Sudan University of Science and Technology

College of Engineering

Electronics Engineering Department

Performance Analysis on LTE Mobility Management in Heterogeneous Networks

تحليل أداء إدارة التنقل على التطور طويل الآمد في الشبكات غير المتجانسة

A Research Submitted In Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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الآية:

﴿فَلَا تَعْلَمُ نَفْسٌ مَا أُخْفِيَ لَهُمْ مِنْ قُرَّةِأَعْيُنٍ جَزَاءً بِمَا كَانُوايَعْمَلُونَ﴾

صدق الله العظيم

السجدة{17}.

DEDICATION

To the woman, who loved me before I was born ...

To the women, which contained my heart before it is formed

Beloved mother.

To the man who enlighten my life...

To the man who is my all time hero

Dear Father.

ACKNOWLEDGEMENT

Much Thanks ….

To the Almighty God, for the Grace and Strength for completion.

To our Supervisor Assoc. Professor Dr. Ibrahim Khider EL-Tahir for his Guidance.

To those whom exert their time for us, our Dedicated teachers .

ABSTRACT

Long Term Evolution was developed to be step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile. Femtocell is a small cellular base station designed for use in subscriber’s home and small business environments .Handover is one of the key components in cellular network mobility management .The objective of this thesis Performance Evaluation Handover in LTE Based on two Handover Algorithms UE Transmit Power Reduction (UTPR) handover decision policy algorithm and Strongest cell handover decision policy algorithm (SCB). Matlab software is used for this evaluation process, the obtained results included UE Power consumption, in which the SCB reduced the power consumption by 8.6% and the UTPR by 52%; the hysteresis margin and the handover , the datarate with the number of users, in which the SCB decrease the data rate by 91.7% and the UTPR by 83.7%; the throughput of the system in it the UTPR increase the throughput by 88.8% and the SCB by 86.4%, the handover probability with respect to the femtoblock deployment Density, and the average interference power , for downlink interference the UTPR mitigate it by a ratio of 17.5% and the SCB by 12.5% while for the uplink interference the UTPR decrease it by 4% and the SCB by 0.2%. founded that UTPR algorithm is better than SCB algorithm.

المستخلص

التطور طويل الأمد , تم تطويره ليكون الخطوة الأولى لإنطلاق شبكات الجيل الرابع ,وذلك لزيادة سعة وسرعة الشبكات الخلوية .نظراً لزيادة عدد مستخدمي الهواتف النقالة ولتوفير خدمات ذات جودة عالية تم استخدام ما يعرف بخلايا الفيمتو وهي عبارة عن محطات خلوية صغيرة تسخدم داخل المنازل أو أماكن العمل الصغيرة.وتعد عملية التسليم هي العملية الأساسية في عملية إدارة حركة المستخدم عند انتقاله من خلية الى أخرى.

وتهدف هذه الأطروحة الى تقييم عملية التسليم عند حركة المستخدم من خلايا الماكرو الى خلايا الفيمتو بإستخدام خوارزميتي الخلية الأقوى وخوارزمية تقليل طاقة الإرسال لجهاز المستخدم . ولقد استخدم برنامج الماتلاب لعملية التقييم, النتائج المتحصل عليها تتضمن تقليل استهلاك طاقة جهاز المستخدم وفيه قللت خوارزمية الخلية الأقوى استهلاك الطاقة بنسبة 8.6% وخوارزمية تقليل استهلاك الطاقة بنسبة 52% ,الهامش التخلفي مع احتمالية التسليم معدل البيانات مع عدد المستخدمين وفيه قللت خوارزمية الخلية الأقوى معدل البيانات بنسبة 91.7%, اما خوارزمية تقليل الطاقة قللت بنسبة 83.7% ,وخرج النظام وفيه زادت خوارزمية تقليل الطاقة الخرج بنسبة 88.8% ,اما خوارزمية الخلية الأقوى زادت الخرج بنسبة 86.4% ,احتمالية التسليم مع الاخذ في الاعتبار كثافة توزيع خلايا الفيمتو , واخيرا متوسط قوة التداخل وفيه تقلل خوارزمية تقليل الطاقة بنسبة 17.5% لقيم التداخل المستقبلة وبنسبة 4% لقيم التداخل المرسلة , اما خوارزمية الخلية الأقوى تقلل قيم التداخل المستقبلة بنسبة12.5% وبنسبة 0.2% لقيم التداخل المرسلة. تبعا لما سبق وجد أن خوارزمية تقليل طاقة الارسال لجهاز المستخدم أفضل من خوارزمية الخلية الأقوى.

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LIST OF SYMBOLS

Symbol	Meaning
γ_{target}^{u}	SINR target.
σ_{s}^{T}	noise power at cells within the time interval T.
C_n	set of LTE cells.
$h_{c\rightarrow u}^{T}$	channel gain from cell to users within the time interval T.
$h_{c'\rightarrow c}^{T}$	channel gain from all cell to target cell within the time interval T .
$h_{u\rightarrow c}^{T}$	channel gain from users to cell within the time interval T.
$h_{u'\rightarrow c}^{T}$	channel gain from all users to cell within the time interval T.
$h_{u\rightarrow s}^{T}$	channel gain from user u to cell s within the time interval T.
$h_{c\rightarrow s}^{T}$	channel gain between cells c and s within the time interval T .
$h_{s\rightarrow u}^{T}$	channel gain from cell s to user u within the time interval T.

$h^{T}_{u'\rightarrow u}$	channel gain from user u' to user u within the time interval T.
$HHM_{C,(dB)}$	HHM for cell c $\in L_u$.
I^T_c	Received Interference Power.
L_u	accessible neighbour cell set.
n	One band in LTE band set.
N	LTE band set .
P^T_u	power transmission of user within the time interval T.
P^{TTT}_u	power transmission of user within the time trigger TTT.
$P^T_{u'}$	power transmission of all user within the timeinterval T.
P^T_c	power transmission of cell c within the time interval T.
$P^T_{c,RS}$	Reference Signal Transmitted Power for cell within the time interval T.
$P^T_{c'}$	Reference Signal Transmitted Power for all cells without serving cell within the time interval T.
$P^T_{s\rightarrow u}$	power transmission of cell s to user u within the time interval T.
$RSRP^{TTT}_{c\rightarrow u,(dB)}$	$RSRP$received from the cell to user within the time to trigger TTT.
$RSRP^{TTT}_{s\rightarrow u,(dB)}$	$RSRP$received from the serving cell to user within the time trigger TTT.

$RSRP^{T}_{c\to u,(dB)}$	$RSRP$received from the cell to user within the time interval T.
$RSRP^{T}_{s\to u}$	$RSRP$ received from the serving cell to user within the time interval T.
U_n	Set of users.

Abbreviations

Abbreviation	Meaning
1G	First Generation
2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation

A

AP	Access Point
APN	Access Point Name
ATM	Asynchronous Transfer Mode

c

CN	Core Network
CSG	Closed Subscriber Group

D

DSL	Digital Subscriber Line

E

EDGE	Enhanced Data rates for GSM Evolution
EIR	Equipment Identity Register
eNB	evolved NodeB
EPC	Evolved Packet Core

ETWS	Earthquake and Tsunami Warning System
E-UTRA	Evolved UMTS terrestrial radio access
E-UTRAN	Evolved UMTS terrestrial radio access network

F

FAP	Femto-access points
FDD	Frequency Division Duplex
FH	Femtocell cluster Head
FMC	Fixed Mobile Convergence

G

GPRS	General Packet Radio Services
GSM	Global System for Mobile communication

H

HeNB	Home NodeB
HHM	Handover HysteresisMargin
HO	Handover
HSDPA	High-Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSS	Home Subscriber Server

I

IMT-Advanced	International Mobile Telecommunications Advanced
IP	Internet Protocol
ISDN	Integrated Services for Digital Network

L

LTE	Long Term Evolution technology

M

MAHO	Mobile-Assisted Handoff
MCHO	Mobile-Controlled Handoff
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MN	Mobile Node
MS	Mobile Station
MT	Mobile Termination

N

NCHO	Network-Controlled Handoff

O

OFDM	Orthogonal Frequency Division Multiplexing

P

PCEF	Policy Control Enforcement Function
PCRF	Policy Control and Charging Rules Function
PDN	Packet Data Network
P-GW	Packet Data Network Gateway
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network

Q

QoS	Quality of Service

R

RAN	Radio Access Network
RB	Resource Block
RIP	Received interference power
RNC	Radio Network Controller
RS	Relay Station
RSRP	Reference Signal Received Power
RSS	Received Signal Strength
RSQ	Received Signal Quality
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator

S

SAE	System Architecture Evolution
SCB	Strongest Cell Based
SeGW	Security Gateway
SGSN	Serving GPRS Support Node
S-GW	Serving Gateway
SIM	Subscriber Identity Module
SINR	Signal to Interference plus Noise Ratio
SIR	Signal to Interference Ratio
SNR	Signal-to-Noise Ratio

T

TE	Terminal Equipment
TDD	Time Division Duplex

TTT	Time To Trigger

U

UE	User Equipment
UICC	Universal Integrated Circuit Card
UMTS	Universal Mobile Telecommunications System
USIM	Universal Subscriber Identity Module
UTPR	UE Transmit Power Reduction

V

VOIP	Voice Over IP

Chapter One

Introduction

Chapter One

Introduction

1.1preface:

With the increasing demands for new data and real-time services, wireless networks should support calls with different traffic characteristics and different Quality of Service (QoS) Guarantees. [1]

In wireless mobile networks, in order to effectively deliver a service to a mobile user, the location of a called mobile user must be determined within a certain time limit. How to achieve a smooth handoff without degrading the service currently in progress over the air; when users do not engage any communications and move around, the system has to track them in order to deliver possible services to them. This requires mobiles to inform the network their where about when they move, thus the system can locate them based on the previously reported information this process is called location management or mobility management. [2]

With the convergence of the Internet and wireless mobile communications and with the rapid growth in the number of mobile subscribers, mobility management emerges as one of the most important and challenging problems for wireless mobile communication over the Internet. Mobility management enables the serving networks to locate a mobile subscriber's point of attachment for delivering data packets (i.e. location management), and maintain a mobile subscriber's connection as it continues to change its point of attachment (i.e. handoff management). [1]

Due to the need of increasing the capacity and speed which is relatively weak in the third-generation (3G) network and for the purpose of simplifying the network architecture it has been resorting to technology called LTE an acronym "Long Term evolution", also called 3.9G.[3]

LTE which is an acronym for Long Term Evolution which is designed to support and effective communication is based on data packets, and was developed by 3GPP (third generation partnership project) organization to be o be step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile.

Being the fastest network available means download speeds four to five times faster than 3G networks, which rivals some home broad band connections. The real hook, though, is the fact that consumers don't have to be at home to appreciate these speeds. Consumers can access the internet wherever there is coverage with any 4G-enabled device, including smart phones, tablets and mobile hotspots .The speed, then, is exactly why so many people are excited about LTE. Cellular data is a part of many peoples' lives and the ability to utilize and experience the internet in a quicker, richer way opens new possibilities for both business and personal lives. [4]

As mobile network operators and carriers transition into long term evolution (LTE) technology, they are faced with the challenge of marrying a successful, running network with increased capacity demands. They must also adhere to the core network architecture of 3GPP's LTE wireless communication standard, known as system architecture evolution (SAE).

The main component of the SAE architecture is the Evolved Packet Core (EPC). Mobility Management Entity (MME) plays an important role in LTE EPC architecture. In fact, MME is the main signaling node in the EPC. LTE MME is responsible for initiating paging and authentication of the mobile device. MME retains location information at the tracking area level for each user and then selects the appropriate gateway during the initial registration process. MME connects to the evolved node b (eNB) through the S1-MME interface and connects to S-GW through the S11 interface. Multiple MMEs can be grouped together in a pool to meet increasing signaling load in the network. MME also plays a vital part in handover signaling between LTE and 2G/3G networks. [5]

The demand of multimedia traffic is high and the existing cellular network system cannot meet the required demands as its coverage area and capacity is not sufficient. Providing these high speed data services to the dense urban areas is quite challenging. Especially in case of indoor environments, where penetration losses and high interferences makes the macrocell antenna's coverage very poor and cellular users feel lot of difficulties in receiving high speed services in the indoor environment. [6]

Femtocell is a small cellular base station designed for use in subscriber's home and small business environments. Femtocells, also known as 'home base station', are cellular network access points that connect standard mobile devices to a mobile operator's network using residential DSL, cable broadband connections, optical fibres or wireless last-mile technologies.

Femto-access points (FAPs) are low-power, small-size home-placed Base Stations (also known as Home NodeB or Home eNodeB) that create islands of increased capacity in addition to the capacity provided by the cellular system. These areas of increased capacity are referred to as femtocells. Femtocells operate in the spectrum licensed for cellular service providers. The key feature of the femtocell technology is that users require no new user equipment (UE).[7]

1.2 Problem Statement:

LTE is all about speed, therefore providing a fast and a seamless handover is a major challenge in 4G heterogeneous networks that are supposed to support real-time high speed multimedia applications that require small handoff delay and high data-rate transmission, the core point for thesis which is handover management on LTE between macro-femto cell , analysis and evaluate the performance of handover in them.

1.3 Thesis Objectives:

The aim of this thesis is to investigate the performance of LTE Mobility Management, by taking two algorithms and analyze their performance from different parameters point of view.

1.4 Methodology:

For the purpose of analysis performance of handover, resort two of handover decision algorithms in MATLAB software the First algorithm is the strongest cell based and the other is the UE transmit power reduction in a two-tier (Macrocell-Femtocell) LTE network; considering different performance metrics and numerical equations.

1.5 Thesis Outline:

This research is composed of five chapters there details are as following:

Chapter 2: describes LTE and femtocell network architecture, basically introduces the entities of network and their function and mobility management in them.

Chapter 3: describe the two of HO decision algorithms.

Chapter4: is aim to analysis result and compare between the two algorithm.

Chapter 5: conclude this thesis and talk about recommendations.

Chapter Two

Literature Review

Chapter Two

Literature Review

2.1 Background:

Over the past 25 years, the evolution of the Internet and the advances of wireless technologies have made a tremendous impact on lifestyles around the world. Together, these two factors have changed the way people communicate, work, and get their entertainment. With the introduction of cellular communications, the increasing demand for wireless services is noticed. The growth was so rapid that by 2002, we witnessed a major shift in network usage: for the first time in the history of telecommunications, the number of mobile subscribers exceeded the number of fixed lines. And that trend continues. [8]

In mobile communication systems, there has been a paradigm shift every decade. The first generation (1G) systems in the 1980s were the original analog mobile voice networks. The second generation 1GSA is an organization dedicated to the promotion of the Global System for Mobile communication (GSM) mobile phone standard worldwide (2G) systems that emerged in the 1990s are based on digital technologies for mobile voice and data traffic. The third generation (3G) systems, firstly introduced in 2001 in Japan, are characterized by high-speed digital mobile voice, data and multimedia services. The pre-fourth generation (pre-4G) systems, a stepping-stone to 4G, will be commercialized around 2012. [9]

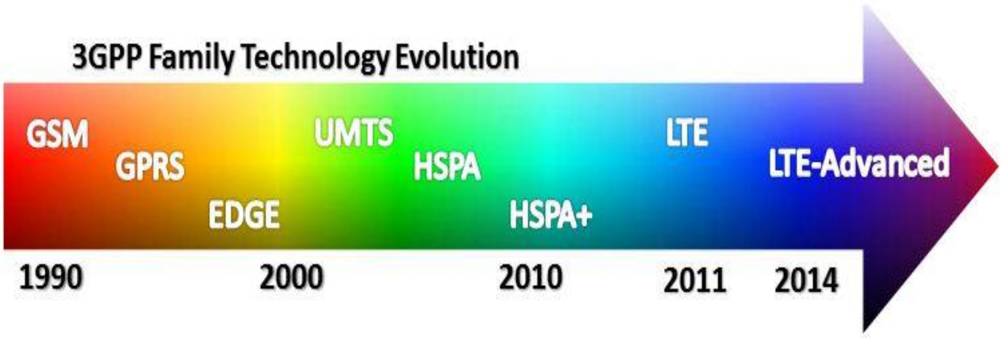

Figure2.1: 3GPP Family Technology Evolution

2.1.1 Long Term Evolution:

Long Term Evolution (LTE) is a significant project of telecommunication body known as the Third Generation Partnership Project (3GPP). Initially proposed on the Toronto conference of 3GPP in 2004 for the sake of achieving higher speed and lower packets latency in UMTS 3G systems and officially started as work item in 2006. LTE as a transition from the 3rd generation (3G) to the 4th generation (4G).

LTE is a step beyond 3G and towards the 4G, evolved after EDGE (Enhanced Data rates for GSM Evolution), UMTS (Universal Mobile Telecommunications System), HSPA (High Speed Packet Access) and HSPA Evolution [10]. SAE (System Architecture Evolution) is the corresponding evolution of the GPRS/3G packet core network evolution. The term LTE is typically used to represent both LTE and SAE.LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System (UMTS), which in turn evolved from the Global System for Mobile Communications (GSM). Even related specifications were formally known as the evolved UMTS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (E-UTRAN). First version of LTE was documented in Release 8 of the 3GPP specifications. [10]

2.1.1.1 About LTE:

LTE introduced to get higher data rates, 300Mbps peak downlink and 75 Mbps peak uplink. In a 20MHz carrier, data rates beyond 300Mbps can be achieved under very good signal conditions. LTE is an ideal technology to support high date rates for the services such as voice over IP (VOIP), streaming multimedia, videoconferencing or even a high-speed cellular modem.

LTE uses both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) mode. In FDD uplink and downlink transmission used different frequency, while in TDD both uplink and downlink use the same carrier and are separated in time. [11]

All LTE devices have to support (MIMO) Multiple Input Multiple Output transmissions, which allow the base station to transmit several data streams over the same carrier simultaneously. All interfaces between network nodes in LTE are now IP based, including the backhaul connection to the radio base stations. [12]

2.1.1.2 LTE - Network Architecture:

The high-level network architecture of LTE is comprised of following three main components: The User Equipment (UE),The Evolved UMTS, Terrestrial Radio Access Network (EUTRAN) and The Evolved Packet Core (EPC).

A. The User Equipment (UE):

The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a mobile equipement(ME). The mobile equipment comprised of the following important modules:

- **Mobile Termination (MT):** This handles all the communication functions.

-**Terminal Equipment (TE):** This terminates the data streams.

-**Universal Integrated Circuit Card (UICC):** This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM).

-A **USIM** stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

B.The E-UTRAN (The Access Network):

The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated in figure below.

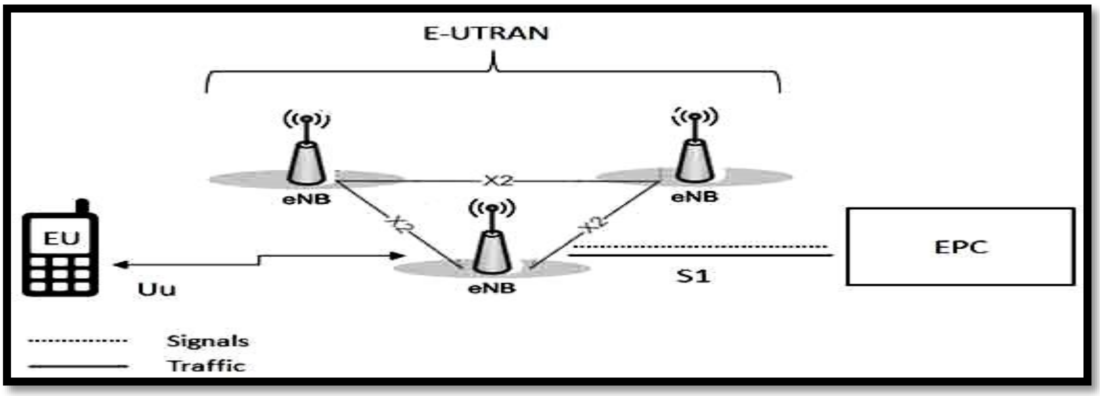

Figure 2.2: Architecture of E-UTRAN

The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called eNodeB or eNB. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB.

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB: The eNB sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.The eNB controls the low-level operation of all its mobiles, by sending them signaling messages such as handover commands.

C.The Evolved Packet Core (EPC):

The architecture of Evolved Packet Core (EPC) has been illustrated below. There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF).

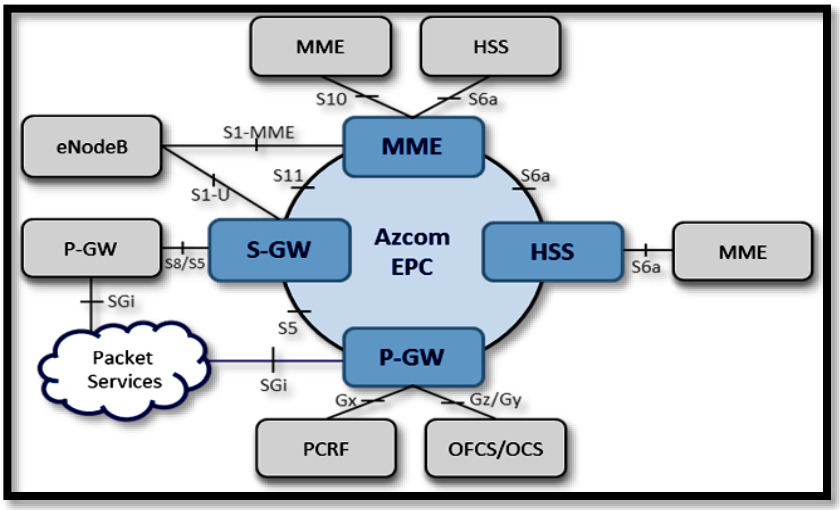

Figure2.3: Evolved Packet Core (EPC)

The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers. The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world .packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN).The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway. The mobility management entity (MME) controls the high-level operation of the mobile by means of signaling messages and Home Subscriber Server (HSS).

The Policy Control and Charging Rules Function (PCRF) is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW. The interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks [13].

Functional split between the E-UTRAN and the EPC:

Following diagram shows the functional split between the E-UTRAN and EPC Figure 2.4.

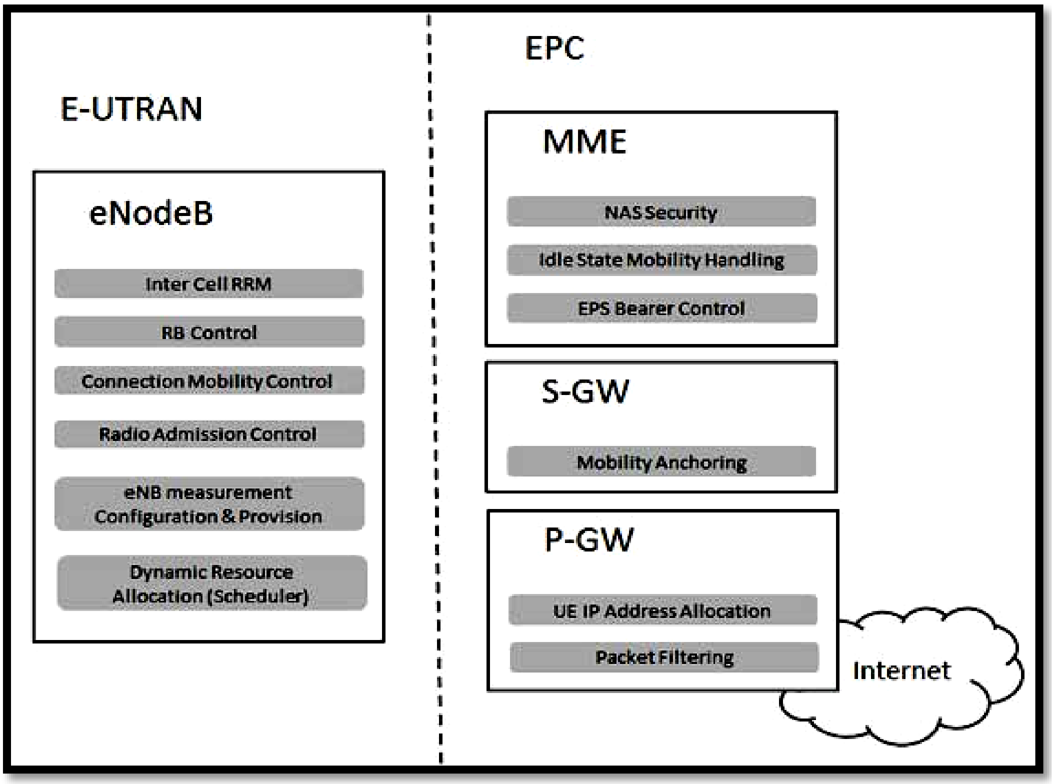

Figure 2.4: Functional split between the E-UTRAN and the EPC

2.1.2 Mobility Management:

Mobility management, or how to track the locations of the users and allow to user movement during conversations.

At the beginning of the 1970s, mobile users could only roam locally or regionally, while international roaming was possible only after the 1990s.With the increase of mobile user population and mobility, and more demands on quality of service (QoS), the current mobility management scheme faces new challenges.

2.1.2. 1 Importance of Mobility Management:

Mobility in wireless networks can take different forms, such as: Terminal mobility: the ability for a user terminal to continue to access the network when the terminal moves, User mobility: the ability for a user to continue to access the network services from different terminals under the same user identity when the user moves, Service mobility: the ability for a user to access the same services regardless of where the user is.

Mobility management contains two components: location management and handover management. Location management enables the system to track the attachment points of MTs between consecutive communications. Handoff (Handover) management enables the network to maintain a user's connection as the MT continues to move and change its access point to the network. [14]

A.Location Management:

Location management is a two-stage process that enables the network to discover the current attachment point of the mobile user for call delivery, as shown in Fig.2.5 The first stage is location registration (or location update). In this stage, the mobile terminal periodically notifies the network of its new access point, allowing the network to authenticate the user and revise the user’s location profile. The second stage is call delivery. Here the network is queried for the user location profile and the current position of the mobile host is found. Current techniques for location management involve database architecture design and the transmission of signaling messages between various components of a signaling network. As the number of mobile subscribers increases, new or improved schemes are needed to support effectively a continuously increasing subscriber population. Other issues include: security; dynamic database updates; querying delays; terminal paging methods; and paging delays. Fig 2.5 associates these research issues with their respective location management operation. Since location management deals with database and signaling issues, many of the issues are not protocol dependent and can be applied to various networks such as PLMN-based networks, the public switched telephone network (PSTN), Integrated Services for Digital Network (ISDN), Frame Relay, X.25, or ATM networks, depending on the requirements.

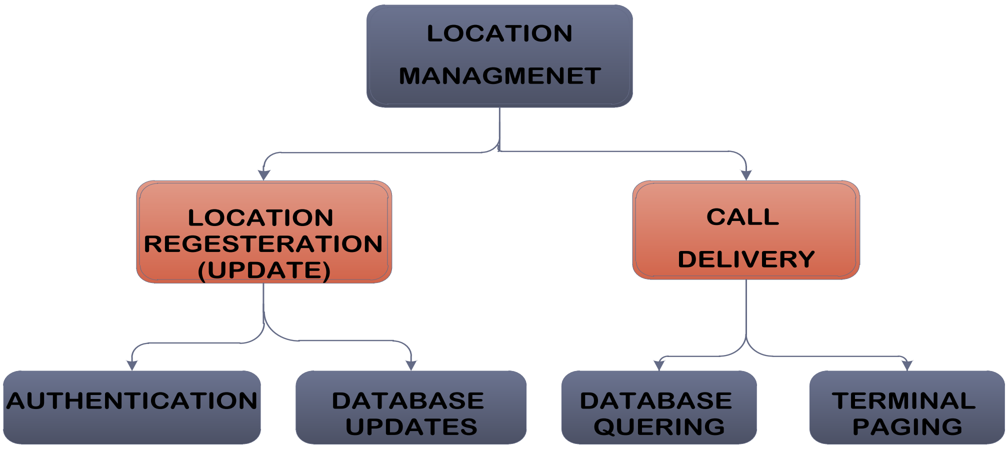

Figure 2.5: Location Management Operations

B.Handoff Management:

Handoff (or handover) management enables the network to maintain a user’s connection as the mobile terminal continues to move and change its access point to the network. The three-stage process for handoff first involves initiation, where either the user, a network agent, or changing network conditions identify the need for handoff. The second stage is new connection generation, where the network must find new resources for the handoff connection and perform any additional routing operations. Under network-controlled handoff (NCHO), or mobile-assisted handoff (MAHO), the network generates a new connection, finding new resources for the handoff and performing any additional routing operations. For mobile-controlled handoff (MCHO), the mobile terminal finds the new resources and the network approves. The final stage is data-flow control, where the delivery of the data from the old connection path to the new connection path is maintained according to agreed-upon service guarantees. The handoff management operations are presented in Fig. 2.6 [15].

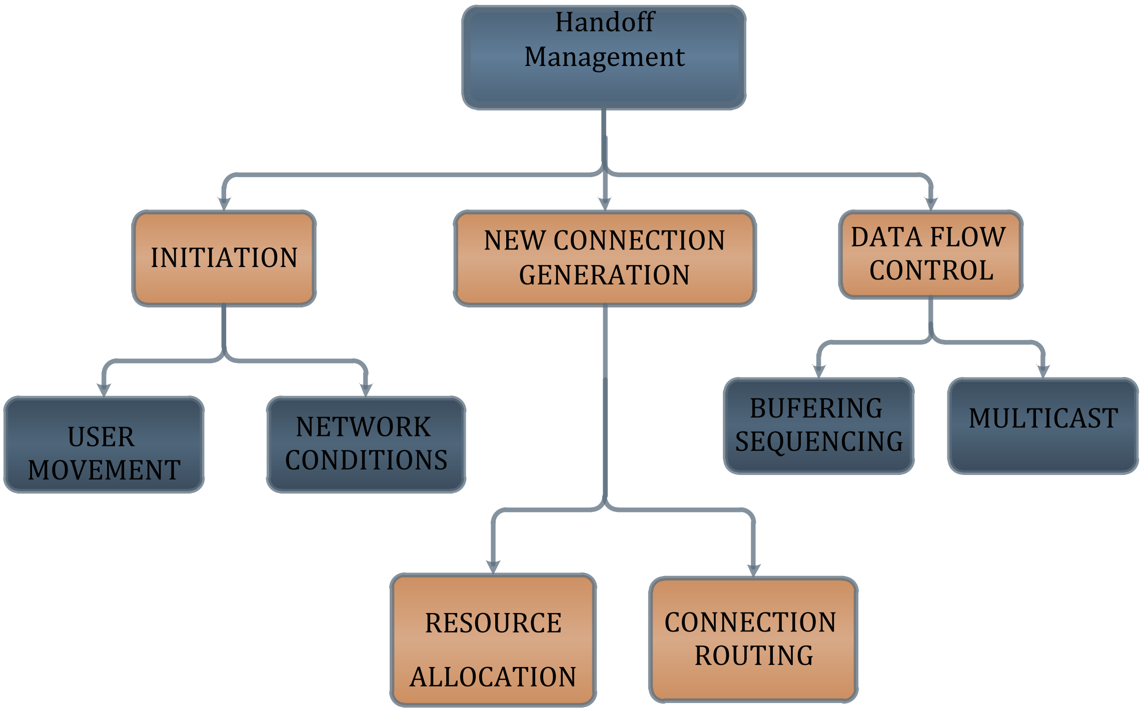

Figure2.6: Handoff Management Operations

C.Mobility Management in LTE:

Mobility management is a very crucial in 4G-Networks as it is heterogeneous network which is more complex to handle. It can take place in different layers of the OSI model including network layer (L3), link layer (L2) and cross-layer (L3 + L2). The layer-2 (L2) mobility refers to the case where the Mobile Node (MN) roams among different access nodes while the point of attachment to IP network remains the same. The layer-3 (L3) mobility involves the change of IP addresses. For efficient delivery of services to the mobile users, the LTE - networks require new mechanisms of mobility management where the location of every user is proactively determined before the service is delivered. Moreover, for designing an adaptive communication protocol, various existing mobility management schemes are to be seamlessly integrated. LTE systems support both horizontal handoff and vertical handoff. Horizontal handoff handles the intra-system handoff when an MN moves between two different cells or access points within the same wireless communication system, while vertical handoff deals with the inter-system handoff when an MN moves from one wireless communication system to another different wireless system. It is difficult to realize the vertical handoff among different wireless communication systems while meeting the various Quality of Service (QoS) requirements. If handoff latency is too long, packets may get lost or disconnections may occur during the handoff. Therefore, fast and seamless handover is a big challenge for LTE heterogeneous networks that are supposed to support real time high speed multimedia applications that require small handoff delay and high data-rate transmission.

There are numerous methods for performing handoff in LTE – Networks. The decision-making process of handoff may be centralized or decentralized. From the decision process point of view, there are three different kinds of handoff decisions: Network-Controlled Handoff, Mobile-Assisted Handoff, and Mobile – Controlled Handoff. In a network-controlled handoff protocol, the network makes a handoff decision based on the measurements of the Mobile Nodes at a number of Base Stations. Where as in case of mobile-assisted handoff process, the Mobile Station (MS) makes measurements and the network makes the decision. In mobile-controlled handoff, each MS is completely in control of the handoff process. [16]

2.1.3 Femtocell:

Femtocell is a small cellular base station designed for use in subscriber’s home and small business environments. It’s the emerging network technology which is defined broadly as low cost, low-power cellular base stations

The femtocell concept can be applied on different radio access technologies it has been discussed in Long Term Evolution LTE system by the name of Home e-NodeB (HeNB), it also known as femto access points (FAPs) a main device in femtocell network that provides radio access network RAN functionality[17]. They have a short-range (10-30m) and require a low power (10-100mW) to provide high-bandwidth wireless communication services in a cost effective way. Femtocells incorporated with the plug and play capabilities work in mobile operator owned licensed spectrum and enable Fixed Mobile Convergence (FMC) by connecting to the core network via broadband communications links (e.g., DSL). Unlike macrocells, FAPs are typically installed and maintained by the end users in an unplanned manner and don’t have X2 interface between them for information sharing. Due to this uncoordinated nature femtocell pose challenge on Handover and Radio Resource Management. [18]

2.1.3.1 Important of Femtocell:

1. It can provide indoor coverage for places where macrocells cannot.

2. It can offload traffic from the macrocell layer and improve macrocell capacity (in the case of using macrocells to provide indoor coverage, more power from the base station will be needed to compensate for high penetration loss, resulting in a decrease in macrocell capacity).

3. Femtocells can provide significant power saving to UEs. The path loss to indoor FAP is much smaller than that to the outdoor macrocell base station, and so is the required transmitting power from UE to the FAP. Battery life is one of the biggest bottlenecks for providing high speed data services to mobile terminals.

4. Assume that good isolation (hence, the signal leakage from indoor to outdoor will be small) can be achieved, the addition of a femtocell layer will significantly improve the total network capacity by reusing radio spectrum indoors.

5. There is a growing demand for higher and higher data rates. Due to the high penetration loss, high data rate services can not be provided to indoors apart from those areas near windows that are facing a macrocell site. This is because high data rate requires high performance RF links. High data rate services such as those facilitated by HSDPA are the key drive of femtocells [7].

2.1.3.2 Femtocell System Architecture in E-UTRAN:

The network architecture of LTE system consists of macrocells with eNodeBs on providing both user plane and control plane to the UEs, femtocells being a new addition to the existing components. The eNodeBs are interconnected with each other by the X2 interface which is mainly used for inter-eNodeB handover purpose and also connected to the Mobility Management Entity MME which the functions is related to handover and the Serving Gateway (S-GW).The Mobility Management Entity MME is the key control node for the LTE access network that processes the signalling between the UE and the CN, It is also responsible for authenticating the users and for the generation and allocation of temporary identities to UEs, the MME also terminates the S6a interface toward the home HSS for roaming UEs, also handles control plane signalling, especially for mobility management. The S-GW is mobility anchoring for the inter-3GPP mobility and routes and forwards the packet show in figure 2.7

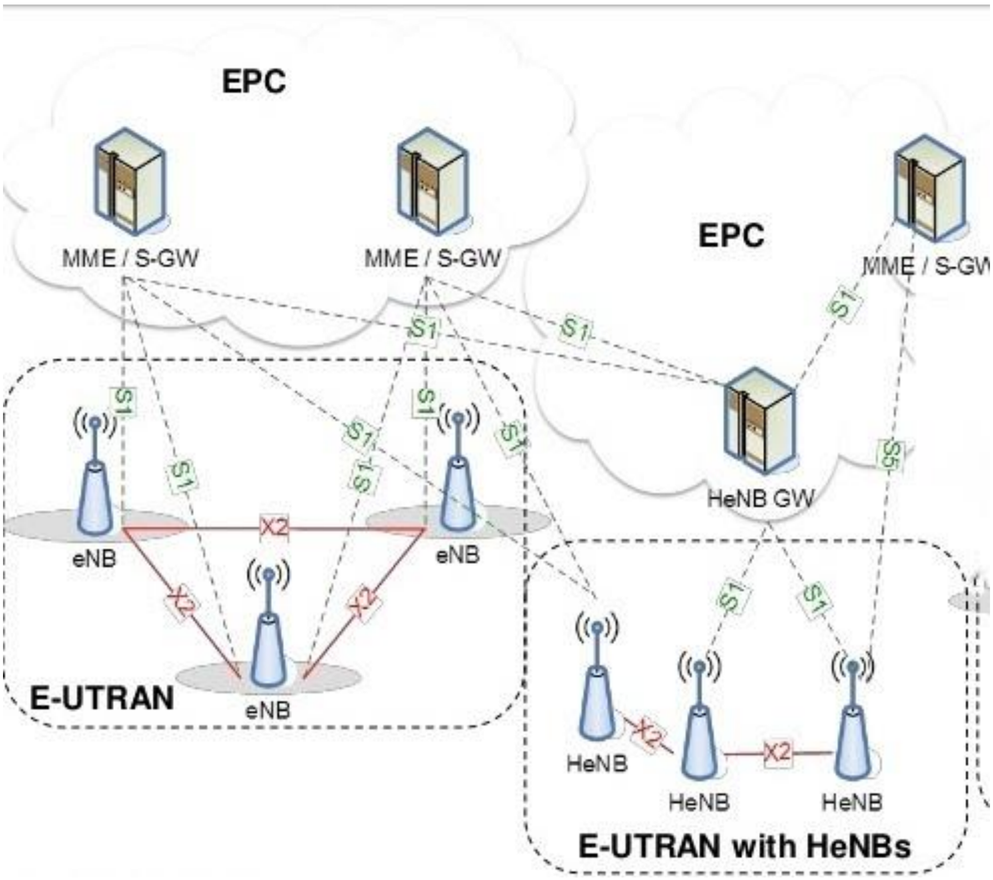

Figure 2.7: The E-UTRAN and the Femtocell Architecture in E-UTRAN

As hundreds of thousands of femtocells are deployed, the scalability issue imposes costly reconfiguration and operation in MME/S-GW because femtocells use residential broadband as the backhaul to connect to the mobile core network (CN), security issue needs be considered in order to protect the integrity of the network from malicious operations. Therefore, the femtocell network needs to consider both of the problems. Figure 2.7 shows femtocell E-UTRAN architecture where femtocell is referred to as Home eNB (HeNB). An intermediate node called HeNB Gateway is proposed to be located between HeNBsand the mobile CN. It acts as a “virtual” macro eNodeB towards CN and as a “virtual” CN node towards the HeNBs. Hundreds of HeNBs are connected to the EPC through the HeNB GW; this one should appear to the MME as an eNodeB and appear to the HeNB as an MME between the HeNB and the Core Network. The interface between every HeNB ↔ HeNB GW and each HeNB GW↔MME/S-GW is S1 interface,no X2 interface exists between neighboring HeNBs .

The most acting elements in the femtocell logical architecture are the security Gateway (SeGW)who’s responsible for the authentication of femtocell, and providing the femtocell with access to the HeNB GW, this latter terminates S1 from femtocell and appears as an RNC to the existing core network using S1 interface, supports femtocell registration and UE registration over S1, and the HeNB entity provides RAN connectivity using the S1 interface, supports RNC functions,HeNB registration and also supports UE registration over S1. In other side having the HeNB Policy Function HeNB PF which responsible for making decisions according to the characteristics of HeNB about whether the admission quest can be accepted or rejected interacts with other policy entity like PCRF [17].

Femtocells can to operate in one of three access modes, i.e., closed access mode, open access mode or hybrid access mode. Closed access mode is generally deployed in residential scenarios and a group of registered users called Closed Subscriber Group (CSG) have the permission to access the femtocell. In case of open access mode, any UE can access the femtocell and benefit from its services but when it comes to resource usage, congestion and security, open access is not a suitable choice. In hybrid access mode, a limited number of unknown MUE may access the femtocell while a fixed number of users defined by the owner can access the femtocell ubiquitously but may suffer the risk of security breach [19].

2.1.3.3 Mobility Management for Femtocells:

The unplanned deployment of femtocells complicates the mobility management procedure in many aspects as well, e.g., the serving cell is unable to provide a complete neighbor cell list to the mobile UEs.The dense network layout and the short cell radii augment the negative impact of user mobility, enlarge the number of candidate cells during the HO decision phase and increase the HO probability even for low speed users. On the other hand, the use of access control may severely degrade the SINR performance for the macrocell and femtocell tiers under certain interference scenarios, e.g., when a nearby operating user is not a member of a closed access femtocell in proximity [20].

2.1.3.4 Handover Scenario in Femtocell:

The handover procedure allows communication during user's movement among the network, it is critical to support the user's mobility in all current mobile systems including the femtocell network. The handover procedure in femtocell network contains three scenarios [17]:

A. Hand-in Procedure (macrocell↔femtocell):

Represents the handover scenario where a UE switch out from macrocelleNodeB to HeNB, this scenario is a difficult procedure and quite demanding since there are hundreds of possible targets HeNBs. In hand-in procedure, the UE needs to select the best target HeNB so the optimal handover decision policy is so critical and difficult, so it take advantage of the entity HeNB PF to select the most appropriate target HeNB according to the predefined rules.

B.Hand-off Procedure (femtocell↔ macrocell):

The handover that is performed from HeNB to macrocelleNodeB, it is not so complicated as the hand-in, because there is only one candidate and UE is no need to select the optimal target cell or to use the HeNB PF entity. That is to say that complex target cell selection mechanism is unnecessary. When the signal strength from the macrocell is higher than the one from serving HeNB, the UE will connect to it and transmit the data packets using the target macrocelleNodeB without considering so many elements as those in the hand-in decision making phase.

C. Inter-HeNB procedure (femtocell↔femtocell):

Represents the interaction between two HeNBs, the handover from one HeNB to another HeNB in the same macrocellnetwork.The inter-HeNB handover is similar to hand-in procedure since in this scenario, there are still hundreds of candidate target HeNBs when UE move out the coverage of its serving HeNB. So in this scenario the target cell selection mechanism is necessary an appropriate selection for the efficient handover is required. Therefore, in this situation the need to use HeNB PF to select the optimal target HeNB is clear.

2.1.3.5 Handover Management:

The development of solutions for mobility scenarios is the challenging issue in the handover management, this latter present the process by which mobile terminal maintains its connection active while moving from one access point to another. Seamless mobility across radio technologies with deployment of the HeNB is complicated to implement therefore, the ability to seamlessly switch between the femtocell and the macrocell networks is a key driver for femtocell network deployment. The handover procedure is mainly divided into three phases: handover information gathering phase, handover decision, and handover execution phase.

The UE collects information about the handover candidates and during the handover decision phase, the best handover candidate is determined, after deciding to perform the actual handover, the UE initiates to connect with new FAP. Otherwise, the biggest challenge in the handover is to select the best target femtocell from so many candidates. Especially, considering the different characteristics of femtocell, like its access mode and radio resource control function, the selection and the decision of which FAP is shared to make.

The handover decision is the most important phase in the handover procedure which contains measurements and information about when and where to perform handover and obtained from one entity or more. This study concerned by the handover decision method to develop the handover policies in order to optimize the selection of the optimal target femtocell in a way that multiple criteria from terminal and network sides and advanced decision is needed, this system is integrated into the HeNB PF entity [17].

1. **Handover Information Gathering**: Responsible for collecting all the contextual information,through monitoring and measurements, require to identify the need for handover and to apply handover decision policies.

2. **Handover Decision**: Defining all requires for the handover (policies) and how to perform it by selecting the most optimal Femtocell based on decision parameters.

3- **Handover Execution**: This means establishing the IP connectivity through the target access femtocell. For that, the fast Mobile IP can be used to functionalities as an IP mobility management solution.

2.1.3.6 Handover Decision Criteria:

Current literature includes various HO decision criteria and parameters for the two-tier macrocell-femtocell network. Below, describe the most widely used [20]:

-Received Signal Strength (RSS) refers to the received power on the reference or pilot signals transmitted by a specific cell. The RSS is the main decision parameter in wireless networks and is used as an equivalent of the path loss between the UE and the target cells. Given that a) the RSS equals to the product of the RS transmit power and the path loss, and b) different RS transmit powers are radiated between the macrocell and femtocell stations it follows that the RSS is a biased parameter for HO decision making in the presence of femtocells.

-Received interference power (RIP) refers to the total received power from cells or users in proximity. When performed at the UE, the RIP measurement is usually referred to as the Received Signal Strength Indicator (RSSI). It is important to note that, different from other RATs, the RSS parameter in LTE-A corresponds to the received power in the RS of a specific cell, whereas the RSSI parameter corresponds to the received power from all interfering cells in proximity .Given that the RIP measurement strongly depends on the physical location of the measuring entity, the RSSI at the UE and the RIP at the target cell can be quite different. Even though the incorporation of the RIP at the target cells enhances the HO decision outcome, it also dictates the use of more complicated signaling procedures at the serving cell.

-Received Signal Quality (RSQ) refers to the ratio of the RSS from a target cell to the total RIP at the UE. The RSQ is frequently used to estimate the SINR performance upon service reception from a target cell .the RSQ corresponds to the Reference Signal Received Quality (RSRQ) measurement performed at the UE.

-UE speed is a widely used parameter for enhancing inbound mobility to femtocells and reducing the number of unnecessary HOs for medium to high speed users. Combined with information for the UE mobility pattern, the use of this parameter may significantly enhance the HO decision phase in the presence of femtocells. Nevertheless, assessing the UE speed comes at the cost of increased monetary, energy consumption, or network signaling overhead.

-Energy-efficiency is a critical issue for IMT-Advanced mobile devices, which are required to support multifarious user applications and a plethora of radio capabilities, e.g., carrier aggregation, multi-antenna and multi-interface transmissions. Some of the key energy-efficiency parameters in current literature are the UE battery power, the mean UE transmit power, and the UE power consumption.

-Path loss includes the impact of various signal attenuation factors caused by the wireless medium and the ambient radio environment, e.g., propagation, absorption and diffraction losses. In contrast with the RSS parameter, which strongly depends on the actual RS transmit power of the target cell, path loss is an unbiased measure of the actual propagation conditions between the UE and the target cell. Current literature includes various HO decision algorithms that account for the path loss parameter. Nevertheless, accurately estimating the path loss parameter is a challenging issue.

-RS transmit power corresponds to the cell transmit power on the RS. Existing algorithms use this parameter to assess the path loss between the UE and the target cell.

-Traffic type is another widely used parameter for enhancing inbound mobility to femtocells. Existing classifications of the UE traffic-type mainly include: a) real time or non-real time traffic and b) voice/video or data traffic.

-Available bandwidth is a measure of the resource availability in the target cell. This parameter is used to minimize the HO failure probability due to admission control. Other bandwidth-related parameters include the cell load and the cell capacity. The number of camped or served UEs is another load indication measure. Bandwidth related criteria are typically used for performing preliminary admission control prior to HO execution.

-UE residence time within the cell refers to the duration that a tagged UE is expected to remain within the coverage of a cell. This parameter is used in combination with other speed related parameters to minimize the number of unnecessary HOs.

2.2 Related Work:

So far, many studies have been done concerning handover algorithms for HO performance optimization and evaluation. More detail works on handover in femtocell network, in [21], it proposed a handover decision algorithm that combined the values of received signal strength from a serving macrocell and a target femtocell in the consideration of large asymmetry in their transmit powers in eNB-to-HeNB handover scenario.

Wu et al. [22] propose Hand-In and Hand-Out procedures for LTE Femtocells. The authors consider a group of parameters for the HO decision which are interference level, RSS, user's velocity, available bandwidth and QoS level. The Hand-In has two kinds of procedures. The First is for CSG users where the UE should chose the most appropriate target FBS. The second is for non-CSG users, if a non-CSG UE causes too much interference; it can handoff to FBS to reduce interference. This HO is different than the normal situation, because the HO is triggered by FBS. The proposed solution does not consider the co-tier interference.

Becvar and Mach [23] propose an adaptive hysteresis margin for HO for LTE networks .The proposed solution utilizes the reported metrics (RSSI or CINR) for the dynamic adaptation of an actual value of hysteresis margin according to the position of the user in a cell. The hysteresis margin decreases with UE's moving closer to the cell border. This proposed solution shows reduction of redundant HO by mainly focusing on avoids ping pong effects. However, this is not a proper way to prevent unnecessary HOs caused by femtocell visitor.

The impacts of triggering setting {hysteresis/TTT} on handover performance have been investigated in [24] for different scenarios with low, medium and high system loads. System level simulations have been done and it has been shown that the setting can affect the handover loss rate, system and service performance. The optimal setting for each case has been proposed. The research in [25] proposed a new handover optimization algorithm which changes the values of the hysteresis and time-to-trigger parameters in an automated manner in response to changes in the network performance. It picks the best hysteresis and time-to-trigger combination for the current network status and the results show an improvement from the static value settings.

Chapter Three

Methodology

Chapter Three

Methodology

3.1 Introduction:

Femtocells are attracting a fast increasing interest nowadays, as a promising solution to improve indoor coverage, enhance system capacity, and lower transmit power.

Currently, the Femtocells are projected to be used in indoor environments, with the main objective to overcome the lack of Macrocell indoor coverage. It is then expected that the UE seamlessly handovers from the Macrocell to the Femtocell, when it enters in the coverage area of the Femtocell. In order for this process to be properly performed, the UE needs to be able to first discover the new cell, receive specific network information (e.g. for synchronization) to further read Femtocell reference signals and then connect [26].

3.2 Macrocell-Femtocell Handover Procedure:

The Procedure of macrocell-femtocell Handover are:

3.2.1. System Description

A two-tier LTE network is considered, operating within the LTE band set $N \coloneqq \{1, \ldots, N\}$. A macrocell station is referred to as evolved Node B (eNB), while a femtocell station as Home eNB (HeNB). To resourcefully sustain its ongoing services, user u is assumed to have amean SINR target, denoted by γ^{u}_{target} . Let C_n denote the set of LTE cells operating in band n∈ N, including both eNBs and HeNBs, and U_n the set of users receiving service from an LTE cell within C_n. Assuming that user u $\in U_n$ is connected to cell s $\in C_n$., the respective mean uplink SINR for a tagged time interval T is given as follows [27]:

$$\gamma_{u\to s}^{T} = \frac{P_u^T \cdot \square_{u\to s}^{T}}{\sum P_c^T \cdot \square_{c\to s}^{T} + \sum P_{u'}^{T} \cdot \square_{u'\to s}^{T} + (\sigma_s^T)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

where P_u^T denotes the power transmission of user u, $\square_{u\to s}^{T}$ the channel gain from user u to cell s, P_c^T the power transmission of cell c, $\square_{c\to s}^{T}$ the channel gain between cells c and s, and $(\sigma_s^T)^2$ the noise power at cell s, all averaged within the time interval T. Accordingly, the mean downlink SINR is given as follows:

$$\gamma_{s\to u}^{T} = \frac{P_{s\to u}^T \cdot \square_{s\to u}^{T}}{\sum P_c^T \cdot \square_{c\to u}^{T} + \sum P_{u'}^{T} \cdot \square_{u'\to u}^{T} + (\sigma_u^T)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

where $P_{s\to u}^T$ denotes the power transmission of cell s to user u, $\square_{s\to u}^{T}$ the channel gain from cell s to user u , $\square_{u'\to u}^{T}$ the channel gain from user u' to user u, and $(\sigma_u^T)^2$ the noise power at user u, all averaged within the time interval T.

Let now focus on the expected UE transmit power for maintaining a link between a tagged user u and cell s. Let $L_u \subseteq U_{n\in N} C_n$ indicate the candidate cell set for user u, which consists of accessible LTE cells and has been identified during the network discovery phase.

Using Eq. (3.1) for the mean SINR target γ_{target}^{u} , it can be readily shown that the mean UE power transmissions for maintaining a link between user u and cell c $\in L_u$ can be estimated as follows:

$$P_{u\to c}^{T} = \frac{\gamma_{target}^{u}(\sum P_{c'}^T \cdot \square_{c'\to c}^{T} + \sum P_{u'}^{T} \cdot \square_{u'\to c}^{T} + (\sigma_c^T)^2)}{\square_{u\to c}^{T}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Note that Eq. (3.3) includes the impact of handing over to cell c $\in L_u$, given that the RF interference caused by the ongoing user link, i.e., P_u^T . $□_{u\to s}^T$, is not included. Eq. (3.3) also corresponds to the UE power consumption, owing to transmit power, for maintaining a link between user u and cell c. The LTE standard describes a wide set of network and UE link quality measurements, which can be utilized to estimate the expected SINR in Eq. (3.1) and (3.2), and the average UE power transmission in Eq. (3.3).

3.2.2 Strongest Cell Handover Decision Policy:

Strongest cell handover decision policy consider is predominant handover algorithm in LTE , the strongest cell HO decision policy results in a HO execution whenever the RSRP of an accessible cell exceeds over the RSRP of the serving cell plus a policy-defined HHM, for a policy-defined time period namely the Time To Trigger (TTT). The HHM is utilized to mitigate frequency-related propagation divergences, and the ping-pong effect. Based on our system model,

The strongest cell HO policy for the LTE system is described as follows:

$$arg\ max_{c\in Lu} RSRP_{c\to u,(dB)}^{TTT} := \{c|\ RSRP_{c\to u,(dB)}^{TTT} > RSRP_{s\to u,(dB)}^{TTT} + HHM_{C,(dB)}\} \ldots\ldots\ 3.4$$

where $HHM_{C,(dB)}$ corresponds to the HHM for cell c $\in L_u$, and the notation $X_{(dB)}$ to the value of X in decibels (dB). Taking into account the definition of the RSRP in, it follows that:

$$RSRP_{c\to u,(dB)}^{T} = P_{c,RS}^{T} \cdot \mathrm{h}_{c\to u}^{T} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3.5$$

Substituting Eq. (3.4) to Eq. (3.5), it follows that the strongest cell policy facilitates mobility towards cells with higher RS power transmissions or improved channel gain. As a result, even though the strongest cell policy may improve the channel gain for the tagged LTE user (Eq. 3.5), it does not necessarily improves the SINR performance (Eq. 3.1, 3.2), given that neither the RF interference, nor the actual RS power transmissions of the target cells, are taken into account. The same implies for the UE power transmissions, which are not necessarily being reduced (Eq. 3.3) having a negative impact on both the UE power consumption and the RF interference network-wide [27].

3.2.3 UE Transmit Power Reduction Handover Decision Policy:

Consists of handing over to the cell with the minimum required UE transmit power, while maintaining the prescribed mean SINR target. The following analysis is pursued to derive the HHM required for minimizing the UE transmit power, It is assumed that user u receives service from cell s, which has consistent LTE measurements describing the status of every candidate cell c $\in L_u$ for user u, for the time interval T=TTT[28].

Using (3.5) under the assumption of a symmetric channel gain, the following estimation can be made

$$h^{T}_{u\to c} = h^{T}_{c\to u} = \frac{RSRP^{T}_{c\to u,(dB)}}{P^{T}_{c,RS}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

By the Received interference power(RIP) measurement , it follows that:

$$I^{T}_{c} = \left(\sum P^{T}_{c'} \cdot h^{T}_{c'\to c} + \sum P^{T}_{u'} \cdot h^{T}_{u'\to c} + (\sigma^{T}_{s})^{2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

Using Eq. (3.3), (3.6), and (3.7), it can be shown that the UE power transmission on the serving cell s is given by (3.8).

$$P_u^T = P_{u\to s}^T = \frac{\gamma_{target}^u \cdot P_{s,RS}^T \cdot I_s^T}{RSRP_{s\to u}^T} \text{ ....3.8}$$

Following a similar approach, the UE transmit power on the candidate cell c can be estimated as follows:

$$P_{u\to c}^T = \frac{\gamma_{target}^u \cdot P_{c,RS}^T \,(I_c^T - P_u^T \,.\mathrm{h}_{u\to c}^T)}{RSRP_{c\to u}^T} \text{ ... ...3.9}$$

where the term P_u^T . $\mathrm{h}_{u\to c}^T$ is introduced to include the positive impact of handing over to cell c $\in L_u$, if cells s and c operate in the same LTE band (if not, it is omitted), i.e , if c, s $\in C_n$.Accordingly, handing over to the candidate cell c, is expected to result in reduced UE transmit power compared to the one used in the current serving cell s.

the parameter $HHM_{c,(dB)}^{UTPR}$ is given by (3.10).

$$HHM_{c,(dB)}^{UTPR} = 10 \log \frac{P_{c,RS}^{TTT} \cdot (I_c^{TTT} - P_u^{TTT} \,.\mathrm{h}_{u\to c}^{TTT})}{P_{s,RS}^{TTT} \cdot I_s^{TTT}} \quad \text{c, s} \in C_n \text{............3.10}$$

The UTPR HO decision policy can be described as follows:

$$arg\ max_{c\in Lu} RSRP_{c\to u,(dB)}^{TTT} :=$$

$$\{c|\ RSRP_{c\to u,(dB)}^{TTT} > RSRP_{s\to u,(dB)}^{TTT} + HHM_{C,(dB)} + HHM_{c,(dB)}^{UTPR}\} \text{.... 3.11}$$

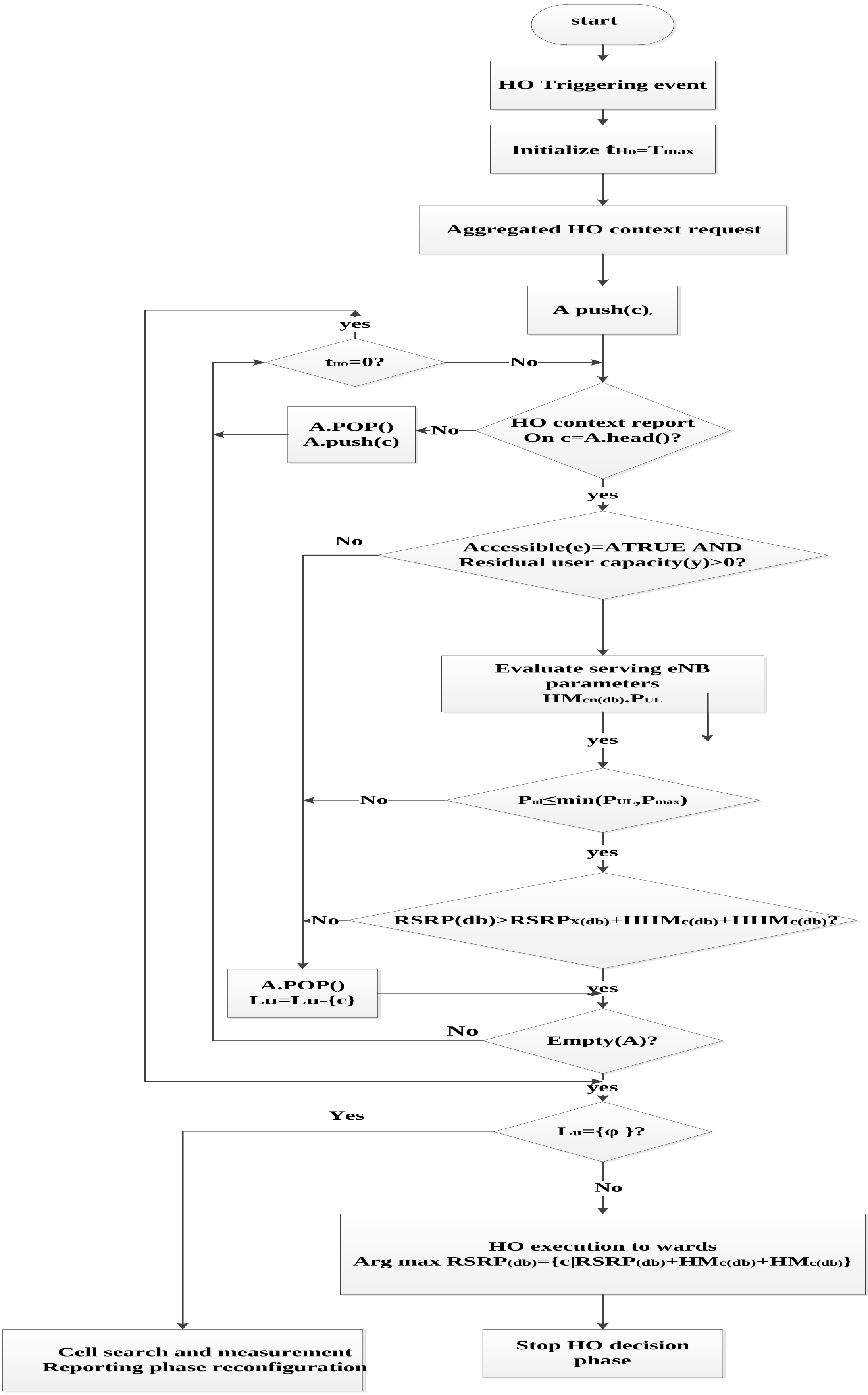

Figure 3.1: UTPR Algorithm [28]

Chapter Four

Simulation Description and Results

Chapter Four

Simulation Description and Results

4.1 Simulation Methodology:

To analyze the performance of the two algorithms under studying, A set of blocks of apartments, referred to as femtoblocks, are uniformly dropped within a main LTE cluster area with respect to the femtoblock deployment density parameter, denoted by dFB, which indicates the percentage of the main cluster area covered with femtoblocks. Femtoblocks are modeled in line with the dual stripe model for dense urban environments in and the path loss models are adapted accordingly.

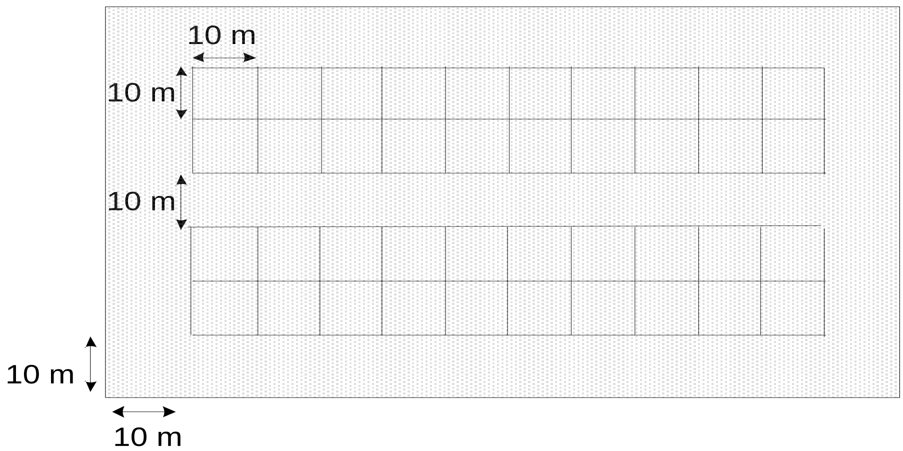

Figure 4.1: Dual-Stripe Femtoblock Model for Dense Urban Environments.

4.2 Simulation Parameters:

To evaluate the performance of the Macro-Femto HO algorithms, The parameters used in the simulation scenario are summarized in Table 4.1

Table 4.1: Simulation Parameters

Parameter	**Value**	
System Parameters		
Bandwidth	10 MHz	
Thermal Noise PSD	-174	
Penetration Loss Outdoor	Low = 15 dB ; IndoorLiw = 5 dB;	
Initial number of UE per femtocell	1 UE	
Max number of users per femtocell	4 UEs	
	Macrocell	Femtocell
Carrier Frequency	2600 MHz;	2500 MHz
Maximum Tx Power	46 dBm	20 dBm
Antenna gain	14 dBi	0 dBi
Noise figure	5 dB	8 dB
Shadowing standard deviation	8 dB	4 dB
UE parameters		
UE power class	23dBm	
UE antenna gain	0 4Bi	
Mean UL SINR target	3dB	
Pathloss Model		
UE is outside	PL (dB) =15.3 + 37.6log10R.	
Dual-stripe model: UE is inside the same apt stripe as Femto	PL (dB) = 38.46 + 20 log10R + 0.7d2D,indoor+18.3n((n+2)/(n+1)-0.46) + q*Liw	

4.3 Simulation Result:

Figure 4.2 depict the performance of the SCB and UTPR algorithms in terms of UE average power consumption; Divergent RS power transmissions are expected among the femtocell layer, in accordance with the adopted self-optimization procedure .Noticed that an increased femtoblock deployment density dFB corresponds to an increased number of femtocells and UEs within the main LTE cluster; As seen, the increase of the dFB results in lower UE power for both algorithms-due to the occurrence of Handover to the cell that require lower transmission power- However, the SCB require a higher number of femtocell in order to achieve a significant reduction in the UE transmit power unlike the UTPR which achieved a much lower UE power consumption in compare; the SCB give a ratio of 8.6% of reducing the UE power consumption while the UTPR give a rario of 52%.

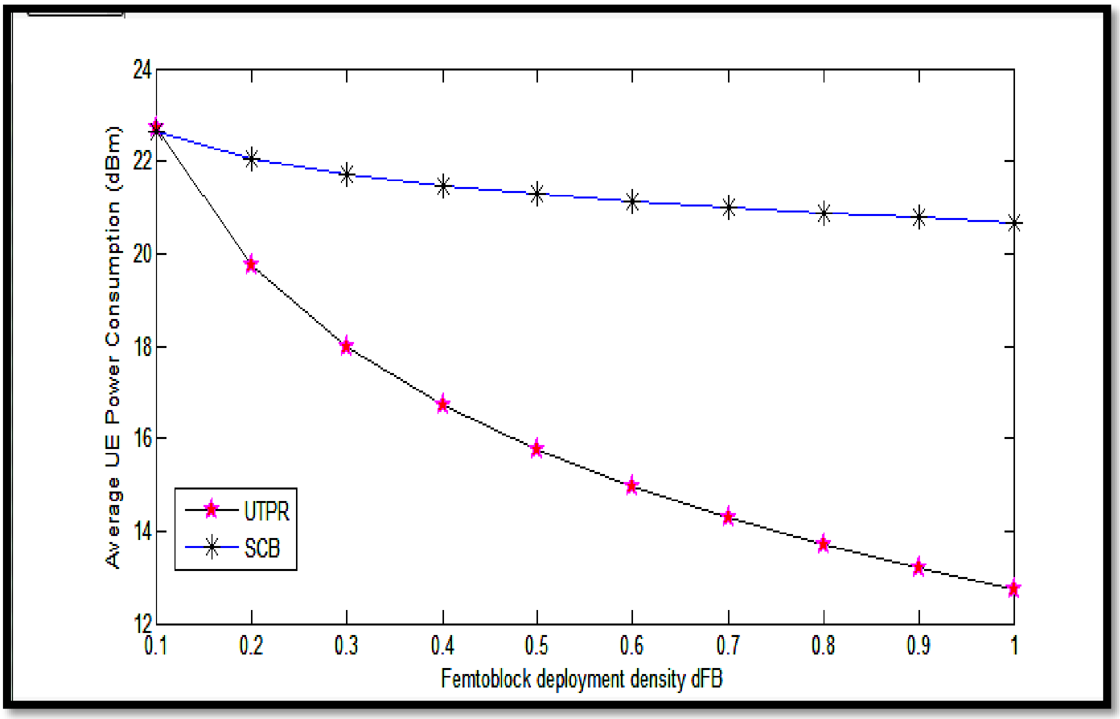

Figure 4.2: Average UE power Consumption vs Femtoblock Deployment Density

Figure 4.3 and Figure 4.4 shows the Handover probability versus the value of the Handover Hysteresis Margin for both algorithms; the adaptive HHM technique adopted by the UTPR algorithm has a great impact on reducing the network signaling in compare by the SCB algorithm. As shown, the increase in user speed raises the number of HO execution events per user and time unit for both algorithms. The UTPR has a Moderate number of HO execution events and it is Converge to the number of HO execution events corresponding to the SCB with the lower HHM values.

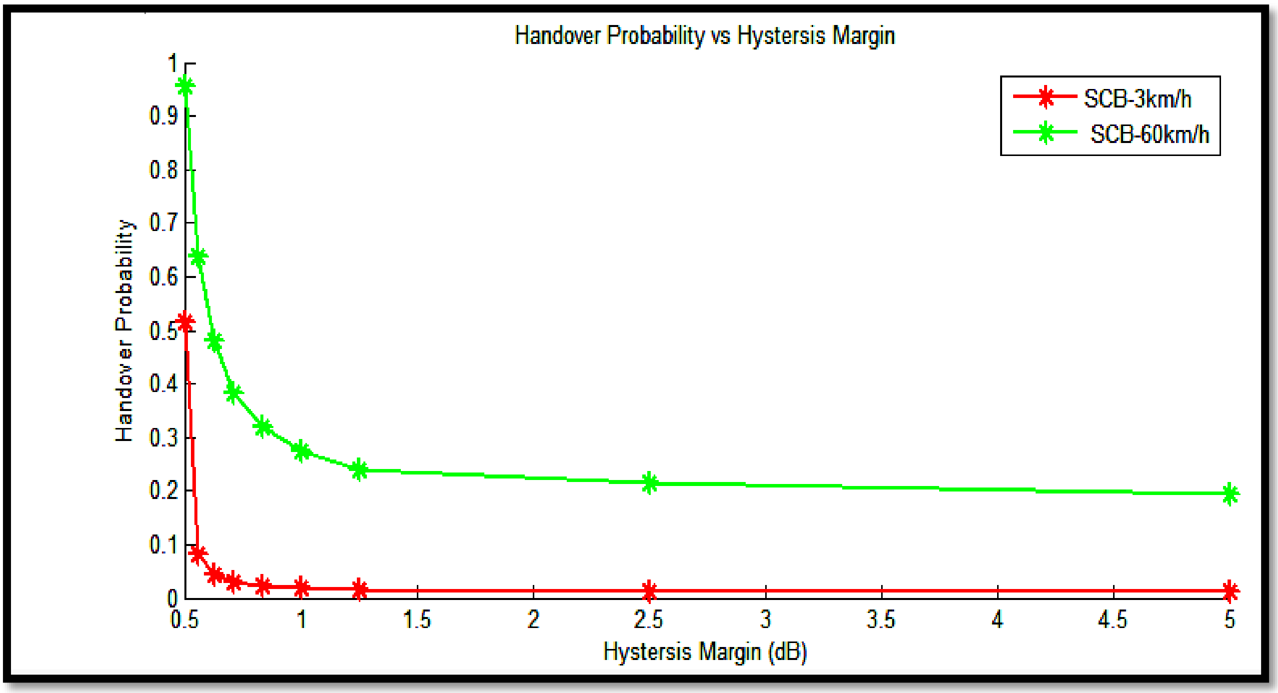

Figure 4.3: Handover Probability vs. Hysteresis Margin (SCB algorithm)

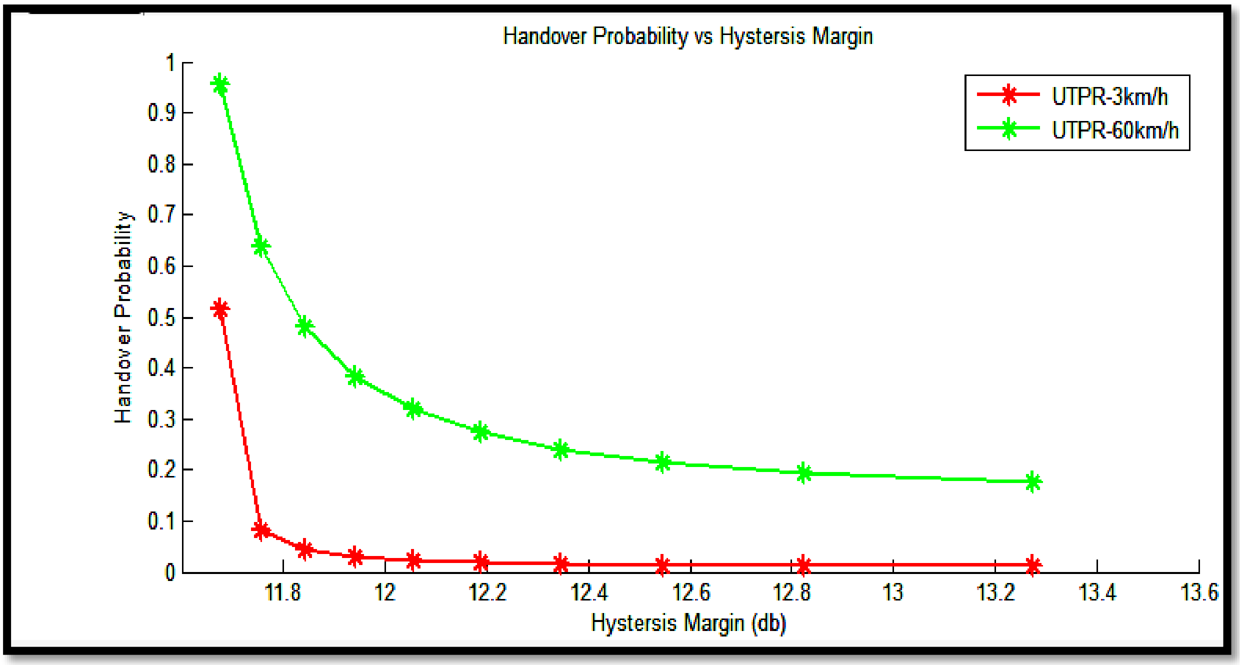

Figure4.4: Handover Probability vs. Hysteresis Margin (UTPR algorithm)

Figure 4.5 depicts the Data rate with the number of users for both approaches; As expected the Data rate values Decreased heavily with the increasing number of users. Notice that the Data rate values of the UTPR is slightly better than the ones of the SCB specially around the allowed number of users served by one HeNB .The decreasing ratio of the data rate is 83.7% for the UTPR and 91.7% for the SCB.

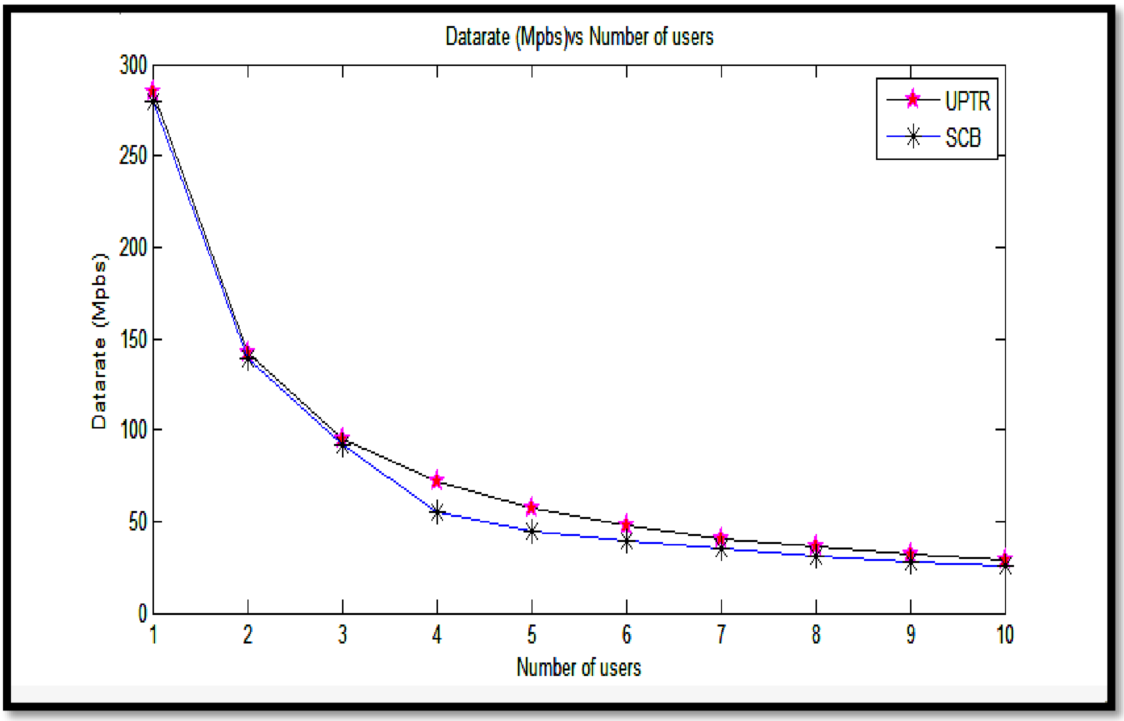

Figure 4.5: Data rate vs. Number of Users

Figure 4.6 portrays the throughput of the system for the two algorithms; the throughput increased substantially as the number of users rises, as cleared the throughput through the UTPR is higher than the one of SCB. The UTPR increases the throughput by 88.8% while the SCB increase it by 86.4%

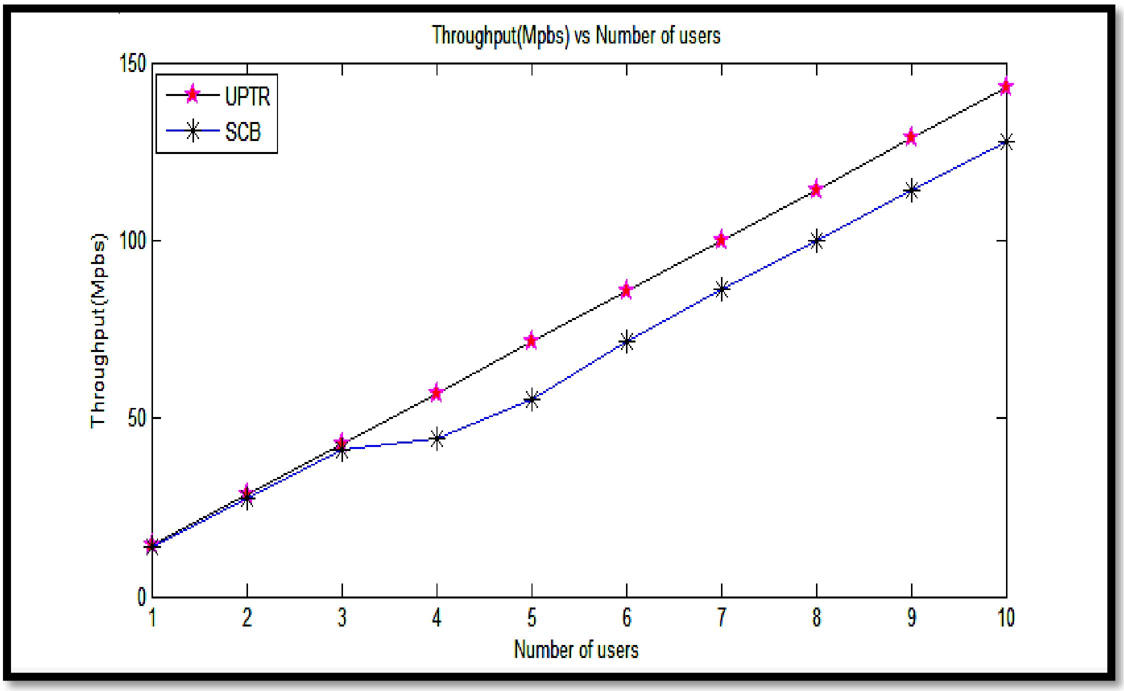

Figure 4.6: Throughput vs. Number of Users

Figure 4.7 depicts the relationship between the Handover probability and Femtoblock Deployment Density; the HO execution events are even more frequent when the femtocell deployment per femtoblock increases .The UTPR tends to increase the Handover probability more than the SCB algorithm.

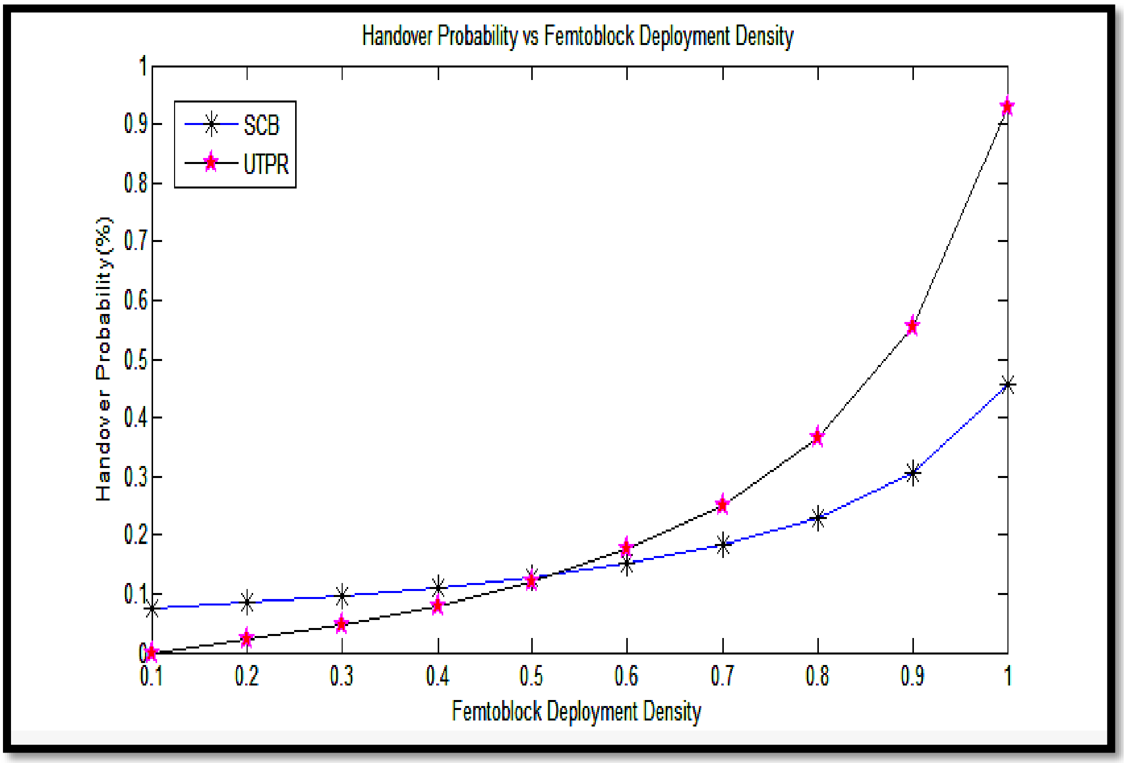

Figure 4.7: Handover Probability vs. Femtoblock Deployment Density

Figure 4.8 and figure 4.9 illustrate the Downlink and Uplink Interference mitigation achieved in the LTE downlink in terms of RSSI and in the LTE uplink in terms of Received Interference Power (R.I.P) at the LTE cells. Increasing the HHM value and reducing the transmission power for both LTE network and UE leads to mitigating the interference values. as cleared the UTPR decrease the interference much more than the SCB by a percentage of 17.5% and 12.5% for the SCB for the downlink and 4% for 4% , 0.2% for the UTPR and SCB respectively for the uplink interference.

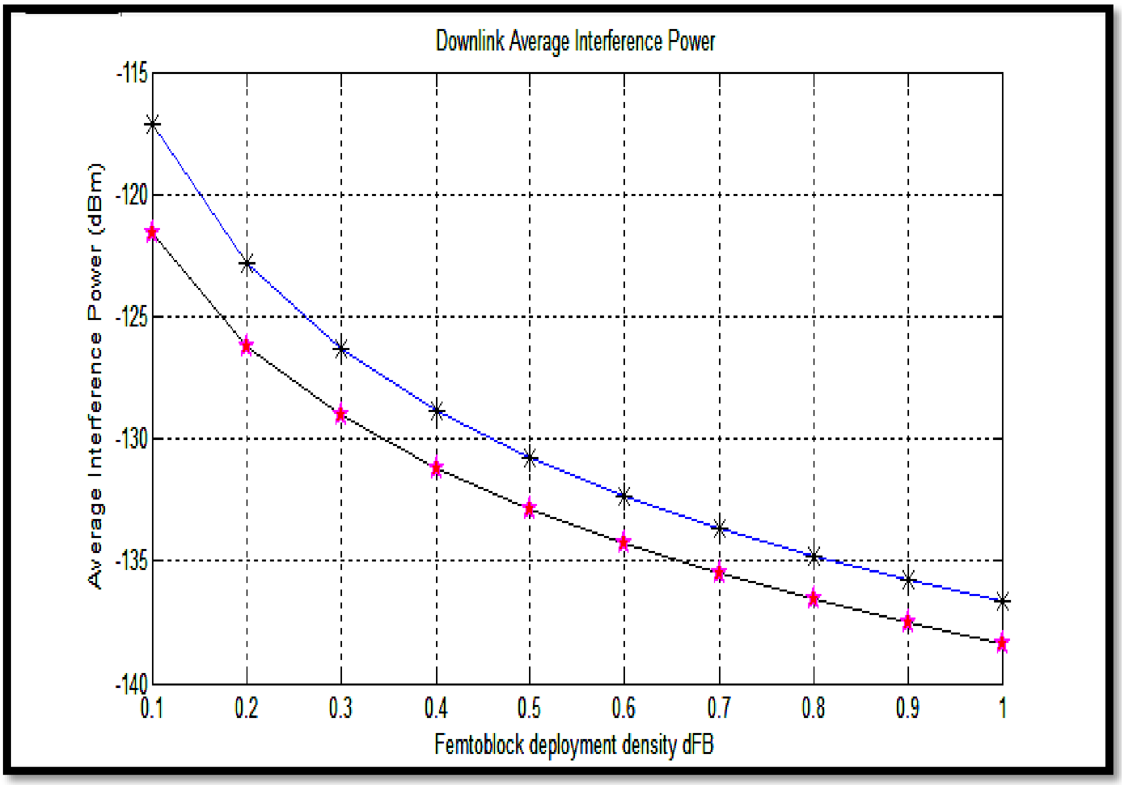

Figure 4.8: Downlink Interference Power vs. Femtoblock Deployment Density

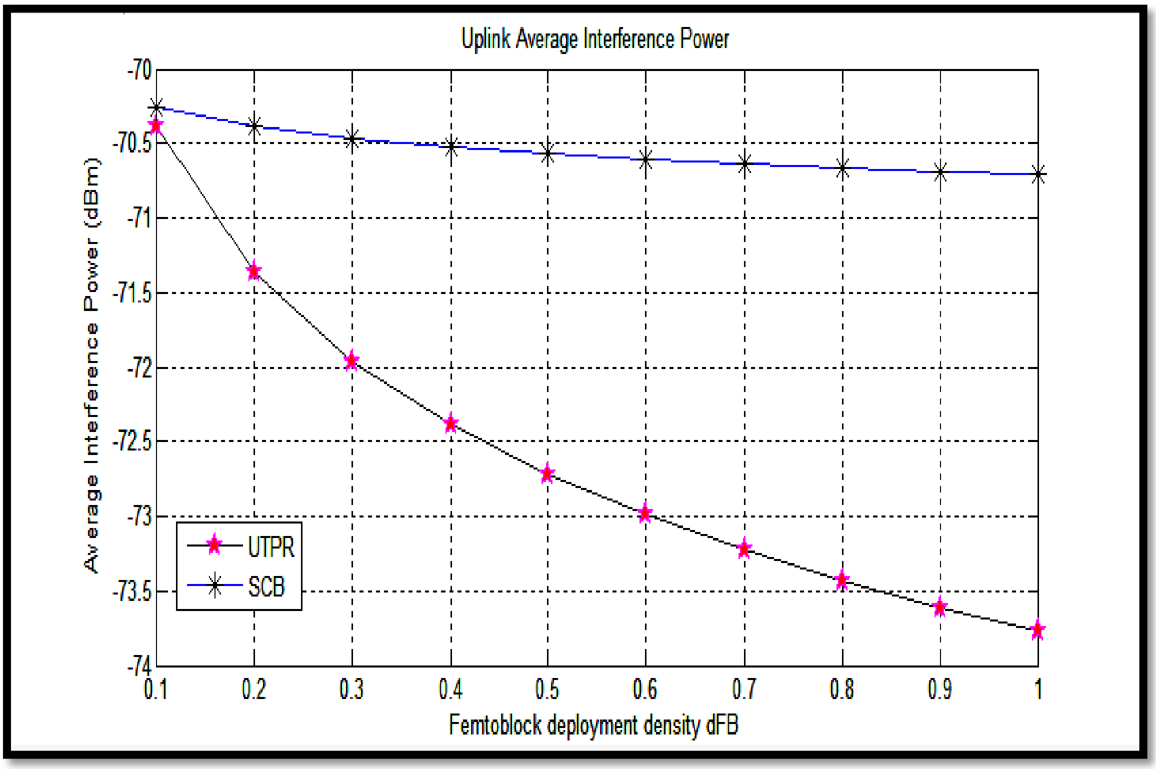

Figure 4.9: Uplink Interference Power vs. Femtoblock Deployment Density

Chapter Five

Conclusion and Recommendations

Chapter Five

Conclusion and Recommendations

5.1 Conclusion:

In this thesis, in order to carry out the handover performance evaluation process, the state of the art of handover between macro-femto cell in LTE, with the Strongest cell handover decision policy consider is predominant handover algorithm in LTE,UE Transmit Power Reduction (UTPR) handover decision policy, consists of handing over to the cell with the minimum required UE transmit power, under the handover parameters (hysteresis margin and time to trigger) and HO decision technique also considers many aspects of HO i.e., bandwidth, SINR (interference),Path Loss ,the speed status of the UE, have been included in the simulator the code in matlab software.

The simulation result showed that, UE Transmit Power Reduction (UTPR) handover decision policy algorithm give the better result compared to Strongest cell handover decision policy algorithm, reduced UE power consumption owing to transmit power, also the incorporation of a HHM in UTPR algorithm has been identified as a powerful tool in anticipating the fast variations of the wireless medium and mitigating the ping-pong effect.

The simulation results showed that the UE Transmit Power Reduction (UTPR) handover decision policy algorithm give the better unnecessary handover minimization scheme is an effective scheme to reduce the number of unnecessary handovers ,also in the presence of femtocells founded main challenge random deployment, mitigate the negative impact of user mobility and cross-tier interference on the Quality of Experience (QoE) and Signal to Interference plus Noise Ratio

(SINR) performance at the UEs, the UE Transmit Power Reduction (UTPR) handover decision policy algorithm minimized this effect by employed adapting the HHM with respect to the user's mean SINR target and standard link quality measurements describing the status of the candidate cells.

After the simulation results and evaluate performance for each algorithms, founded the UE Transmit Power Reduction (UTPR) handover decision policy algorithm better than Strongest cell handover decision policy algorithm and good choice to be implemented in LTE.

5.2 Recommendations:

Enhancements towards lower HO probability while sustaining comparable energy consumption gains.

Adapt the UE Transmit Power Reduction (UTPR) handover decision policy algorithm to compatible with LTE-Advanced ,this thesis has not considered for signaling overhead, so Comprehensive study of the required to network detailed signaling procedure for employing the UTPR policy, and a UTPR-based HO decision algorithm to further enhance the effectiveness of the HO decision phase in LTE-Advanced extensive simulation results.

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Appendix A:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    UE power  consumption              %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

fdl = 2120e6;  % DL carrier freq Hz, EARFCN = 100
ful = 1930e6;  % UL carrier freq Hz, EARFCN = 18100
nrbs = 25; % txbandwdith configuration in number of RBs
nres = nrbs * 12;
putprx=zeros;
zx=zeros;
bw = 2000000000 / 12; % bandwidth per RE in Hz
%%bwtot = xxx %%, note that this is smaller than the nominal Channel Bandwdith, see TS 36.101 fig 5.6-1
kT = -174; % noise PSD in dBm / Hz
ndBm = kT + 10*log10(bw);  % noise power dBm for a RE
pur=.1995;
dlpdBm = 135;
dlp = (10.^((dlpdBm - 30)/10))/nres; %% txpow per RE in W in DL
dlnf = 9; % receiver noise figure in dB in DL
dln = 10.^((ndBm-30+dlnf)/10); %% noise per RE in W in DL

ulpdBm = 23;  % tx power dBm in UL
ulp = 10.^((ulpdBm - 30)/10); %% txpow in W in UL
ulnf = 5; % receiver noise figure in dB in UL
uln = (10.^((ndBm-30+ulnf)/10)); %% noise in W per RE in UL

ber = 0.00005;
gamma = -log (5*ber)./1.5;

for d1 = [10 20 50 100 200 100 200 500 1000 2000 5000 10000 20000 50000 100000 200000 500000 1000000]



for d2 = 10000
```

```
  g11dl = gain_freespac (d1, fdl);
  g11ul = gain_freespac (d1, ful);
  g21dl = gain_freespac (d2, fdl);
  g21ul = gain_freespac (d2, ful);


  %% RSRP (linear)
  rsrp1 = g11dl.*dlp;
  rsrp2 = g21dl.*dlp;


end
end

k=1;
f=linspace(0,.5,11);
prs=.3;
h=(rsrp1/(prs));
ndBm = kT + 10*log10(bw);
np=(10.^(ndBm./10)).*(10.^-3);

R=.3;
Low=20; %dB
Liw=5; %dB
n=1;
q=1;
dD=1;
pmac=19.5;
Pmac=pmac-(15.3 + 37.6.*log10(R) + Low);

pfem=.1;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-
0.46)+q*Liw);
pfn=(10.^(Pfem./10));

st=3;
for k=1:1:10
x1=0;
for l=1:k;
```

```
x1=Pfem.*g11dl+x1;



end

  y=0;
for j=1:k;

   y=pur.*+ g21ul+y;
 Is=x1+y+(np^2);

end
z=k/10;
putpr2=((st.*Pmac.*Is)./ rsrp2);
pscb=(10.*(log10(st.*Is)./g21ul).*-1);
putpr=((10.*log10((st.*pfem.*(Is-putpr2.*g21ul))./rsrp1)+30).*-1)+1;

putprx(k)=putpr;
zx(k)=z;


end
plot(zx,putprx,'-kp','lineWidth',1.5,...
'MarkerEdgeColor','m',...
'MarkerFaceColor','r',...
'MarkerSize',10);
holdon
legend('UTPR')



fdl = 2120e6;
ful = 1930e6;
nrbs = 25;
nres = nrbs * 12;
bw = 20000000 / 12;

kT = -174;
ndBm = kT + 10*log10(bw);
zx=zeros;
pscbx=zeros;
dlpdBm = 43;
```

```
dlp = (10.^((dlpdBm - 30)/10))/nres;
dlnf = 9;
dln = 10.^((ndBm-30+dlnf)/10);

ulpdBm = 23;
ulp = 10.^((ulpdBm - 30)/10);
ulnf = 5;
uln = (10.^((ndBm-30+ulnf)/10));

ber = 0.00005;
gamma = -log (5*ber)./1.5;


rsrpdBmv1 = [];
rsrqdBv1 = [];
sinrdBv1 = [];
for d1 = [10 20 50 100 200 100 200 500 1000 2000 5000 10000 20000
50000 100000 200000 500000 1000000]




for d2 = 10000


  g11dl = gain_freespac (d1, fdl);
  g11ul = gain_freespac (d1, ful);
  g21dl = gain_freespac (d2, fdl);
  g21ul = gain_freespac (d2, ful);


  %% RSRP (linear)
  rsrp1 = g11dl.*dlp;
  rsrp2 = g21dl.*dlp;


end
end

k=1;
f=linspace(0,.5,11);
prs=30;
h=(rsrp1/(prs));
```

```
ndBm = kT + 10*log10(bw);
np=(10.^(ndBm./10)).*(10.^-3);

R=300;
Low=100; %dB
Liw=3.16; %dB
n=1;
q=1;
dD=1;
pmac=.195;
Pmac=pmac-(15.3 + 37.6.*log10(R) + Low);

pfem=.1;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-
0.46)+q*Liw);
pfn=(10.^(Pfem./10));

st=3;
for k=1:1:10
x1=0;
for l=1:k;

x1=Pfem.*g11dl+x1;



end

  y=0;
for j=1:k;

   y=ulp.*+ g21ul+y;
 Is=x1+y+(np^2);

end
z=k/10;

pscb=3.*(((10.*(log10(st.*Is)./g21ul).*-1))./10.^13);
pscb1=pscb-1;
pscbx(k)=pscb1;
zx(k)=z;
```

```
end
plot(zx,pscbx,'-b*','lineWidth',1.5,...
'MarkerEdgeColor','k',...
'MarkerFaceColor','r',...
'MarkerSize',10);
holdon
grid

xlabel('Femtoblock deployment density dFB')
ylabel('Average Energy Consumption per Bit (joules/bit)')



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
% Hysterisis Margin SCB         %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
Tn = 200; % Time of channel holding
r = linspace(10000,100,10);

v = [3*ones(1,10);60*ones(1,10);125*ones(1,10)]; % km/h
v = v*1000/3600;
hm=[0 2 4 8 10 12 14 16 18 20]./10
hm1=(1./hm)
for m = 1:3
    v1 = v(m,:);
Th = (pi*r)./(2*v1);
    T = 1./Th;
    P = T./(T+1./Tn);
   k=0;
for l=1:1:10
       P = T./(T+1./Tn);

end
holdon;
switch m
case 1 ,
plot(hm1,P,'-r*','lineWidth',2,...
'MarkerEdgeColor','r',...
```

```
'MarkerFaceColor','w',...
'MarkerSize',10);
case 2 ,
plot(hm1,P,'-g*','lineWidth',2,...
'MarkerEdgeColor','g',...
'MarkerFaceColor','w',...
'MarkerSize',10);
case 3 ,
plot(hm1,P,'-cx','lineWidth',2,...
'MarkerEdgeColor','c',...
'MarkerFaceColor','w',...
'MarkerSize',10);
otherwise,
end
end
ylim([0 1])
title('Handover Probability vsHystersis Margin')
legend('SCB-3km/h ',' SCB-60km/h ',' SCB-125km/h ');
xlabel('Hystersis Margin (dB)')
ylabel('Handover Probability')



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Hysterisis Margin UTPR                          %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
R=.3;
Low=20; %dB
Liw=5; %dB
n=1;
q=1;
dD=1;
pmac=19.5;
Pmac=pmac-(15.3 + 37.6.*log10(R) + Low);

pfem=.1;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-
0.46)+q*Liw);
pfn=(10.^(Pfem./10));

st=3;
```

```
for k=1:1:10
x1=0;
for l=1:k;

x1=Pfem.*g11dl+x1;



end

  y=0;
for j=1:k;

   y=pur.*+ g21ul+y;
  Is=10.*(log10(x1+y+(np^2)));

end
z=k/10;
putpr2=((st.*Pmac.*Is)./ rsrp1);

putpr=st.*pfem.*(Is-putpr2.*g21dl)./rsrp1;
putpr1=((10.*(log10(putpr)))+30);
pscb1=(10.*(log10((st.*Is)./g21dl))+30);
putprf=10.*log10(putpr1);
pscbf=10.*log10(pscb1);
putpr3(k)=putprf;

z3(k)=z;
  HHM=10.*(log10((pfem.*(Is-putprf.*g21ul)./pmac.*Is)));
HHM1(k)=HHM
holdon



end
legend('UTPR')


Tn = 200; % Time of channel holding
r = linspace(10000,100,10);

v = [3*ones(1,10);60*ones(1,10);125*ones(1,10)]; % km/h
v = v*1000/3600;
```

```
for m = 1:3
    v1 = v(m,:);
Th = (pi*r)./(2*v1);
    T = 1./Th;
    P = (T./(T+1./Tn));


holdon;
switch m
case 1 ,
plot(HHM1+1,P,'-r*','lineWidth',2,...
'MarkerEdgeColor','r',...
'MarkerFaceColor','w',...
'MarkerSize',10);
case 2 ,
plot(HHM1+1,P,'-g*','lineWidth',2,...
'MarkerEdgeColor','g',...
'MarkerFaceColor','w',...
'MarkerSize',10);
case 3 ,
plot(HHM1+1,P,'-cx','lineWidth',2,...
'MarkerEdgeColor','c',...
'MarkerFaceColor','w',...
'MarkerSize',10);
otherwise,
end


end

title('Handover Probability vsHystersis Margin')
legend(' UTPR-3km/h ',' UTPR-60km/h ',' UTPR-125km/h ');
xlabel('Hystersis Margin (db)')
ylabel('Handover Probability')



%%%%%%%%%%%%%%%%%%%%%%%%
%      Data rate    %
%%%%%%%%%%%%%%%%%%%%%%%
pmac=43;
Pmac=pmac+15-(15.3 + 37.6.*log10(R) + Low-8);
```

```
pfem=20;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-
0.46)+q*Liw-4);


st=3;
for k=1:1:10
x1=0;
for l=1:k;

x1=Pfem.*g11dl+x1;



end

  y=0;
for j=1:k;

   y=pur.*+ g21ul+y;
Ic=((x1+y+(np^2)));
 Is=((y+(np^2)));

end
z=k/10
rsrp11=Pmac.*h;
putpr2=((st.*Pmac.*Is)./ rsrp11);
rsrp12=Pfem.*h;
putpr=(st.*pfem.*(Ic-putpr2.*h)./rsrp12);
putpr1=((10.*(log10(putpr)))+30);
pscb1=(10.*(log10((st.*Is)./h)))+30;
putprf=10.*log10(putpr1);
pscbf=10.*log10(pscb1);
putpr3(k)=putprf;
pscb3(k)=pscbf;
sinrp=(putpr3.*h)./Is;
sinrp2=(pscb3.*h)./Is;
n(k)=k;
th=log2(1+(sinrp))./n;
 th1=log2(1+(sinrp2))./n;
dr=(bw.*th)./10.^6;
dr1=(bw.*th1)./10.^6;
z3(k)=z;
```

```
z4(k)=z;



Tn = 200; % Time of channel holding
r = linspace(1000,10,10);
v = [3*ones(1,10);60*ones(1,10);125*ones(1,10)]; % km/h
v = v*1000/3600;
for m = 1:3
   v1 = v(m,:);
Th = (pi*r)./(2*(v1.^2));

end




end

plot(n,dr,'-kp','lineWidth',1,...
'MarkerEdgeColor','m',...
'MarkerFaceColor','r',...
'MarkerSize',10);

holdon
plot(n,dr1,'-b*','lineWidth',1,...
'MarkerEdgeColor','k',...
'MarkerFaceColor','r',...
'MarkerSize',10);

title(' Datarate (Mpbs)vs Number of users')
legend('UPTR','SCB')
xlabel(' Number of users')
ylabel('Datarate (Mpbs)')



%%%%%%%%%%%
%THROUGHPUT%
%%%%%%%%%%%
```

```
pmac=43;
Pmac=pmac+15-(15.3 + 37.6.*log10(R) + Low-8);

pfem=20;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-
0.46)+q*Liw-4);


st=3;
for k=1:1:10
x1=0;
for l=1:k;

x1=Pfem.*g11dl+x1;



end

  y=0;
for j=1:k;

   y=pur.*+ g21ul+y;
Ic=((x1+y+(np^2)));
 Is=((y+(np^2)));

end
z=k/10
rsrp11=Pmac.*h;
putpr2=((st.*Pmac.*Is)./ rsrp11);
rsrp12=Pfem.*h;
putpr=(st.*pfem.*(Ic-putpr2.*h)./rsrp12);
putpr1=((10.*(log10(putpr)))+30);
pscb1=(10.*(log10((st.*Is)./h)))+30;
putprf=10.*log10(putpr1);
pscbf=10.*log10(pscb1);
putpr3(k)=putprf;
pscb3(k)=pscbf;
sinrp=(putpr3.*h)./Is;
sinrp2=(pscb3.*h)./Is;
n(k)=k;
th=log2(1+(sinrp)).*n;
 th1=log2(1+(sinrp2)).*n;
```

```
dr=(bw.*th)./10.^6;
dr1=(bw.*th1)./10.^6;
z3(k)=z;



z4(k)=z;



Tn = 200; % Time of channel holding
r = linspace(1000,10,10);
v = [3*ones(1,10);60*ones(1,10);125*ones(1,10)]; % km/h
v = v*1000/3600;
for m = 1:3
    v1 = v(m,:);
Th = (pi*r)./(2*(v1.^2));

end




end

plot(n,th,'-kp','lineWidth',1,...
'MarkerEdgeColor','m',...
'MarkerFaceColor','r',...
'MarkerSize',10);

holdon
plot(n,th1,'-b*','lineWidth',1,...
'MarkerEdgeColor','k',...
'MarkerFaceColor','r',...
'MarkerSize',10);
title('Throughput(Mpbs) vs Number of users')

legend('UPTR','SCB')
xlabel('Number of users')
ylabel('Throughput(Mpbs)')
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%Handover Probability vsFemtoblock Deployment Density%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%
pmac=43;
Pmac=pmac+15-(15.3 + 37.6.*log10(R) + Low+8);

pfem=20;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-0.46)+q*Liw+4);


st=3;
for k=1:1:10
x1=0;
for l=1:k;

x1=Pfem.*h+x1;



end

   y=0;
for j=1:k;

    y=pur.*+h+y;
Ic=(x1+y+(np^2));
  Is=(((y+(np^2))));

end
z=k/10
rsrp11=Pmac.*h;
putpr2=((st.*Pmac.*Is)./ rsrp11);
rsrp12=Pfem.*h;
putpr=(st.*pfem.*(Ic-putpr2.*h)./rsrp12);
putpr1=((10.*(log10(putpr)))+30);
pscb1=(10.*(log10((st.*Is)./h)))+30;
putprf=10.*log10(putpr1);
pscbf=10.*log10(pscb1);
putpr3(k)=putprf;
pscb3(k)=pscbf;
```

```
sinrp=(putpr3.*h)./Is;
sinrp2=(pscb3.*h)./Is;


z3(k)=z;



z4(k)=z;

end
hm1=([0 2 4 6 8 10 12 14 16 18 ]);
%hm1=1./hm;

Tn = 200; % Time of channel holding
r = linspace(1000,100,10);

v = [3*ones(1,10)]; % km/h
v = v*1000/3600;



Th = (pi*r)./(2*v);
   T = 1./Th;

     P = ((T./(T+1./Tn))./HHM1).*10;

   P1 = ((T./(T+1./Tn)).*hm1)./10;


plot(z3,P,'-b*','lineWidth',1,...
'MarkerEdgeColor','k',...
'MarkerFaceColor','r',...
'MarkerSize',10);

holdon

plot(z3,P1,'-kp','lineWidth',1,...
'MarkerEdgeColor','m',...
'MarkerFaceColor','r',...
'MarkerSize',10);
```

```
title('Handover Probability vsFemtoblock Deployment Density')
xlabel('Femtoblock Deployment Density')
ylabel('Handover Probability(%)')





%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%Downlink Average Interference Power%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
pmac=43;
Pmac=pmac-(15.3 + 37.6.*log10(R) + Low-8);

pfem=20;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-0.46)+q*Liw-4);


st=3;
for k=1:1:10
x1=0;
for l=1:k;

x1=(Pfem.*g11dl+x1);



end

  y=0;
for j=1:k;

   y=-(pur.*+ g21ul+y);

  rssi2=(((log10(((2*(dlp*h+ dln)*nrbs))))+30));
        rssi12=3000./(-rssi2-pscbx);

end
z=k/10;
```

```
Is(k)=Iss;
zx(k)=z;




end

plot(zx,rssi12,'-kp','lineWidth',1,...
'MarkerEdgeColor','m',...
'MarkerFaceColor','r',...
'MarkerSize',10);

holdon
grid
legend('SCB')
title('Uplink Average Interference Power')
xlabel('Femtoblock deployment density dFB')
ylabel('Average Interference Power (dBm)')






%%%%%%%%%%%%%%%%%%%
%% Uplink Average Interference Power%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
pmac=43;
Pmac=pmac-(15.3 + 37.6.*log10(R) + Low-8);

pfem=20;
Pfem=pfem-(38.46 + 20.*log10(R) + 0.7.*dD+ 18.3.*n.*((n+2)/(n+1)-
0.46)+q*Liw-4);


st=3;
for k=1:1:10
x1=0;
for l=1:k;
```

```
x1=(Pfem.*g11dl+x1);



end

  y=0;
for j=1:k;

   y=-(pur.*+ g21ul+y);

 rssi2=(((log10(((2*(dlp*h+ dln)*nrbs))))+30));
       rssi12=3000./(-rssi2-pscbx);

end
z=k/10;


Is(k)=Iss;
zx(k)=z;




end

plot(zx,rssi12,'-kp','lineWidth',1,...
'MarkerEdgeColor','m',...
'MarkerFaceColor','r',...
'MarkerSize',10);

holdon
grid
legend('SCB')
title('Uplink Average Interference Power')
xlabel('Femtoblock deployment density dFB')
ylabel('Average Interference Power (dBm)')
```