ANALYSIS AND OPTIMISATION OF INTER CELL HANDOVER DYNAMICS IN A GSM NETWORK

(A CASE STUDY OF AIRTEL KANO, NIGERIA)

BY

ABEDNEGO ANDIRYA GALADIMA

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING,
FACULTY OF ENGINEERING,
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

AUGUST, 2014

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Abednego Andirya GALADIMA, B.Eng. (ATBU) 1998
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NIGERIA**

AUGUST, 2014

DECLARATION

I declare that the work in this thesis entitled the Analysis and Optimization of Intercell Handover Dynamics in a GSM Network (a case study of Airtel Kano, Nigeria) has been carried out by me in the department of Electrical and Computer Engineering. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

Galadima Abednego Andirya **……** **……**

Signature **Date**

CERTIFICATION

This thesis entitled THE ANALYSIS AND OPTIMIZATION OF INTERCELL HANDOVER DYNAMICS IN A GSM NETWORK (A CASE STUDY OF AIRTEL KANO, NIGERIA) by Galadima Abednego Andirya meets the regulation governing the award of the degree of master's of Science (M.sc) in Electrical Engineering of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Chairman, Supervisory Committee:	**……**	**……**
Dr. (Engr.) D. D. Dajab	**Signature**	**Date**
Member, Supervisory Committee:	**……..**	**……**
Prof. B. G. Bajoga	**Signature**	**Date**
Head of Department:	**……..**	**……**
Dr. M. B. Mu'azu	**Signature**	**Date**
Dean, School of Postgraduate Studies:	**……..**	**……**
Prof. A. A. Joshua	**Signature**	**Date**

DEDICATION

This thesis is dedicated to God Almighty who made it possible by granting me abundant mercies and grace. Then, to my wife, sons and daughters.

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I wish to express my profound gratitude to my supervisors Dr. D. D. Dajab and Prof. B. G Bajoga for putting in time and other resources in making this work what it is. The guidance, instructions and moral support I enjoyed are quite invaluable. The excellent interpersonal relationship we shared I will eternally cherish.

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ABSTRACT

Efficient Handover mechanism in a GSM network is one of the parameters critical to GSM network service quality (QoS) and customer satisfaction. Handover is the process that transfers an ongoing call from one cell to another as the users move through the coverage areas of the cellular systems. This research focuses on analyzing and optimizing intercell handover dynamics in Airtel Network in Kano. A three months call record sample data was used. Several cells in the Airtel Network in Kano were investigated by profiling and analysing their performance using standard mathematical relationships of Handover success rate, Call setup success rate, Blocking probability, Call drop rate which are relevant Key Performance Indicators. Data was obtained in Microsoft Excel format. Performance evaluation was carried out using Nigerian Communication Commission (NCC) QoS standard for Macrocell as benchmark. The evaluation revealed that seventy two percent (72%) of cells considered performed below NCC targets for Call Setup Success Rate (CSSR), sixty four (64%) failed to achieve NCC targets for Handover Success Rate (HSR) and sixty four percent (64%) failed to achieve Standalone Dedicated Control Channel blocking rates targets, twenty one percent (21%) failed to achieve congestion targets. Average call drop rate per cell was predicted to be six percent (6%). An optimal solution was provided using dynamic cutoff priority channel allocation scheme, this improves performance of handover dynamics when simulated. An object oriented simulation technique was employed using a JAVA variant NETBEANS 6.1 because of its moderate system resource requirement, fast and responsive user interface. The result showed that handover failure rate was reduced by an average of Ninety percent (90%) for varying loads. System validation was achieved by comparing the real and simulated load characteristics which have similarities. A correlation coefficient was calculated using MATLAB to be 0.9122.

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LIST OF ABBREVIATIONS

BER	Bit error rate
BSC	Base station controller
BTS	Base transceiver station
C/A	Adjacent channel interference
CBHS	Channel borrowing handover scheme
CCR	Call completion rate
CCRS	Collaborative channel reservation scheme
CDMA	Code division multiple access
CD	Code division
CDP	Call dropping probability
CDR	Call drop rate
CSSR	Call setup success rate
DCAS	Dynamic channel allocation scheme
DCCAS	Dynamic cutoff priority channel allocation scheme
DHQS	Dynamic handover queuing scheme
DRS	Dynamic reservation scheme
EIR	Equipment identity registers
ETS	European telecommunication standards
FCA	Filled channel allocation
FD	Frequency Doppler
FDMA	Frequency division multiple access
GCS	Guard channel scheme
GHS	Genetic handover scheme
GSM	Global system for mobile communication

HCA	Hybrid channel allocation scheme
HDP	Handover dropping probability
HHS	Hybrid handover scheme
HLR	Home location register
HQS	Handover queuing scheme
HSR	Handover success rate
MAH	Mobile assisted handover
MCH	Mobile controlled handover
MSOEL	Modeling specification or evaluation language
MSC	Mobile switching centre
MS	Mobile station
NCC	Nigerian communication commission
NCH	Network controlled handover
NPS	Non -prioritized scheme
OMC	Operation maintenance centre
PCS	Personal communication system
QOS	Quality of service
RED	Random early detection
RSQ	Received signal quality
RSS	Received signal strength
SCRS	Static channel reservation scheme
SDCCH	Standalone dedicated control channel
SHO	Soft handover
SNR	Signal to noise ratio
TCH	Traffic channel

TDMA	Time division multiple access
VLR	Visitor locations register

LIST OF SYMBOLS

λ_P	The arrival rate of originating calls in a cell
β_o	Blocking probability of originating calls
P_h	Probability that a near call is not blocked would require at least one handoff
P_{rh}	Probability that a call that has already been handed off successfully would require another handover
R_e	Constant determined by transmitted power, wavelength and antenna gain
ε	Slope index
ξ	Logarithm of shadowing component
d	Distance between MN or BS of a cell
P_{rx}	Received Signal Power
Log	Logarithm
P_{rho}	Absolute value of Received Power
P_{rmin}	Minimum Value of Received power
K_1, K_2	Constants due to path loss
μ	Mean
G_{ch}	Guard channels
OC	Open channels

C	Channels
T_h	Threshold
H_f	Handover failure
A_d, A_u	Constants
t	Time
%	Percentage

CHAPTER ONE
INTRODUCTION

1.1 GSM System

Global System for Mobile Communications (GSM) is a digital wireless network standard designed by standardization committees from major European telecommunications operators and manufacturers. The GSM consists of cells as building blocks. A cell is a geographical area served by a base transceiver station (BTS). GSM is characterized by mobility and limited resource. The cells enable mobile users to be served. User mobility during call can result in a change of cell (Base transceiver station). The effect of mobility is handover. Handover is the process that ensures retention of the ongoing call into another cell (Busra *et al*, 2010). GSM supports automatic hard handovers.

1.2 Handover Process

The process of handover within any cellular system is of great importance. It is a critical process and if performed incorrectly can result in the loss of calls. Dropped calls are particularly annoying to users and if the number of incidences of dropped calls rises, dissatisfaction increases that can lead a subscriber to change of network. Accordingly GSM handover is an area to which particular attention was paid when developing the GSM ETS standards (Ghaderi, 2006).

One of the key elements of a mobile cellular telecommunications system is that the system is split into many smaller cells to provide good spectrum utilisation and coverage. However as the mobile moves out of one cell area into another, it is expected to retain the connection.

Handover process in cellular network automatically transfers a call from one radio channel to another radio channel while maintaining good quality of services (QoS) of a call (Adegoke, 2008). The number of cell boundaries increases because smaller cells are deployed in order to meet the demand of increased capacity. Each handover requires network resources to route the call to next base station (Jahangir, 2010).

Efficient handover algorithms cost-effectively preserve and enhance the capacity and Quality of Service (QoS) of communication systems (Pollini, 1996). The overall handover procedure can be thought of as having two distinct phases (Corazza *et al*, 1994): the initiation phase (in which the decision about handover is made) and the execution phase (in which either a new channel is assigned to the mobile station or the call is forced to terminate). Handover algorithms normally carry out the first phase. Handover is generally designed to

i. Maximize quality of service QoS and capacity by ensuring maximum reliability and communication quality,
ii. Maintain cell borders and proper traffic balancing
iii. Minimize number of handovers and global interference

These are the desirable qualities of a good handover algorithm. But the complexities of handover may arise due to the cell dynamics i.e (cell, topography, propagation, traffic, mobility, delay, and system constrain(s).

1.3 Motivation

The motivation for this thesis is the need to improve on mobility management and GSM channel resource utilization. The increasing mobile network subscriber base in Nigeria has placed on GSM service providers the need to increase capacity. This is mostly achieved by increasing coverage areas and channel resources to meet up. Inherently, this creates mobility management problems because of intercell handovers which if not properly and efficiently implemented leads to degradation in quality of service and consequently call dropping. Call dropping affects subscribers directly and is a key quality of service indicator that regulatory bodies look at when evaluating service quality. Another problem associated with poor handling of handover is overloading of the system processor which can bring about incessant system breakdown this also leads to revenue loss and degrades quality of service.

A careful cell performance evaluation when carried out will reveal the impart of intercell handover dynamics on quality of service. Also, a cutoff priority scheme that employs dynamic algorithm which increases or decreases cutoff priority channels based on the handover failure rates will be implemented to perform optimal channel resource and mobility management.

1.4 Statement of Research Problem

In wireless cellular systems handover is key to mobility management and affects resource allocation. The handover process is expected to be successful, imperceptible and less frequent. Unsuccessful handover can be very annoying to subscribers. It terminates established connections forcefully leading to dropped calls and quality of service get

degraded in the process. In densely populated cities like Kano, High intercell handover requests significantly increase traffic loading and could degrade QoS, increase call set up time, call drop and call blocking probabilities. Channel allocation schemes if not properly chosen and efficiently performed can lead to high intercell handovers as well.

The research profiles performance of cells with specific attention on the impact of blocking probabilities, expected call dropping probability, handover failure rates and traffic channel call drop. Performance evaluation will employ Nigerian Communication Commission's recommended quality of service standards for these parameters as the benchmark. Real GSM cell call data statistics from an OMC of Airtel in Kano is sought and processed. Attempt to optimize handover calls is made using a simulated cutoff priority based performance model.

1.5 Research Methodology

The methodology adopted in carrying out this work includes the following

a. Data obtained from the Network Operation Maintenance Centre (OMC) section of Airtel Network in Kano for this study are: Traffic, Call success set rate, Handover success rate, SDCCH call drop, TCH call drop, Congestion, SDCCH blocking, TCH call blocking, TCH Availability, Cell ID, Time and Cell Availability.

b. Analysis and extraction of relevant parameters from raw data in (a) ,

c. Compute overall arithmetic averages of extracted parameters and graphically display it using MATLAB plot the extracted parameters are: call setup success rate, handover Success rate, traffic channel call drop rates, Blocking probability, Standalone dedicated control channel drop rates.

d. Compute weekly arithmetic averages and analyse using MATLAB plot weekly trends of call blocking probability, traffic, traffic channel call dropping, handover failure rates, and standalone dedicated control channel from data.

e. Compute using established standard mathematical equations expected call dropping probability for each cell. Process from obtained handover statistics average handover failure rates values and subsequently, compute handover dropping probability from the results and qualitatively display it applying MATLAB plot.

f. Simulate a Cut- priority model using an object oriented technique (Netbeans 6.1)

g. Validation through comparing the actual load derivable from processed data and simulated result.

1.6 Aims and Objectives of the Research

The aim of the research is the analysis of intercell handover dynamics with a view of optimizing the process using Airtel, Kano as a case study.

The objectives of the research work are as follows:

1) Profile performance of cells with specific attention on the impact of blocking probabilities, call dropping probabilities, handover rates, and congestion.
2) Quality of service (QoS) impact assessment due to handover dynamics using NCC standards as the Benchmarks.
3) Simulated system validation Using Data obtained from Airtel Kano for a period of three months
4) To provide optimal solution using dynamic cut-off priority channel allocation

1.7 Research Outline

Chapter One contains general introduction to the various aspect of the work. It begins with a brief on GSM network and then handover process. These are followed by the statement of the research problem, methodology, aims and objective of the work.

In chapter Two a detail theoretical background beginning with an overview of a GSM system, then followed by handover processes, methods, algorithms, protocol, schemes and some key quality of service indicators were represented. The chapter was concluded with a rigorous literature review.

System modeling and simulation, data collection methods, bench marks, simulation algorithm and simulation parameters were presented in Chapter Three.

Chapter Four present our results, analysis and discussions of the results.

In Chapter Five summary of the work was presented, conclusions were drawn including limitation encountered in the course of the work and a suggestion for further work was presented.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of a GSM system, some fundamental concepts of handover processes, handover schemes, key quality of service performance indicators and a rigorous review of similar works.

2.2 Review of Fundamental Concepts

In this subsection theoretical background of the work is set and relevant fundamental concepts are reviewed. Beginning with a discussion on generic GSM system followed by several other related concepts.

2.2.1 Generic GSM system

The basic building block of a typical GSM network is the cell-site also called Base Transceiver Station (BTS) or called just Base Station. Next in the hierarchy is the Base Station Controller (BSC). This controls a number of base transceiver stations. Depending on the density of users and the topology, each BSC can control anywhere between 5-20 BTSs (Madhusmita *et al*, 2008). Finally the upper most crucial element is the Mobile Switching Center (MSC). Each MSC covers about 5-15 BSCs (Ghaderi, 2006). Each service provider has at least one MSC. The MSC normally houses the Home Location Register (HLR), Visitor Location Register (VLR), the Authentication center (AuC) and the Equipment Identity Register (EIR). The HLR has all the relevant details of a particular subscriber like the service plan, the supplementary services, and the details

about the mobile station, the latest coverage areas visited and billing details. The VLR primarily deals with roaming and exchange details of users gotten from foreign networks and also holds latest details of its own users roaming in other networks. The VLR also assists in handovers. In order to ensure that network operators have several sources of cellular infrastructure equipment, GSM decided to specify not only the air interface, but also the main interface that identify different GSM parts. Figure 2.1 describes a typical GSM network architecture.

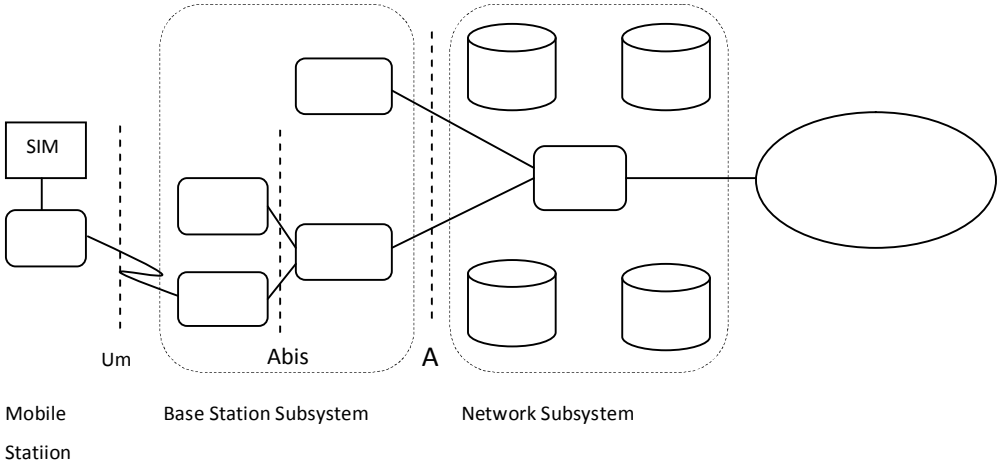


Figure 2.1 Generic GSM Network Architecture (Madhusmita *et al*, 2008)

There are three dominant interfaces, A interface between MSC and BSC, A-bis Interface between BSC and BTS and an Um interface between the BTS and MS.

2.2.1.1 Basic cell structure

When designing hand over algorithms, the characteristics of the communication system must be taken into account. Several cellular structures are categorized as; Macrocells, Microcells, overlay system and picocell (Nishith, 1998).

Different cellular structures or layouts put different constraints on handover algorithms. Disconnected microcells and macrocells are expected to coexist in the cellular systems (Polini, 1996). In this case, microcells cover hot spots, while macrocells cover low traffic areas. Different radii cells require different handover algorithm parameters (RSS, SIR threshold, etc.) to obtain good performance as in (Tripathi, 1998). Some service areas may contain microcell-macrocell overlay in which microcells serve high traffic areas and macrocells serve high speed users and overflow traffic. As the cell size decreases, the number of handovers per call increases, the variables such as RSS, SIR, and BER change faster, and the time available for processing the handover requests decreases (Munoz-Rodriguez *et al*,1992). Moreover, the number of MSs to be handled by the infrastructure also increases

2.2.1.2 Frequency re-use distance and cluster size

Frequency reuse is the use of radio channels on the same carrier frequency to cover different areas which are separated from one another by sufficient distance so that co-channel interference is not a problem. The reuse of frequencies enables a cellular system to handle huge number of calls with limited numbers of channels but causes mutual interference that is Co-channel interference and adjacent channel interference (trade off link quality versus subscriber capacity) (Michael, 2004)

A GSM cellular network is made up of a number of radio cell or cells served by fixed base stations. These cells are used to cover different areas to provide radio coverage over wider area. These radio cells are combined into clusters and each frequency is used once per cluster. Cells need to be represented by regular polygon. The Hexagon was found to be an ideal choice. Each cell is assigned a-group of radio channels which is completely

different from the neighboring cells. The cells will form sets called clusters where cluster size N can take any value that satisfies the equation 2.1 where i and j are shift parameters

$$N = i^2 + j^2 + ij \quad (2.1)$$

For any integer i and j. Figure 2.2 shows the case when cluster size is seven (7) where cells with the same number use the same group of channels. The cells are called Co-channels cells. It is shown in (Gunnar, 1999) that

$$N=\frac{D\hat{}2}{3R\hat{}2} \quad (2.2)$$

$$Q= D/R= \sqrt{3N} \quad (2.3)$$

Where D is the distance between the centers of any two CO-channel cells (i.e. having same frequency), and R is the cell radius. Equation 2.3 is called Co-channel reuse ratio 'Q' Figure 2.2 illustrates GSM Cellular layout with frequency reuse.

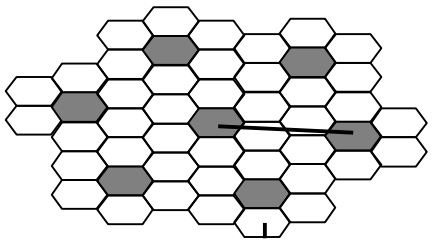


Figure 2.2: GSM Cellular Layout with Frequency Reuse (Chako, 2004)

The value of N is 7 for TDMA system and co- channel interference is a serious problem in this scheme while adjacent co-channel interference is not a big problem. (Chako, 2004).

2.2.1.3 Co-channel interference (C/I)

Reusing an identical carrier frequency in different cells is limited by co-channel Interference or C/I. Co-channel interference is the relation between the desired signal C and the undesired re-used signal I, both using the same carrier frequency.

Suitable values for this ratio are obtained through evaluation by a large group of listeners as to what is acceptable speech quality. The value given in the GSM recommendation European Telecommunication Standards (ETS) (Ghaderi, 2006) for Co-channel interference ratio is ≥9 dB. It should be mentioned that co–channel interference requires not only channels to be assigned to different cells but also that they are actually in use simultaneously. This means that interference will be more of a problem during busy hours than at other times (Michael, 2005)

2.2.1.4 Adjacent channel interference (C/A)

The filters limiting each carrier to its domain of 200kHz, are not ideal, the carriers will somewhat affect each other. The relation between the desired signal C from the correct carrier and the undesired signal (A) from the carrier 200 kHz away is called adjacent channel interference (C/A). When a frequency re-use pattern such as the 3/9 pattern is used, adjacent frequencies will be used in neighboring cells. This means that some of the energy of the adjacent frequency will leak into serving cell and cause interference. The limit for this ratio in GSM is C/A ≥-9 dB (Lee, 1995).

2.2.2 Handover Criteria

The handover is needed mainly under two situations i.e Noise limited environment and Interference limited situations. Figure 2.3 illustrates occurrence of handover.

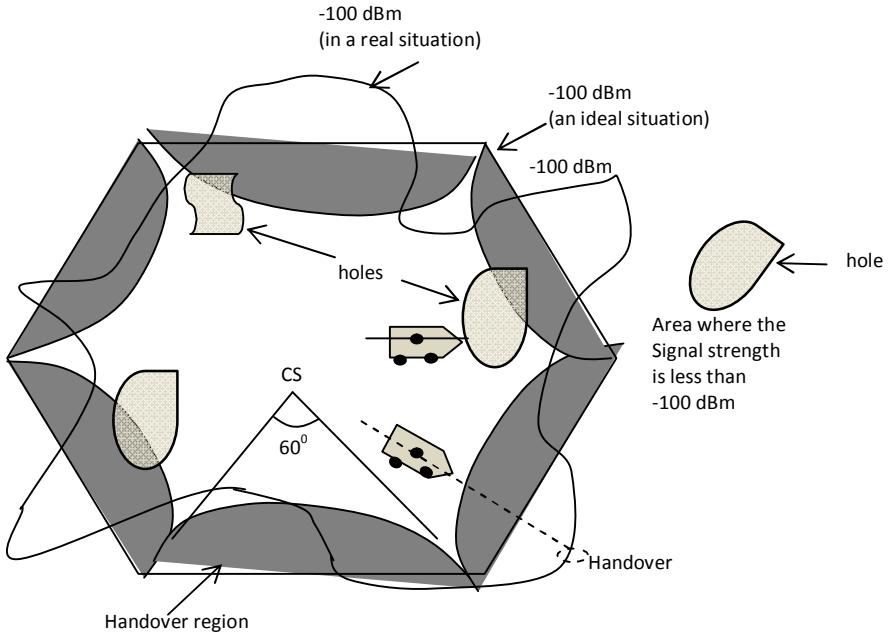


Figure 2.3: Handover Criteria (Lee, 1995)

Figure 2.3 clearly shows that handover is needed in two situations. Noise limited: under this situation as the mobile station approaches the cell boundary, the signal strength of the serving cell decreases to say, -100dBm, which is the level for requesting a handover in a noise limited environment. A noise limited handover condition is a function of cell configuration and deployment, this work will focus on this handover scenario because noise is an inherent condition in the domain of study (Lee, 1995)

a. Interference limited: In this situation when the mobile unit is reaching the signal-strength holes within the cell site. Under this situation signal strength adequately indicate the signal quality. An advantage of using the Signal-to-Interference Ratio (SIR) as a criterion is that it is a parameter common to voice quality, system capacity and dropped call rate. In an interference-limited environment, deterioration in BER does not necessarily imply the need for an intercell handover; an intracell handover may be sufficient (Lee, 1995)

2.2.3 Other criteria for handover process

Apart from the two major criteria stated in section 2.2.2, other criteria that could be applied are discussed in the following subsections..

2.2.3.1 Traffic

Traffic level as a handover criterion can balance traffic in adjacent cells (Rappaport, 1993). Traffic have been used to develops an analytical model for traffic performance analysis of a system. Statistics of dwell times are important for teletraffic performance evaluation (Rappaport, 1993).

2.2.3.2 Call and handover statistics

Statistics such as total time spent in the cell by a call and arrival time of a call in a cell can also be used as handover criteria (Anagnostou and Manos, 1994). Elapsed time since last handover is also a useful criterion since it can reduce the number of handovers (Lee, 1995). This work would use handover call statistics in a noise limited situation as earlier stated.

2.2.3.3 Velocity

Velocity is an important handover criterion, especially for overlay systems and velocity adaptive algorithms. Several algorithms use an estimate of velocity to modify handover parameters. In Holtzman and Sampath (1995), a method to adaptively change the averaging interval in a handover algorithm for both small and large cells is presented. The method is based on the estimation of mobile velocity through maximum Doppler frequency (FD).

2.2.4 Qualities of handover

A good handover design will maximize quality of service (QoS) and capacity by providing high communication quality and retainability, it ensures proper cell borders and load balancing. Lastly it will give minimal number of handovers and lower global interference levels. Other desirable features according to(Anagnostou,1994) ; (Mende, 1990); are summarized as follows:

i. Handover should be fast so that the user does not experience service degradation or interruption. Service degradation may be due to a continuous reduction in signal strength or an increase in co-channel interference(CCI). Service interruption may be due to a “break before make" approach of Hard handover (HHO). Note that the delay in the execution of a handover algorithm adds to the network delay at the Mobile Switching Center (MSC). Fast handover also reduces CCI since it prevents the MS from going too far into the new cell.

ii. Handover should be reliable. This means that the call should have good quality

before handover, Signal to interference ratio and RSS help determine the potential service quality of the candidate target cell.

iii. Handover should be successful; a free channel should be available at the candidate target cell. Efficient channel allocation algorithms and some traffic balancing can maximize the probability of a successful handover.

iv. The effect of handover on the quality of service (QoS) should be minimal. The quality of service may be poor just before handover due to a continuous reduction in Received signal strength, etc. The network under study uses a threshold of 102dB for handover initiation or the call is dropped.

v. Handover should maintain the planned cellular borders to avoid congestion, high dropping probability

2.2.5 Handover challenges

To design an effective and efficient handover, several factors need to be addressed. These factors are mainly due to cell dynamics with constituents like cell as discussed in section 2.2.1.1, topography, propagation, traffic and mobility this poses serious challenges. Also striking a good balance between power and delay can be a herculean task. These challenges and/or parameters are described as follows:

i. Topographical Features: A signal profile is characterized by the magnitude of the propagation path loss exponent and the breakpoint (i.e., the distance at which the magnitude of the propagation path loss exponent changes) and varies according to the terrain. The performance of a handover algorithm depends on the signal profile in a region. (xia *et al,* 1993)

ii. Traffic: In practice, traffic distribution is a function of time and space (Falciasecca *et al*, 1991). The system should perform well under traffic variations. Some of the approaches to cope with spatial non-uniformities of traffic are traffic balancing in adjacent cells, use of different cell sizes, non-uniform channel allocation in cells, and dynamic channel allocation

iii. Propagation Phenomena: The radio propagation is strongly affected by surroundings. For example, due to a certain topological environment, the received Signal strength can be higher at places far from a base station than at places near the base station (BTS). Propagation characteristics in microcells are different from those in macrocells (e.g., the street corner effect) (Grimlund and B. Gudmundson, 1991).

iv. System Constraints: Some cellular systems are equipped with dynamic power control algorithms that allow the MS to transmit the least possible power while maintaining a certain quality of transmission. These systems coordinate power control and handover algorithms to achieve their individual goals (Mende, 1990). It may be beneficial to do channel allocation in conjunction with handover and/or power control.

v. Mobility: When a MS moves away from a base station (BTS) at a high speed, the quality of communication degrades quickly. In such a case, handover should be made quickly. More importantly, the evolution of a network is usually an on-going process (Mouly and Pautet, 1992); new cells are gradually introduced,

increasing the capacity to meet the demand. This network evolution necessitates adaptive resource management. The performance of growing cellular systems needs to be monitored and re-engineered frequently to maintain the QoS cost-effectively (Verdone & Zanella , 2002) .

In summary, to obtain high performance in the dynamic cellular environment, handover algorithms should adapt to changing traffic intensities, topographical alterations, and the stochastic nature of the propagation conditions

2.2.6 Types of handover

There are different categories of GSM handover which involve different parts of the GSM network. The complexity depends on the number of elements involved in the process, for example, changing cells within the same BSC is not as complex as changing of cells belonging to different MSC. There are mainly two reasons for handover. First, when the mobile station moves out of the coverage range of a station or the antenna of BTS respectively. Secondly the infrastructure in the MSC or the BSC may decide that the traffic in one cell is too high and move some to other cells with lower load. These are the main reasons that lead to the different types of handover. The following are the different types of handover and their main characteristics.

i. Handover between Channels (time slots) in the same cell. This is illustrated in Figure 2.4

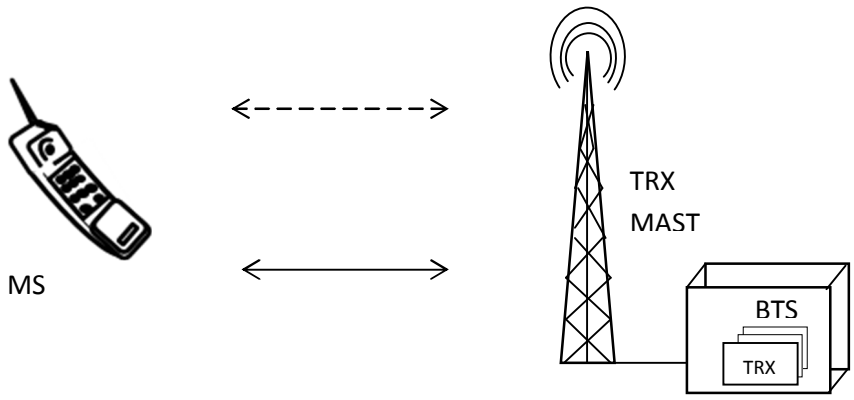


Figure 2.4: Illustration of Intracell (Intra BTS) Handover (Gunnar, 1999)

ii. Handover between Cells (Base Transceiver Stations) under the control of the same Base Station Controller (BSC).This is illustrated in Figure 2.5.

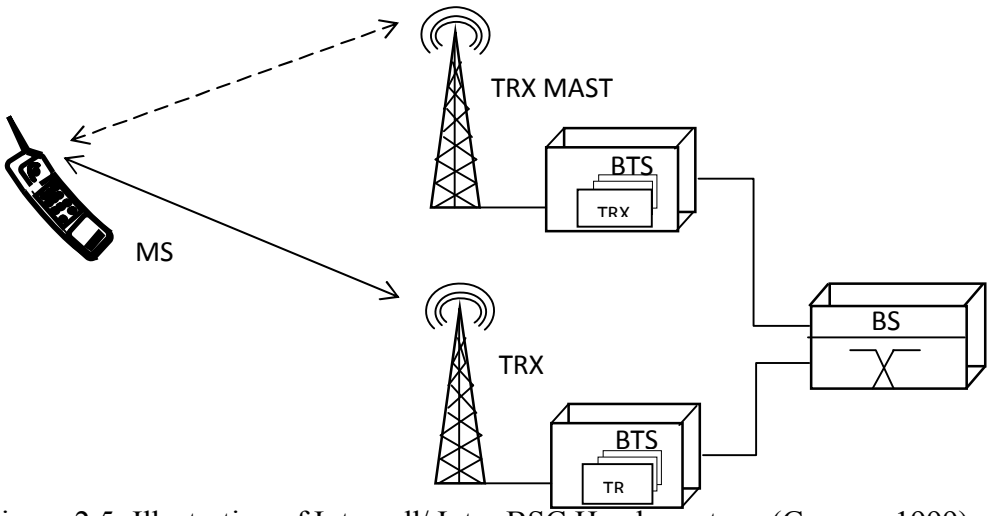


Figure 2.5: Illustration of Intercell/ Intra BSC Handover type (Gunnar, 1999)

iii. Handover between Cells under the control of different BSCs, but belonging to the same Mobile services Switching Centre (MSC). This is illustrated in Figure 2.6.

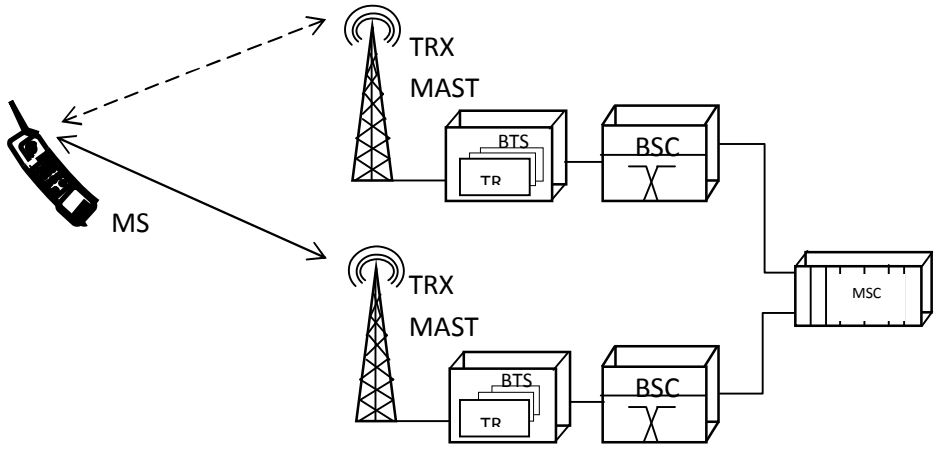


Figure 2.6: Illustration of Inter BSC/ Intra MSC Handover Type (Gunnar, 1999)

iv. Handover between Cells under the control of different MSCs. This is referred to as Inter MSC Handover. This is illustrated in Figure 2.7

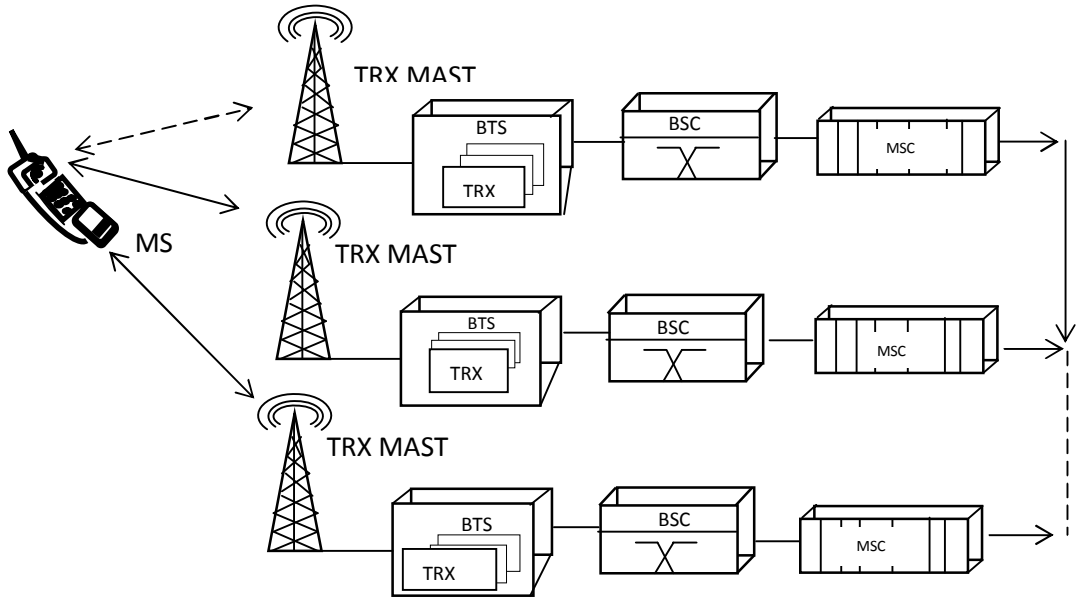


Figure 2.7: Illustration of Inter MSC Handover scenario (Gunnar, 1999)

The first two types of handover (i-ii) are called internal handover. In this kind of handover there will not be any MSC involvement. Internal handover occurs between channels on the same cell or between channels pertaining to different cell of the same BSC. It is decided and executed autonomously by the BSC, so that no message is

generated at the BSSMSC interface, until the completion of the handover execution (ETS GSM 80.08, 1998).

In Intercell handover, if the handover measurements show a low Received Signal Quality (RXQUAL) it will handover the call from-one channel/timeslot in the Servicing cell to another channel/timeslot in the another cell. Main reason for such a handover is because of the poor signal quality due to the interference. Inter-cell handover can occur either to a timeslot on a new carrier or to a different timeslot on the same carrier (ETS GSM 05.08, 1997).

In the last two types of handovers the MSC is involved. This type of handover is called External handover or Inter MSC handover. At any given time during a call MS will be measuring the signal quality from 16 different neighboring cells. Among that 16, the best 7 Cell identity (Base Station Identity Code) will be transmitted back to the network. This information will be passed to BSC and MSC for handover decision at least once each and every second (ETS GSM 05.08, 1997).

2.2.7 The mobile radio channel environment

The mobile radio channel is a fading channel (Marichamy *et al* ,1999), since handoff decision is to detect the mobile user crossing the cell boundary. This can be accomplished by measuring received signal strength (RSS) at mobile stations (Mobile Assisted and Mobile Controlled Handoff) from the base stations (Sharma, 2002). Since the signal strength varies considerably due to multipath fading (e.g. deepest fade typically 30 dB). Also this rapid multipath fading is accompanied by slow variation in the average signal pattern due to scatters and different terrain variations as the mobile moves.

. To avoid "ping-pong" effect the mobile station (MS) is allowed to continue maintaining a radio link with the current base station, until the signal strength from Base station 2 exceed that of Base station1 by some pre-specified threshold value h and sometime named handover Margin (HO-Margin) as shown in Figure 2. 8 (Marichamy*et al*,1999)

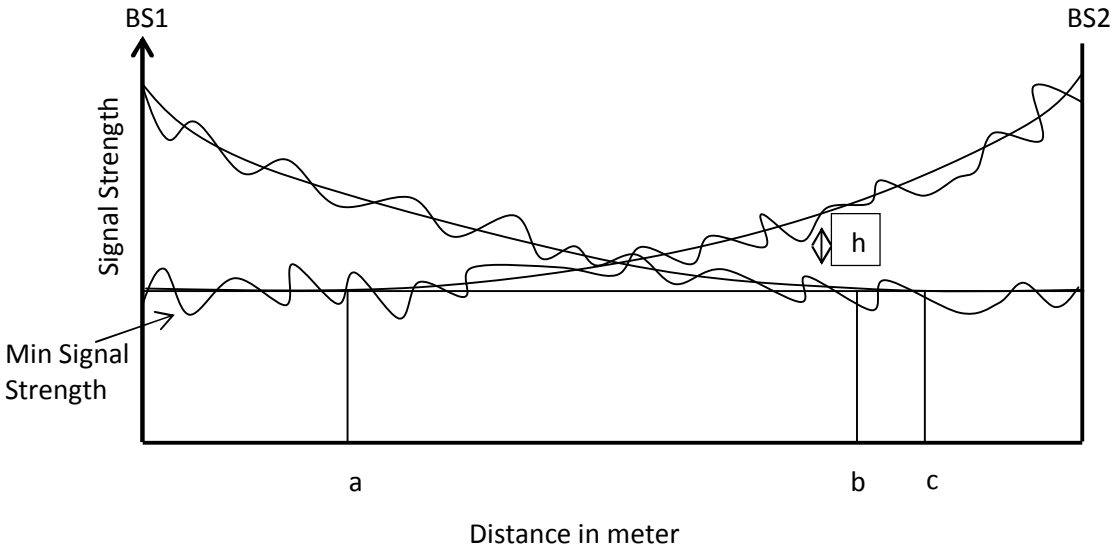


Figure 2.8: Power Budget Handover

Besides transmitting power, the handover also depends on the mobility of the MS. In normal operation a threshold (H) of 5-10 dB is used to prevent minor variation in signal level at different base stations from causing a handover.

With medium and high mobility of a mobile station (MS), this results in handover to a neighboring station back to the original base station within a short period of time (< 10 sec) (ping-pong handover). Handover is only possible theoretically between points a and c as indicated in Figure 2.8, but is recommended at point b because that is where the level of BS_2 has first fallen below the allowable hysteresis value h, in other word sufficiently

above that of BS_1. Due to propagation-related signal level fluctuations at the receiver, the curved characteristics shown only apply to the statistical average as in Figure 2.8.Therefore the location of a handover is randomly distributed in the area around b.

2.2.8 Handover methods

The following generic handover methods are described: Threshold, Hysteresis, Threshold with Hysteresis and Fuzzy methods.

2.2.8.1 Threshold method

The threshold method (Shirvani *et al*, 2000) initiates handoff when the average signal strength of the current base station falls below a given threshold value and the signal strength of a neighboring base station is greater than that of the current base station. Proper selection of threshold value is necessary here as it reduces the quality of communication link leading to call dropping. This method is recommended by GSM Technical Specification GSM 08.08 (ETSI, 2000). The network under consideration uses a threshold of 102dB to initiate handover or the call is dropped.

2.2.8.2 Hysteresis method

The Hysteresis method (Vijayanand Holtzman, 1993) initiates a handover only if the signal strength of one of the neighboring base stations is higher than a certain given hysteresis margin of the current base station. The advantage of this method is that it prevents the ping-pong effect, but this method still initiates unnecessary handovers even

when the current serving base station signal strength is strong enough. Typically a value of 6dB is used.

2.2.8.3 Threshold with hysteresis

The Threshold with Hysteresis method (Zhang and Holtzman,1996) initiates a handover when the signal strength of the serving base station drops below a given threshold and the signal strength of a neighboring base station is higher by a given hysteresis margin to that of the current base station. This method is often used in practice with +3dB hysteresis.

2.2.8.4 Fuzzy handover algorithm

The Fuzzy Handoff Algorithm (FHA) (Zhang and Holtzman, 1996) is a complex scheme using a set of prototypes assigned to each cell to calculate the serving base station. This uses a similarity measure to calculate the closeness of the membership function of a user to that of a base station to determine the need for a handover. A fuzzy logic rule base is created based on the known sensitivity of handover algorithm parameters (e.g., RSS threshold and RSS hysteresis) to interference, traffic, etc. Typically the Fuzzy Logic System rule base for RSS threshold and RSS hysteresis use fuzzy inputs variables as assigned to one of three sets: 'Normal', 'Low', 'High'.

2.2.9 Ping-pong handover

It is possible that strong shadowing caused by large obstacles found in the line of sight with the serving base station, or a highly mobile user in a boundary region between two base stations causes handover from the serving base station to the neighbouring base station for a short period (generally for less than 10 s) until it gets back to the older

serving base station (Walke, 2002). This effect, called the ping pong effect, can add too many unnecessary handovers.

Two commonly suggested methods to reduce this effect are:

i. increase the hysteresis value,
ii. Introduce a high averaging length for the signal strength measure to reduce small-scale fading (Markopoulos, 2004).

However, neither of the above methods is practicable. A high hysteresis value may delay a necessary handover at a boundary between two cells and high averaging time may also slow the dynamics of handover processes to the extent that calls could be lost. Therefore, finding an appropriate solution to this problem without causing delays for necessary handover is a question that currently has the attention of many researchers. If the hysteresis can be variable, and the ping-pong case can be distinguished uniquely from the genuine boundary crossing case, this problem can be solved.

2.2.10 Some Key QoS performance indicators

In this section some relevant key Quality of Service (QoS) performance indicators are Outlined and their respective mathematical relationships are given. These serves as valuable tools in QoS service impact assessment as a result of dynamics of intercell handover.

2.2.10.1 Call setup failure rate

This refers to the number of the blocked call attempts divided by the total number of call attempts. It is also called the Blocking Probability and expressed in percentage. (Shoewu, and Edeko, 2011):

$$\text{Call Setup Failure Rate} = \frac{\text{Number of Blocked Calls}}{\text{Number of call attempt}} \text{ x } 100\% \quad (2.4)$$

$$\text{Call Setup Failure Rate} = 1 - \text{Call Setup Success Rate} \quad (2.5)$$

2.2.10.2 Call drop rate

The Call Drop Rate (CDR) is the number of dropped calls divided by the total number of call attempts (Shoewu, and Edeko , 2011):

$$\text{CDR} = \frac{\text{Number of Dropped Calls}}{\text{Number of Call Attempts}} \text{ x } 100\% \quad (2.6)$$

$$\text{CDR} = 1 - \text{Call Completion Ratio} \quad (2.7)$$

A dropped call is a call that is prematurely terminated before being released normally by either the caller or called party

2.2.10.3 SDCCH congestion ratio

The Stand-Alone Dedicated Control Channel is the channel used for signaling messages. It is concerned with call setup, location update message and Short Message Services (SMS) (Adegoke et al, 2008).

2.2.10.4 TCH availability

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 (Shoewu, and Edeko, 2011):

Traffic Channel Availability

$$= \frac{\text{Busy Hour TCH Traffic (Erlang)} - \text{Average TCH Traffic (Erlang)}}{\text{Busy Hour TCH Traffic (Erlang)}} \text{ x } 100\% \qquad (2.8)$$

2.2.10.5 Handover success rate

Handover Success Rate is the ratio of the number of successfully completed handovers to the total number of initiated handovers. This ratio can be expressed as a percentage (Shoewu, and Edeko, 2011).

$$\text{Handover Success Rate} = \frac{\text{Number of successfully completed handovers}}{\text{Number of initiated handovers}} \text{ x } 100\% \quad (2.9)$$

$$\text{Therefore, Handover Failure Rate} = 1 - \text{Handover Success Rate} \qquad (2.10)$$

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

a) $$HSR_{BSC} = \frac{HO_succBSC}{HO_{succBSC} + HO_{unsucc_R} + HO_unsucc_L} \qquad (2.11)$$

Where;

i) HSR_{BSC} is handover success rate

ii) $HO_{succBSC}$ is successful intercell handover in a BSC

iii) HO_{unsucc_R} is unsuccessful intercell handover with reconnection per BSC

iv) HO_unsucc_L is unsuccess intercell handover with loss of connection per BSC

a. $$HSR_{CELL} = \frac{HO_suceout}{HO_total} \quad (2.12)$$

Where;

HSR_{CELL} is successful intercell handover per cell

$HO_{succout}$ is successful outgoing handover percell

HO_{total} is total outgoing handover percell

2.2.11 Handover arrival rates

Hong and Rappaport (1986) proposed a traffic model for a hexagonal cell (approximated by a circle) assumed that vehicles are spread evenly over the service area; thus, the location of a vehicle when a call is initiated by the user is uniformly distributed in the cell.

They also assumed that a vehicle initiating a call moves from the current location in any direction with equal probability and that this direction does not change while the vehicle remains in the cell.

From these assumptions it showed that the arrival rate of handover calls is

$$\lambda_H = \frac{P_{h(1-B_0)}}{1-P_{hh}(1-P_f)}\lambda O \quad (2.13)$$

Where;

P_h = the probability that a new call that is not blocked would require at least one handover

P_{hh} = the probability that a call that has already been handed off successfully would require another handover

B_O = the blocking probability of originating calls

P_f = the probability of handoff failure

λ_O = the arrival rate of originating calls in a cell

2.2.12 Received signal strength indicator

The RSSI from a particular cell, can be formulated as in Hong and Rappaport (1986) to be:

$$RSSI\ (dB) = R_0 - \varepsilon \log d + \xi \qquad (2.14)$$

Where,

R_0 is a constant determined by transmitted power, wavelength, and antenna gain of cell .

ε is a slope index (typically, $\varepsilon = 20$ for highways and $\varepsilon = 40$ for microcells in a city), and

ξ is the logarithm of the shadowing component, which is found to be a zero-mean Gaussian random variable with standard deviation 4–8 dB.

d represents the distance between the MS and BS of cell

2.2. 13 Overview of handover schemes

The handover process is managed by the so-called handoff schemes; the main interest is focused on them. The handover schemes that may be found in the literature can be broadly classified into Non-Prioritized and Prioritized Schemes (Figure 2.9) (Bartoli, 2001, Iraqi and Boutaba, 2005)

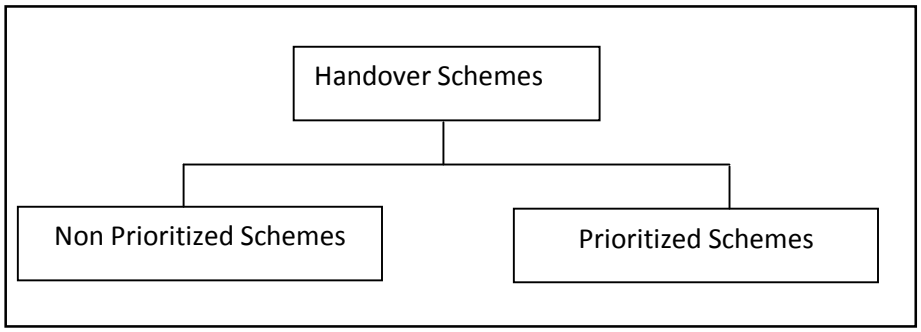


Figure 2.8: Broad Categorization of Handover schemes

2.2.13.1 The non-prioritized scheme

This has been employed by the typical radio technologies proposed for the Personal Communication Systems (PCS) operating in the band of 2GHz. This scheme does not differentiate handover and new or originating request calls. Thus, either an originating or a handover call request will be served, as long as, there is a channel available in the cell. If there are not any free channels, the request is blocked immediately. The main disadvantage of this scheme is that, since no priority is given to handoff request calls over originating calls, the forced termination probability is relatively higher than it is normally anticipated (Bartolini, 2001). Since the wireless bandwidth is limited, an efficient handoff scheme should allow a high utilization of the wireless channel capacity; while at the same

time it should preserve the QoS of handover calls, mainly by minimizing the call blocking probabilities, the transmission delay and the call dropping probabilities. However, all these requirements cannot be satisfied simultaneously, and therefore, tradeoffs among all of them are carried out. From the user's perspective, the termination of an ongoing call is more annoying than the blocking of a new call (Xiao et al, 2005). Consequently, the handover blocking and the forced termination probabilities ought to be minimized. To achieve these requirements several handover prioritizing schemes have been proposed (Aggeliki and Dimitrios, 2009).

2.2.13.2 Prioritization schemes

The basic concept of all handover prioritization approaches is to give handover requests priority over the new call requests in some way (Aggeliki and Dimitrios, 2009). Handover prioritization schemes provide improved performance at the expense of a reduction in the total admitted traffic and an increase in the blocking probability of new calls (Aggeliki and Dimitrios, 2009). However, the improvement in performance is related with the way that each scheme gives priorities to handover calls Therefore, several handover prioritization schemes, that support different services and different traffic requirements, may be found in literature. These handover prioritization schemes may be further subdivide into Channel Reservation, Handover Queuing, Channel Transferred, SubRating, Genetic and Hybrid, as it is depicted in Figure2.9

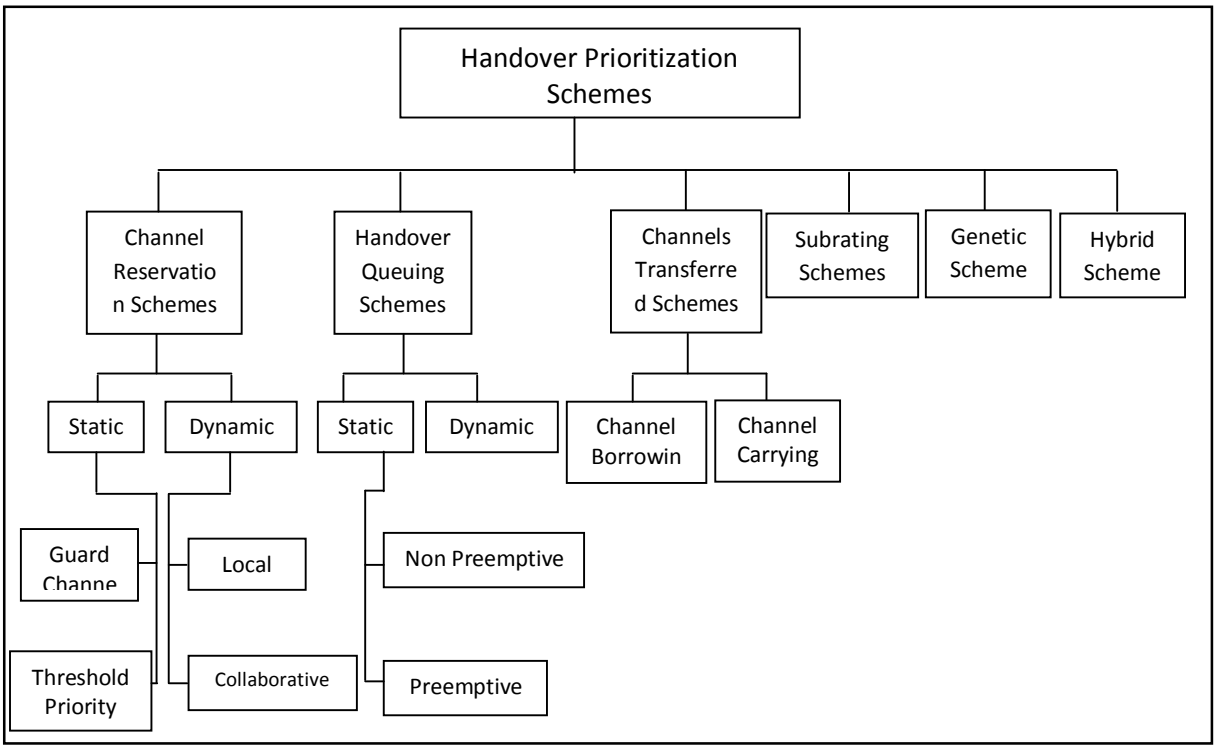


Figure 2.9: Graphical illustration of handover prioritization scheme

2.2.14 Channel allocation

The bandwidth available to the cellular system is limited. Generally the total available bandwidth is divided permanently into a number of channels and these channels are allocated to cells without violating the minimum reusable distance constraint. Cells use the allocated channels for call handling. For better utilization of available channels, cellular communication systems exploit the advantage of channel reuse, by using same channel simultaneously in different cells, where the cells are separated physically at least to minimum reusable distance, so that calls do not interfere with one another. In channel allocation, multiplexing, one of the basic concepts of data communication is used. Multiplexing uses the idea of allowing several transmitters to send information

simultaneously over a single communication channel. Concept of multiplexing, allows many users to share a bandwidth of frequencies. With the use of multiplexing, a given radio frequency resources available in cellular system, can be divided into a set non-interfering radio channels. There are several techniques of multiplexing these includes frequency division (FD), time division (TD), or code division (CD). In FD, the frequency spectrums are divided into disjoint frequency bands with each channel being assigned to a unique frequency range, whereas in TD separate channels are achieved by dividing the signal into different time slots. In CD, the channel separation is achieved by using special coding schemes (Mishra and Saxena, 2011). Further, more complex techniques can be designed by combining TD, FD and CD techniques. For example, with combination of TD and FD, a hybrid technique of multiplexing was developed which will divide each frequency band of an FD scheme into time slots. No matter which multiple access technology (FDMA, TDMA, or CDMA) is used, the system capacity in terms of effective or equivalent bandwidth can be measured. (Sanabani, 2006)

Assume a situation in which three cells *A, B,* and *C* share two channels, that is channel_1 and channel_ 2. These three cells are in line and no two adjacent cells can use the same channel because of the channel reuse constraints. In a scenario of channel allocation, as shown in Figure 2.10a where, the cell *A* is serving a call on channel_1 and cell *C* is serving another call on channel _2. If at the same time, a new call arrives in the cell *B,* then it cannot be handled by cell *B* because of non-availability of channel, as channel_ 1 and channel_ 2 are already in use by cell *A* and cell *C* respectively. Hence cell *B* cannot use any of these two channels, because of the reusable distance constraint. In this

situation any new call arriving in the middle cell *B* must be blocked. This example provides some basic idea about the nature of the channel allocation problem

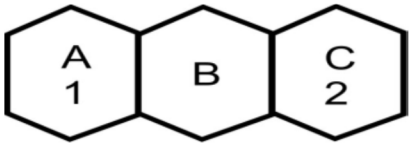


Figure 2.10a: Example of Simple Channel Allocation

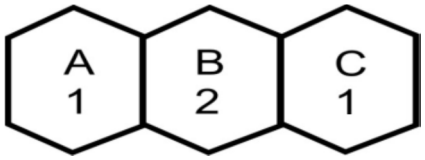


Figure 2.10b: Example of Simple Channel Allocation

A better scenario is shown in Figure 2.10b where both cell *A* and cell *C* use channel_1, satisfying channel reuse distance constrains for their calls. Then a new call in cell *B* could be assigned channel_2 while taking care of the channel reuse distance constraints. Such a solution of channel allocation is an attempt of possible optimization and is typical of the channel assignment problem. In a real world cellular system with more realistic cases which have many cells, channels, and calls, along with the uncertainty about when and where a call will be arriving to or exiting from a cell, calls will cross from one cell to another cell etc., the problem of allocating channels become complex (Mishra and Saxena, 2011). With added QoS parameters such as minimal call blocking probability and call dropping probability; channel allocation problem really becomes very complex, especially in cases of high and dynamic traffic loads

2.2.15 Channel allocation schemes

Many schemes for channel allocation (Mishra and Saxena, 2012) have been proposed in Literatures in the last three decades, these channel allocation schemes can be divided into a number of different categories on the basis of comparison of strategies, they have for channel allocation.

2.2.15.1 Fixed channel allocation scheme

The fixed channel allocation scheme (FCA) permanently allocates channels to cells in such a way that the channel reuse constraint can hardly be violated even if all channels of all cells are used simultaneously. A key advantage of FCA scheme is its simplicity, but it is not adaptive to changing traffic conditions. The major disadvantage of FCA scheme is high blocked calls, because of lag of flexibility in the scheme (Mishra and Saxena, 2012). In FCA, initial channel assignment is important because each cell in the system is allocated specific channels and cannot be changed during system operation. To gain more efficiency and effectiveness, FCA systems normally allocate channels in a manner that maximizes frequency reuse, under minimum reuse distance constraint. The common fundamental idea in all fixed assignment strategies is the permanent assignment of a set of channels to each cell. In the basic FCA strategy, a new call or a handover call can only be handled if the free channels are available in the cell; otherwise, the call must be blocked (Aggeliki and Dimitrios, 2009). In FCA systems, the role of MSC is restricted and is to inform the new base station about handover requests, and to receive a confirmation or rejection message from the new base station, about the handover (Mishra and Saxena, 2012).

2.2.15.2 Dynamic channel allocation (DCA) scheme

In dynamic channel allocation scheme, channels are dynamically assigned to cells (Mishra and Saxena, 2012) this is in contrasts to Fixed channel allocation (FCA). In DCA available channels are reserved in a central pool and from there channels are allocated to the cells on demand basis as per their needs. Also, a base station does not own any particular channels and a channel is released by the base station to the central pool when a call is completed. In case when traffic loads in few cells are higher compared to other cells in the system, then cells with higher traffic loads can be assigned more channels than those with low call traffic loads. This helps in minimizing the call blocking rate in these high traffic load cells. In DCA scheme (Mishra and Saxena, 2012), channels are allocated in real-time based on the actual cell conditions to make decision about allocation of channels this creates computational overhead. Hence, due to its real-time computational requirements DCA scheme is complex and is less efficient than FCA. The real-time channel allocation makes DCA scheme adaptive to interference and traffic changes. In general, DCA scheme strategies assume that all channels can be used by any cell or base station (BS) and there is no fixed relationship between the communication channels and cells. Contrary to FCA, the number of channels in each cell keeps on adaptively changing, to accommodate traffic fluctuations. In DCA schemes (Rana, 2006), during heavy traffic in a given cell, more channels are made available for that cell and during light traffic periods in a cell allocated channels are reduced. Released channels are made available to other cells that require more channels. This channel readjustment process requires a lot of communication and information exchange among cells. Therefore, a DCA strategy should be implemented in such a way that it requires the

minimum information exchange among base stations in order to reduce the signaling overhead and complexity.

2.2.15.3 Hybrid channel allocation scheme

Hybrid channel allocation (HCA) combines FCA and DCA schemes. In HCA, advantages of both FCA and DCA are harnessed. HCA scheme allocates some channels statically and other channels dynamically. In HCA schemes (Rana, 2006), total channels of mobile cellular system are partitioned into fixed and dynamic sets. The channels included in the fixed set are assigned to each cell through the FCA schemes. Whereas, the dynamic set of channels is shared by the base stations. The channel allocation procedure from the dynamic set can be used by any of the DCA strategies. When a mobile host needs a channel for its call, and all the channels in the fixed set are busy, then a request from the dynamic set is made. In HCA scheme, the ratio of the number of fixed and dynamic channels plays an important role in deciding QoS of the system (Rana, 2006).

Channel allocation schemes can be implemented in different ways. While allocating a channel to a base station, information regarding the system and network condition is required. This information may include: pattern of users, current information on the status of network operations, and status of available channels.

2.2.16 Handover management schemes

There are several channel allocation management schemes (Aggeliki and Dimitrios, 2009) that have been studied with more focus on handover management and provision of good QoS guarantees in terms of handover call handling. The aim of any handover

management scheme is to minimize the probability of forced call termination or call dropping. Handover management schemes are designed to provide better *QoS* (Mishra and Saxena, 2012). To ensure minimal call dropping probability, handover calls need to be handled on priority basis, and for this, a fixed or dynamically adjustable numbers of channels are assigned to cells exclusively for handover calls (Choi and Shin, 2002). The following section itemizes and briefly describes various handover prioritization schemes as in Figure 2.9.

2.2.16.1 Channel reservation schemes

The Channel Reservation handover Schemes (CRS) is a method that grants successful handover requests by reserving a number of channels exclusively for handover requests. It can be further divided into static and dynamic reservation schemes, depending on whether the set of reserved channels is fixed or varies according to the actual handover resource demand. This further classification of the channel reservation

Schemes into static and dynamic can be seen in Figure 2.9

A) Static Channel reservation scheme (SCRS): The Static Channel Reservation Schemes (SCRS) set fixed threshold in order to guarantee that the proper bandwidth is allocated to a handover call, so as to fulfill its service requirements. Furthermore, the static channel reservation scheme may be subdivided into Guard Channel and Threshold Priority Schemes (Fang and Zhang, 2002), (Bartolini, 2001) as in Figure 2.9

i) The Threshold Priority Schemes (TPS) or New Call Bounding Schemes (NCBS) Fang and Zhang (2002) ensured the priority of the handover calls by limiting the

number of admitted new calls to the system by a predefined threshold (Bartolini, 2001). If the number of the admitted new calls in a cell exceeds a threshold, and another call arrives, the new call is blocked. A handover call is rejected only when there is no available channel in the system. This scheme performs well in heavy traffic load environments, since the new call bouncing scheme could handle the problem by spreading the potential bursty calls (users will try again, when the first few trials fail).

ii) On the other hand, in the Guard Channel Schemes (GCS), also referred as Cut-Off Schemes, a number of channels are reserved from the onset for handover calls (Aggeliki and Dimitrios, 2009).The remaining channels are shared equally between new and handover calls.

B) Dynamic Channel Reservation Schemes (DCRS*):* In the DCRS, each base station dynamically adapts the channels reserved for handover requests based on the variation in system parameters (e.g. traffic conditions and the position of users). This enables the base station to estimate and reserve the actual resources and thereby to accept more new connection requests when compared to a fixed scheme (Aggeliki and Dimitrios 2009).

Dynamic Reservation Schemes (DRS) is further categorized into Local and Collaborative or Distributed (Ghaderi and Boutaba, 2005) Schemes based on the way they obtain the required information for the variation in the system

parameters: Local information is used by the base station or information is obtained from the neighboring base stations.

i) Local Channel Reservation Schemes (LCRS) adjust the number of reserved channels according to the variation of the system parameters (e.g. the current handover dropping rate, the traffic conditions and the position of users), by only using locally available information (Wei et al, 2004).

ii) The Collaborative Channel Reservation Schemes (CCRS), determines the number of reserved channels mostly from a base station exchange information or on mobility prediction and a location system, in order to be informed on the resource usage in neighboring cells (Aggeliki and Dimitrios 2009).

2.2.16.2 Handover queuing schemes

Handover queuing scheme (HQS) allow either the handover to be queued (Aggeliki and Dimitrios 2009) or both the new calls and handover requests to be queued. The HQS scheme gives priority to handover attempts by permitting them to be queued, instead of denying them access in the potential new base station when it is busy. This is possible due to the time a mobile station spends in the handover area. If a mobile station is in the handover area and the destination cell has no free channels, then the mobile station maintains its communication with the source cell. The handover request is queued and sent to the base station of the destination cell. If a channel, in the destination cell, is

available before the mobile station (MS) crosses the handover area, then the channel is assigned to the MS. Otherwise, the call is terminated (Aggeliki and Dimitrios 2009). Queuing is more effective when handover requests arrive in groups and call traffic is low. When handover requests occur uniformly, queuing is not needed. Applying queuing policy in the handover schemes, decreases the probability of forced termination at the expense of increased new call blocking. This occurs due to the fact that channels are not assigned to new calls until handover requests in the queue are served. Queuing schemes, as Figure 2.9 presents, can be further classified into static and dynamic schemes.

i) Static Handover Queuing Schemes (SHQS*):* There are two general policies in the static priority queuing, that is: preemptive or non-preemptive. A non-preemptive queuing discipline requires a call that begins service until it complete its service without interruption. In a preemptive priority queuing, if a call arriving at the queue, finds a call of lower priority in service, then the arriving call preempts the lower priority call in the queue and begins service immediately. A preempted call will resume the service, at the point at which its service was suspended, as soon as there are no higher priority calls remaining in the queue. A preemptive scheduling policy that resumes call service is called preemptive resume.

ii) Dynamic Handover Queuing Schemes (DHQS)

DHQS considers different system parameters, and dynamically reorder the handover requests in the queue with a view of reducing the probability of forced termination.

Dynamic reordering is necessary, since the handover requests need to be queued taking into consideration the dynamics of the user motion (i.e., the change of his moving speed).

2.2.16.3 Channel transferred handover scheme

In this scheme, when there are no available channels to accommodate a handover call request, a channel from a neighboring cell may be transferred. After handover, the selection of the transferred channel may follow the two decision categories: the Channel Carrying Approach (CCA), which selects its current channel to carry it in the destination cell, and the Channel Borrowing Approach (CBA), that selects a new channel from the neighboring cells. This classification is presented in Figure 2.9.

i) Channel Carrying Handover Schemes *(CCHS):* The CCHS allows the Mobile station to carry its channel under certain mobility patterns from its current cell into the target cell, without violating the minimum reuse distance requirement. Thus, communication is now maintained via the base station in the new cell using the old channel (Aggeliki and Dimitrios 2009).

ii) Channel Borrowing Handover Schemes (CBHS*):* The CBHS was proposed in the early seventies by Engel *et al* .(Aggeliki and Dimitrios 2009).

The key issue of this approach may be summarized as: an acceptor cell, that has used all its nominal channels, can be allowed to borrow free channels from its neighboring cells (donors), to accommodate new calls. A channel may be borrowed by a cell if the borrowed channel does not interfere with existing calls. When a channel is borrowed, several other cells are prohibited from using it. This is called channel locking. The

number of such cells depends on the cell layout and the type of initial allocation of channels to cells (Ghaderi and Boutaba, 2005).

2.2.16.4 Sub-rating schemes

The Sub Rating Schemes degrade the bandwidth of an ongoing call in order to accept more handover calls. More specifically, in these schemes, some ongoing calls may be forced to operate under a degraded mode in order to accommodate more calls in an overloaded system (Xiao et al, 2006).

In this scheme, certain channels are allowed to be temporarily divided into two channels at half the original rate in order to accommodate handover calls. By applying this scheme, the one half of the original channel can be used to serve the existing connection and the other one to serve the handover request so that the forced termination call is very minimal.

2.2.16.5 Genetic handover scheme

This scheme uses genetic algorithms (Aggeliki and Dimitrios 2009), in order to assign the channels using local state-based call admission double-threshold policies. In this case, a base station only keeps track of the state information of a small number of cells and makes decisions based on the abbreviated state information.

Xiao et al, 2006 proved that the GAS finds better admission policies compared with other well-known methods of handover reservation for both one-dimensional (1-D) and two-dimensional (2-D) (Manhattan model) cellular networks. However, the time needed to assign channels for the GAS scheme is the main weakness of this scheme (Xiao et al, 2006).

2.2.16.6 Hybrid handover scheme

Hybrid Handover Schemes (HHS) combines channel reservation, handover queuing, channel transferred, genetic and sub rating schemes (Aggeliki and Dimitrios 2009). The main objective is to combine the different prioritization policies as a means to further decrease the blocking probabilities or to improve the channel utilization.

2.2.17 Evaluation of handover schemes

The main advantage of the static reservation schemes is their simplicity because there is no need for exchange of control information between the base stations. However, such schemes are not flexible to handle the changing traffic conditions, since they do not use the traffic information in the current cell and their neighboring cells, and hence, they cannot be adapted to the real-traffic conditions (Hou and Fang, 2001). Also, the critical element of static schemes is how to determine the optimal number of reservation channels (Aggeliki and Dimitrios 2009), because this number has a tremendous effect on the performance of wireless cellular networks.

The number of reserved channels in these schemes is an integer; consequently, the determination of the optimal solution is made more difficult.

Efficient usage of guard channels requires the determination of an optimum number, the knowledge of the traffic pattern of the area, and the estimation of the channel occupancy time distributions (Tripathi et al, 1998), (Bartoli, (2001) prioritized handover call requests using a cost function, in the form of a linear combination of loss probabilities of the handover requests and the new calls. It was proved that the guard channel policy is optimal while using an objective cost function, where no queuing device is considered.

Dynamic channel reservation schemes have the advantage of better channel utilization, since the adjustments allow better adaptation to traffic conditions. More specifically, the FGCS schemes have also the advantage over the GCS schemes that they distribute the new calls evenly over time, and this leads to a more stable control (Wu *et al* 2002). However, the local dynamic reservation schemes, in order to be adapted to the current traffic conditions, have the disadvantage of the continuing need of traffic monitoring, resulting in signal and computational overhead. Iraqi and Boutaba (2005) proved that the local dynamic reservation schemes can succeed only in controlling a local parameter, like the handover dropping probability and not an inherently global parameter, like the call dropping probability.

In the collaboration dynamic reservation schemes the estimation of traffic is more accurate and the channel utilization is better than the local dynamic reservation schemes. However, in these schemes, due to the fact that more calculations are needed in order to predict the reservations, the problem of signal and computational overhead is more intensive in comparison with the local dynamic reservation schemes (Deiderich and Zitterbart, 2005).

In the static handover queuing schemes, the probability of forced termination is decreased. However, a handover call maybe still dropped, because the handover requests can only wait until the receiver's threshold is reached; in the case of high demand for handovers, handover calls will be denied to be queued due to the limited size of the handover queue (Bartoli, 2001). Moreover, static handover queuing schemes need large buffers to deal with real-time multimedia traffic.

By the priority reordering of handover in the queue, DPQS schemes achieve the reduction of the forced termination probability in comparison with the FIFO handover queuing schemes. However, to enable the system to be adapted to the new traffic situation, additional information is required, which results in computational or signaling overhead (Aggeliki and Dimitrios 2009).

The channel transferred schemes ensures that an ongoing call is not forcibly terminated due to lack channels. Since channels do not need to be reserved from onset, the system utilization is increased. However, the major disadvantage of the schemes is that carrying a channel into a new cell or even borrowing a channel from neighboring cells, it results in an increased signaling overhead due to negotiation activities with the neighboring cell of the channel in use (Aggeliki and Dimitrios 2009).

Sub Rating schemes achieve better performance in terms of call-blocking probability and forced-termination probability in saturated conditions. However, the degradation of wideband calls may reduce the QoS. Finally, the genetic handover scheme has the advantage of finding better admission policies compared with other well-known methods of handover reservation. However, the time needed to assign channels for the GAS scheme is the main drawback of this scheme (Xiao et al, 2006).

2.2.18 Handover decision phases

Handover decision procedures are referred to as algorithms. Several algorithms exist examples includes Received signal strength, Received signal quality etc and can be utilized to make the correct decision to handover an ongoing connection. Regardless of the nature of the algorithm, there are three sequential phases that are involved in all of them (Verdone and Zanella , 2002) .

2.2.18.1 Measurement phase

The measurement of the overall link or communication quality is measured either by the base station, the mobile station or both. The measurement data is processed and evaluated again by one or both of them and appropriate action is taken according to the result of the evaluation; that is either to perform handover or not. The measured parameters could be: Received signal strength and total power in up- and downlink, interference levels in up- and down link, received signal levels from the neighboring cell, bit error rates in both up- and downlink, estimate of the distance between the terminal and the Base transceiver station, and estimate of the terminal velocity.

2.2.18.2 Initiation and resource allocation phase

This phase includes the decision whether a handover is needed, regardless of the actual availability of a new channel on a target (or on the serving) base station; it is based on processed measurement results or network variables, including offered traffic. Once the need for the handover is determined, the new channel is selected taking the actual radio resource availability and network load into account.

2.2.18.3 Execution phase

Once the new channel is selected, the handover is executed. All of these phases are prone to errors. The measurement results, which the decision phase is based upon, may be incorrect or exposed to noise, thus making the decision inappropriate for the situation. The feedback to the channel reservation enquiries may suffer from erroneous transmission, and the execution of the handover may also take so much time that the conditions in the target destination may have changed while waiting for the handover connection. All possible precaution is needed to avoid the aforementioned incidents

disturbing the handover procedure, by choosing a suitable handover protocol and handover algorithm

2.2.19 Handover protocols

There are four basic types of handover protocols:

i. Network controlled handover (NCHO)
ii. Mobile assisted handover (MAHO)
iii. Soft handover (SHO), and
iv. Mobile controlled handover (MCHO).

Handover delay and measurement information availability are the tradeoff associated with the handover protocols. As the handover decision making process is decentralized (i.e., moving from NCHO to MCHO), handover delay (i.e., the time required to execute a handover request) decreases (Tripathi, 1998)., but the measurement information available to make a handover decision also decreases. These protocols are described in the following sections:

2.2.19.1 Network controlled handover

In network controlled handover (NCHO) protocol, the network makes a handover decision based on measurements of the RSSs of the MS at a number of base transceiver station (BTSs). The handover command is sent on the voice channel by blanking the voice and sending data. Sometimes the network sets up a bridge connection between the current and target base transceiver station and thus minimizes the duration of handover. In general, the handover process (including data transmission, channel switching, and

network switching) takes 100-200 ms and produces a discernible click in the conversation. This click is imperceptible in a noisy voice channel; but it is perceptible if handover occurs at a reasonable signal quality (Frech, 1998). Information about the signal quality for all users is domiciled at a single point (the MSC). This information facilitates resource allocation. According to Ostling, (1995), the overall delay can be approximately halved to ten seconds. This type of handover is not suitable for a rapidly changing environment and a high density of subscribers due to associated delay.

2.2.19.2 Mobile assisted handover

A mobile assisted handover (MAHO) protocol distributes the handover decision process. The Mobile station (MS) makes measurements, and the MSC takes decisions. This is adopted by the GSM. According to Ostling,(1995), there can be a delay of one sec; this delay may be too much to counteract the corner effect.

A list of parameters used as handover criteria in GSM is given here (Mouly and Pautet, 1992):

i. static data such as maximum transmit power of the MS, the serving BTS, and the BTSs of the neighboring cells;
ii. real-time measurements performed by the MS (such as the downlink transmission quality indicated by raw BER, downlink reception level on the current channel, and downlink reception levels from the neighboring cells);
iii. The BTS measurements (such as the uplink transmission quality quantified by raw BER, the uplink received level on the current channel, and the timing advance);

iv. Traffic considerations, cell capacity, and load.

2.2.19.3 Soft handover

Soft handover (SHO) is a “make before break" connection, i.e., the connection to the current base station (BTS) is not broken until a connection to the target BTS is made. SHO utilizes the technique of macroscopic diversity. Macroscopic diversity is a technique in which transmissions from a MS are received at different BTSs and then used to obtain good quality communication link (Simmonds and Beach, 1993). The same concept can be used at the MS too.

2.2.19.4 Mobile controlled handover

In mobile controlled handover (MCHO), the MS is completely in control of the handover Process. This type of handover has a short reaction time (on the order of 0.1 sec) and is suitable for microcellular system (Ostling, 1995). The MS does not have information about the signal quality of other users, and yet handover must not cause interference to other users. The MS measures the signal strengths from surrounding base stations and interference levels on all channels. Handover can be initiated if the signal strength of the serving base transceiver station is lower than that of another base transceiver station by a certain threshold. The MS requests the target BTS for a channel with the lowest interference.

The MCHO is the highest degree of handover decentralization. Advantages of decentralization of handover, handover decisions can be made fast, and the MSC does not have to make handover decisions for every mobile, which is a very difficult task for MSC of high capacity microcellular systems (Gudmundson, 1991).

2.2.20 Analysis of handover algorithm

To analyse handover algorithm based on signal strength, a two base station model shown in Figure 2.11 is assumed for simplicity. The model has two base stations, BTS1 and BTS2, separated by D meters (Singh, *et al*, 2005) and (Sanjay,2009) Figure 2.11. 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:

$P_{rx1(d)}$=K_1- $K_2\log_{10}(d)$+ y_1(d) d□ (0,D) (Sanjay,2009) (2.15)

$P_{rx2(d)}$=K_1- $K_2\log_{10}(D-d)$+ y_2(d) (Sanjay,2009) (2.16)

P_ry1(d) and P_ry2(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. y_1(d) and y_2(d) are two independent zero mean stationary Gaussian processes. Hence received power from BTSs may also be considered to be Gaussian processes with mean, μ_1= K1 – K2 log(d) and μ_2= K1 – K2 log(D-d) respectively. y_1(d) and y_2(d) are assumed to have exponential correlation proposed by Gudmundson (1991) based on experimental results.

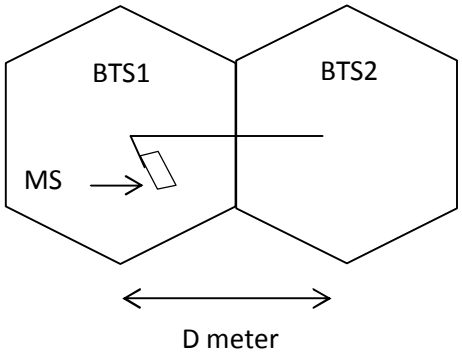


Figure 2.11: Inter BTS System model (Sanjay, 2009)

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.

$P_ry_1(d)$ <Prho and $P_ry_2(d)$ >Prmin: HO: BTS1 TO BTS2

$P_ry_2(d)$ <Prho and $P_ry_1(d)$ >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

2.3 Review of similar works

In their work on handover in cellular systems, (Tripathi et al, 1998), explained that efficient handover algorithms are a cost effective way of enhancing the capacity and quality of service (QoS) of cellular systems. The study described several parameters like

rate of handover, handover dropping probability, call dropping probability for evaluation of handover- related system performance. They affirmed that if the resource management related tasks are treated in an integral manner, better overall performance can be obtained. Their proposal did not provide specific examples or models to be used in terms of intercell handover and channel assignment schemes.

Xuemin (2001) analysed GSM handover based on real data, and using fuzzy logic based prediction techniques found that the received signal strength and the received signal quality are the prime parameters in the handover decision. However, considering received signal strength and received signal quality only are not sufficient to provide an accurate result for optimum handover management solution. A more robust mechanism is required especially for intercell handover that interact more closely with channel assignment schemes.

Kyriazakos *et al*, (2001) in their work opined that in order to be able to measure the network performance, the patterns of a normal day should be considered, while for performance evaluation congestion situations should also be analyzed. The performance indicators presented are Traffic, Call Setup Success Rate, Handover Success Rate (HOSR), Standalone dedicated channel Blocking Rate and Traffic channel Blocking Rate. The work was focused on general performance evaluation as such it did not reveal the impact of the interplay among the parameters, specifically the dynamics of intercell handover success rate on network performance.

Agustina *et al*, (2003) in their work agreed that an event-driven technique is needed to evaluate the performance degradation of GSM handover traffic due to introduction of

GPRS in a GSM/GPRS network when various priority schemes for handover traffic over new call traffic are applied. Their work revealed that the performance of GSM handover traffic can be significantly degraded by the capacity reduction resulting from the introduction of GPRS but can be amended by using appropriate priority schemes. But, the GPRS traffic model used is a simple one therefore, a complex simulation environment is necessary in order to further validate their obtained results.

Sung – Ho (2003) analysed mobile cellular systems with hand-off priority and hysteresis control. They modeled a system with Quasi-Birth and Death (QBD) structure. The model extended, generalized and unified the existing models for cut-off priority schemes in wireless cellular networks. Their new cut-off priority scheme produced a better grade of service to handover traffic while maintaining high throughput for originating calls and the hysteresis control provided more robustness. Though, the system was robust and produced improved throughput and reduced the new call failure rate but there was an increase in the handover failure probability.

In performance analysis of cellular networks with generally distributed handover inter arrival times Dharmaraja *et al,* (2003) provided numerical solutions for new and handover traffic distribution. They used Markov regenerative process and mathematical theory to develop techniques for important QoS measures. The obtained results for various types of inter arrival times, distribution, e.g. exponential Erlang, and hyper exponential and validated the fact that the variance in addition to the mean is important in determining the handover call blocking measures. The work involved complex and complicated mathematical models which mean that applying this to a large network will pose a great challenge.

Matias *et al.,* (2003) proposed an automatic optimization algorithm for optimization of handover margins in a GSM/GPRS network which is able to maximize the overall traffic carried in the network by equalizing long-term blocking effects. Automatic optimization of radio network parameters is agreed to be crucial for both operability and performance. The principle of handover boundary modifications was applied in a real network in other to deal with congestion. Modifying the handover margins twice a day on an adjacency – by – adjacency basis, it was shown that more traffic could be carried in the network while blocking of call set up attempts could also be reduced and better call dropped rate figures were achieved. This provided a cost-effective method to increase network capacity but there was call quality deterioration and there were no quality indicators in the adoption rules applied in the optimization to handover margins.

Wang *et al*, (2003) worked on a probability based adaptive algorithm for call admission, the algorithm is similar to that of RED (Radom Early Detection) which is based on probability to control the guard channels according to controlled QoS measure. Using simulation the performance of probability based algorithm, the guard channels algorithm and adaptive algorithm was compared. The result showed that the probability based algorithm outperformed the later two algorithms in QoS measures which included Handover call blocking and new call blocking probabilities. The analysis was comprehensive and came out with a mature adaptive solution but strategies for deployment in a real network were not considered.

Youssef and Raouf (2005) in their work on handover and call dropping probabilities in a wireless cellular network using mathematical analysis proved that even if the handover dropping probabilities is controlled to be below a maximum value in every cell in the

network, the call dropping probability experienced by users is not controlled independently from the admission control scheme used to control handover dropping probability. Using simulation and assuming a fixed value of 2% for handover dropping probability in all the cells, when evaluated it produced a mean call dropping probability of 17.37% which is very good but the work assumed that handovers occur only at cell borders and did not consider signal constraints and other effects.

Nishanthi (2006) discussed handover as an important component of resource allocation of cellular networks and revealed that Handover is implemented on the voice channel and the rate varies with the size of the cell. The study did not say anything about possibility of integrating handover algorithm and resource allocation schemes.

Zreikat (2007) analysed the numerical solution of one GSM cell using the Modeling Specification and Evaluation Language (MOSEL-2) and provided an intelligent underlay-overlay principles on the handover criteria based on the carrier to interference ratio. From the work the amount of loss probability is higher in the regular layer than the supper layer. This is in-line with the fact that both intra cell and inter cell handovers are possible in the regular layer and the solution failed to address it.

In their work, Vikram and Boache (2007) applied fixed channel allocation in 81 – Cell system having uniform traffic, square shape cell and cluster size of nine were considered for the model using GSM 1800 specifications. The result of simulation and an analytical model indicated that handover dropping probability reduces with increase in percentage of priority channels and velocity based handover boundary threshold. However, fixed

channel allocation adopted have an inherent poor channel utilization problem and produce higher blocking probability.

Jahangir (2010) presented an analytical framework that can enhance the handover call mechanism in wireless network using cell overlap and load balancing scheme to enhance the GSM cellular capacity using an overlapping coverage area. The aim of the investigation was first to define some appropriate performance measures for inter-cell handovers. The work was very theoretical without any experimental or practical application.

Moses (2011) carried out performance optimization of call handover in realistic wireless cellular Network. The study took measurement of rate of handover calls in a real wireless network at some base stations. A system model with priority for handover was simulated and analytical equations were derived. Blocking and force termination probabilities were used as evaluation parameters. From simulation results it was discovered that the model improved the system by eighty-six percent (86%). Although, handover was assumed to have priority over new calls, the network model reserved a fixed number of channels strictly for handover calls. This definitely created a problem of poor traffic and channel resource utilization. Also, the study considered only measured handover data and neglected the impact of its relational behavior on other quality of service parameters.

Alagu and Meyyappan, (2012), devised a new dynamic channel allocation scheme for call admission control. This employed a number of guard channels that are adjusted automatically, using simulation to evaluate the performance of the scheme. The results showed that their proposed scheme achieved optimal performance by maximizing the

resource utilization and adapt it to changing traffic conditions automatically. The object oriented technique applied for the simulation is rudimentary and the program has difficulty in stabilizing.

From the review of similar works it has become clearer, that poorly performed handover operation and management can negatively affect service quality and poor resource utilization. An optimum solution must integrate an effective and efficient channel allocation scheme. Attempt was made at improving on the work of Moses (2011) by improving the poor traffic and channel resource utilization through development and simulation of a dynamic cutoff priority channel algorithm and consideration is also given to the impact of relational behavior of handover to other quality of service parameters by way of analysis.

CHAPTER THREE

MODELING AND SIMULATION

3.1 Introduction

This chapter presents the qualities of a good handover, challenges that may be encountered when developing a good handover process. The Data collection method was described. Included also are tables displaying both NCC and Airtel benchmarks, model description, Algorithms, flow chart and simulation codes.

3.2 Data Collection Methods

The main data used in this work was obtained from Airtel network in Kano See Appendix I (HKNBSx9 call data records). The data obtained covered the period from June 2011 to August 2011. Also used was the Nigerian Communication Commissions' technical standard data which was downloaded from their website (www.ncc.gov).

3.3 Table of NCC Benchmarks

The Nigerian Communication Commission (NCC) is the statutory regulating b*o*dy for all Operators in the Telecommunication industry, in order to ensure uniform standards and quality service delivery to subscribers they have specified benchmarks for compliance by each industry operator.

Table 3.1 is an extract of NCC benchmarks extracted from their April 2012 QoS standards.

Table 3.1: NCC Benchmarks (www.ncc.gov).

S/no	KEY PERFORMANCE INDICATORS (KPI)	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

3.4 Airtel Key Performance Indicators and Their Target Values

Table 3.2: Airtel Network Benchmarks

S/NO	KEY PERFORMANCE INDICATORS (KPI)	TARGET VALUES
1	TCH Drop	□1.1%
2	Handover Success Rate	□97%
3	Call Setup Time	□5Sec
4	Network Availability	□99.4%
5	% of cell having Radio Availability	□98
6	% of cell having SDCCH Blocking ≤0.25%	□94%
7	% of cells Having drop ≤1.5%	□94%
8	% of cells having TCH Blocking ≤1%	□94%
9	% cell having TCH Assignment Success Rate ≥98%	95.5%
10	Power Level Threshold	102dB

3.5 Predicting Expected Call Drop Probability from a Cell

A handover could fail due to insufficient bandwidth in the target cell, and in such a case, the connection is dropped. The Call Dropping Probability (CDP) is a very important connection level QoS parameter. It represents the probability that a call is dropped due to a handover failure. Another related parameter is the Handover Dropping Probability (HDP). It represents the probability of a handover failure due to insufficient available resources in the target cell. From both the user's and service provider's perspectives CDP is considered more crucial (Youssef and Raouf, 2005).

In Youssef and Raouf, (2005) while investigating the call dropping probability of a cellular network they adopted square shaped cells i.e. Manhattan-like, however agreed that due to interference and other factors, the actual cell coverage can have a changing amoeba-like shape. Generally, the shape of a cell in a cellular network is theoretically hexagonal while the ideal shape is considered as a disk.

These and other works agree that the real user mobility is much more complicated than the traditionally used models like simple random motion models, i.e. Random Waypoint model and the Road Topology model (Wee-Seng and Kim, 2003) to more sophisticated purposeful motion models like the Travelling Salesman Model , the Three Dimensional Model. In this work it is assumed that values for handover dropping probability are fixed for individual cells and assuming only the minimum number of handover during a call experienced by subscribers is considered independent of user trajectory between two points i.e independent from the mobility model which means we are only interested in point when a call start begins and the point when a call ends. Attempt is made to predict call dropping probability bearing in mind aforementioned assumptions.

Call dropping probability (CDP) can be computed using equation (3.1) assuming the number of handovers during a call. This in a real network normally depends on one or more factors such as: cell size, call duration, speed, direction.

Mathematically it is shown that, (Youssef and Raouf, 2005).

$$\text{CDP}^{\text{AB}} = \sum_{I=1}^{h^{AB}} HDP * (1 - HDP)^{i-1} \quad (3.1)$$

$$= \quad 1\text{-}(1 - HDP)^{h^{AB}}$$

Where HDP is handover dropping probability and the expression

$$\text{CDP}^{\text{AB}} = HDP * (1 - HDP)^{i-1} \quad (3.2)$$

The expression in (3.2) is the probability that the i^{th} handover fails while all other previous handover succeeded. And h^{AB} is the total number of handover between two points A and B in space.

In the next chapter, equation (3.1) will be employed for computational analysis of the data to predict the expected call dropping probability of cells using average values of handover dropping probability for each cell.

3.6 Cutoff priority model description

A performance improvement model Figure 3.1 that accords priority for handover is proposed in an attempt to reducing handover failure rate. Figure 3.1 depicts a Channel

allocation model with cutoff priority for handover is adopted (Alagu and Meyyappan, 2012). This is considered to improve on the handover success rate of the existing network analysed and it was observed that seventy two percent of the cells (72%) failed to achieve NCC recommended Handover Success Rate (i.e ≥ 98%).

The model is of a cell with 'C' channels. It's comprised of open channels 'OC' and guard channels 'G_{ch}'. Mathematically,

$$OC = C - G_{ch} \tag{3.3}$$

$$C = G_{ch} + OC \tag{3.4}$$

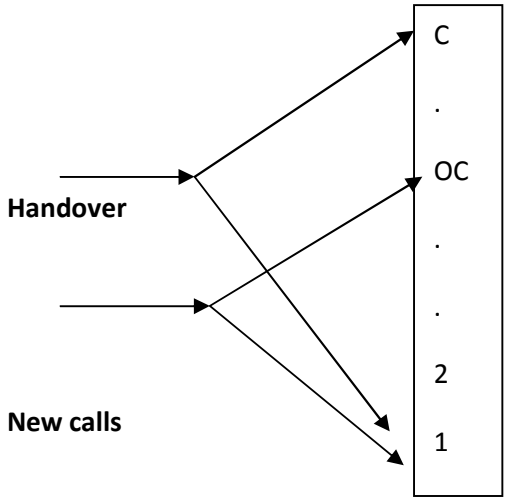


Figure 3.1: Channel Allocation Model with Priority for Handover (Alagu and Meyyappan, 2012)

The channel allocation model in Figure 3.1 depicts how channels are allocated to handover and new calls. From equation (3.3) open channels are less the number of total channels by a number called guard channels (cutoff priority). For effective use of channel

resources less number of guard channels are allocated to handover calls at low traffic load than at high traffic load periods (Alagu and Meyyappan, 2012). This avoids wasting channel resources since guard channels serves only handover calls, hence denying new calls channel resources leading to unnecessary revenue loss.

Priority is given to handover request by assigning a set number of channel(s) (G_{ch}) exclusively for handover request among total number of channels 'C' in a cell. The remaining channels referred to here as open channels (OC) which is equal to ($C - G_{ch}$) are shared and competed for by both new and handover call requests. A Handover call is admitted as long as there is a channel available and is blocked when all channels are occupied. Whereas a new call is blocked when available channels is/are less than open channels.

The channel allocation model with cut-off priority for handover used in the simulation initially allocates a set number of channels referred to as guard channels (Gch) and dynamically alters guard channels based on the handover failure rate according to equations (3.5) and (3.6)

$$H_f \geq A_u * T_h \tag{3.5}$$

$$H_f \leq A_d * T_h \tag{3.6}$$

Where H_f is ratio of handover failure rate to total handover, A_u and A_d are numbers choosen between 0<1 by choosing this values less than one the Algorithm try to keep the handover blocking rate below its given threshold. T_h is a threshold of handover blocking probability.

The simulation system generates both handover and new calls according to Poisson process (Sanabani, 2006) this is to match the discrete nature of both handover and new calls.

The initial assignment of guard channels is done with a view to getting minimum values of both new call blocking probability and handover blocking probabilities which are key factors in getting good quality of service (QoS).

3.7 Dynamic Cutoff Priority Channel Allocation Scheme

The dynamic cutoff priority channel scheme (DCCAS) is developed by integrating two algorithms one according to (Alagu and Meyyapa, 2012) see Appendix II and the other according to Weng et al, (2003) see Appendix III. Integrating the two Algorithms enable us to obtain a hybrid which is more robust and is able to improve system adaptability to different traffic and has a better system response characteristic. The probability based adaptive nature ensures that the integrated algorithm developed in section 3.10 does not frequently change thresholds.

3.8 Integrated Algorithm: Dynamic Cutoff Priority Channel Allocation Scheme (DCCAS)

```
Input (t,C)
{
   Initialize_timer
   Co=C-GCh
   For each periodic timer, generate a call
   {
      For every handoff call request Do
       {
          if Oc < C, then
          {
            Hc = Hc + 1 and grant admission
            Oc = Oc +1
```

```
        Wait till handoff call ended
        Release channel
      }
     Otherwise,
      {
        Pf = Pf +1 and reject.
        Compute current HPB
        FOR each dropped-handoff-call DO
        if (current HPB >= upper_limit then)
              {
                   if(rand()>Pinc)
                   Ch=max{Ch-1,Cmin}
               }
             else
               if(rr>ru=){
                   if((rand()>(1-Pinc)) && (IsDropped()))
                  Ch=min{Ch+1,Cmax}

            }
      }
   }
For every new call request Do
   {
     If Oc < Co, then
       {
         Nc=Nc+1 and grant admission
         Oc = Oc +1
        Wait until call ends
        Release channel
       }
    Otherwise,
      {
        Pb = Pb +1 and increment number of rejected call.
        Reject new call
      }
   }
If a call is completed or handed off  to another cell
  {
     Oc = Oc – 1
     Check with MSC whether the ended call is handover call or new call
     If handover call then Hc = Hc-1
     Else Nc = Nc-1
```

```
        }
    }
END FOR
```

}//end of the algorithm:

The integrated algorithms also referred to as Dynamic cutoff priority channel allocation scheme (DCAS) used in developing the simulation flow chart as in Figure 3.2 and the coded simulation program in Appendix v. Integrating the Algorithms I (appendix II) and algorithms II (appendix III) enables us to provide solution to the weaknesses of Algorithm I . For example, It is reported that after individual experimental trial of both algorithm I and II (Weng et al, 2003), Algorithm II reached steady state earlier, remained steady, and it also reduced new call blocking probability better than algorithm I appendix II). The probability based adaptive nature of algorithm II (appendix III) ensures that the integrated algorithm adapt easily to different traffic load therefore improving on the system response characteristics.

The simulation takes in number of channels and time as inputs and other chosen simulation parameters are as contained in section 3.11. The simulation program ensures that when a high handover failure rate is experienced, the number of guard channels determined through equations (3.5) and (3.6) are decreased or increased as the case may be. When the system does not use a significant portion of the guard channels and equation 3.6 is met the number of guard channels is gradually decreased until most of the guard channels are used frequently. In this way the handover dropping rate is expected to be controlled in most cases within NCC recommend threshold of less than or equal to 0.02.

The probability method adopted in the simulation in decreasing threshold used probability of increase (pinc) as (pinc= 0.2) which means the system is expected to decrease threshold at a probability of 80% and if systems stays at the upper bound or lower bound of handover blocking probability system will increase the threshold reserved resources at a probability of 20%.

3.9 Simulation Flow Chart

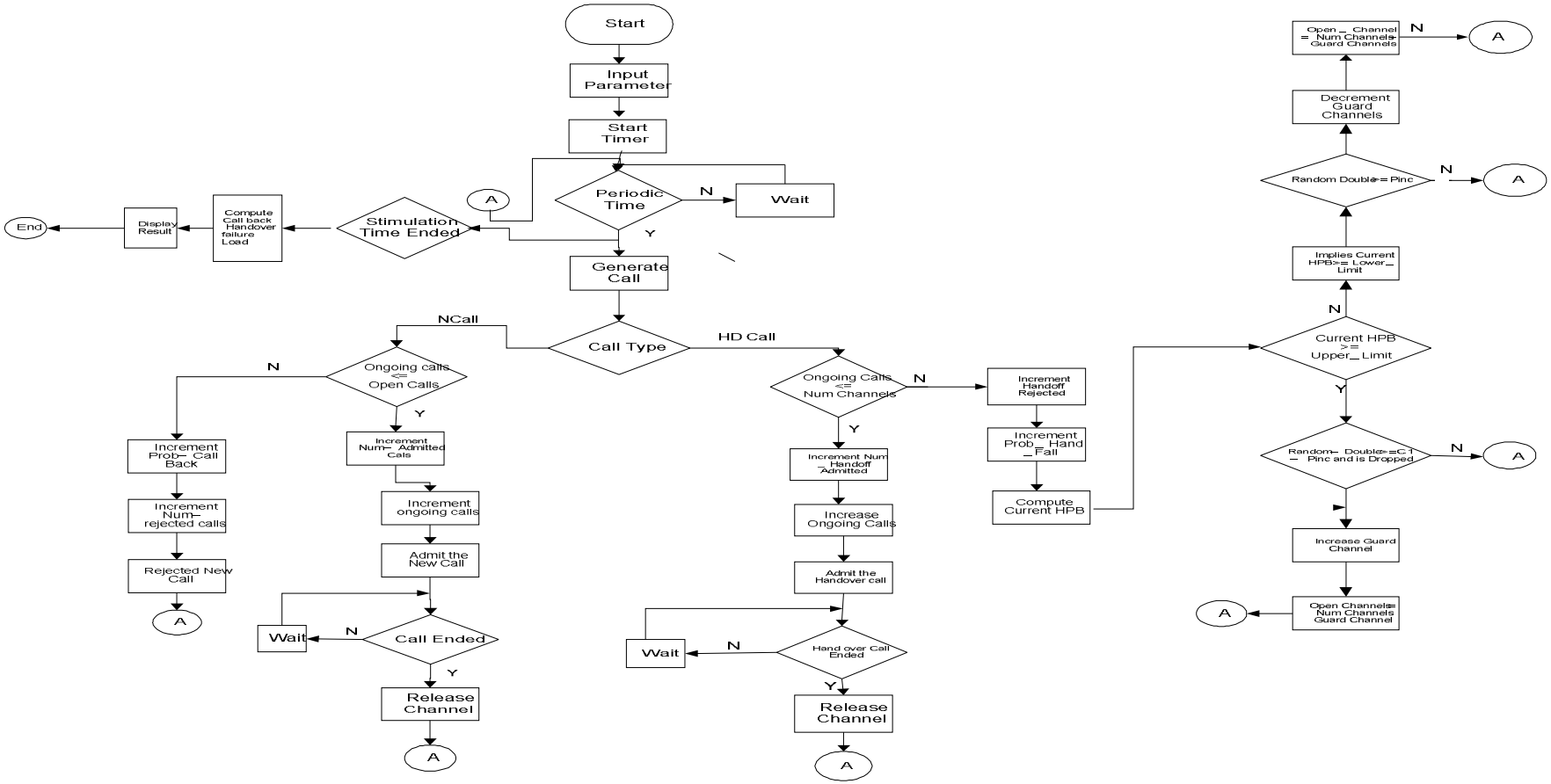


Figure 3.2: Simulation flow chart

3.10 Simulation

The simulation employed the use of a JAVA variant NETBEANS 6.1 which provided lower memory consumption, fast and responsive user interface than Eclipse and very robust built –in support. It also provides quick fixes and semantic checks these make it highly user friendly and it is not sluggish. The above features put Netbeans 6.1 above other possible candidates like ECLIPSE, J developer these unlike Netbeans 6.1 are sluggish, take more system resources and has less built –in support.

The coded program for the simulation (Appendix V) was developed following the integrated Algorithm section 3.10 and followed the flow chart as shown in Figure 3.10. The program trial ran repeatedly for total of 45000 seconds simulation time at each run.

Results were processed in accordance with equations (3.7) , (3.8) and (3.9) as follows:

$$\text{Call Blocking} = \frac{\text{Total number of new calls rejected}}{\text{Total number of calls processed}} \qquad (3.7)$$

$$\text{Handover Failures} = \frac{Total\ number\ of\ handover\ calls\ not\ admitted}{Total\ number\ of\ calls\ processed} \qquad (3.8)$$

$$\text{Throughput} = \frac{Handover\ calls\ admitted + New\ calls\ addmited}{Total\ number\ of\ calls\ processed} \times 100 \qquad (3.9)$$

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 of calls.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results of data analysis, significance of the results were discussed and presented. Simulated solution to handover failure problems were carried out, discussed and presented.

4.2 Data Analysis

From the data obtained for a Base Station Controller HKNBSx9 (as in Appendix I) HKNBSx9 call record data. The statistical mean of relevant parameters was computed and tabulated as shown in Table 4.1

This qualitatively presents the general picture of the individual cells performances. The aim is to compare our values with NCC recommended standards refer to Tables3.1 which is a tabulation of the various parameters and NCC recommended targets. In Table 4.1 the results for fourteen different cells are presented. The system under study performs handover when the signal strength is at 102dB or else the call is dropped.

Table 4.1: Mean Cell call Data Records

CELL	Mean CSSR	Mean Handover Success Rate (%)	Mean TCH Call Drop Rate (%)	Mean TCH Congestion Rate (%)	Mean SDCCH Blocking Rate (%)	Mean Traffic Load(Erl)	Calls per Day	Prob. Blocking	Handover Failure Rate(%)
KN0002A	94.024	95.057	0.917	2.204	0.977	110.443	53012.400	0.0598	4.943
KN0002B	95.468	93.603	0.795	2.292	0.254	51.283	24616.070	0.0453	6.397
lKN0002C	97.621	97.277	0.999	1.166	0.223	41.407	19875.548	0.0238	2.723
KN0002D	97.682	98.428	0.456	1.419	0.486	148.017	71048.191	0.0232	1.572
KN0002E	97.308	98.595	0.407	2.157	0.153	60.660	29116.643	0.0269	1.405
KN0002F	98.464	99.005	0.330	1.121	0.142	65.989	31674.730	0.0154	0.995
KN0003A	97.444	97.376	0.306	0.452	0.043	9.957	4779.287	0.0256	2.624
KN0003B	93.955	98.185	0.597	0.435	0.096	12.788	6138.157	0.0604	1.815
KN0003C	97.510	97.252	0.579	0.602	0.087	71.533	34335.965	0.0249	2.748
KN0006A	98.326	98.212	0.361	0.547	0.341	83.020	39849.496	0.0167	1.788
KN0006B	97.694	94.817	0.568	1.102	0.369	168.382	80823.496	0.0231	5.183
KN0006C	97.445	95.551	0.511	0.683	0.968	182.319	87512.922	0.0255	4.449
KN0007A	98.031	94.477	0.437	0.766	0.495	85.839	41202.835	0.0197	5.523
KN0007B	98.190	96.654	0.465	0.423	0.590	123.114	59094.887	0.0181	3.346

4.2.1 Call setup success rate

Call Setup Success Rate (CSSR) is a critical parameter in evaluating the network accessibility and retain ability perceived by subscribers. From Table 4.1where we presented mean Call Setup Success Rate values for all the cells in cluster 'A' when compared with NCC targets (as in Table 3.1) for CSSR, Only KN0002F was able to achieve NCC target 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. To qualitatively present the mean Call Setup Success Rate computed results as tabulated in Table 4.1 a bar chart was plotted for both groups using Matlab R2009b as shown in Figure 4.1. On the plot a horizontal thick red line was drawn to indicate NCC minimum CSSR recommended target (98%).

In the second group of seven cells (cluster B) the cells Call Setup Success Rate performance improved a little bit with cells KN0006A, 7A and 7B achieving the NCC minimum CSSR set target. Note that 57% of the cells in this group did not meet up. These percentages are significantly high. According to international best practices and standards it is recommended that only 5%-10% is acceptable (Michael, 2004).

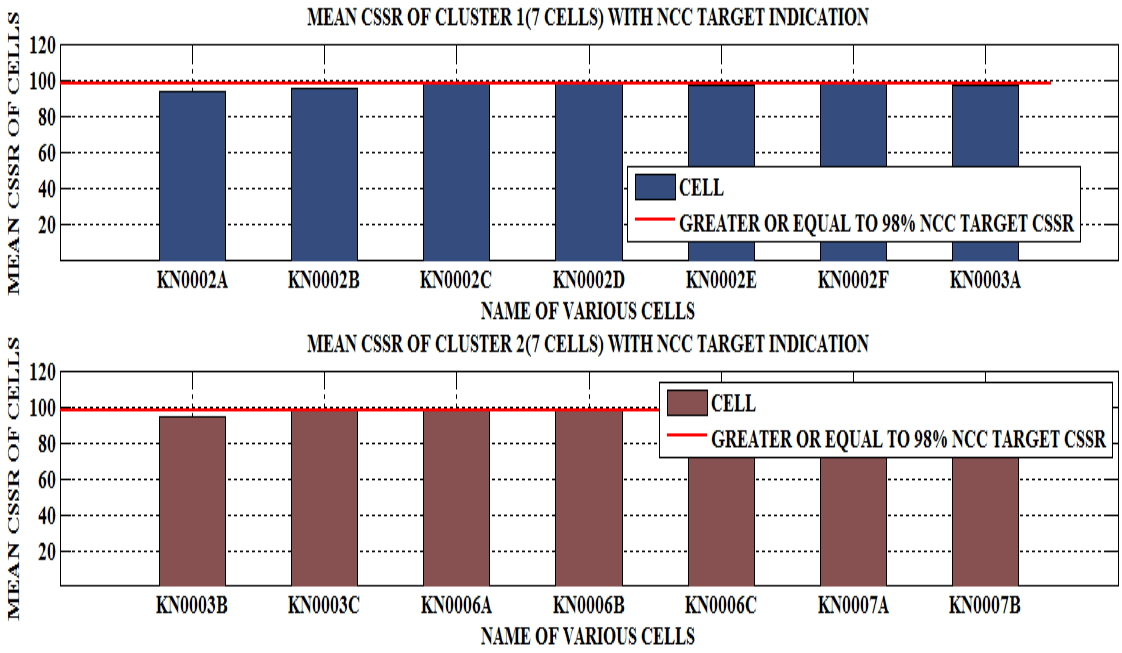


Figure 4.1: Mean CSSR of Two clusters with NCC Target Indication

4.2.2 Handover success rate

Handover Success Rate (HSR) indicates the success of handovers. As earlier indicated the system will normally initiate handover when the signal strength is 102dB below which the call is handed over or dropped. In Table 4.1 computed statistical mean of cell handover success rates was presented among the first group of seven cells, cells KN0002D, 2E, and 2F achieved slightly above the NCC recommended minimum target of ninety eight percent (98%) refer to Table 3.1. It is not so impressive because 57% of the cells in a group of (7) performed below NCC recommended minimum targets. This have a negative effect on inter cell/Inter BTS handover dynamics. To qualitatively reinforce the computed results of mean handover success rates for cells as seen in Table

4.1 a bar chart is drawn with MatLab R2009b M-files. The bar chart graph is displayed in Figure 4.2 with a horizontal red line drawn across the bars to indicate the NCC recommended minimum handover target.

In the second group of seven cells there are only two cells (KN0003B & KN0006A) achieving the NCC recommended minimum target of 98%. This means that 71% of the cells fell below the target. This clearly shows that a significant number of cells are not performing as desired hence there is a compelling need for optimization.

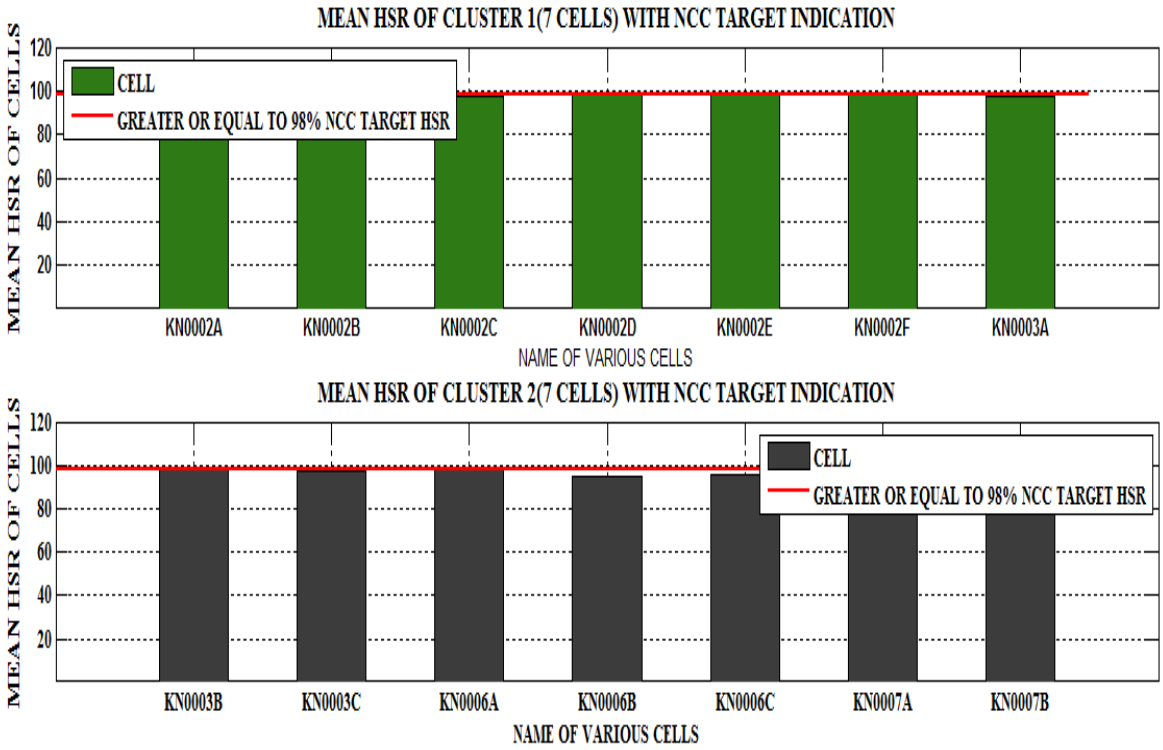


Figure 4.2: Mean HSR of Groups 1and 2 with NCC Target Indication

4.2.3 Mean TCH congestion and mean SDCCH blocking

These are two critical parameters for resource allocation in a GSM network from computed results in Table 4.1 it can be seen that whereas 43% of the cells in a group

(cluster) have the congestion value exceeding the NCC recommended limits the number is up to 57% for the standalone dedicated control channel blocking. Knowing that this congestion leads to non- availability of traffic channels it is easy to see that intercell dynamics will significantly suffer due to the fact that most channel resources will not be available. Load balancing which is central to the role of a good inter cell handover algorithm will be seriously hampered because of non -availability of most channel.

Also in the second cluster 'B', the standalone dedicated control channel blockage mean values computed and presented Table 4.1 produced only two good results in cell KN0003B and 3C other 71% of the cells performed outside the NCC recommended limits of <0.2%. This means that availability of traffic channels in the non -performing cells are greatly diminished therefore hampering the success of intercell handover.

In Summary, the overall mean values of our parameters for the various cells in the two clusters indicate clearly that 72% of the cells failed to achieve the NCC recommended Call setup success rate (CSSR) target values of greater than 98% and 64% also did not meet the Handover success rate NCC recommended minimum targets value of greater than 98%. For congestion values 21% of the cells failed to achieve the NCC recommended minimum target of ≤.2% traffic channel congestion rate and finally the standalone dedicated control channel blocking rate produced 64% of cells that could not meet the recommended NCC target of <0.2%. From our general analysis it was observed that the network is losing revenue needlessly this we believe optimizing the network can improve on the performance significantly and reduce loss of revenue.

4.3 Weekly Analyses of Cells KN0002A and KN0003A

To further analyze our data with a view to determining the influence of inter cell handover on the system. The weekly statistical average of traffic channel and standalone dedicated control channel blocking rates, handover failure rates and blocking probability, traffic Load etc., were computed and are presented in Table 4.2.

Table 4.2: Weekly Mean of Call Data Records of Cell KN0002A specified handover threshold level (102dB)

CELL	WEEKLY MEAN TRAFFIC LOAD (ERL)	Weekly TCH Congestion Rate (%)	WEEKLY TCH Call Drop Rate (%)	Weekly SDCCH Drop Call Rate (%)	Weekly SDCCH Blocking Rate (%)	Weekly Handover Success Rate (%)	Weekly Handover Failure Rate (%)	Weekly CSSR (%)	WEEKLY average Call Blocking Prob.
KN0002A	81.373	0.006	0.699	1.470	0.414	97.729	2.271	97.651	0.023
KN0002A	97.514	0.937	1.531	1.304	2.966	98.003	1.997	97.107	0.029
KN0002A	147.743	0.520	0.919	1.659	0.240	97.874	2.126	97.061	0.029
KN0002A	142.557	1.219	0.644	1.094	0.697	98.412	1.588	97.400	0.026
KN0002A	105.204	0.013	0.597	1.100	0.084	97.967	2.033	96.064	0.039
KN0002A	105.127	0.066	0.667	1.239	0.303	97.492	2.508	72.654	0.273
KN0002A	103.477	0.003	0.629	1.399	0.041	92.719	7.281	92.999	0.070
KN0002A	118.707	0.126	0.833	1.183	0.166	91.616	8.384	91.437	0.086
KN0002A	155.330	0.750	0.889	1.183	0.920	94.624	5.376	95.324	0.047
KN0002A	72.976	24.386	0.553	1.700	0.744	92.367	7.633	97.474	0.025
KN0002A	87.141	0.259	1.140	2.236	1.406	86.512	13.488	94.380	0.056
KN0002A	140.834	0.591	1.769	1.914	4.803	92.752	7.248	97.174	0.028
KN0002A	75.419	0.051	0.989	1.774	0.050	94.561	5.439	97.661	0.023

Table 4.3: Weekly Mean of Call Data Records of Cell KN0003A handover threshold level (102dB)

CELL	WEEKLY MEAN TRAFFIC LOAD (ERL)	Weekly TCH Congestion Rate (%)	WEEKLY TCH Call Drop Rate (%)	Weekly SDCCH Drop Call Rate (%)	Weekly SDCCH Blocking Rate (%)	Weekly Handover Success Rate (%)	Weekly Handover Failure Rate (%)	Weekly CSSR (%)	WEEKLY average Call Blocking Prob.
KN0003A	6.703	0.014	0.220	1.340	0.006	98.340	1.660	97.904	0.0210
KN0003A	7.674	3.981	0.341	1.169	0.120	98.584	1.416	98.519	0.0148
KN0003A	7.026	0.231	0.271	1.534	0.006	98.886	1.114	98.097	0.0190
KN0003A	7.556	0.037	0.260	1.331	0.016	98.846	1.154	97.543	0.0246
KN0003A	9.533	0.014	0.246	1.144	0.169	98.345	1.655	97.390	0.0261
KN0003A	10.070	0.014	0.246	1.196	0.169	98.710	1.290	97.438	0.0256
KN0003A	9.540	0.186	0.210	1.740	0.169	98.910	1.090	98.047	0.0195
KN0003A	6.274	0.186	0.216	1.301	0.024	98.759	1.241	97.957	0.0204
KN0003A	7.507	0.169	0.215	1.319	0.024	98.414	1.586	98.011	0.0199
KN0003A	9.343	0.169	0.109	1.429	0.036	97.974	2.026	97.183	0.0282
KN0003A	10.426	0.475	0.139	1.199	0.177	96.327	3.673	96.946	0.0305
KN0003A	9.910	0.474	0.414	1.119	0.177	86.163	13.837	96.293	0.0371
KN0003A	11.430	0.460	0.353	1.689	0.021	98.343	1.657	95.166	0.0483
KN0003A	26.193	0.197	0.956	1.474	0.177	97.316	2.684	92.030	0.0797

Considering one cell each from the two groups of seven cells sample i.e.KN0002A and KN0003A. Attempt was made to observe the behavioral pattern of some of the parameters under consideration on a weekly basis this will help us extract certain facts. Tables 4.2 and 4.3 presents computed weekly mean of call data records for cells KN0002A and KN0003A respectively.

4.3.1 Behavioral trend effect of traffic load and SDCCH call drop on intercell handover in cells KN0002A and KN0003A

SDCCH is one of most important resources where the system relies to accommodate user needs like call establishments both new and handover calls. That is why intercell handover is always evaluated on traffic channel and standalone dedicated control channels in almost all GSM BSC equipment.

4.3.2 Influence of traffic load and SDCCH call drop on intercell handover in cells KN0002A

From the computed data in Table4.2 for cell KN0002A a graph of weekly pattern of behavior for traffic load, standalone dedicated control channel call drop, and handover failure rate was plotted as shown in Figure 4.3.

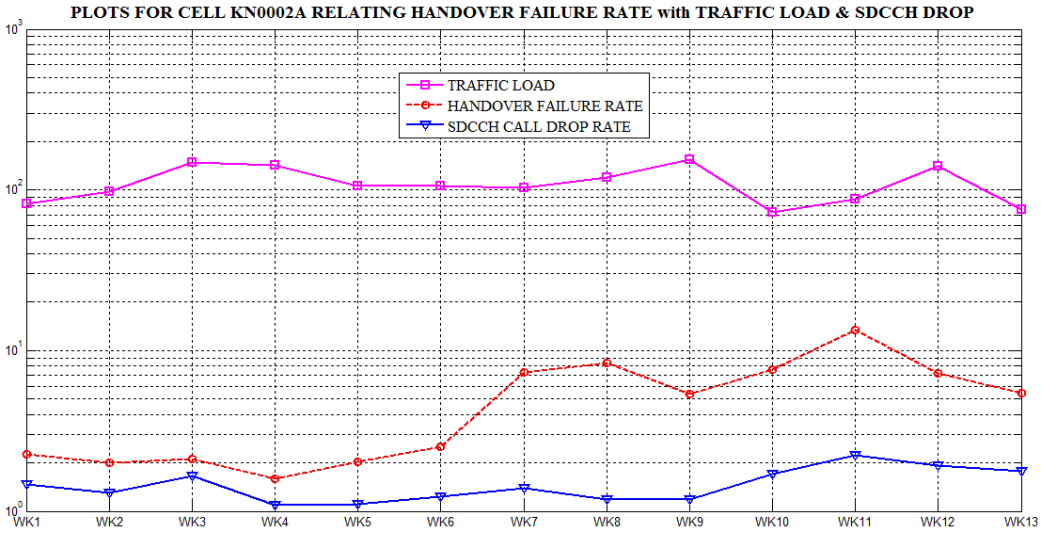


Figure 4.3: Plot for cell KN002A Relating Handover Failure Rate with SDCCH Drop& Traffic Load

It was observed that increase in standalone dedicated control channel call drop lead to proportional increase in handover failure. From the computed data in Table 4.2 standalone dedicated control channel blocking rates are below the NCC recommended target of ≤0.2% an average of 70% of the period under consideration. This definitely gave rise to high standalone dedicated control channel drops and this translates into substantial revenue loss by the operator. The situations gave rise to congestion which must be avoided always since it degrades handover performance and therefore negatively affect QoS. The weekly mean traffic load is high in this cell and the handover failure is proportionally high. Intercell/Inter BTS handover procedure needs improving on to ensure optimum traffic resource utilization ultimately improving on revenue and QoS.

4.3.3 Influence of traffic load and SDCCH call drop on intercell handover in cell KN0003A

Similarly, from computed results in Table 4. 3 a plot of weekly behavioral pattern of traffic load, standalone dedicated control channel call drop rate and handover failure rates was presented in Figure 4.6 for cell KN0003A.MatLab R2009b was used for the plot.

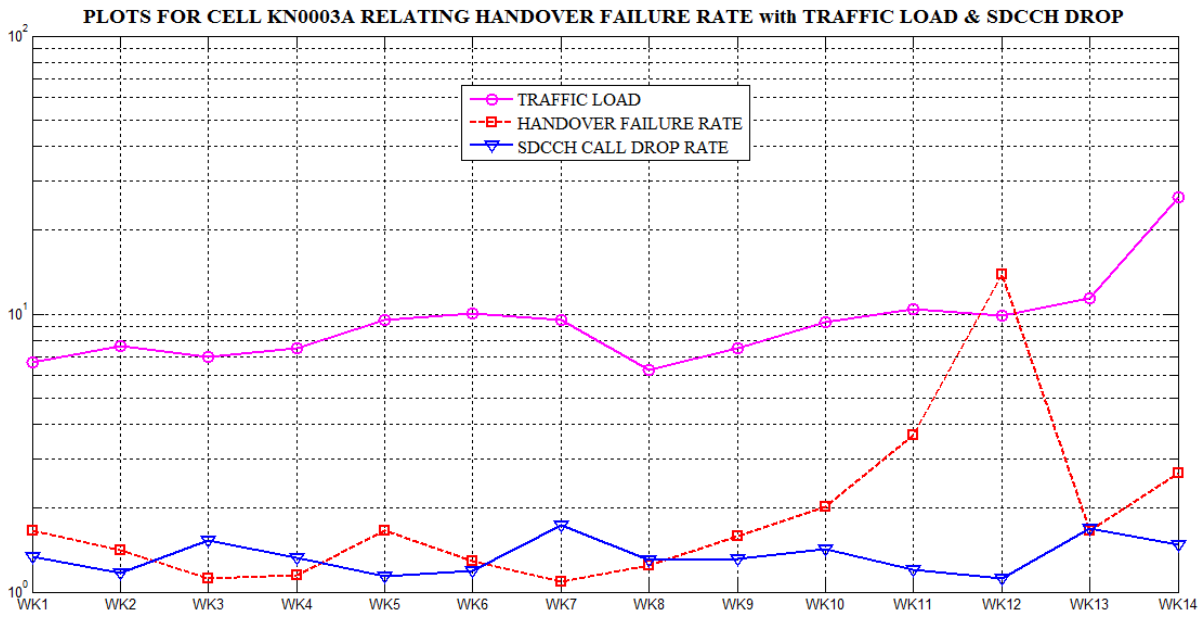


Figure 4.4: A Plot of Traffic Load, SDCCH Call Drop rate and Handover Failure Rate

The increase in mean traffic load tends to produce a corresponding increase in handover failure rates almost all the time. The mean standalone dedicated control channel blocking probability have been poor with over 78% percent of the time performing outside the recommended NCC target. Increase in traffic load produced an increase in handover failure rates. While there was steady rise in handover failure rate from week7 until it got to a peak in week12, it steadily declined within the week. A sudden sharp rise in handover failure in week12 could be attributed to a fault condition this is collaborated by a corresponding decline in standalone dedicated control channel call drop rates. The trend indicates poor dynamics of intercell/ Intercell BTS on call resources.

4.4 Comparing the Influence of TCH Call Drop and Congestion on Intercell Handover in Cells KN0002A and KN0003A

Here cells KN0002A and KN0003A are Compared in terms of traffic channel call drop rates and traffic channel congestion values with the aim of deducing the dynamics of intercell/ inter BTS handover.

4.4.1 Effect of TCH call drop and congestion on intercell handover in cell KN0002A

In Figure 4.5, traffic channel call drop and Congestion are presented graphically alongside handover failure rate based on the computation made in Tables 4.2 and 4.3. With zero congestion, call drop on traffic channel was minimal until congestion begins to build- up and call drop in traffic channel increased. It was observed that increase in traffic channel call drop produced a corresponding increase in handover failure rates most times. In week nine the system suffered from unusually high congestion in the system it was seen also that, handover failure was observed to be equally high and rising between week 9 and week 12. This clearly indicates that poorly performed handover procedures can lead to congestion which degrades QoS. Again congestion could lead to increased demand for handover which must be avoided to prevent system switch processor overload. Traffic channel call drops are largely due to intercell handover failures. From Table 4.3 (Appendix VI), it can be observed that the highest handover failure rate produced the highest Standalone Dedicated control channel call drop this clearly will reduce capacity of the system too for lack of resources and revenue is lost in the process. In Figure 4.5, weekly behavioral pattern of traffic channel call drop, congestion and handover failure rate are presented graphically with a view to observing the trends.

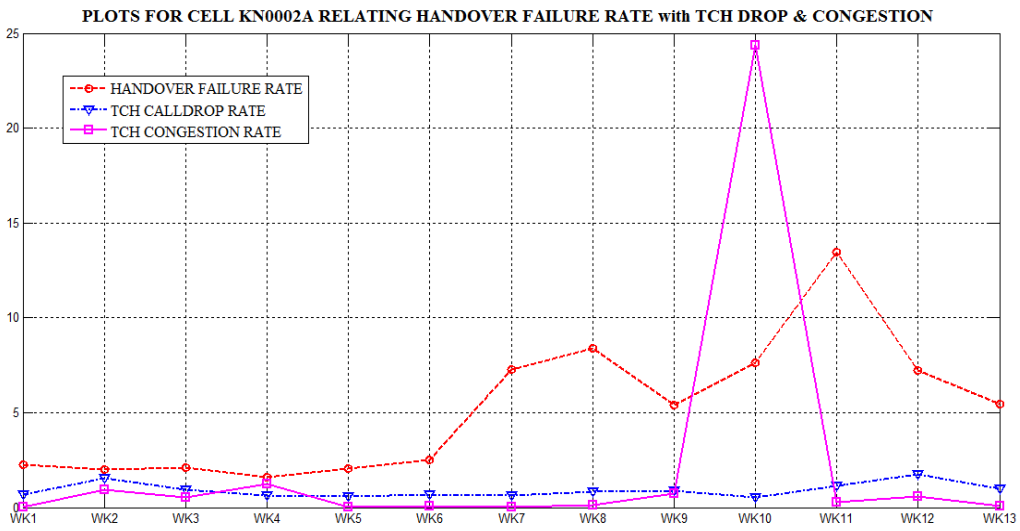


Figure 4.5 Weekly Behavioral Pattern of Traffic Channel Drop, Congestion and Handover failure

4.4.2 Effect of TCH call drop and congestion on intercell handover in cell KN0003A

Figure 4.6 presents computed traffic channel call drop, traffic channel congestion and handover failure rate weekly behavioral patterns. It was observed that in week eleven (11) there was steady sharp rise in handover failure while in week 12 a steep decline was observed this points to a fault condition in week eleven. It is believed that the problem was rectified in week twelve (12). It was also observed that during the week 11 handover problems which could have been due to hardware fault, corresponding increase in traffic channel congestion and traffic channel call drop was recorded clearly showing the negative effect of handover failure. It was also observed that traffic channel call drop and handover failure rates are directly proportional i.e. increase in handover failure rates produces a corresponding increase in traffic channel call drop rate. Week one also witnessed rising congestion which peaked in week 2 and ended at almost zero in week 3. Traffic channel call drops equally increased also within the period. It was also observed

that decreasing congestion in week 2 produced decreasing handover failure rate this can be attributed to availability of more channels for the handover. During high traffic channel congestion periods like as in week1, subscribers would have experience poor service qualities because of limited traffic resources and consequently substantial revenue would have been lost

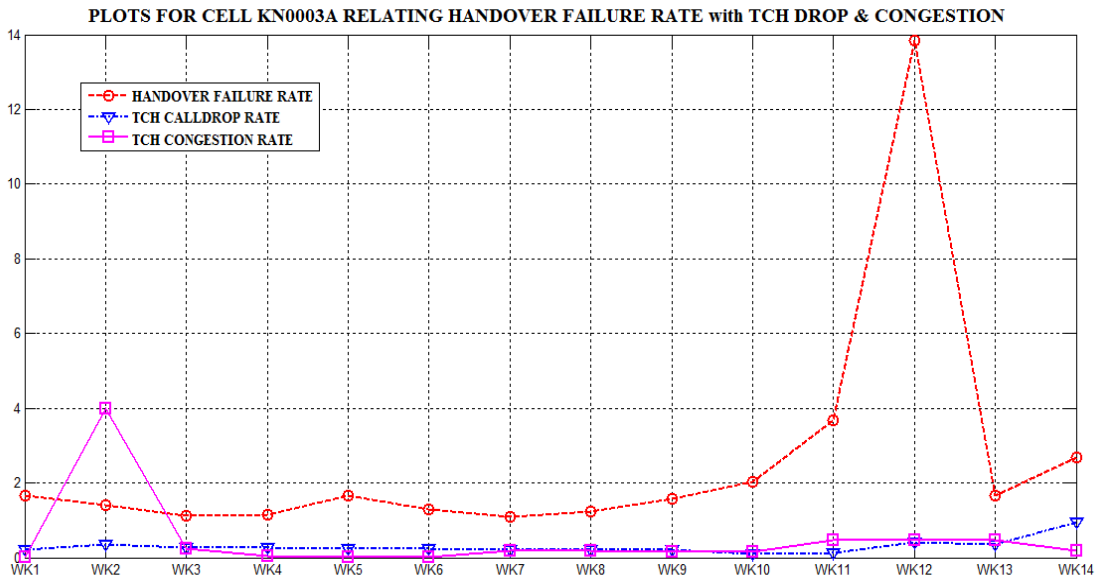


Figure 4.6: Plot for Cell KN003A Relating Handover Failure Rate, TCH Call Drop and TCH Congestion

4.5 Impact of Intercell Handover on Call Drops

Here the impact of intercell handover on call drops is analyzed. From the sample data Handover dropping probability was processed and was used to predict call dropping probability for each cell by computation. Equation (3.1) was employed for the computation and the parameter (h^{AB}) that is number of handover was assumed to be two The assumption is based on that fact that call duration is strongly affected by user mobility class hence the number of handover. The user mobility classes like (pedestrian, Okada, Bus services, private car passengers) share the same characteristics with those evaluated in the work of Ernst, (1999). The average call duration for these classes ranges from 95 seconds to 150 seconds. Based on this it is not expected in practice that there will be more than two handovers per call. Table 4.4 shows the computed results of call and handover dropping Probabilities for cells.

Table 4.4 Computed Call and Handover Dropping Probabilities

CELL ID	Handover Failure Rate(%)	Handover Dropping Probability (HDP)	Predicted Call Dropping Probability (CDP)
KN0002A	4.943	0.049	0.096
KN0002B	6.397	0.064	0.124
KN0002C	2.723	0.027	0.054
KN0002D	1.572	0.016	0.031
KN0002E	1.405	0.014	0.028
KN0002F	0.995	0.010	0.020
KN0003A	2.624	0.026	0.052
KN0003B	1.815	0.018	0.036
KN0003C	2.748	0.027	0.054
KN0006A	1.788	0.018	0.035
KN0006B	5.183	0.052	0.101
KN0006C	4.449	0.044	0.087
KN0007A	5.523	0.055	0.107
KN0007B	3.346	0.033	0.066

It can be observed from Table 4.4 that higher handover failure rates, leads to higher handover dropping probability resulting in higher call dropping probability see Figure 4.7.

Using MATLAB R2009b and the results of Table 4.4, is plotted in Figure 4.7

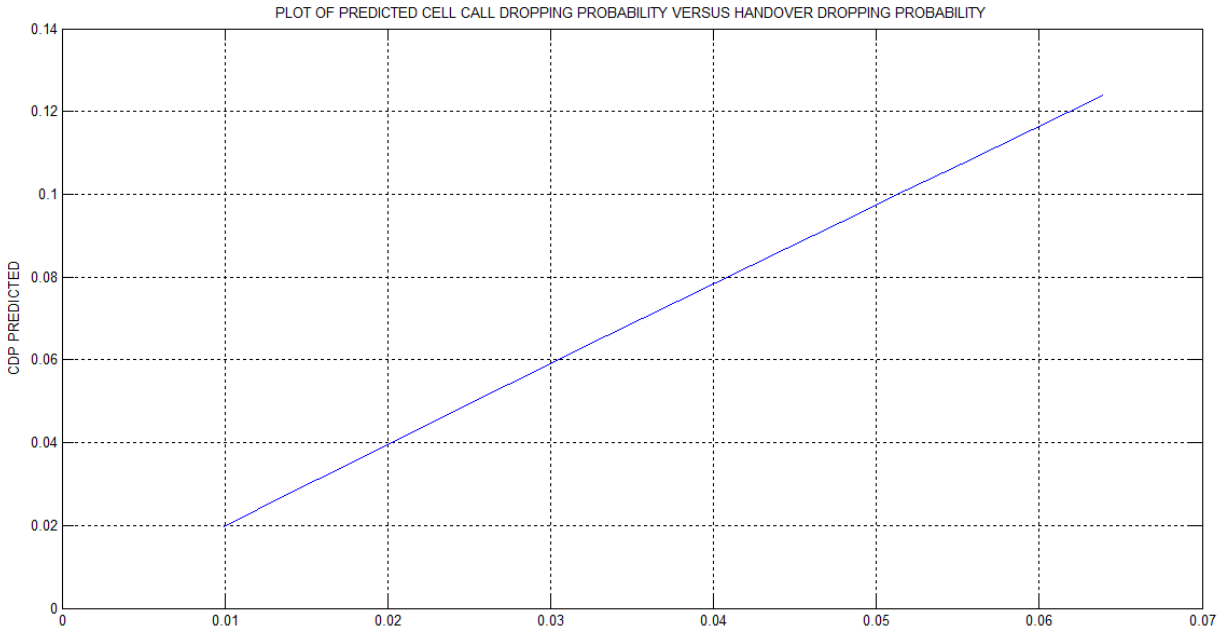


Figure 4.7: Predicted Cell Call Dropping Probability versus Handover Dropping Probability

The plot in Figure 4.7 clearly presents a linear relationship between handover dropping probability and call dropping probability. Call dropping probability is considered a global parameter while handover dropping probability is local. It is worthy to note that the average call drop rate per cell is more than 6% computed from table 4.4. This means that at least six out of every hundred calls are dropped due to handover failure `this is quite significant considering the volume of calls.

4.6 Simulation Results

The simulation results was processed based on equations (3.7), (3.8) and (3.9) and presented in Table 4.5.

Table 4.5: Average Simulated Values

Time(Sec)	**Average Load(Erl)**	**Average HFR**	**Average Call Blocking Probability**
1000	76.343	0.0268	0.21
2000	63.707	0.0255	0.335
3000	62.252	0.023	0.355
4000	63.55	0.0205	0.344
5000	64.182	0.0143	0.344
6000	65.378	0.0205	0.325
7000	66.856	0.014	0.318
8000	65.419	0.013	0.329
9000	66.121	0.019	0.320

The parameters are: computed averages of load, handover failure rates and call blocking probability this is repeated nine different times.

The result of Table 4.5 is further presented graphically in Figure 4.8 a, b.

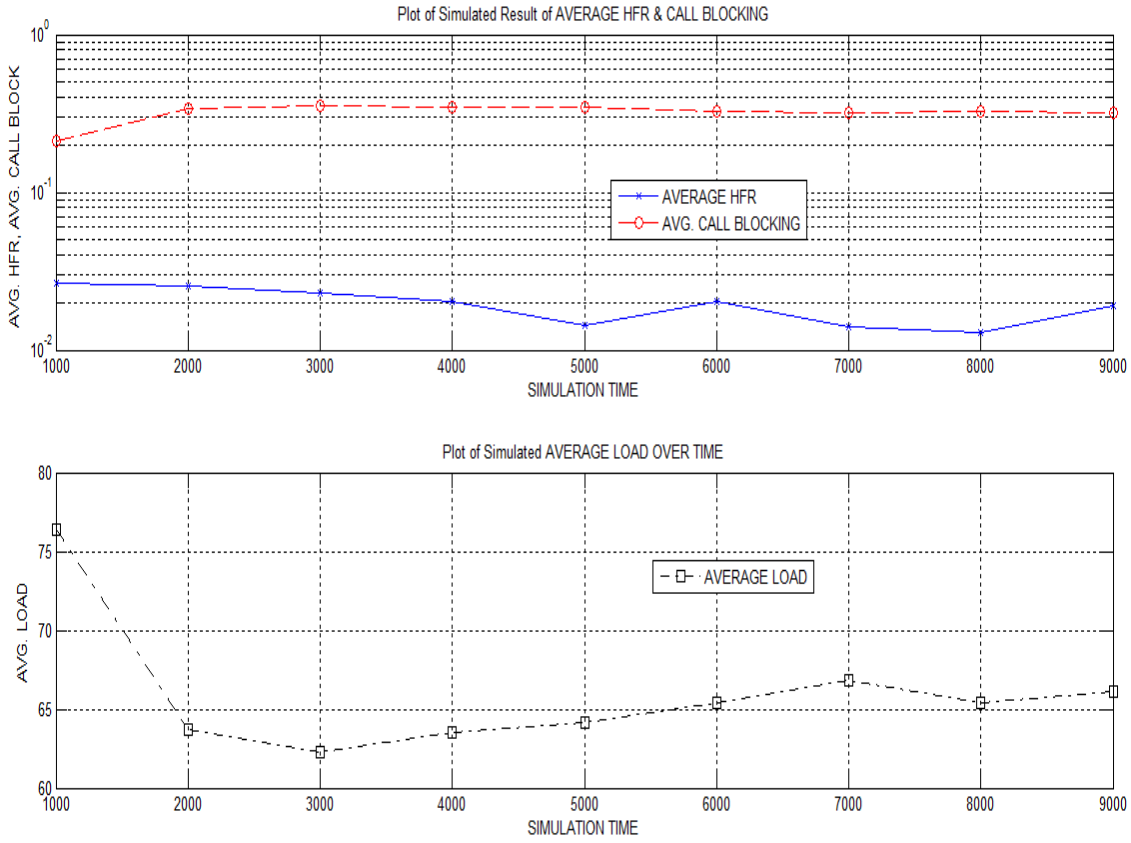


Figure 4.8: Plot of simulated results for Average Handover Failure Rate, Call Blocking and Load

It was observed that data load and simulated loads are non-uniform. It was observed also that average handover failure rates were far less than those obtained from the system analysed based on the obtained data. In Table 4.6 simulated and real handover failure rates were compared.

Table 4.6: Comparison Between Real And Simulated Handover Failure Rate

Load (Erl) Real	**Load (Erl) Simulated**	**HFR Real**	**HFR Simulated**
60.606	62.252	1.405	0.02
65.789	65.373	0.995	0.026
83.186	81.841	1.788	0.009
72.927	66.856	7.281	0.01
75.294	76.343	5.439	0.012

Table 4.6 is a tabulation of data load; real handover failure rate both derived from obtained data, simulated load and simulated handover failure rate values processed based on equations (3.7), (3.8) and (3.9). It was observed that when handover failure rate from data and simulated handover failure values compared the simulated values are better than those obtained from data when evaluated against NCC recommended target of (≤ 0.02).

Also mathematically, comparing simulated handover failure rate and real handover failure rate of some cells, their percentage difference represent improvement. The percentage improvement on handover failure rate averages were over ninety (90%) in most cases.

It can also be observed from Table 4.6 that handover failure rate was highly minimized. When load increases handover failure rate reduces this is as a result of making the guard channel flexible thereby improving on channel resource utilization.

Also it was observed from Table 4.6 that simulated handover failure rate was ninety percent (90%) of the time within NCC recommended standard of (<=0.02).

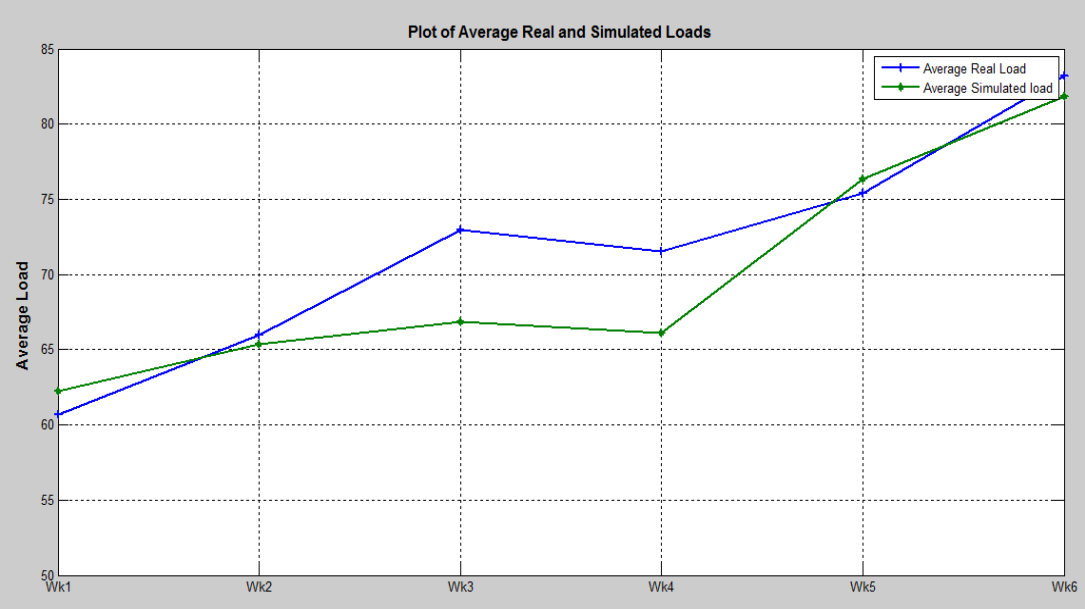


Figure 4.9: Plot of average real and simulated loads.

The plot of Figure 4.9 is used to validate our simulation system. Both real average loads as derived from obtained data were plotted together with the simulated average loads. The plot shows a lot of similarities including being equal at various points and their dynamic nature. A correlation coefficient was calculated using MATLAB to be 0.9122 which is quite significant and an indication that the two loads are virtually the same except for minor errors.

CHAPTER FIVE

CONCLUSION AND SUGGESTIONS FOR FURTHER WORKS

5.1 Introduction

This chapter contains succinct effort made in realizing the aims and objectives of this work. Also included are the summary of results obtained after analyzing the inter cell handover dynamics based on the data obtained from an OMC of Airtel in Kano, Nigeria. A simulated solution aimed at improving the performance of the handover dynamics, the limitations encountered and the suggestions for further research work.

5.2 Summary

The research analysed the intercell handover dynamics by profiling the performance of cells. Data was obtained in Microsoft Excel format from Airtel Kano, Quality of service (QoS) key performance indicators parameters like (HSR, CSSR, SDCCH Drop rate, TCH call Drop, SDCCH Blocking, TCH congestion) were extracted, computed and analysed Using MATLAB as our main tool. Evaluation by way of benchmarking with NCC recommended standards was carried out.

The evaluation revealed that seventy two percent (72%) of cells considered performed below NCC targets for Call Setup Success Rate (CSSR), Sixty four (64%) failed to achieve Handover Success Rate (HSR) , Sixty four percent (64%) failed to achieve Standalone Dedicated Control Channel blocking rates targets, twenty one percent (21%) failed to achieve congestion targets. Using mathematic methods Average call drop rate per cell was predicted to be six (6%). This without doubts negatively impacted on the QoS.

To improve the inter cell handover performance, a dynamic cutoff priority handover management scheme algorithm was developed. The algorithm gives priority to handover by reserving some channels exclusively for handover initially and dynamically alters it with a view of getting minimum handover failures.

The algorithm was simulated using Netbeans 6.1 which is a JAVA variant. From the simulation an average of Ninety percent (90%) performance improvement was realized after comparing the real Handover failure rates per cell and those obtained from simulation. This is a far better result taking into consideration that from obtained data seventy two (72%) percent of the cells did not achieve the NCC recommended standard for handover success rate (>=98%), while by simulation only an average of twenty percent (20%). These clearly are an indication for optimum utilization of channel resources and maximized intercell handover performance.

Simulation System validation was achieved by comparing properties and values of simulated load and load obtained from data. MATLAB was used to graphically presents the two values.

5.3 Limitation of the Study

The research objectives were met in spite of some Limitation encountered.

Limitations encountered in the cause of this work includes lack of a physical GSM Simulator that could have been used for test and trials of the program, this could have given room for real experimental experience. Deployment issues were not undertaken and the Operator only allowed use of data without access to OMC.

The research focused on GSM network but our methodology can be applied to 3G and 4G

5.4 Conclusion

The research largely achieved the set objectives. It improved on the performance of GSM intercell handover dynamics especially in area of its impact on key performance indicators and signaling resources.

Significant contributions are made in the following areas:

1. Assessment of quality of Airtel Network in Kano due to Handover traffic
2. Performance evaluation of individual cell in the network
3. Using dynamic cut-off priority an optimal solution of channel allocation was proposed based on this proposed solution an average of 90% handover failure rate was reduced.

5.5 Recommendation on Areas for Further Work

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

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APPENDIX II

Algorithm for Dynamic Channel Allocation Scheme (DCAS)

Alagu and Meyyapa (2012) DCAS (t, C) // the algorithm takes time period and channels as input

```
        Input (t,C)
{
        Co=C-GCh
        For every handoff call request Do
{
If Oc < C, then
{
        Hc = Hc + 1 and grant admission
        Oc = Oc +1
}
        Otherwise, Pf = Pf +1 and reject.
}
        For every new call request Do
{
        If Oc < Co, then
{
        Nc=Nc+1 and grant admission
        Oc = Oc +1
}
        Otherwise, Pb = Pb +1 and reject.
}
        If a call is completed or handoff to another cell
{
        Oc = Oc – 1
        Check with MSC whether the ended call is handoff call or new originated call
        If handoff call then Hc = Hc-1
        Else Nc = Nc-1
}
        If a handoff call is dropped and Pf/H >= AuTh then
{
        GCh = min {GCh +1, Cmax}
        If Pf/H <= AdTh for N consecutive handoff calls, then
        GCh = max {GCh – 1, Cmin}
}
        Nc and Hc are reported to understand the successful handoff and new calls at a
        specified time period.
}//end of the algorithm:
```

APPENDIX III

Algorithms for A Probability-Based Adaptive Algorithm for Call Control in Wireless Networks (Weng et al, 2003)

T_h threshold of HBP

H total amounts of handoff-call

a,b two number between 0 and 1, and 0<a<b<1

```
rr=Dh/h        // rr current actual HBP
rd=a*Th        //lower limit of HBP, usually set rd=0.6
ru=b*Th        //upper limit of HBP, usually set rd=0.98
Pinc=0.2       //prob. to increase threshold, usually
Pinc<0.5
FOR each dropped-handoff-call DO
if ( rr<=rd ) {
        if(rand()>Pinc)
        Ch=max{Ch-1,Cmin}
}else
        if(rr>ru=){
        if((rand()>(1-Pinc)) && (IsDropped()))
        Ch=min{Ch+1,Cmax}
}
}
END FOR
```

APPENDIX IV

Parameters Used in the Simulation Program

num_Channels:	Number of channels in the system
open_Chanels:	Shared channel between New call and Handover call
guard_Chanels:	Cutoff Priority Channels (Guard Channels)
ongoing_Calls=0	Ongoing Calls
new_originate_calls=0	Keep counts New Originating Calls
handoff_calls_admitted=0	Keeps count Handover Calls admitted
handoff_calls_rejected=0	Keeps count Handover Calls rejected
all_handoff_calls=0	Sums admitted and rejected Handover Calls
time_period:	Simulation time
Cmax=10	Maximum value of threshold
Cmin=1	Minimum value of threshold
new_call_delay=3000	Channel occupancy time of New Calls
handoff_call_delay=3700	Channel occupancy time of Handover Calls
generall_delay=1000	Rate of call generation time
num_rejected_calls=0	Keeps count of rejected New Calls
num_calls_admitted=0	Keeps count of admitted New Calls
all_new_calls=0	Keeps count of admitted and rejected New calls
prob_hand_fail=0	Keeps count of Handover failure rate
prob_call_block=0	Keeps count of New Calls blocking rate
lower_limit=0.06	Adjustable coefficient lower limit

upper_limit=0.09	Adjustable coefficient upper limit
Pinc=0.2	Probability to decrease or increase threshold
current_actual_HPB:	Current actual Handover blocking rate
call_blocking:	Computed Call blocking rate
handoff_failures:	Computed Handover failure rate
load:	Simulated offered load
total_num_calls_proces:	Total number of all calls processed
timer_calls	New Call Timer
timer_handoff	Handover Call Timer

APPENDIX V: Netbeans 6.1 simulation program

```
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
package channelmanagement;
/**
 *
 * @author bodori
 */
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
import java.io.*;
import javax.swing.border.TitledBorder;
import java.util.*;
import java.awt.*;
import javax.swing.Timer;
import javax.swing.*;
import java.awt.event.*;
import java.math.BigDecimal;

public class BaseStation extends JFrame implements ActionListener
{
   private int cur_chunck, num_periods,num_Channels, open_Chanels[], guard_Chanels[], ongoing_Calls[], new_originate_calls[],
         handoff_calls_admitted[],handoff_calls_admitted_copy[], handoff_calls_rejected[], all_handoff_calls[], time_period,
         Cmax=10, Cmin=1, N=0, new_call_delay=4500, handoff_call_delay=6000, generall_delay=1000,
         num_rejected_calls[], num_calls_admitted[],num_calls_admitted_copy[], new_incoming_handoff_calls[],all_new_calls[];

   private double prob_call_drop=0, prob_hand_fail[], prob_call_block=0, threshold=0.2,
               lower_limit=0.06, upper_limit=0.09, Pinc=0.2;
   private float[] current_actual_HPB, call_blocking, handoff_failures, load, total_num_calls_proces, all_originate_calls;
   String all_times[];
   private Timer[] timer_gen, timer_calls, timer_handoff, end_prog_time;
   private Vector<Vector> cells=new Vector<Vector>();
   Vector<Integer> all_times_basket=new Vector<Integer>();
   String[] columnNames2={"S/N",  "Call Blocking", "Handoff Failures", "Load", "Simul.Time "};
   private String CALL_TYPE;
   JLabel gen_table;
   JPanel panel=new JPanel();
   JProgressBar bar;
   Thread t[];
   StringBuffer buffer[];
   Font font=new Font("SansSerif", Font.PLAIN, 14);
```

```
  private ArrayList<Timer> allTime=new ArrayList<Timer>(), all_handoff_time=new ArrayList<Timer>(), all_call_time=new ArrayList<Timer>();

  Random rand=new Random();

  private JTextField text1, text2;
  private JButton button;
  private JTextArea textArea;

  public BaseStation()
  {
    buildGUI();
  }
  private void buildGUI()
  {
    //setLayout(null);
    panel.setLayout(null);
    //panel.setBackground(Color.white);
    JLabel lab1=new JLabel("Enter Time Period: ");
    lab1.setBounds(20, 50, 140, 20);
    panel.add(lab1);

    JLabel lab2=new JLabel("Enter no. Channels: ");
    lab2.setBounds(20, 90, 140, 20);
    panel.add(lab2);

    text1=new JTextField(20);
    text1.setBounds(170, 50, 150, 20);
    panel.add(text1);

    text2=new JTextField(20);
    text2.setBounds(170, 90, 150, 20);
    panel.add(text2);

    button=new JButton("Start Base Station");
    button.setBounds(100, 130, 170, 20);
    button.addActionListener(this);
    panel.add(button);

    textArea=new JTextArea(100, 100);
    textArea.setFont(new Font("Sanseriff", Font.PLAIN, 16));
    //textArea
    textArea.setLineWrap(true);
    textArea.setWrapStyleWord(true);
    JScrollPane scrol=new JScrollPane(textArea, ScrollPaneConstants.VERTICAL_SCROLLBAR_AS_NEEDED,
    ScrollPaneConstants.HORIZONTAL_SCROLLBAR_NEVER);
```

```
   scrol.setBorder(new TitledBorder("Output of Simulation"));
   scrol.setBounds(20, 190, 450, 400);
   panel.add(scrol);
   add(panel);

   bar=new JProgressBar();
   bar.setBounds(20, 600, 300, 30);
   bar.setBorderPainted(true);
   bar.setMaximum(100);
   bar.setMinimum(0);
   bar.setValue(2);
   bar.setString("0:0 mins");
   panel.add(bar);
   add(panel);

   setTitle("Simulating Calls and Handoffs");
   setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
   setSize(1250, 700);
   setVisible(true);
}
 private synchronized void dynamicChannelAllocationScheme(int n) throws Exception
 {
    timer_gen[n]=new Timer(generall_delay, this);
    allTime.add(timer_gen[n]);
    timer_gen[n].start();
 }
 private synchronized void computeCallorHandoffCompleted(int call_type, int call_no, int n)
 {
  ongoing_Calls[n]=ongoing_Calls[n]-1;
  //open_Chanels, guard_Chanels,
  if(call_type==1)//This means that if 1 is passed as a parameter to this method, then it is handoff call
     {
       handoff_calls_admitted_copy[n]=(handoff_calls_admitted_copy[n]-1 < 0 ? 0 : handoff_calls_admitted_copy[n]-1);
       displayOutput("Handoff call has been completed. Remaining "+handoff_calls_admitted_copy[n], n);
       all_handoff_calls[n]=handoff_calls_admitted[n]+handoff_calls_rejected[n]; //handoff_calls_admitted+handoff_calls_rejected;
     }
  else //This means that if 2 is passed as a parameter to this method, then it is new call
    {
       num_calls_admitted_copy[n]=(num_calls_admitted_copy[n]-1 < 0 ? 0 : num_calls_admitted_copy[n]-1);
       displayOutput("New call has completed. Remaining "+num_calls_admitted_copy[n], n);
       all_new_calls[n]=num_calls_admitted[n]+num_rejected_calls[n];
    }
  displayOutput("The total number of available channels: "+(num_Channels - ongoing_Calls[n]), n);

 }
private synchronized void signalCallorHandoffGenerated(int generated_random_num, int n)
 {
```

```
   ongoing_Calls[n]=handoff_calls_admitted_copy[n] + num_calls_admitted_copy[n];
   displayOutput("The total number of ongoing calls are: "+ongoing_Calls[n], n);
     if(generated_random_num%2 == 0)
      {
       CALL_TYPE="New Call";
      }
     else
      {
       CALL_TYPE="Handover";
      }

   /*
    * Lines of code below checks the type of calls that enters
    * and then carries out a particular task relevant to the call type.
    */
    if(CALL_TYPE.equals("Handover"))
     {
      handoverHandler(n);
     }
    else
     {
      newcallHandler(n);
     }
 }
private synchronized void handoverHandler(int n)
 {
   ++new_incoming_handoff_calls[n];
   if(ongoing_Calls[n] <= num_Channels)
         {

          handoff_calls_admitted[n]=handoff_calls_admitted[n]+1;
          ++handoff_calls_admitted_copy[n];//
          displayOutput("Handoff call #"+new_incoming_handoff_calls[n]+" has just entered and was granted admission!",n);
          N=0;
          incrementOngoingCalls(n); //ongoing_Calls=ongoing_Calls+1;
          displayOutput("The total number of handoff calls are: "+handoff_calls_admitted_copy[n],n);
          timer_handoff[n]=new Timer(handoff_call_delay, this);
          timer_handoff[n].start();
         }
       else
         {
          prob_hand_fail[n]=prob_hand_fail[n]+1;
          handoff_calls_rejected[n]=handoff_calls_rejected[n]+1;
          raiseAlarm(true, n);
          displayOutput("Handover call #"+new_incoming_handoff_calls[n]+" has just entered and was rejected!",n);
          displayOutput("The total number of handoff calls rejected are: "+handoff_calls_rejected[n],n);
         }
```

```
}
private synchronized void newcallHandler(int n)
{
     new_originate_calls[n]=new_originate_calls[n]+1;
      if(ongoing_Calls[n] <= open_Chanels[n] )
        {    //grant admission
          ++num_calls_admitted[n];
          ++num_calls_admitted_copy[n];
          incrementOngoingCalls(n);  //ongoing_Calls=ongoing_Calls+1;
          displayOutput("New call #"+new_originate_calls[n]+" has just entered and was admitted!",n);
          displayOutput("The total number of new calls admitted are: "+num_calls_admitted_copy[n],n);
          timer_calls[n]=new Timer(new_call_delay, this);
          timer_calls[n].start();
        }
       else
        {
         ++num_rejected_calls[n];
         displayOutput("New call #"+new_originate_calls[n]+" has just entered and was rejected!",n);
         displayOutput("The total number of new calls rejected are: "+num_rejected_calls[n],n);
          prob_call_block=prob_call_block+1; //call regected
        }

}
private synchronized void raiseAlarm(boolean isDrooped, int n)
{
  all_handoff_calls[n]=handoff_calls_admitted[n]+handoff_calls_rejected[n]; //new_incoming_handoff_calls; //
  current_actual_HPB[n]=(float)handoff_calls_rejected[n]/all_handoff_calls[n];
  Random rand_num=new Random(1);
  double rand_double=rand_num.nextDouble();
  BigDecimal bd = new BigDecimal(Double.toString(rand_double));
  bd = bd.setScale(1, BigDecimal.ROUND_CEILING);
  double up_rand_double=bd.doubleValue(); //.floatValue();
  displayOutput(current_actual_HPB[n]+"- current_actual_HPB and rand_double="+up_rand_double, n);
   if(current_actual_HPB[n] >= upper_limit )
           {  displayOutput("Almost incresed guard channel ",n);
             if((up_rand_double >= 1-Pinc)&& (isDrooped))
              {
                guard_Chanels[n]=Math.min(guard_Chanels[n]+1, Cmax);
                open_Chanels[n]=num_Channels-(guard_Chanels[n]);
                displayOutput("Guard channels increased to "+guard_Chanels[n]+" and number of open channels is "+open_Chanels[n],n);
              }
           }
   else  {
             if(up_rand_double >= Pinc)
             {
              guard_Chanels[n]=Math.max(guard_Chanels[n]-1, Cmin);
              open_Chanels[n]=num_Channels-(guard_Chanels[n]);
```

```
                displayOutput("Guard channels decreased to "+guard_Chanels[n]+" and number of open channels is "+open_Chanels[n],n);
              }

}
private void displayOutput(String msg, int n)
{
  buffer[n].append(msg+"\n");
}
private synchronized void  incrementOngoingCalls(int n) //synchronized
{
  ++ongoing_Calls[n];
}
private int getNextRandomNum(double gauge)
{
  int rand_num=0;
  double elambda=Math.exp(- gauge);
  double prod=1;
  Random rand=new Random();
  while(prod > elambda)
   {
      prod*=rand.nextDouble();
      rand_num++;
   }
  //System.out.println("Poisoon val is "+(rand_num-1));
  return rand_num-1;
}
private synchronized void formulaImplementer(int n)
{
  all_originate_calls[n]=num_calls_admitted[n]+num_rejected_calls[n];
  total_num_calls_proces[n]=new_incoming_handoff_calls[n]+new_originate_calls[n]; //all_handoff_calls+all_new_calls; new_originate_calls
  call_blocking[n]=num_rejected_calls[n]/total_num_calls_proces[n];
  handoff_failures[n]=handoff_calls_rejected[n]/total_num_calls_proces[n];
  load[n]=((handoff_calls_admitted[n]+num_calls_admitted[n])/total_num_calls_proces[n])*100;
  displayOutput("total_num_calls_proces="+total_num_calls_proces[n],n);
  displayOutput("num_rejected_calls="+num_rejected_calls[n],n);
  displayOutput("handoff_calls_rejected="+handoff_calls_rejected[n],n);
  displayOutput("handoff_calls_admitted+num_calls_admitted="+(handoff_calls_admitted[n]+num_calls_admitted[n]),n);
  displayOutput("Call blocking: "+call_blocking[n],n);
  displayOutput("Handoff Failures: "+handoff_failures[n],n);
  displayOutput("Load: "+load[n],n);
}
private synchronized void  outputFormatter(int n)
{
  Vector<Object> vec=new Vector<Object>();
  vec.addElement(n+1);
  vec.addElement(call_blocking[n]);
  vec.addElement(handoff_failures[n]);
```

```
  vec.addElement(load[n]);
  vec.addElement(Integer.parseInt(all_times[n])*1000);
  cells.addElement(vec);
  boolean still_running=true;
  System.out.println("One ended");
  all_times_basket.removeElement(Integer.parseInt(all_times[n])); //.remove(n);
  end_prog_time[n].removeActionListener(this);//
  end_prog_time[n].stop();
  textArea.append(buffer[n]+"\n");
  System.out.println(buffer[n]);
  System.out.println("End of Process "+n+".....");
  if(all_times_basket.size()== 0) //if(t[k].isAlive())
        still_running =false;
 if(!still_running)
   {
    TablePanel table=new TablePanel(cells, columnNames2 );
    table.setBounds(480, 100, 750, 300);
    panel.add(table);
    gen_table.setText("Result of Simulation");
    panel.add(table);
    panel.validate();
    this.validate();
    panel.repaint();
    this.repaint();
 }
}
private synchronized void  periodicSimulationLauncher(int n)
{
   time_period=Integer.parseInt(all_times[n].trim());
   end_prog_time[n]=new Timer(1000*60*time_period, this);//1000  time_period*1000*60
   end_prog_time[n].setRepeats(false);
   try{
       double temp_val=num_Channels * 0.10;
       guard_Chanels[n]=1; //(int)temp_val;
       displayOutput("==============================================",n);
       displayOutput("Simulating for time period "+all_times[n]+" minutes and "+num_Channels+" numbers of Channels
       and number of Guard Channels is: "+guard_Chanels[n],n);
       displayOutput("==============================================",n );
       open_Chanels[n]=num_Channels-guard_Chanels[n];
       displayOutput("The total number of Channels are: "+num_Channels,n);
       displayOutput("The total number of open Channels are: "+open_Chanels[n],n);
       end_prog_time[n].start();
       dynamicChannelAllocationScheme(n);
     }
   catch(Exception ex)
     {
       System.out.println(ex);
```

```
        //JOptionPane.showInternalMessageDialog(this, ex, "Error", JOptionPane.ERROR_MESSAGE);
      }

}
public void actionPerformed(ActionEvent ev)
{
   if(ev.getSource() instanceof Timer)
      {
        for(int n=0; n < end_prog_time.length; n++)
          {
            if(ev.getSource()==end_prog_time[n])
              {
                formulaImplementer(n);
                timer_handoff=null;
                timer_calls=null;
                num_calls_admitted_copy=0;
                num_calls_admitted=0;
                handoff_calls_admitted_copy=0;
                handoff_calls_admitted=0;
                new_originate_calls=0;
                ongoing_Calls=0;
                prob_call_block=0;
                prob_hand_fail=0;
                guard_Chanels=1;
                cur_chunck=0;
                displayOutput("Program is terminated after : "+time_period+" minutes");
                        displayOutput("\n\n");
                bar.setValue((100/all_times.length)*(n+1));
                ++n;
                if(n < all_times.length)
                   periodicSimulationLauncher(n);
              }
          }
      }
    if(ev.getSource()==button)
      {
        if(text1.getText().isEmpty() && text2.getText().isEmpty())
          {
            JOptionPane.showInternalMessageDialog(this, "Invalide Entry", "Error", JOptionPane.ERROR_MESSAGE);
          }
        else
          {
            //time_period=Integer.parseInt(text1.getText());
            all_times=text1.getText().split(",");
            time_period=Integer.parseInt(all_times[0].trim());
            int sum_time=0;
            for(int k=0; k < all_times.length; k++)
```

```
 {
   sum_time+=Integer.parseInt(all_times[k].trim());
   all_times_basket.addElement(Integer.parseInt(all_times[k].trim()));
 }
JLabel time_ind=new JLabel("Running Time: "+(sum_time*1000)+" simulation time");
time_ind.setBounds(50, 155, 400, 20);
time_ind.setFont(font);
panel.add(time_ind);
gen_table=new JLabel("Generating tables...");
gen_table.setBounds(600, 30, 150, 20);
gen_table.setFont(font);
panel.add(gen_table);
panel.repaint();
this.repaint();
num_Channels=Integer.parseInt(text2.getText());
t=new Thread[all_times.length];
buffer=new StringBuffer[all_times.length];
current_actual_HPB=new float[all_times.length];
call_blocking=new float[all_times.length];
handoff_failures=new float[all_times.length];
load=new float[all_times.length];
total_num_calls_proces=new float[all_times.length];
all_originate_calls=new float[all_times.length];
timer_gen=new Timer[all_times.length];
timer_calls=new Timer[all_times.length];
timer_handoff=new Timer[all_times.length];
end_prog_time=new Timer[all_times.length];
open_Chanels=new int[all_times.length];
guard_Chanels=new int[all_times.length];
ongoing_Calls=new int[all_times.length];
new_originate_calls=new int[all_times.length];
handoff_calls_admitted=new int[all_times.length];
handoff_calls_admitted_copy=new int[all_times.length];
handoff_calls_rejected=new int[all_times.length];
all_handoff_calls=new int[all_times.length];
num_rejected_calls=new int[all_times.length];
num_calls_admitted=new int[all_times.length];
num_calls_admitted_copy=new int[all_times.length];
new_incoming_handoff_calls=new int[all_times.length];
all_new_calls=new int[all_times.length];
prob_hand_fail=new double[all_times.length];
for(int k=0; k < all_times.length; k++)
 {
     num_periods=k;
     buffer[k]=new StringBuffer();
     t[k]=new Thread(new Runnable()
       {
```

```
                public void run()
                   {
                      periodicSimulationLauncher(num_periods);
                   }
                });
              t[k].start(); t[k].isAlive();
              try{
                 Thread.sleep(generall_delay);
                }
              catch(Exception ex){}
          }
       }
  }
 if(ev.getSource() instanceof Timer)
  {
    int n=0;
    while( n < end_prog_time.length)
       {  System.out.println("n is A "+n);
         if(ev.getSource()==timer_gen[n])
          {System.out.println("n is B "+n);
           if(end_prog_time[n].isRunning())
           {System.out.println("n is C "+n);
              int random_num = getNextRandomNum(rand.nextDouble()); //;
              int temp=100/all_times.length;
              int g=(Integer.parseInt(all_times[n])*1000*60)/generall_delay;
              double chunck=0.41;//temp/g;
              cur_chunck+=chunck;
              int cur_val=((temp*n)+cur_chunck); //(100/(n+1))*(n+1);
              System.out.println(all_times[n]+">>>>>>"+n+">>>>>>>."+(temp/g)+""+chunck+"    "+cur_val);
              bar.setValue(cur_val);
              signalCallorHandoffGenerated(random_num, n);
           }
          }
         ++n;
       }
  }
if(ev.getSource() instanceof Timer)
  {
    for(int n=0; n < timer_calls.length; n++)
       {
         if(ev.getSource()==timer_calls[n])
         {
           if(end_prog_time[n].isRunning() && timer_calls[n]!=null)
               computeCallorHandoffCompleted(2, 0, n);
         }
       }
  }
```

```
    if(ev.getSource() instanceof Timer)
       {
         for(int n=0; n < timer_handoff.length; n++)
            {
               if(ev.getSource()==timer_handoff[n])
                 {
                   if(end_prog_time[n].isRunning() && timer_handoff[n] !=null)
                      computeCallorHandoffCompleted(1, 0, n);
                 }
            }
       }
  }
  public static void main(String[] args)
  {
    try
     {
       for (javax.swing.UIManager.LookAndFeelInfo info : UIManager.getInstalledLookAndFeels())
        {
           if ("Nimbus".equals(info.getName()))
           {
                UIManager.setLookAndFeel(info.getClassName());
               break;
           }
        }
       BaseStation bs=new BaseStation();
       SwingUtilities.updateComponentTreeUI(bs);
     }
    catch( Exception e )
     {

     }

  }
}
```