LTE PERFORMANCE EVALUATION BASE ON POWER BUDGET HANDOVER ALGORITHM

by

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A Special Study submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Telecommunications

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Abstract

Long Term Evolution (LTE) is the 4th generation cellular mobile system that is being developed and specified in 3GPP as a successor of UMTS; compared with 2G/3G, LTE shows many differences in architecture, key technologies, network design and planning, and so on.
LTE-A support carrier aggregation for improve speed and reliability. Carrier aggregation enhanced network capacity by adding more bandwidth of up to 100 MHz across five component carriers with 20 MHz bandwidth each. One of the main goals of LTE is to provides fast and seamless handover from one cell to another to meet a strict delay requirement while simultaneously keeping network management simple. Hence, the decision to trigger a handover is a crucial component in the design process of handover, since the success and the efficiency, to a large extent, depends on the accuracy and timeliness of the decision. The design of an efficient and successful handover requires a careful selection of HO parameters and the optimal setting of these. The LTE-A support two parameters to trigger the handover and select the target cell: hysteresis margin and Time- to- Trigger (TTT).

The main goal of this special study is to evaluate the LTE handover performance. For this purpose some specific objectives are achieved: first the handover procedure within 3GPP LTE and the designing and optimization principles are studied, and the different parameters affecting handover are identified.Then, the LTE Power Budget Handover Algorithm (PBHA) is selected and an evaluation methodology is defined. At the same time the deployment scenarios according to 3GPP specifications are chosen for simulation.

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List of Abbreviations

BSS	Base station Subsystem
CDMA	Code Division Multiple Access
CoMP	Coordinate multiple point operation
CRS	Cell-specific reference
E-CID	Enhance cell Identifier
eNodeB	E-UTRAN Node B
eICIC	Enchanced inter-cell interference coordination
EPC	Evolved packet core
EPS	Evolved packet service
EPS	Evolved packet service
EDGE	Enhanced data Rates for GSM Evolution
E-UTRANE	Evolved Universal Terrestrial Radio Access
EV-DO	Evolution data optimized
GPRS	General packet radio services
HSDPA	High speed downlink packet access
HRPD	High rate packet data
HSUPA	High speed uplink packet access
HSPA	High speed packet access
LTE	Long Term evolution
MBM	Multimedia broadcast multicast service
MME	Mobility Management Entity
MTC	Machine type communication
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OTDOA	Observed Time difference of arrival
PBHA	Power Budget Handover Algorithm
PWS	Public warning system
QoS	Quality of Service
RSSI	Received Signal Strength Indicator
SINR	Signal to Inter-ference plus Noise Ratio
SON	Self-organizing Networks
RN	Relay Node
TTT	Time-to-Trigger
TTI	Transmission Time Interval
TD-SCDMA	Time division synchronized code division multiple access
WiMAX	Worldwide Interoperability for Microwave
3GPP	3rd Generation partnership project(3GPP)

Chapter 1
Introduction

1.1 Overview

Mobile telecommunication system was first introduced in the early 1980s.The first generation,1G, systems made of analogue communication systems, mostly like traditional analogue radio. It had lots of disadvantages it did not use available spectrum efficiency, so it capacity was very small. Mobile device was larger and expensive. In 1990s mobile technology take huge uplift by the introduction of 2G, this is the first technology which support digital technology system, they use radio spectrum frequency efficiently and help to develop small and cheaper devices. Most popular 2G was Global System for mobile communication (GSM), it originally designed as pan- European technology, but soon popular throughout the world. Also, at same time IS-95 known as cdmaOne, design my qualcome, which is very dominate communication technology in USA.(**Cox**,2012).

The revised version of 2G communication system came at same time, it allowed to user to download data on the mobile. Success of 2G is known as 2.5G which is, build on same platform of 2G, it includes the core network packed switch domain and, modify the air interface so that It can handle the voice as well as data. The General packet Radio service (GPRS) incorporated these technologies in GSM.IS-95 was develop in system known as IS-95B. During the same time data rates available is increasing, to address this 2G performance is enhanced by using technique as Enhanced Data Rates for GSM Evolution (EDGE) and finally more powerful third 3G system in year 2000, it uses different technology then 2G. It increases the peak date rates which they can handle and make efficient use of radio spectrum. Despite of massive hyped for 3G it did not survive for long it successor 3.5G it optimized the air interface that are targeted at data application, which increase the average of user can upload and download data, with cost of greater variability into the data rate and arrival time.2G mobile handsets had longer battery life because of low power radio signals (**Cox**,2012).
World was dominated by 3G system is the Universal Mobile Telecommunication System. UTMS was developed from GSM by completely changing the air interface, keeping core network same. Later system was enhanced by 3.5G technology as high-speed downlink packed access (HSDPA) and high speed uplink packet access (HSUPA) combinedly known as HSPA. In 2008 3GPP Released 8 from this point there is start of LTE (Long Term Evolution)
UTMS air interface has two different technology, one is wideband code division multiple access (WCDMA) it was original version and other one is Time division synchronized code division multiple access (TD-SCDMA) was a derivative of WCDMA. It is also known as cheap rate option of UMTS TDD mode. TD-SCDMA was developed by china to break the dependence on western technology. There is two main difference between WCDMA and TD-SCDMA, WCDMA usually segregates the base station and mobile transmission by the frequency division duplex, while TD-SCMA time division duplex, also WCDMA use 5MHZ, while TD-SCMA use 1.6 MHZ. Cdma200 was introduced from IS-95 and is mainly used in North America. 3G technology was know as cdma2000 1X radio transmission technology (1X RTT), similar 3.5 G system with two alternative name, cdma200 high rate packet data (HRPD) or evolution data optimized (EV-DO). The specification for IS-95 and cdma2000 are produce and standardized by 3GPP, Third generation partnership project. Main technical difference between UMTS and cdma2000 are cdma2000 uses a bandwidth of 1.25MHZ, secondly is cdma2000 has backwards compatible with IS-95, in the sense that

IS-95 can communication with cdma2000 base stations and vice versa and third one is it separate voice and optimized the data on different frequencies, on the other hand UMTS is not backward compatible with GSM, and another is UMTS allow to share same frequencies between voice and data.
The final stage of 3G technology is Worldwide Interoperability for Microwave Access(WiMAX) it was standardized by Institute of Electrical and Electronics Engineer(IEEE) under standard 802.1, originally (IEEE 802.16-2001) it was used in point to point data communication in microwave links instead of fixed cable. Later it is revised to IEEE 802.16-2004 which is used for point to multipoint communication between an omni directional base station and fixed devices. Revised version of this I know as IEEE 802.16e also known as mobile WiMAX.
At 2010 ITU-radio communications group(ITU-R) specified the IMT-Advance requirements for 4G standards, 3rd Generation partnership project(3GPP) presented standardized Long Term Evolution Advance(LTE-A) as upcoming 4G standard In the 3GPP LTE- A standard and the IEEE 802j.16 standard, it can perform multi hop in- band and out- band relays which help in increasing coverage area also make network energy efficiency .Main disadvantage of 4G is use of cell- specific reference signals(CRS) which increase the networks overhead and decrease energy efficiency

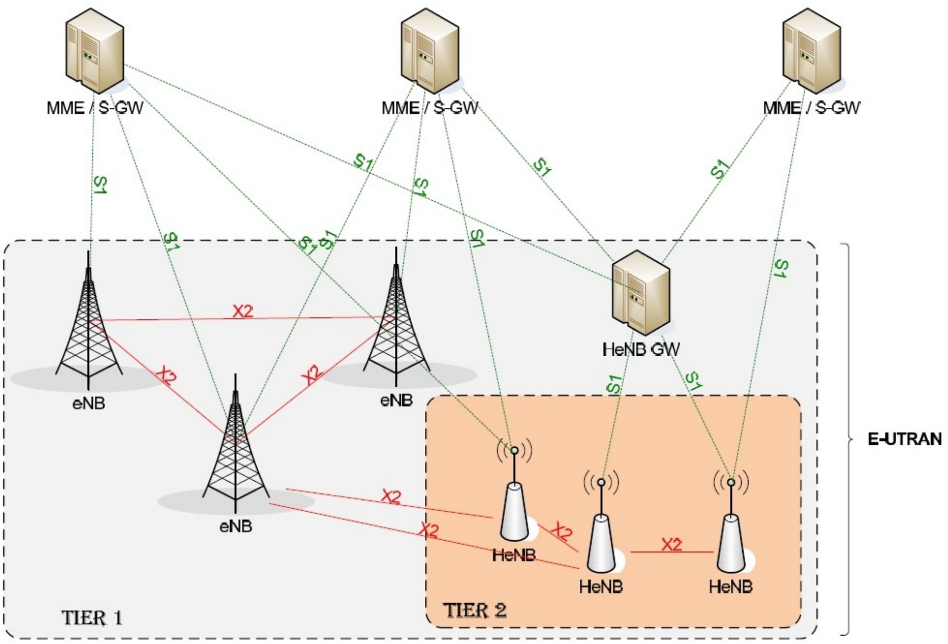


Figure 1.1: The Two-tier LTE-A architecture with the HeNB GW and small cells

(**Knapp & Gódor**,2014)

1.2 Statement of the Problem

The main goal of this special study is to evaluate the LTE handover performance. For this purpose some specific objectives are achieved: .The specific problems recognized for carrying out this study are as follows:

- Long Term Evolution (LTE) is to provide seamless access to voice and multimedia services with strict delay requirements which is achieved by supporting handover.

- It is very important to implement an efficient handover according to the design and optimization principles such as minimizing the number of unnecessary handovers, decreasing handover delay and increasing system throughput.
- The optimal setting of HOM and TTT depends on UE speed, radio network deployment, propagation conditions and the system load. In this study i try to analysis the handover using HOM and TTT parameters.

1.3 Objectives

The main objective of this study is to understand the Handover mechanism in LTE system using power budget handover algorithm and LTE specifications. The objectives of this special study are as follows:

- To understand basic idea about handover in mobile communication,
- To understand the factor affecting handover.
- To get knowledge about present scenario of handover regarding its achievements till dates, challenges and research areas.
- To study on paper as a base paper and get overview current scenario of research and demonstrate the understanding.

1.4 Scope and limitations

Due to software limitation and time shortage mainly I evaluate simple deployment. In scenario where there is larger number of UE, higher speeds and high loaded systems, this simulation will not work properly, we need to research to deal with complex scenarios.Thus, my study is mainly for to acquire basic knowledge of understanding in LTE handover in simple scenario of LTE, this study is carried in downlink only one can research in uplink too.

1.5 Research Outline

The rest of this special study was organized as follows.

In Chapter 2 overview of LTE and LTE-A technology was presented including the recent and related works In Chapter 3 general concept of handover was presented also methodology of whole simulation process was described.In Chapter 4 simulation results and analysis of output was performed which was concluded in chapter 5 with conclusion and recommendation.

Chapter 2
Literature review

2.1 LTE

Many paper were published in the recent years proposing more and more sophisticated solutions of the handover decision procedure.Some of them use different network provided information during the decision, which are typically not consider as standard. In khalid et.al propose a mobility handover decision procedure which take consideration of UE speed value and does not allow a high speed user to switch to femtocell.In () authors describe a policy-based decision procedure, where decision is based on different policies, e.g. RSSI(Received Signal Strength Indicator), load information of cells, Function entity in Evolved Packet Core(EPC). The new architecture was design as a part of the two 3GPP works, system architecture evolution (SAE) and long-term evolution (LTE), SAE cover the core network, while LTE cover radio access network, air interface and mobile. Later LTE was developed as Enhanced UTRAN (E-UTRAN) and SAE was enhanced as all IP packet core network know as Evolve packet core (EPC), Officially their whole system is known as the Evolved packet system (EPS), despite the official name is different it is wide popular name is LTE, LTE became the colloquial for the whole system. In 2004 3GPP stated study in long term evolution of UMTS. From this study they get the specification for long term evolution. LTE was required to support a spectral efficiency which is 3 to 4 times greater than the Release 6 WCDMA in the downlink and two to three times greater than the uplink. LTE is designing to work with different bandwidth range from 1.4 MHz up to maximum of 20 MHz LTE optimized for cell sized up to 5km, can also performed up to 30 km with degraded.The output of study in LTE is summarized in Table 2.1(**Cox**,2012).

Table 2.1: The output of study in LTE

Features	WCDMA	LTE
Multiple access scheme	WCDMA	OFDMA and SC-FDMA
Frequency re- use	1	Flexible
Use of MIMO antennas	From Released 7	yes
Bandwidth	5MHz	1.4,3,5,10, or 20 MHz
Frame duration	10ms	10ms
Transmission time interval	2 or 10ms	1
Mode of operation	FDD and TDD	FDD and TDD
Unlinking time advance	Not required	
Transport channels	Dedicated and share	Share
Uplink power control	FAST	Slow

Comparison of UMTS and LTE is shown below 2.2 (**Cox**,2012).

Table 2.2: Key features of Radio access networks of UMTS and LTE.

Features	UMTS	LTE
Radio access network components	Node B, RNC	eNB
RRC protocol status	CELL_DCH, CELL_FACH, CELL_PCH, URA_PCH, RRC_IDLE	RRC_CONNECTED
		RRC_IDLE
Handovers	Soft and hard	Hard
Neighbor list	Always required	Not required

2.1.0.1 Need for LTE

- Peak data rate:z Peak data rate in downlink of 100Mbps and 50 Mbps in uplink.
- Mobility: E-UTRAN should be optimized for low mobile speed from 0 to 15 km/hr.
- Radio Resource Management requirements Enhanced support for end to end Qos
  Efficient support for transmission of higher layers
  Support of load sharing and policy management across different Radio Access Technology.
- Complexity

  1. No redundant mandatory features,
  2. Proliferation of smart mobile device

2.1.1 From LTE to LTE- Advanced

In the late 1990s, the ITU had helped to develop the design of 3G technologies by giving the set of requirements for 3G mobile communication which was named as International mobile telecommunication (IMT) 2000.On a similar manner in 2008 ITU published set of requirements for 4G communication system under the name of the IMT- advance. According to this document peak data rate of compatible system should be at least 600 Mbps on the downlink and 270Mbs on the uplink on the bandwidth of 40MHz, which exceed the limits of the LTE system. To enhance the capabilities of the LTE, 3GPP started to study as a specification of the LTE, main output from this study was specification for LTE-Advance. LTE-Advance was required to deliver a peak data rate of 1000 Mbps in the downlink,500Mbps in the uplink. Also, LTE-Advance is designed to be backwards compatible with LTE i.e. LTE mobile can communicate with a base station that Is operating LTE-Advanced and vice-versa. LTE-Advanced have higher capacity, LTE Release 10 was to give cost effective higher bit rates to user fulfilling the requirement provided by the ITU for IMT Advance, also known as 4G.

Higher spectral efficiency, 16bps/Hz in R8 and 30bps/Hz in R10 Simultaneously active subscribers are increased. Improving the performance of the edge cell. The core contribution of the LTE-Advance is Carrier Aggregation (CA), enhanced use of multi-antenna techniques and support for Relay Nodes (RN)

- Carrier Aggregation:
  It helps to increase the channel capacity adding the bandwidth. It is important to have backwards comp ability with R8 and R9 to increase in bandwidth in LTE-Advance was provided through aggregation of R8/R9 carriers. Carrier aggregation can be used for both TDD and FDD.
- MIMO, Multiple input Multiple output- or spatial Multiplexing:
  To increase overall bits rate, it uses the two or more-transmission antenna to flow two different data stream using same resources in both frequency and time, which is separated only through use of different reference signal, which is received by two or more antenna.
- Relay Nodes:
  In LTE- Advance, for efficient heterogeneous network planning, combination of large and small cells, is increased by adding of Relay Nodes (RNs). Relay nodes are low power base station which help to increase coverage and capacity of cell edge, hot-spot area, it is wireless communication.
- Coordinated multi point operation (CoMP)-R11:
  To increase the cell edge performance ITU introduced CoMP.In this technology number of Tx points provides coordinated transmission in DL, similary number of RX provides coordinated reception in the UL(Upper link).The set of Tx/Rx points used in CoMP can be at co-site or at different location providing coverage in different segments, they may also belong to same or different eNBs.CoMP can be perform on different way, coordination can be perform in both homogeneous networks as well as heterogeneous networks . When two or more Tx transmission point transmit on same frequency in the same subframe it is called Joint transmission. Though there is available of two or more TX point but only Schedule from one TX-point in each subframe it is called Dynamic Point Selection. When number of RX points receive the UL data form one UE, it is called Joint Reception(***3GP***,n.d.).

2.1.2 The Meaning of 4G

Initially, ITU want to use the term 4G for only those technology which will meet the requirement of IMT-Advance. LTE never do so neither the WIMAX 1.0(IEEE 802.16e). Because of this ITU engineer community member came to call the system as 3.9G but this consideration didn't stop due to marketing communities keep on describing LTE and WIMAX 1.0 as 4G technology although this was not authorized by ITU it was gone famous in worldwide. Later, 2010 ITU decided to give 4G to all technology which surpass the 3G technology, so in today world LTE is known as 4G communication.

2.1.3 3GPP Specifications for LTE

The specifications for LTE are produced by the Third-generation partnership project. They are organized as released each of which contain stable and clearly defined features. New functionality can be added on the successive version after the release, until the date of frozen, after the date of Frozen only clarification, correction and refinement in technical details can be performed.

Table 2.3: 3GPP specification for UMTS and LTE

Release	Date of Frozen	Features
R99	March 2000	WCDMA air interface
R4	March 2001	TD- SCDMA air infterface
R5	June 2002	HSDPA,IP multimedia subsystem
R6	March 2005	HSUPA
R7	December 2007	Enhancements to HSPA
R8	December 2008	LTE, SAE
R9	December 2009	Enhancements to LTE
R10	March 2001	LTE-Advance
R11	September	Enchantments to LTE-A
R12	June 2012	Futher enchancement to LTE- Advance
R13	Decmber 2015	Meeting the growing throughput demand
R12	On going	The star of 5G

- Release 8-
  1. High peak data rate,
  2. High spectral efficiency,
  3. All IP Network,
  4. OFDMA in down-link and SC-FDMA in up-link.
- Release 9
  1. Public warning system(PWS); It give alert to public regarding natural disasters and another vital situation,
  2. Femto cell: To provide networks through landline broadband connection,
  3. MIMO Beam forming: Beam-forming is used to increased cell edge throughput by directing beam towards specific UE estimating position with help of eNB,
  4. Self-Organizing Networks(SON): This means self-initialization, optimization and healing of networks to reduce manual work and cost associated with technical support,

5. eMBMS: with multimedia broadcast multicast service(MBMS) users have capability to broadcast services, MBMS channel has evolved from data rate and capacity perspective,
6. LTE positioning : Three position methods are specified which are Assisted GPS(A-GPS),Observed Time difference of arrival(OTDOA) and Enhanced cell ID(E-CID), aim is to increase accuracy of user location.

- Release 10
  1. Enhanced Up-link multiple access
  2. MIMO enhancements
  3. Relay Nodes: to decrease coverage loop holes, relay nodes are being used.
  4. Enhanced inter-cell interference coordination(eICIC): introduced to deal with interference issues in heterogeneous Networks.
  5. Carrier Aggregation: introduced to minimized the cost to utilize their fragmented spectrum spread across different or same bands in order to enhanced end user throughput as specified by IMT-Advance.
  6. Support for Heterogeneous Networks: Combination of large cell and small result in heterogeneous Network.
  7. SON improvement: Enhancements to SON features.
- Release 11
  1. Carrier Aggregation Enhancements: Multiple timing advances for up-link CA., Non contiguous intra band CA.
  2. Coordinated multipoint transmission and reception (CoMP): with CoMP transmitter can share data load even if they are not in same frame/location.
- Release 12
  1. Small cells enhancements
  2. Carrier aggregation enhancements
  3. Machine type communication(MTC)
  4. Wifi integration with LTE: user have more control on managing wifi sessions since wifi and LTE are integrated in LTE in unlicensed spectrum
- Release 13(LTE-Pro)
  1. Carrier Aggregation enhancements Enhancement for Machine-Type communication(MTC): Help to reduce cost and power consumption for latency-tolerant IOT devices.
  2. LTE in unlicensed spectrum enhancement.
  3. Indoor Positioning.
  4. Enhanced multi- user transmission techniques.
  5. MIMO enhancement: Massive MIMO.
- Release 14 The start of 5G standardization.

- 4G network will soon be replace by 5G it is expected to take it take by the end of 2019. 5G network meet the increasing demands for high data rate. Green communication will expect to play vital role in 5G.5G includes techniques like Massive MIMO, Beam division multiple access, D2D communication and use of multiple radio access technology 5G is today most interesting and intensive research is ongoing area.(***3GPP Lte overview***,2013)

Table 2.4: Comparison of all Generations of Mobile Technology

Tech.	Deploy	Bwdt.	Tech.	Service	Multiplexing	Switching	Core
1G	1970-2004	2Kbps	Analog Cellular	Mobile Telephone	TDMA, CDMA	Circuit	PSTN
2G	1990-2004	64Kbps	Digital Cellular	Digital Voice, Sms, Packet data	CDMA	Packet circuit	PSTN
3G	2004-2010	3Mbps	CDMA2000 (1XR TT, EVDO, UMTS, EDGE)	Integrated ,High Quality Audio, Video and Data	CDMA	Packet	Packet N/W
4G	Now	1Gpbs	WiMAX, LTE,Wi-Fi	Dynamic Information Access Wearable Device	CDMA	All Packet	Internet

5G	Soon (Expected on 2020)	Higher than 1Gpbs	Coming	Dynamic Information Access, AI Capabilities	OFDMA	All Packet	Internet

2.1.3.1 Handover

The mobile technology is growing rapidly to meet the future users' demands such as high data traffic that is expected to grow 20,000 times from 2010 to 2030 (**Aziz & Sigle**,2009). Handover is the mechanism that transfers an ongoing call from one cell to another as a user moves though the coverage area of a cellular system, Each handover required network resources to reroute the call to new base station. Minimizing the expected number of handover minimizes the switching load. Another concern is delay. If handover does not occurs as fast as it can then Quality of Service (QoS)may degrade below acceptance level.In process of handover there is brief service interruption ,as these interruption increased QoS also deduced. When the number of handover attempts increased due to factor like channel availability chances of dropping call also increased. When the rate of handover increase, handover algorithm need to be sophisticate so that it can achieve perceived QoS and cost to cellular infrastructure does not get higher. Traditional purpose of handover is to keep going connection without interruption, which is a very important function for service continuity and quality of mobile user. Traditional handover was highly influence by the fact that the coverage area of a single base station does not cover the whole service area. In overlaid heterogeneous cellular handover not only maintain the ongoing call uninterrupted it also improve the performance of the whole network providing QoS to user by transferring an active mobile user from one base station to another. overlaid heterogeneous network have different coverage range, transmission power and radio propagation which make it more complication and Intelligent. when the mobile is moving and signal it received is dropping out then it might have to move to neighboring cell, in such case connection must be switched to new base station, i.e. a handover has been made, this type of handover is called inter-cell handover. When there is strong interference on the same channel, it may be possible to switch to another channel, but remain connected to the same base station such type of handover is call intra- cell handover.Handover is important features of mobile commination network which mainly occurs in Base Station Subsystem (BSS). QoS should be maintain during the process of handover mechanism within the high mobility speed and increasing attempts of handovers. The handover in LTE and LTE-Advance system is purely based on hard handover as opposed to soft handover. Handover mechanism are of : Hard handover: It is the handover in which connection is break-before-make method, it means UE connection is break from sources cell before it established connection with target cell. This handover is very simple but very limited in terms of QoS (high latency, link quality, unreliability, etc.) Soft handover: It is the handover in which a make- before – break method. It means connection is established to target before it is disconnected with source. Several soft handover techniques were proposed to solve difficulties associated to LTE and LTE-A system. Softer handover is a special kind of handover in which radio links are added and removed belong to same Node B, it is simply handover between two sectors of a Node B. From user equipment (UE) side is it just another SHO. In all the radio links connected to the UE at a time are part of the ACTIVE SET and the number can vary from 1 to 8, this means at least one of radio link relates to UE. Soft handover is part of WCDMA system which fundamentally same in concept of CDMA (***3GPP Lte overview***,2013). Depending on the access network point of attachment or simply connectivity it can be classified as:

- Horizontal handover:
  This kind of handover occurs or triggered when mobile station transferring from one access point to another with in the same technology, they are mostly triggered in homogeneous cellular network when UE is moving from one cell to another in in same technology.
- Vertical handover:
  It will have triggered when mobile station moving from one access point to another between to different technology, example Wi-Fi to WiMAX and WiMAX to LTE (**Khiat et al.**,2016).

The performance matrices used to evaluate handover are as follows:

- Call blocking probability:
  the probability that a new call attempt is blocked.
- Handover probability:
  the probability that a handover attempt is blocked.
- Call dropping probability:
  the probability that call terminate due to handover failure. This metric can be derived directly from the handover blocking probability and the handover probability.
- Probability of an unnecessary handover:
  the probability that a handover is stimulated by a handover algorithm when the existing radio link is still adequate.
- Rate of handover:
  the number of handover per unit time. Combined with the average call duration, it is possible to determine the average number of handover per call, and thus the handover probability.
- Duration of interruption:
  the length of time during a handover for which mobile terminal is in communication with neither base station. This metric is heavily dependent on the network topology and the scope of the handover.
- Delay:
  the distance the mobile moves from the point at which the handover should occur to the point at which it does.

2.1.4 Handover initiation

A hard handover, as opposed to a soft handover, occurs when the old connection is broken before a new connection is activated. Figure 1 shows a mobile moving from one base station (base 1) to another base station (base 2). Signal strength of base1 decrease as it is moving away from base1 and similarly signal strength of base2 increase as it approach near to it. Using this figure following discussion explains various approaches.

- Relative signal strength
  Choosing the strongest received base station always. The decision is based on averaged measurement of the received signal. The handover will occur at position A.
- Relative signal strength with threshold
  Allows a user to hand over only if the current signal is sufficiently weak (less than a threshold) and the other is the stronger of the two. The effect of the threshold depends on its value compared to the signal strength of the two base stations at the point at which they are equal. If the threshold is higher than this value, say T1 in fig 1, this scheme performs exactly like the relative signal strength scheme, so the handover occurs at position A. If the threshold is lower than this value, say T2 in fig 1, the mobile will delay handover until the current signal level crosses the threshold at position B. In the case of T3, the delay may be so long that the mobile drifts far into the new cell. This reduces the quality of the communication link and may result in a dropped call. In addition, this causes addition interference to co- channel users. Thus, this scheme may create overlapping cell coverage areas. A threshold is not used alone in practice because its effectiveness depends on prior knowledge of the crossover signal strength between the current and candidate base stations.
- Relative signal strength with hysteresis
  Allows a user to handover only if the new base stations is sufficiently stronger (by a hysteresis margin, h, in fig .1) than the current one. In this case the handover will occur at point C. This technique prevents the so-called ping pong effect, the repeated handover between the base station causes by rapid fluctuations in the received signal strengths from both base stations.
- Relative signal strength with hysteresis and threshold:hands a user over to a new base only if the current signal level drops below a threshold and the target base station is stronger than the current one by a given hysteresis margin. In fig1 the handover will occur at point C if the threshold is either is T1 or T2 and will occur at point D if the threshold is T3(**Pollini**,1996).
- Prediction techniques base the handover decision on the expected future value of the receive signal strength.

In summary, handover criteria are analyzed in the literature are based on essentially four variables: the length and shape of averaging window, the threshold level, and the hysteresis margin. After choosing the new base station user then must choose the channel at the base station, some algorithm and channel selection as a single decision, often call as joint base station and channel assignment. One such study simulates a signal to interference ratio (SIR)-based handover algorithm for one dimension. Similarly, they use the simulation tool to evaluate the maximum power handover (MPH) scheme, different then relative signal strength method that includes multiple handover candidates, with compare to SIR- based handover, for a slight increase in call blocking MPH shows a notable decrease in call dropping at the expense of an increase in the number of unnecessary handover and ping- pong. To erase this problem a timer is introduced into the MPH.A handover is allowed only after the time is expires. It shows that it decreases the number of unnecessary handover compare to MPH, but have little effect on call blocking or drooping, thus both hysteresis margin and timer can be used to reduce ping- pong effects.

2.1.4.1 Flow diagram for handover in 3GPP-LTE

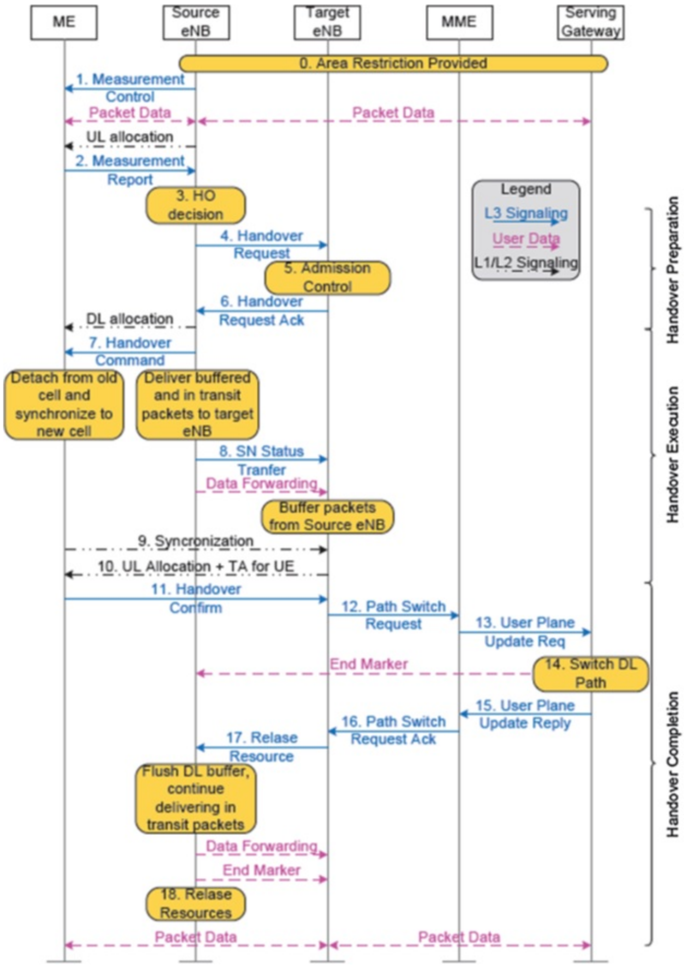


Figure 2.1: Messages flow diagram of handover procedure in 3GPP-LTE

(**Xenakis et al.**,2014)

1. Measurement control/report (message 1/2) in 2.1. The serving eNB configures and triggers the UE measure procedure and the UE sends the measurement report to the serving eNB.
2. Handover decision (message 3/4). The serving eNB decides about the handover based on the received measurement report.
3. Admission control (message 5/6) The target eNB performs the admission control process depending on the QoS information and prepares handover at the L1/L2 level.
4. Handover command (message 7). The serving eNB sends to the UE the handover command.
5. Handover execution,detachment from the old cell and synchronization with the new one (messages 8-10). The UE synchronizes with the t cell and accesses the target cell.
6. Handover completion: handover confirmation and path switching (message 11-16). The serving-gateway hands over the down-link connection to the target eNB. To do this, the serving- gateway exchanges the massage with Mobility Management Entity (MME).
7. Release of resources (message 17/18). Upon reception of the release message, the serving eNB can continue with the downlink data transmission (**Xenakis et al.**,2014).

2.1.5 Some of terminology used in LTE-A handover are:

- Ping pong effect: It is very common phenomenon in the mobile networks, which can cause inefficiency, call dropping and degrading of the network performance. Coverage parameter, user Location area and its movement and speed are the main considerations that can cause the target ping pong. The ping-pong HO in LTE means two subsequent HOs between the source and the target eNB and vice versa.The ping pong effect occurs due to the frequent movement of UE between the source and the target eNB, or high signal fluctuation at the common boundary of the eNB. Since ping-pong effect HO disperses the resources between releasing and reserving, which result the reducing of QoS, so it is very important for network operator to mitigate this effect (**Gódor et al.**,2015).
- The core Network: Evolved Packet core(EPC):

The core network is responsible for the overall control of the UE and establishment of the bearers. It is the main element of the LTE SAE network. This consists of four main elements and connects to the eNodeB's as shown in figure

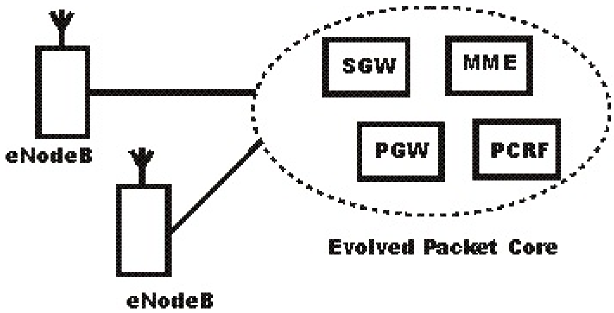


Figure 2.2: LTE SAE Evolved Packet Core.

(**Chavarría**,2014)

- Mobility Management Entity (MME): The MME is the main control node for the LTE SAE access network, handling a number of features, it can therefore be seen that SAE MME provides a overall control functionality. The protocols running between the UE and CN are know as the Non Access stratum(NAS) protocols. Some of the main functionality are mention below.
  a. Function related to bearer management
  It includes the establishment, maintenance and release of the bearers and is handled by the session management layer in the NAS protocol.
  b Function related to connection management
  This includes the establishment of the connection and security between the network and UE and is handled by the connection or mobility management layer in the NAS protocol Layer (**Iñiguez Chavarría**,2014).
- Serving Gateway (SGW) The Serving Gateway, SGW is a data plane element within the LTE SAE. Its main purpose is to manage the user plane mobility and it also acts as the main border between the Radio Access Network, RAN and the core network.

It also maintains the data paths between the enodeB's and the PDN Gateways. In this way SGW forms an interface for the data packet network at the E-UTRAN.

- PDN Gateway (PGW)
  The LTE SAE PDN (Packet Data Network) gateway provides connectivity for the UE to external packet data networks, fulfilling the function of entry and exit point for UE data. The UE may have more than one PGW connectivity for accessing multiple PDNs.

- eNodeB
  The eNodeB is a radio base station of a LTE network that controls all radio-related functions in the fixed part of the system. These radio base stations are distributed throughout the coverage region and each of them is place near a radio antenna. One of the biggest differences between LTE network and legacy mobile communication system 3G is a base station. Practically, an eNodeB provides bridging between the UE and EPC. All the radio protocols that are used in the access link are terminated in the eNodeB. The eNodeB does ciphering /deciphering in the user plane as well as IP header compression/decompression. The eNodeB also has some responsibilities in the control plane such as radio resource management and performing control over the usage of radio resources(**Iñiguez Chavarría**,2014)

- Radio Resource Management
  The main objective of the RRM is to make the mobility feasible in cellular wireless network so that the network with the help of UE takes care of the mobility without user interference. It covers all the function related to the radio bearers, such as radio bearer control, radio admission control, radio mobility control, scheduling and dynamic allocation of resources to UEs in both uplink and downlink.

- IP header compression
  It helps to use of the radio interface by compression the IP packets headers which could otherwise represent a significant overhead, especially for small packets such as VOIP. In LTE header compression is very important because there is no support for the transport of voice service via the Circuit-Switched (CS) domain.

- X2 Interface
  The X2 interface has a key role in the intra-LTE handover operation. The source eNodeB will use the X2 interface to send the Handover Request message to the target eNodeB. If the X2 interface does not exist between the two eNodeB's in question, then procedures need to be initiated to set up before handover can be achieved.

- The handover request message initiates the target eNodeB to reserve resources and it will send the handover request Acknowledgement message assuming resources are found.

- Different kinds of information elements provided on the handover Request message, such as:

- Requested SAE bearers to be handed over.

- Handover restriction list, which may restrict following handovers for the UE.

- Last visited cells the UE has been connected to, if the UE historical information collection functionality is enabled. This has been useful in avoiding the ping-pong effects between different cells when the target eNodeB is given information on how the serving eNodeB has been changing in the past. This help to limit frequent X2 User Plane.

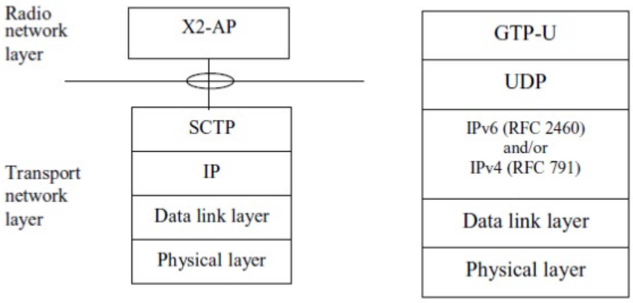


Figure 2.3: Protocol stack for the user-plane and control - plane at X2 interface

(**Iñiguez Chavarría**,2014)

- S1 interface: The radio network signaling over S1 consists of the S1 Application part(S1AP). The S1AP protocol handles all procedures between the EPC and E-UTRAN. It is also capable of carrying message transparently between the EPC and the UE. Over the S1 interface the S1AP protocol primarily supports general E-UTRAN procedures from the EPC, transfers transparent non-access signaling and performs the mobility function.

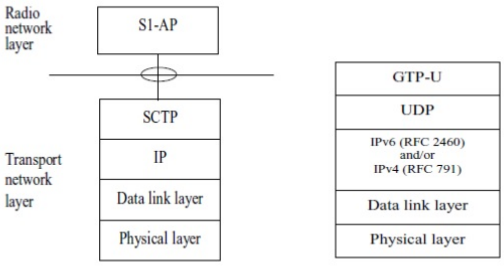


Figure 2.4: Protocol stack for the user-plane and control-plane at S1 interface.

(**Iñiguez Chavarría**,2014)

2.1.6 Handover Parameters

The handover procedure has different parameters which are used to enhance its performance and setting these parameters to the optimal values is very important task. In LTE the triggering of handover is usually based on measurement of the link quality and some other parameters to improve the performance. Some of them are listed below,

- Handover initiation threshold level RSRP and RSRQ It is used in handover initiation. When the handover threshold decrease, the probability of a late handover decrease, and the pin-pong effect increase. It can be varied according to different scenarios and propagation conditions to make these trade-offs and obtain a better performance.
- Hysteresis margin It is also called HO margin, it is main parameters that governs the HO algorithm between two eNB's. The handover is initiated if the link quality of another cell is better than current link quality by a hysteresis value. It is used to avoid

ping-pong effects. However, it can increase handover failure since it can also prevent necessary handover.

- Time-to-Trigger Whenever we apply Time-to-Trigger, the handover is initiation only if the triggering requirement is fulfilled for a time travel. This parameter can decrease number of unnecessary handovers and effectively avoiding ping-pong effects. But it can also delay the handover which increase the probability of handover failures.
- The Length and shape of averaging window The effect of the channel variation due to fading should be minimized in handover decision. Averaging window can be used to filter it out. Both the length and shape of the window can be used to filter it out. Both the length and the shape of the window can affect the handover initiation. Long windows reduce the number of handover but increase the delay. The different shape of window like exponential shape can also affect the number of handover and probability of unnecessary handovers(**Chavarría**,2014).

2.1.6.1 Related works in LTE

So far, many studies have been done concerning problems related to handover algorithms for HO performance optimization and evaluation. In (**Lin et al.**,2011) a new handover algorithm known as LTE Hard Handover Algorithm with Average Received Signal Reference Power (RSRP) Constraint (LHHAARC) is proposed in order to minimize number of handovers and the system delay as well as maximize the system throughput. The system performance is evaluated and compared with other three HO algorithms: LTE Hard Handover Algorithm, Received Signal Strength based TTT Window Algorithm and the Integrator Handover Algorithm. The results showed that the LHHAARC algorithm can efficiently reduce the number of handovers, minimizing the total system delay and maximizing the total system throughput. The study in (**Dimou et al.**,2009) considers the setting of HO triggers of primary importance for the design of a good performing HO procedure. It is inferred that adaptation of the HO triggers on the basis of speed, propagation conditions and cell sizes is needed. Considering the difficulties in adapting properly the HO triggers, another solution using a series of HO triggers is proposed. LTE specific HO issues are considered by (**Anas et al.**,2007) and (**Anas et al.**,2007). The study in (**Anas et al.**,2007) recommends us a range of HOM in dB considering the average number of HO for different user speeds.Research in (**Anas et al.**,2007) provides us linear and dB domain L3-filter performance improvements in terms of global number of handovers. In (**Aziz & Sigle**,2009) they have investigated the improvements of LTE handover performance through ICIC. It has been shown that optimum HO performance can be achieved through optimum parameters selection by finding a compromise between HO rates and Residual BLER for HO Command message. In paper (**Racz et al.**,2007) has shown that the user perceived performance at handovers will not degrade due to the relocation based handover scheme of LTE. There is no radio efficiency drawback associated with the restart of user plane protocols (i.e., RLC/MAC) at the target cell. However, they recommend to employ packet forwarding from the source to the target cell and to ensure the correct delivery order of packets in order to achieve high TCP throughput performance. The impacts of triggering setting hysteresis/TTT on handover performance have been investigated in (**Xenakis et al.**,2014) 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 (**Jansen et al.**,2010) 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. Some of algorithm in LTE/LTE-A are follows:

- **Mobility-based decision algorithms** When we consider mobility-based decision, usually we consider the threshold velocity for user speed (citation need) , if UE(user equipment) moves with higher speed than threshold speed, handover is forbidden to a small cell, this solution has benefit beyond the simplicity to avoid the too frequent, unnecessary handovers but relatively accurate positioning information is required at the base station , which is typically not available in most active networks.
- **Policy-based decision algorithm** The policy-based decision can take into consideration several different parameters, handover mechanism based on the decision made by the entity named HeNB policy function(HeNB PF) it take the user type access mode of HeNB and its current load into consideration to make the optimal decision about the target femtocell (**Bai et al.**,2011). In (**Xenakis et al.**,2012) it proposed policy is LTE backward- compatible, as it be employed by suitably adapting the handover hysteresis margin with respect to a arranged SINR target and standard LTE measurements. (**Knapp & Gódor**,2014)

Speed based algorithms of this class typically compare the UE speed with absolute speed thresholds to lower the HO probability for medium to high speed users. We should note that majority of speed- based algorithms incorporate other factors like RSS, traffic-type and available bandwidth on the target cell. In the following, we discuss three representative speed-based HO decision algorithms.

- Speed and traffic-type based HO Algorithm for the Macrocell- Femtocell Network This (Ulvan et al.,2013)algorithm consist of two different type of HO decision strategies: the proactive and the reactive. In the proactive strategy, a HO is initiated before the RSS of the serving cell reaches an absolute HO hysteresis threshold. To perform this, the algorithm estimates the residual time prior to the HO execution. In the reactive strategy, the HO execution is initiated when the minimum required RSS is almost reached. The proactive strategy objective at minimizing the packet lossand the delay of the HO decision, whereas the reactive strategy aims at lowering the number of unnecessary Hos. The proposed algorithm applies to the multiple microcell and multiple femtocell HO decision scenario figure show the fundament of proposed algorithm. When the UE speed is higher than 10km/h, the proposed algorithm avoids inbound mobility to femtocells and performs normal RSS- based HO decision. On the other hand, if user speed varies between5km/h and 10km/h the proposed algorithm uses mobility prediction and employs the proactive strategy for real-time traffic similar approach is perform when speed is lower than 5km/h. The use of mobility prediction in combination with the UE speed is a strong feature of the algorithm, which is expected to lower the HO probability for medium to high speed users. An improved QoE is also expected for the proposed algorithm, using different HO decision strategies depending on the traffic- type.

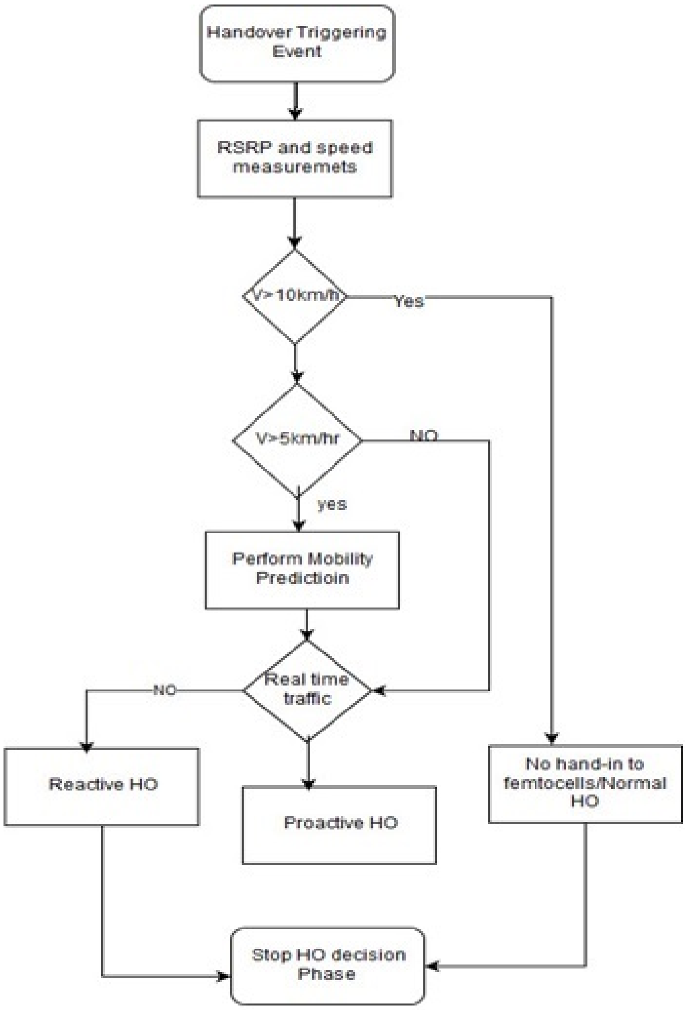


Figure 2.5: Zhang et.al Speed HO algorithm

(**Zhang et al.**,2011)

2.1.6.2 Low-complexity HO Algorithm for the Macrocell- Femtocell LTE-Advance Network

This algorithm (**Zhang et al.**,2011) applies to the single microcell single -femtocell station whenever a) the RSRP Status of the femtocell exceeds over the RSRP status of the microcell plus a HHM b) the UE speed is less then threshold, among the advantages of the algorithm in it is that it attains backwards compatibility with the LTE-A system and its signaling performance is validated by a performance analysis it is expected to lower the handover probability, disadvantage of this algorithm is that selection of appropriate speed threshold is not thoroughly investigate.

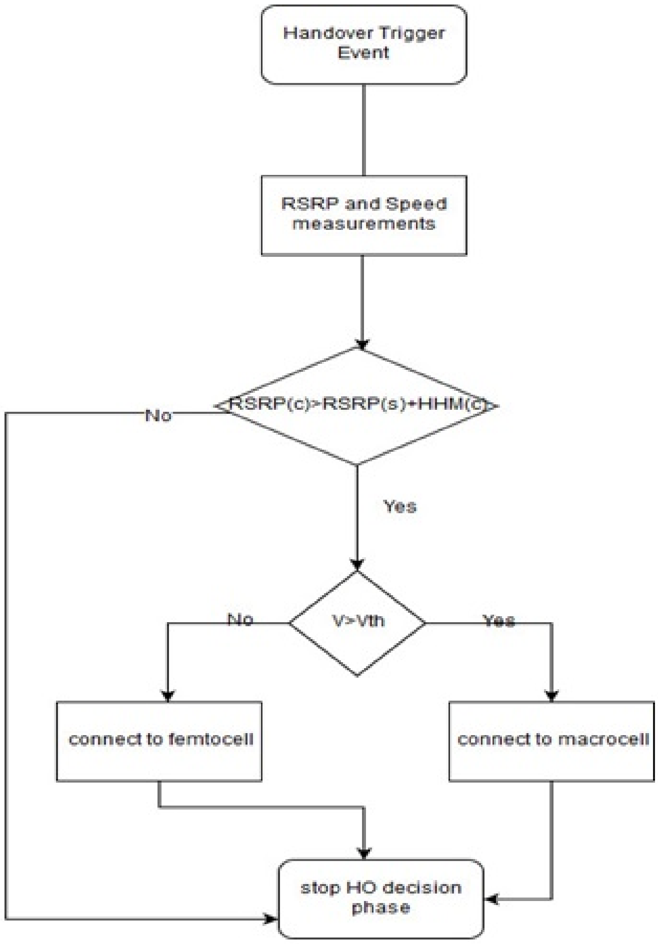


Figure 2.6: Zhang et.al Speed HO algorithm

(**Zhang et al.**,2011)

2.1.6.3 HO Algorithm for the LTE Network with hybrid Femtocells:

The algorithm in (**Shih-Jung & Lo Steven**,2011) incorporate wide rag of parameters to reach the HO decision, mainly including RSS of the Serving and the target cell, the UE speed, the interference level at target femtocells, the bandwidth availability on the target cell, the UE membership and traffic type.The algorithm is use to i) remain in current serving cell, ii)handover to the macrocell iii) handover to a hybrid femtocell. If serving cell is a HeNB, the proposed algorithm performs a HO to the microcell only if a) the speed exceeds over a predetermined speed threshold V(t,1) and microcell can support the bandwidth requirements of the UE. Or b) the RSRP status of the serving HeNB decrease and the microcell can support the bandwidth requirement of the UE. If serving cell is not belong to the HeNB and the UE is not member of the CSG supported by the target, HO is performed only if a) the interference level at the hybrid femtocell is greater than a prescribed threshold Ith b) the UE speed is lower then prescribe threshold V(t,2) and c) the target femtocell can support the bandwidth requirements of the UE. On the other hand, if the UE belongs to the CSG of target femtocell, the give algorithm performs and inbound HO depending up on a) absolute RSS and relative RSS with hysteresis margin, b) UE speed, c) traffic-type, and d) bandwidth-related criteria. The proposed algorithm in accounts for a wide range of HO decision criteria, which are expected to minimize the HO failure probability.

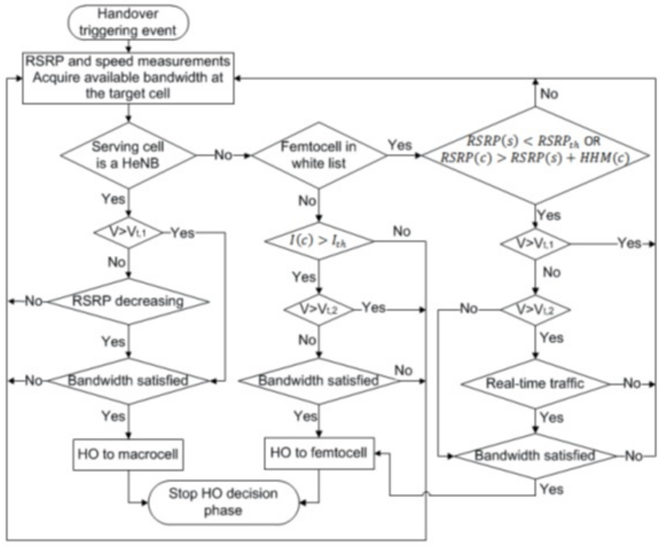


Figure 2.7: Zhang et.al Speed HO algorithm

(**Zhang et al.**,2011)

Chapter 3
Methodology

3.1 System Overview

The LTE power Budget Handover Algorithm (PBHA) is a basic but effective handover algorithm used for performance evaluation consisting of two variables: handover margin (HPM) and time to trigger (TTT) value. HOM is usually measured in decibels and TTT is measured in seconds.

HOM or hysteresis is a constant variable that represents the thresholds of the difference in Received Signal Strength (RSS) between the serving and the target cells. HOM ensures the target cell is the most appropriate cell the mobile camps on during handover. A TTT value is the time interval that is required for satisfying HOM condition. Both HOM and TTT are used for reducing unnecessary handovers which is called "Ping-Pong effect". When a mobile is experiencing this effect, it is handed over from a serving cell to a target cell and handed back to original serving cell again in a small period. This effect increases the required signaling resources, decreases system throughput, and increases data traffic delay caused by buffering the incoming traffic at the target cell when each handover occurs. Therefore effectively preventing unnecessary handovers is essential. TTT restricts the handover action from being triggered within certain time duration. A handover action can only be performed after the TTT condition has been satisfied. When a mobile is moving away from the serving cell, the RSRP which the mobile receives from the serving cell will degrade as time increases. Meanwhile, the mobile will move towards the target cell, therefore the RSRP the mobile receives from the target cell will increase as time increases . A handover is triggered when the triggering condition 3.1 and 3.2 are both satisfied, followed by the handover command.

$$\mathrm{RSRPT} \ > \ \mathrm{RSRPS} + \ \mathrm{HOM} \tag{3.1}$$

$$\mathrm{HO\ Trigger} > \ \mathrm{TTT} \tag{3.2}$$

Where RSRPT and RSRPS are the RSRP received from the target cell and the serving cell, respectively, and HO Trigger is the handover trigger timer which starts counting when condition (1) gets satisfied. Figure shows the basic concept of LTE hard handover algorithm. The design of an efficient and successful handover requires the careful selection of HO performance based on RSRP measurements within certain deployment scenarios. The evaluation methodology of this study is based on the method developed in This study measures the absolute number of handovers, which is a very important variable for the network operators, in relation with the Average Signal to Interference plus Noise Ratio (SINR) measured to select the connected cell and possible handover candidate. This is done through different combinations of HOM and TTT with the main objective to minimize the number of handovers. Thus, minimizing the expected number of handovers minimizes the signaling overhead. To computes for each sub channel, the SINR for the received signal considering the received power, the noise, and the interference, as it follows:

$$\mathrm{SINR}_{i,j} = \mathrm{Pr}_{xi,j}/(\mathrm{FN_0B}) + \mathrm{I} \tag{3.3}$$

Where,
F= Fading noise figure (default value 2.5),
No=Gaussian noise
B=Background noise
I= Interference noise

Pr= Single Power.
F,No, B and I are the noise figure(default 2.5)
The noise spectral density (default value -174dBm), the bandwidth of a resource block (i.e., 180kHz) and the interference, respectively. The interference is the total power received from the eNB's sharing the same frequency resources. SINR value is obtained as a weighted average among SINR of a set sub channels per UE and evaluated in the moment where handover occurs.

3.1.1 Performance Metrics

The PBHA picks the best hysteresis and time- to – trigger combination to evaluate the system performance in terms of number of handovers, throughput, delay, packet lost and SINR.

3.1.2 System Level Simulator description

The study is done using a dynamic system level simulato ns3 LTE-Sim an open source framework to simulate LTE network. To ensure modularity, polymorphism, flexibility and high performance. LTE-Sim has been written in C++, using the object- oriented program, as an event-driven simulator. LTE-Sim encompasses several aspect of LTE networks, including both the Evolved Universal Terrestrial Radio Access(E-UTRAN) and the Evolved packet system (EPS). It supports single and heterogeneous multi- cell environments, QoS management, multi-user environment, user mobility, handover procedures, and frequency reuse techniques. Four kinds of network nodes are modeled: user equipment (UE), evolved Node B (eNB), Home Enb (HeNB), and Mobility Management Entity/Gateway (MME/GW). Four different traffic generators at the application layer have been implemented and the management of data radio bearer is supported. Finally, well-known scheduling strategies (such as Proportional Fair, Modified Largest Weighted Delay First, and Exponential Proportional Fair, Log and Exp rules), AMC scheme, Channel Quality Indicator feedback, frequency reuse techniques, and models for physical layer have been developed. There are four main components in LTE-Sim:

1. The Simulator
2. The Network Manager
3. The Flows Manager
4. The Frame Manager

A system level inter cell handover procedure is implemented in the simulator to support user mobility. Two types of mobility models are supported; Random Direction and Random Walk. For each of them, a dedicated class has been developed, extending the basic Mobility Model class, i.e., Random Direction and Random Walk classes. In Mobility Model class `m_speed` and `m_speed` direction variables are used to define the speed and the travel direction of the user, respectively. User speed should be chosen among the values 0, 3, 30, and 120km/h, equivalent to static,pedestrian, and vehicular scenarios, respectively. When the Random Direction model is used, the UE randomly chooses the speed direction that remains constant during the time and moves towards the simulation boundary area. Once the simulation boundary area is reached, the UE chooses a new speed direction.
When the Random Walk is used, the UE randomly chooses the speed direction and moves accordingly for a given travel distance that depends on the user speed. The UE changes its speed direction after covering this distance or, as in the previous model, once the simulation

boundary area is reached. As default, the travel distance is equal to 200, 400, 1000m. when user speed is equal to 3, 30, and 120km/h, respectively. The user mobility is managed by the Network Manager that, every TTI updates the user position according to the selected mobility model and parameters, and verifies, through the Network Manager: Handover Procedure () function, if the handover procedure is necessary. In LTE-Sim both cell re-selection and handover procedures are implemented. Moreover, handover decisions are carried out by the Handover Manager defined for each UE. Handover management consists of the following,

1. For the UE that triggered the handover procedure, the function Handover Manager: Select Target ENodeB() is used for selecting a new target eNB (Using one of the two algorithms explained below, Position based or Power-based).
2. All the information about the UE is transferred from the old eNB to the new one.
3. Between the UE and the new target eNB, a new radio bearer is created.
4. The UE updates the list of available sub-channels for downlink and uplink, according to those assigned to the new target eNB.

During the handover, the UE switches to a detached state for a given time interval, so that no flows directed to and coming from the UE can be scheduled; such a time interval is a simulator parameter and can be modified (default value is 30ms). Currently LTE-Sim is supporting two algorithms:

1. Position-based(if `(d2>d1)`, then choose eNB2 to be your serving eNB).
2. Power-based (if `RSRP2>RSRP1`, choose eNB2 to be your new serving eNB).

For the study of the LTE Handover Performance Evaluation, Power-based algorithm is used, but for its simiplicity, two parameters are added to carry out the study, these are Hysteresis Margin and the Time to trigger value.Changes in the code of the LTE handover performed introducing parameters of HOM and TTT. To introduce HOM the following condition is used(`RXpower > targetRXpower+ HOM`)For TTT, a counter associated to each eNB is introduced, that counts the time where the previous condition is guaranteed.

`If (RXpower > targetRXpower + HOM)`
{
`TTT_counter++;`
If `TTT_counter`$\geq$ `TTT_threshold)`
{
$targetRXpower = RXpower$;
$targetNode = probableNewTargetNode$;
} Another variable is introduced (`TTT_counter`) for each eNB that keeps trace of the time where the condition (`RXpower >targetRXpower + HOM`) is guaranteed.Once this time overtakes the`TTT_threshold` (that is a system parameter) a handover occurs.

3.1.3 Modelling simulation

The system is modeled and simulated in the dynamic system level simulator. A radio network consisting of 7 cells of 5 MHz bandwidth with 25 resource block and 2 GHz carrier frequency is built. Each resource block is consisted of 12 subcarriers of size 15kHz each. A time slot is 0.5 ms. In duration and the Transmission Time Interval (TTI) is 1 ms. A fixed number of users are uniformly distributed over the area with random initialized positions and they are moving at a fixed speed in random directions. The traffic model is defined as infinite- buffer, an ideal greedy source that always has packets to send. Both at the eNB and the UE,1 antenna is used for transmission and 2 for reception (Single input Multiple Output).

The most relevant simulation parameter are listed in table 3.1 (**Chavarría**,2014) The 3GPP common scenarios adopted for simulation are:

- UE speeds at 30Km/h, 60Km/h and 120Km/h.
- Number of users:1UE/cell,3UE's/cell.
- Cell sizes 500m and 1000 m.

Table 3.1: Simulation Parameters

Parameter	Value
Cellular layout	7 cells
Cell radius	500m. 1000m.
Traffic model	INF BUF
BS Tx Power	20 w./43 dBm
Antenna	Onmidirectional with Gain=14 dBi
Channel model	3GPP Typical Urban
Carrier frequency	2 GHz
UE speed	(3 km/h, 30 km/h, 120 km/h)
Number of UE's	1UE/cell and 3 UE's/cell
UE direction	Randomly chosen within [0, 360)
TTI	1 ms.
Subcarrier spacing	15Khz.
Resource Block	180Khz
Super frame Time	10 ms.
Noise Figure	2.5
Update time of UE position	1ms
Noise Spectral Density	-174 dBm
Simulation Time	60s.
Max, Handover delay	30ms.
System bandwidht	5MHz. 25RBs/TTI
Hysteresis/Time-to-trigger	0dB/0ms, 3dB/960ms, 6dB/120ms, 9dB/0ms

The study model of this study is show below in block diagram 3.1

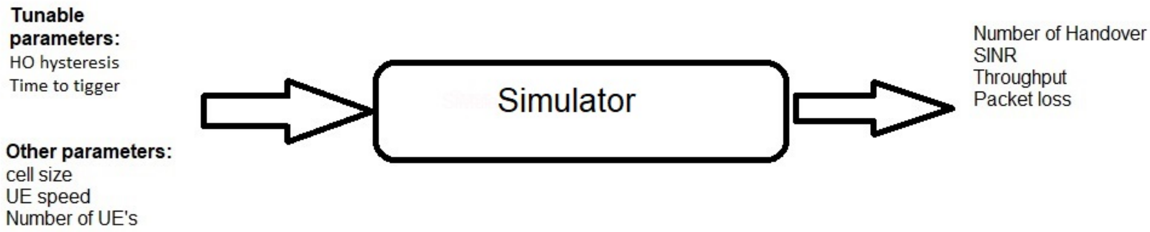


Figure 3.1: Study model

Chapter 4
Experimental Results

There are two case , case1 and case2 which are analysis for study ,The case with 1 UE in the whole system is studied. This is easiest case for handover study in order to confirm the performance of the simulator.

4.1 Simulation Results

Case 1: HO Triggering Setting for 1UE/cell at 3, 30, 120km/h and cell Radius 500m. The case with 1 UE/cell is studied. The evaluation methodology stated is applied to evaluate the performance of different handover triggering settings including (0db/0ms), (3dB/960ms), (6dB/120ms) and (9dB/0ms).
The evaluation methodology is applied to choose a best triggering setting. Increasing the Hysteresis margin and decreasing values of TTT.

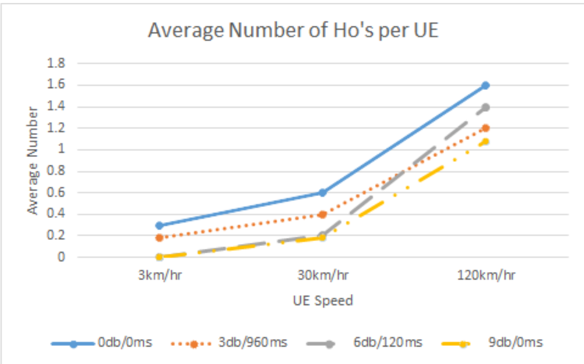


Figure 4.1: Obtained Average number of handover per UE

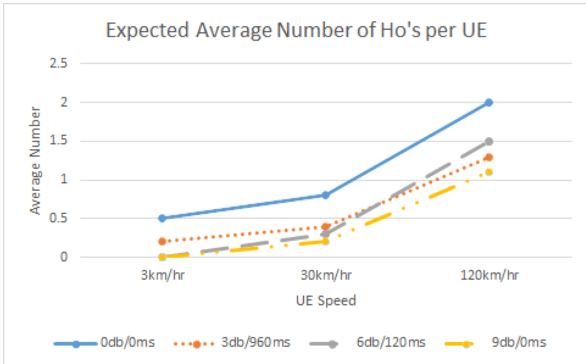
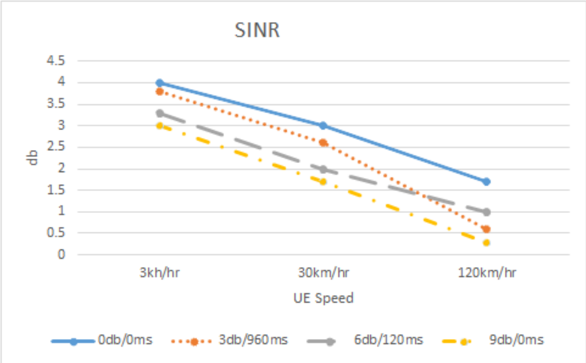


Figure 4.2: Expected Average number of handover per UE.

For all cases in 4.1(0dB/0ms) generates the highest number of handovers. For a slow UE, the setting with small hysteresis and long TTT is easier to trigger handovers since it takes a long time for the slow UE to meet the large hysteresis condition. (3dB/960ms) trigger more handovers than other settings for 3km/h. It can be noticed that for, (6dB/120ms) and (9dB/0ms), the number of handovers remain the same. Although (3dB/960ms) generates the highest number of handovers besides (0dB/0ms) for3km/h, it is still proposed because the handovers are not unnecessary. It is not harmful to generate a few more handovers. For 30 Km/h, (3dB/960ms) generates more handovers compared with the rest of the configurations.The tendency is like the one observed for UE's moving at 3Km/h. If the hysteresis is large like 9 dB, it is difficult to trigger a handover. For UE's going at 120 Km/h (6dB/120ms) triggers more handovers followed by (3dB/960ms) because the hysteresis will be easier to be fulfilled at this speed. Operators prefer less handovers. However, this does not mean to choose the setting which can result in least handovers because several necessary handovers are needed.We can clearly see that expected graph and simulated obtain graph are not so far different.



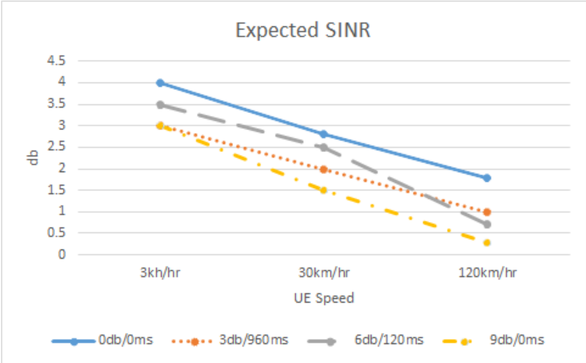
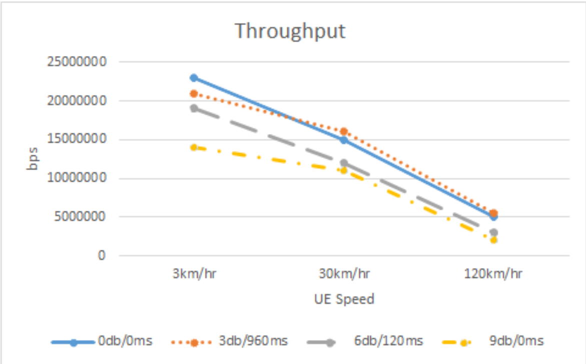


Figure 4.3: Obtained SINR

Figure 4.4: Expected SINR.

The 4.3 show difference of SINR values for UE's moving at 120 km/hr is relatively larger than UE's moving at slow velocities. (0dB/0ms) performs better for all velocities than other settings because it is always connected to the best cell.We can clearly see that expected graph and simulated obtain graph are not so far different.



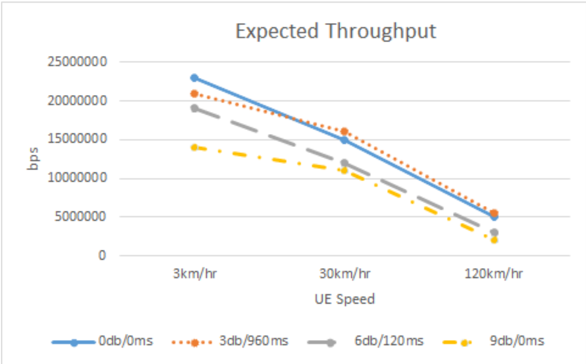
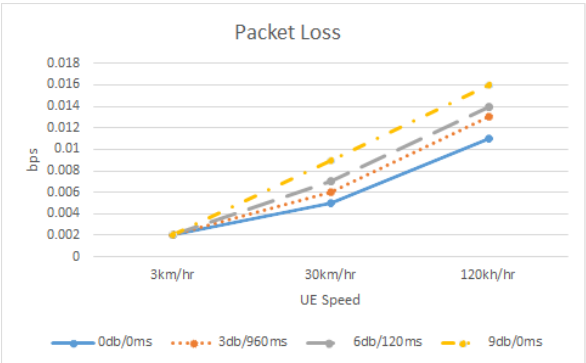


Figure 4.5: Obtained Throughput

Figure 4.6: Expected Throughput.

Figure 4.5 that (3dB/960ms) and (0dB/0ms) have the highest throughput (21.45Mbps and 23.02Mbps) at 3km/h because the handover is done for cells that have better channel quality at low speed. The throughput drops to 15.95 and 7.054Mbps in the case of (3dB/960ms) at 30 and 120 km/h respectively, due to the increase in number of handovers resulting in the drop of the system performance. The same tendency is observed for UE's moving at 30 and 120Km/h.



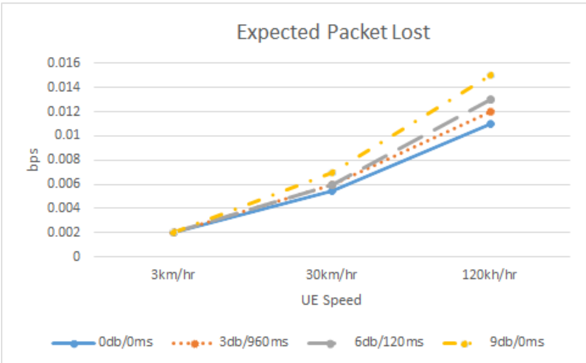


Figure 4.7: Obtained Packet loss

Figure 4.8: Expected packet loss.

According to the figure4.7 UE's moving at 3km/h with different handover settings have relatively the same performance. At 30 km/h and 120 km/h, (0db/0ms) and (3db/960ms) perform better. The packet lost ration for (9 db/0ms) is 0.006941 percentage and 0.155percentage for both velocities.We can clearly see that expected graph and simulated obtain graph are not so far different.

Case 2: HO Triggering setting for 3 UE's/cell at 3, 30 and 120 Km/h with cell radius 1000m. The tendencies are like the ones observed for 1UE/cell. With larger cell size, relatively smaller hysteresis and lager TTT trigger more handovers because the large hysteresis margin is harder to be fulfilled for bigger cells.

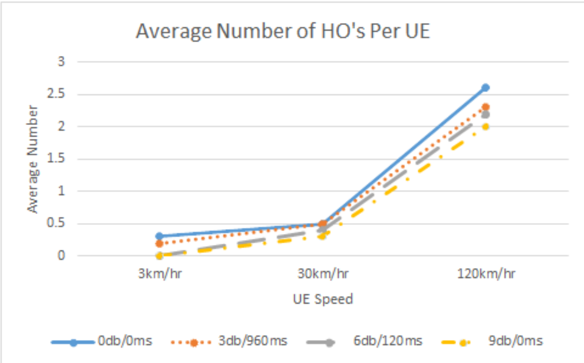


Figure 4.9: Obtained average number of HO

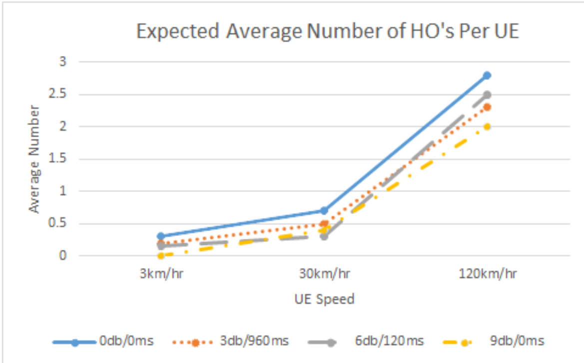


Figure 4.10: Expected average number of HO.

For all cases in figure 4.9 (0dB/0ms) generates the highest number of handovers. For a slow UE, the setting with small hysteresis and long TTT is easier to trigger handovers since it takes a long time for the slow UE to meet the large hysteresis condition.(3dB/960ms) trigger more handovers than other settings for 3km/h. It can be noticed that for, (6dB/120ms) and (9dB/0ms), the number of handovers remain the same. Although (3dB/960ms) generates the highest number of handovers besides (0dB/0ms) for3km/h, it is still proposed because the handovers are not unnecessary. It is not harmful to generate a few more handovers. For 30 Km/h, (3dB/960ms) generates more handovers compared with the rest of the configurations. The tendency is like the one observed for UE's moving at 3Km/h. If the hysteresis is large like 9 dB, it is difficult to trigger a handover. For UE's going at 120 Km/h (6dB/120ms) triggers more handovers followed by (3dB/960ms) because the hysteresis will be easier to be fulfilled at this speed.We can clearly see that expected graph and simulated obtain graph are not so far different.

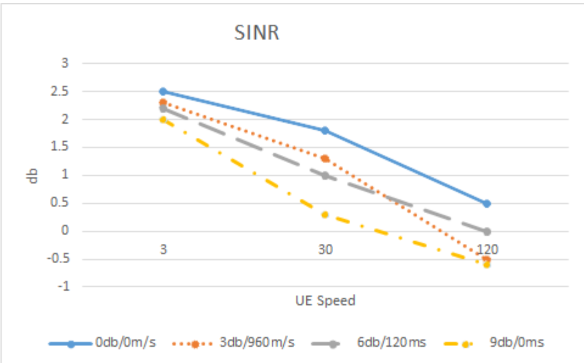


Figure 4.11: Obtained SINR

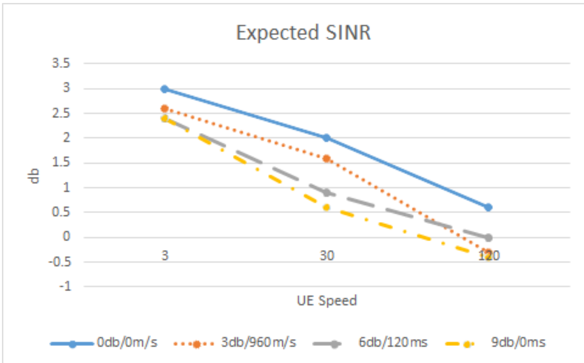


Figure 4.12: Expected SINR.

Figure 4.11 show the result is similar the one obtained for cells of 500m. The difference of SINR values for UE's moving at 120 Km/h is relatively larger than UE's moving at slow velocities. (0dB/0ms) performs better for all velocities than other settings because it is always connected to the best cell.We can clearly see that expected graph and simulated obtain graph are not so far different.

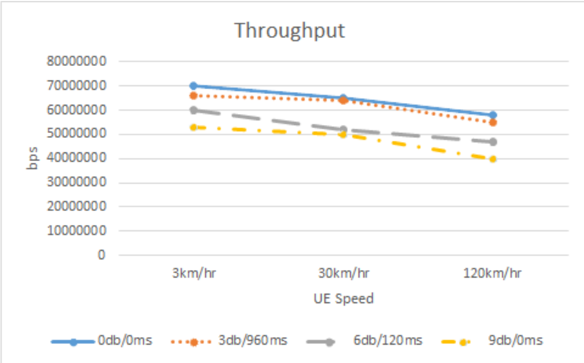


Figure 4.13: Obtained throughput

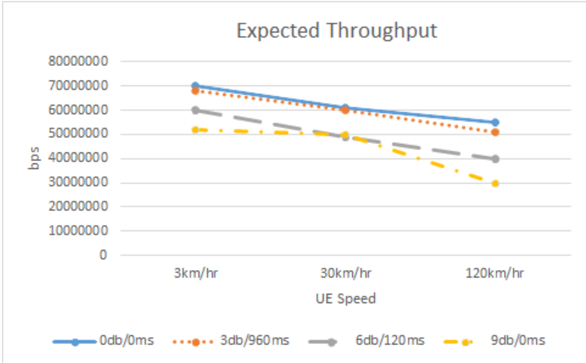


Figure 4.14: Expected throughput.

Figure 4.13 demonstrates that (3dB/960ms) and (0dB/0ms) have the highest throughput (65.56 Mbps and 69.73 Mbps) at 3 km/h because the handover is done for cells that have better channel quality at low speed. The throughput drops to 64.84 and 43.37 Mbps in the case of (3dB/960ms) at 30 and 120 km/h respectively, due to the increase in number of handovers resulting in the drop of the system performance.We can clearly see that expected graph and simulated obtain graph are not so far different.

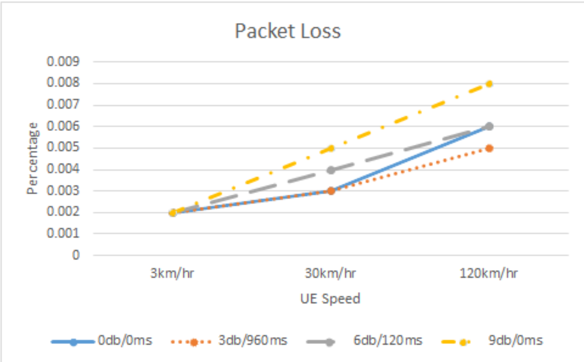


Figure 4.15: Obtained Packet loss

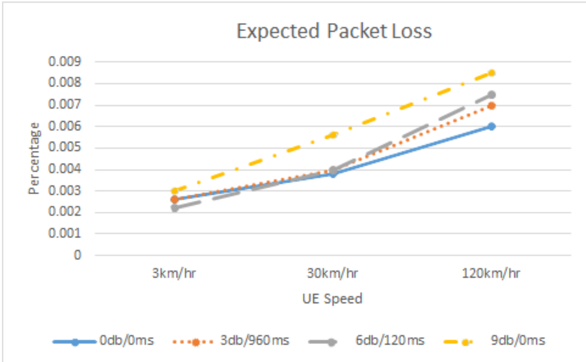


Figure 4.16: Expected packet loss.

According to figure 4.15 show, UE's moving at 3Km/h with different handover settings has relatively the same performance. At 30 Km/h and 120 Km/h, (0dB/0ms) and (3dB/960ms) perform better. The packet lost ratio for (9dB/0ms) is 0.005527In this special study, to carry out the handover performance evaluation process, the state of the art of handover in LTE, together with the LTE power budget handover algorithm (PBHA) and the LTE specifications have been studied. The operation and performance of the simulator LTE-Sim have been investigated as well. Moreover, the handover parameters (hysteresis and time to trigger) have been included in the simulator modifying the code to carry out the study.We can clearly see that expected graph and simulated obtain graph are not so far different.

Chapter 5
Conclusion, Discussion and Future Works

5.1 Conclusion

In this special study, to carry out the handover performance evaluation process, the state of the art of handover in LTE, together with the LTE Power Budget Handover Algorithm (PBHA) and the LTE specifications have been studied. The operation and performance of the simulator LTE-Sim have been investigated as well. Moreover, the handover parameters (hysteresis and time to trigger) have been included in the simulator modifying the code to carry out the study.Since the setting of HO triggers is of primary importance for a good performance of the handover procedure, different triggering settings for the selected parameters have been performed. The optimal settings for each scenario have been proposed and performance evaluation has been carried out using the number of handovers, SINR, throughput, and packet lost.

The results show that the system load does not affect significantly the optimal setting of handover hysteresis and TTT. It can also be concluded that the optimal triggering setting can improve the performance, thus, by tuning the handover triggering setting, the operator can have some gains. But it be well that some medium triggering settings, such as (3dB/960ms), have usually good performances for all the scenarios and they can be widely used as a simple way to improve the handover performance. Coverage limitations are the main reasons for a poor performance of the handover.

5.2 Recommendations for Future Work

This study has considered for HO performance evaluation simple deployment scenarios due software limitations mainly; however, it would be advisable to investigate the handover performance considering more complex scenarios, i.e. large cells higher speeds and high loaded system.

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