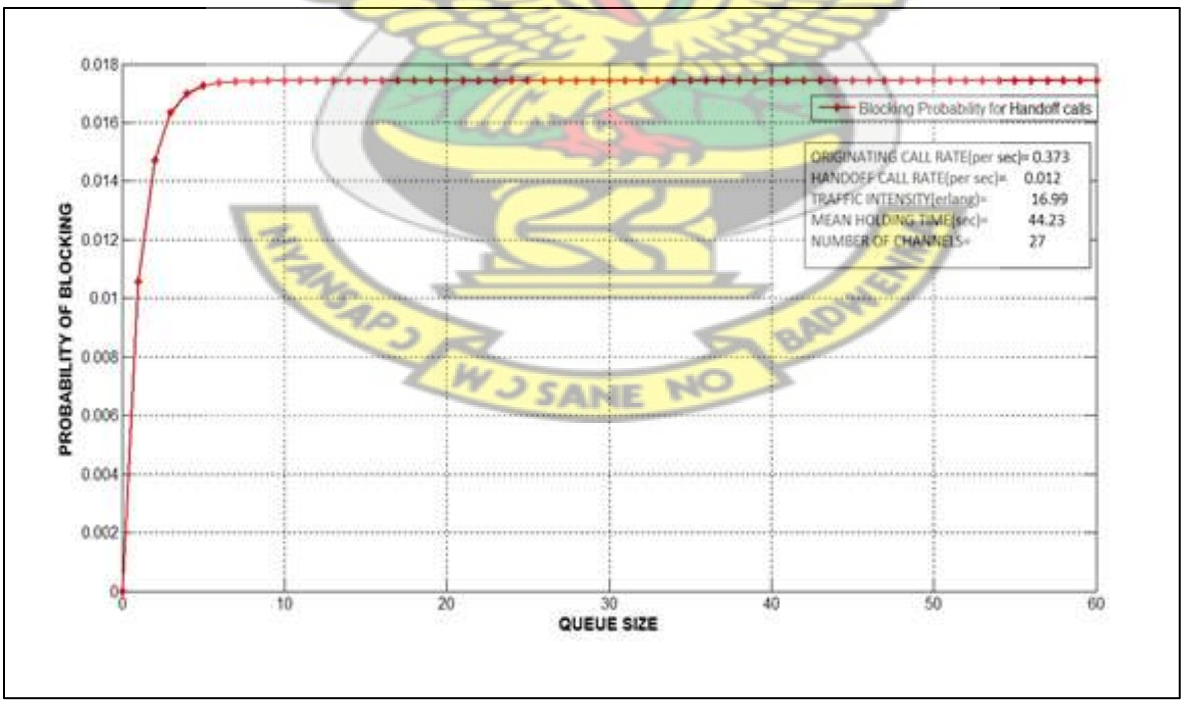

Fig 4.27: Queuing OC and HC Blocking Probability for HC (Accra Mall -DIA)

It is noticed from fig 4.25 that the initial probability of blocking is way below the GOS value of 0.02 and it further retarded for that reason it would be very unlikely for either the originating call or the handoff call to experience delay that could result in call block or call drop. It is also noticed in Figure 4.26 and Figure 4.27 respectively, the originating call decelrated likewise the handoff call.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this chapter we summarize the thesis, depict conclusions about the proposed solution, and graph future directions of the research. At Valley View cell site the traffic intensity per channel value is 0.373, and hence, the simulation results conformed to the case in the reference. It is observed from the graphs that, queuing originating calls caused an increase in the handoff blocking probability and queuing of handoff calls also caused an increase in originating calls, yet, this blocking actually was also within the desired blocking limit of 0.02. However, for such cell sites, either queue performs well.

Here, at Ebony cell site the traffic intensity to channel value is 0.75. This is in consistence with the reference case. Queuing originating calls only have an effect on handoff calls, which is the handoff blocking probability increases as compared to the delay probability. However, this effect is quite insignificant due to the smallness of the maximum blocking probability value; this automatically makes the system perfect. Though, queuing handoff calls also cause an increase in the blocking probability of the originating call, yet, it does not make any difference, since the system itself do not have any effect on either call. Queuing of either call performs well and anyone can be implemented

At Achimota, there is a traffic intensity to channel rate of 0.89 with an initial probability of blocking of 0.02. The simulation results conformed to the reference model. Queuing originating calls results in a decrease in blocking probability of originating calls but queuing originating calls almost caused a total blockage of handoff calls. On the other hand, when handoff calls are queued, the blocking probability of handoff calls drop shapely to 0 ensuring blocking free system for the handoff calls. The blocking probability of originating calls increased initially and then reduced, however, the reduction was still above the grade of service (GoS). Such a cell site will perform better when different queues are employed for the originating calls and handoff calls.

From the Adenta cell site results, we noticed a significant decrement in the blocking probability of the originating calls when the originating calls are given priority but the blocking probability of handoff calls increased to 0.24 which is above the GoS. When the handoff calls are queued the blocking probability of the handoff calls again dropped to 0 at a very small queue size of 3, making the system convenient for the handoff calls. The impact of originating calls at Adenta cell site is the same as that of Achimota. Also, the reduction is above the GoS. Hence, there is the need to implement different queue for the originating calls and the handoff calls respectively.

Kotobabi cell site simulation results did not conform to the reference model, the traffic intensity per channel value of 1.25 which is way above that of the reference case. Queuing originating calls caused total blocking of handoff calls at 21 queue size. However, queuing handoff calls only cause a slim increase above the probability of blocking with queue curve and subsequently dropped in to within the desired GoS.

It is deduced from the Osu cell site queuing originating calls caused total blocking of handoff calls, whilst, we noticed a fringy rise in blocking of originating calls from the delay probability when handoff calls are queued.

Finally, the table below makes clear the best queuing system for the studied cell sites.

SITE NAME	**PREFERRED METHOD OF QUEUING**
VALLEY VIEW	USING OF EITHER QUEUE
EBONY	USING OF EITHER QUEUE
ACHIMOTA	USING OF TWO SEPERATE QUEUES
ADENTA	USING OF TWO SEPERATE QUEUES
KOTOBABI	QUEUING HANDOFF CALLS
OSU	QUEUING HANDOFF CALLS

Table 5.1: Preferential methods for the selected DIA sites.

5.2 Recommendation

From the foregoing, it is evident that the cell sites with traffic intensity to channel ratio range of 0-0.75, either queuing of originating calls or queuing of handoff calls may be employed since both performs very well. It is observed that the cell sites with traffic intensity to channel ratio range of 0.76 - 1, queuing originating calls yield a better result only for the originating calls but poor result for handoff call. Queuing handoff calls also yield better result for itself and quiet good result for the originating calls. Therefore, it is recommended to have separate queues for originating calls and the handoff calls. Cell sites having traffic to channel intensity value greater than 1, sees a total blockage of handoff calls when originating calls are queue, queuing handoff calls yields better result for handoff calls and a good result for originating calls. Hence, queuing of handoff is the only choice for such sites.

Generally, the below recommendations are made.

TRAFFIC INTENSITY TO CHANNEL RATIO	**PROPOSED QUEUING SCHEME**
0 – 0.75	QUEUING OF EITHER ORIGINATING CALLS OR HANDOFF CALLS
0.76 – 1	SEPARATE QUEUES FOR BOTH ORIGINATING AND HANDOFF CALLS
>1	QUEUING OF HANDOFF CALLS

Table 5.2: Proposed queuing scheme for various cell sites.

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Appendix A

Definition of Functions

$$\Pr = [delay > 0] = \frac{A^C}{A^C + C!\left(1 - \frac{A}{C}\right)\sum_{k=0}^{C-1}\frac{A^k}{k!}} \qquad (A.1)$$

$$P_b = \frac{A^c}{C!}\left[\sum_{k=0}^{C}\frac{A^k}{k!}\right]^{-1} \qquad (A.2)$$

$$P_{bq}(0) = \left[\mathrm{C}!\sum_{C=0}^{C-1}\frac{A^{c-C}}{\mathrm{c}!} + \frac{1-\left(\frac{b_1}{C}\right)^{M_1+1}}{1-\left(\frac{b_1}{C}\right)} \right]^{-1} \qquad (A.3)$$

$$B_{oq} = \left(\frac{b_1}{C}\right)^{M_1} P_{bq}(0) \qquad (A.4)$$

$$B_{hq} = \frac{1-\left(\frac{b_1}{C}\right)^{M_1+1}}{1-\left(\frac{b_1}{C}\right)} P_{bq}(0) \qquad (A.5)$$

$$B_{hq} = \left(\frac{b_2}{C}\right)^{M_2} P_{bq}(0) \qquad (A.6)$$

$$B_{oq} = \frac{1-\left(\frac{b_2}{C}\right)^{M_2+1}}{1-\left(\frac{b_2}{C}\right)} P_{bq}(0) \qquad (A.7)$$

$$P_{bq}(0) = \left[C! \sum_{c=0}^{c-1} \frac{A^{c-C}}{c!} + \frac{1-\left(\frac{b_1+b_2}{C}\right)^{M_1+M_2}}{1-\left(\frac{b_1+b_2}{C}\right)} \right]^{-1} \qquad (A.8)$$

$$B_{oq} = \left(\frac{b_1+b_2}{C}\right)^{M_1+M_2} P_{bq}(0) \qquad (A.9)$$

$$B_{hq} = \frac{1-\left(\frac{b_1+b_2}{C}\right)^{M_1+M_2}}{1-\left(\frac{b_1+b_2}{C}\right)} P_{bq}(0) \qquad (A.10)$$

A.1 MATLAB SOURCE CODE

Queuing Originating Calls

```
clc;
close all;
clear all;
%Initialising parameters
s1 = 40.2030 %input('Average arrival time for originating calls in per
seconds')
s2 = 0.5018 % input('Average arrival time for handoff calls in per
seconds')
H = 21.57 %input('Average holding time in seconds')
%Number of channels
```

```
N = 114 %input('Enter number of channels')
%Average holding time or mean holding time
u = 1/H
% Describing the various equations
a = (s1 + s2)/u
b1 = s1/u
sed = 0
M1q = 0:1:30
K = 0:1:(N-1)
n = 0:length(K)
%Queue size length
for i = 1:length(K)
    J(i) = (a.^(n(i)-N))
    c1(i) = (factorial(n(i)))
    prisy(i) = (J(i)/c1(i)) + sed
    sed = prisy(i)
end
for e = 1:length(M1q)
    top(e) = 1 - (b1/N)^(M1q(e)+1)
    bottom = 1 - (b1/N)
    y = factorial(N) * sed
    yayra(e) = top(e)/bottom
    all(e) = y + yayra(e)
    Pq(e) = 1/all(e)
    Boh(e) = yayra(e) * Pq(e)
    mum(e) = (b1/N)^M1q(e)
    Boq(e) = mum(e) * Pq(e)
end
axis equal
% plot(M1q,Pq,'-b*')
% hold on
% plot(M1q,Boq,'-g*')
% hold on
plot(M1q,Boh,'-r*')
grid on
ylabel('PROBABILITY OF BLOCKING')
xlabel('QUEUE SIZE')
title('QUEUING THE ORIGINATING CALLS BUT NOT THE HANDOFF CALLS FOR
ABLEKUMA')
legend('Blocking Probability for Handoff Calls')
```

Queuing Handoff Calls

```
clc;
close all;
clear all;
%Initialising parameters
s1 = 4.2030 % input('Average arrival time for originating calls in per
seconds')
s2 = 0.5018 % input('Average arrival time for handoff calls in per
seconds')
H = 21.57 %input('Average holding time in seconds')
%Number of channels
N = 114 %input('Enter number of channels')
%Average holding time or mean holding time
u = 1/H
% Describing the various equations
a = (s1 + s2)/u
b1 = s1/u
b2 = s2/u
sed = 0
M1q = 0:1:30
K = 0:1:(N-1)
n = 0:length(K)
%Queue size length
for i = 1:length(K)
    J(i) = (a.^(n(i)-N))
    c1(i) = (factorial(n(i)))
    prisy(i) = (J(i)/c1(i)) + sed
    sed = prisy(i)
end
for e = 1:length(M1q)
    top(e) = 1 - (b1/N)^(M1q(e)+1)
    bottom = 1 - (b1/N)
    y = factorial(N) * sed
    yayra(e) = top(e)/bottom
    all(e) = y + yayra(e)
    Pq(e) = 1/all(e)
    %Boh(e) = yayra(e) * Pq(e)
    mum(e) = (b2/N)^M1q(e)
    %Boq(e) = mum(e) * Pq(e)
    %========================================================================
```

```
    % Cases with the third situation
    %=========================================================================
    cooper(e)  = 1 - (b2/N)^(M1q(e)+1)
    jemima = 1 - (b2/N)
    dorothy(e) = cooper(e) / jemima
    Bho(e) = dorothy(e) * Pq(e)
    Bhq(e) = mum(e) * Pq(e)
end
axis equal
% plot(M1q,Pq,'-b*')
% hold on
% plot(M1q,Bhq,'-r*')
% hold on
plot(M1q,Bho,'-g*')
grid on
ylabel('PROBABILITY OF BLOCKING')
xlabel('QUEUE SIZE')
title('QUEUING THE HANDOFF CALLS BUT NOT THE ORIGINATING CALLS FOR
ABLEKUMA')
legend('Blocking Probability for Originating Calls')
```

Queuing Originating Calls and Handoff Calls in a Single Queue

```
clc;
close all;
clear all;
%Initialising parameters
s1 = 0.373 %input('Average arrival time for originating calls in per
seconds')
s2 = 0.012 %input('Average arrival time for handoff calls in per seconds')
H = 44.23 % input('Average holding time in seconds')
%Number of channels
N = 27  % input('Enter number of channels')
%Average holding time or mean holding time
u = 1/H
% Describing the various equations
a = (s1 + s2)/u
b1 = s1/u
b2 = s2/u
sed = 0
M1 = 30
```

```
M2 = 30
M1q = 0:1:(M1 + M2)
K = 0:1:(N-1)
n = 0:length(K)
%Queue size length
for i = 1:length(K)
    J(i) = (a.^(n(i)-N))
    c1(i) = (factorial(n(i)))
    prisy(i) = (J(i)/c1(i)) + sed
    sed = prisy(i)
end
for e = 1:length(M1q)
    top(e) = 1 - ((b1+b2)/N)^(M1q(e)+M1q(e))
    bottom = 1 - ((b1+b2)/N)
    y = factorial(N) * sed
    yayra(e) = top(e)/bottom
    all(e) = y + yayra(e)
    Pq(e) = 1/all(e)
    Boh(e) = yayra(e) * Pq(e)
    mum(e) = ((b1+b2)/N)^(M1q(e)+M1q(e))
    Boq(e) = mum(e) * Pq(e)
end
axis equal
% plot(M1q,Pq,'-b*')
% hold on
% plot(M1q,Boq,'-r*')
% hold on
plot(M1q,Boh,'-g*')
grid on
ylabel('PROBABILITY OF BLOCKING')
xlabel('QUEUE SIZE')
title('QUEUING THE ORIGINATING CALLS BUT NOT THE HANDOFF HANDOFF CALLS')
legend('Blocking Probability for no queuing','Blocking Probability for
Originating Calls','Blocking Probability for Handoff calls')
```