Forward Handover in LTE Heterogeneous Network

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List of Acronyms

3G	3rd Generation
3GPP	3rd Generation Partnership Project
4G	4th Generation
ABS	Almost Blank Sub frame
ACK	Positive Acknowledgement
AMC	Adaptive Modulation and Coding
ARQ	Automatic Repeat Request
BBU	Base-Band Unit
BLER	Block Error Rate
CA	Carrier Aggregation
CC	Component Carrier
CP	Cyclic Prefix
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CRSIC	Common Reference Signals Interference Cancellation
CRS	Common Reference Signals
CSG	Closed Subscriber Group
DL	Downlink
eICIC	Enhanced Inter-Cell Interference Coordination
eNB	Enhanced NodeB
EPC	Evolved Packet Core
EPS	Evolved Packet System
FDD	Frequency-Division Duplexing
GSM	Global System for Mobile Communications
HARQ	Hybrid Automatic Repeat Request
HeNB	Home enhanced NodeB
HetNet	Heterogeneous Network
IMT-A	International Mobile Telecommunications-Advanced
IP	Internet Protocol
ISD	Inter-Site Distance
ISI	Inter-Symbol Interference
ITU	International Telecommunications Union
ITU-R	ITU Radiocommunication Sector
KPI	Key Performance Indicator
LA	Link Adaptation
LPN	Low-Power Node
LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIMO	Multiple-Input Multiple-Output
MME	Mobility Management Entity
MMSE	Minimum Mean Square Error
MU-MIMO	Multiuser MIMO
NAK	Negative Acknowledgment
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access

PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PF	Proportional Fair
P-GW	Packet Data Network Gateway
PRB	Physical Resource Block
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
RAN	Radio Access Network
RE	Range Extension
RLF	Radio Link Failure
RNC	Radio Network Controller
RRC	Radio Resource Control
RRH	Remote Radio Head
RRM	Radio Resource Management
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
SAE	System Architecture Evolution
SC-FDMA	Single-Carrier Frequency Division Multiple Access
S-GW	Serving Gateway
SINR	Signal-to-Interference-and-Noise Ratio
SMS	Short Message Service
SNR	Signal-to-Noise Ratio
SON	Self-Organizing Networks
TDD	Time-Division Duplexing
TDPS	Time-Domain Packet Scheduler
TTI	Time Transmission Interval
TTT	Time To Trigger
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System

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Abstract

One of the essential targets of LTE HetNet is to provide seamless and fast handover from one cell to another to achieve a strict delay requirement while, at the same time, keeping network management as simple as possible. Hence, the decision to trigger a handover is very important in the design of handover process. Handover performance in heterogeneous networks deployments is not as good as in homogenous deployments. The handover triggering is highly depended on the UE speed, which means that as the UE speed changed, the handover triggering time is correspondingly varied. It means high speed user equipment (UE) suffers much higher handover failure rate than low speed UE. Determining a more accurate handover triggering point is a critical issue. Too late handover triggering caused by UE speed change will lead to handover failure. For handover to be successful, it requires to choose handover parameters correctly and optimize their setting. In this paper we proposed a forward handover scheme that allows pico to macro cell handover process to be fast. Because of faster handover procedure we can ensure better RSRP for the user moving at high velocity at the cell edge region.

Chapter 1

Introduction

1.1 Introduction

In this chapter the background and motivation of this Thesis are introduced, as well as the problem statement and the objective of this study.

1.2 Background and Motivation

In recent years, the development of wireless communications has experienced a huge revolution. While just a couple of decades ago mobile phones were mostly used for making calls and sending messages via SMS, the introduction of 3G, which allowed the use of broadband data granting access to browse the internet, and later 4G, which gets higher speeds, marked the development of mobile broadband and data oriented devices such as smartphones and USB modems. These devices are responsible for a fast growth in mobile data traffic [1]. In 2012, global mobile data traffic grew 70 percent and it is expected to increase 13-fold between 2012 and 2017. Moreover, the number of laptops and tablets mobile-connected is increasing exponentially too, meaning even more growth in mobile data traffic. By 2017, mobile data traffic generated by mobile-connected tablets will be 1.5 times higher than the traffic generated by the whole global mobile network in 2012 [1].

Mobile networks have to deal with the increase of the number of devices and also the demands of users for higher speeds to allow diversions like real time video streaming and online games. Therefore, mobile networks have to evolve in order to fulfill these demands. In the past years the required increase in capacity would have been achieved by adding more macro nodes in the network. However, the high costs and the space needed for such an approach represent an important problem for the operators [2]. Moreover, spectral efficiency per link is reaching theoretical limits [3].

At the sight of this, LTE-Advanced (LTE-A) in conjunction with Heterogeneous Networks (HetNets) are seen as the keys for further enhance the performance in mobile networks by improving spectral efficiency per unit area.

LTE-A is a technology that was designed to meet the demands of the growing traffic. It includes several advanced techniques such as carrier aggregation, multiple-input multiple-output (MIMO), and the introduction of HetNets.

One of the main technical challenges of LTE-HetNet is handover between picocell and macrocell due to non-availability of direct communication links between pico eNBs and macro eNBs. Due to small and discontinued picocell coverage, frequent handovers between pico cells and macro cells would occur. Therefore, a fast handover scheme using small signaling overhead is required for LTE Heterogenous networks to support fast and seamless handovers.In the LTE handoverprocess the traffic of the S1-U and S1-MME interfaces are rerouted. The S1-based handover scheme specified in the LTE standards [4] for handovers between eNBs, which are not directly connected through X2 interface, can also be used for handovers between a picocell and macrocell.However, the latency of the S1-based handover process increases significantly with the Internet delay as HeNBs are connected to eNBs through public Internet.

High handover latency, high power consumption due to the multiple network interfaces involved during a handover,and high bandwidth overhead due to additional information requirement for a handover, are some of the primary challenges in developing an efficient vertical handover scheme to manage handovers between a picocell and a macrocell in LTE networks. If There is no direct X2 interface between HeNBs and eNBs and therefore, X2-based handover between a HeNB and an eNB is not possible. However, the HeNB can communicate to a particular target eNB through S1 interface (via theMME). Hence, handover between a HeNB and an eNB has, naturally, to be based on the S1 interface. The standard S1-based handover procedure is more time consuming than an X2-based handover, due to Internet delays on the S1-backhaul interfaces between the HeNB and the MME, and the eNB and the MME. Therefore, it is important that the picocell backhaul connection should have a sufficient capacity to fulfill the QoS requirements for delay-sensitive traffic [11].There is a possibility that the broadband IP backhaul of picocells is provided by a different service provider.

Furthermore, the current IP backhaul networks are not designed to provide delay resiliency. In this situation, the mobile service provider will not be able to assure the required service parity from the backhaul service provider [12]. Hence, it is clearly justified that, at least, essential network operations, such as handover, should be facilitated within the purview of the mobile operator. Furthermore, similar issues may occur due to Internet delays, if the forward handover scheme is directly used to manage the handovers between picocells and macrocells. Therefore, in order to improve the efficiency of picocell-to-macrocell handovers, the number of subprocesses of the forward handover mechanism, which are based on IP backhaul links, needs to be minimized.

LTE-A is a technology that was designed to meet the demands of the growing traffic. It includes several advanced techniques such as carrier aggregation, multiple-input multiple-output (MIMO), and the introduction of HetNets.

1.3 Thesis Outline

This report is structured as follows:

- **Chapter 1: Introduction**

  This chapter outlines the motivation of this study and explains the problem and the objective of the study.
- **Chapter 2: LTE and Advanced Heterogeneous Networks**

  Definition of the main features of LTE-Advanced, especially those related to this study. Besides, description of key design features for Heterogeneous Networks.
- **Chapter 3: Handover at LTE Heterogeneous Network**

  We have discussed the overview of Handover. It includes handover parameters, events along with various scheme of handover operations.
- **Chapter 4: HetNet Handover Problems**

  In this chapter, the problems faced in the Handover procedure for the HetNet discussed along with simulation results
- **Chapter 5: Proposed Handover Scheme**

  We have presented our proposed handover scheme over the previous one with the differences in the methods.
- **Chapter 6: Simulation of Proposed Handover Scheme**

  Simulation and the results of our proposed handover scheme are shown.
- **Chapter 7: Conclusion**

  Summary of the main ideas and conclusions presented in this study, along with The considerations for the study and what could be done in the future.

Chapter 2

LTE and Heterogeneous Network

2.1 Introduction

This chapter focuses first on describing LTE-Advanced, explaining its architecture and most relevant features. After that, Heterogeneous Network concept is depicted, along with an explanation of main challenges and techniques used in co-channel and dedicated carrier deployments.

2.2 LTE - Advanced Overview

As mentioned before, mobile data traffic is growing fast. This is mainly due to the introduction of new devices that are capable of providing a variety of data-oriented services such as web browsing, video and audio streaming, online gaming, etc. This represents a huge challenge for the operators since they are responsible for carrying most of this data.
In order to fulfill these demands, the 3rd Generation Partnership Project (3GPP) developed a new mobile broadband technology called Long Term Evolution (LTE). The first version of LTE (called LTE Release 8) was completed in March 2009 with the purpose of satisfying the current and future demands. LTE introduces new features, such as flexible spectrum and a flat network architecture, which help to achieve much higher performance over previous 3GPP standards (e.g. HSPA), especially in terms of DL and UL peak data rates, spectral efficiency and latency [4]. However, these improvements do not meet the needs of the expected demands, and, for that reason, at the end of 2010, the 3GPP submitted a major enhancement of the existing LTE standard called LTE Release 10 or LTE-Advanced1 (LTE-A) as a proposal to fulfill the International Mobile Telecommunications-Advanced (IMT-A) requirements issued in 2008. As seen in [13], some of these requirements are:

• 100 Mbps peak data rate support for high mobility and up to 1 Gbps peak data rate for low mobility case;

• Allow inter-working with other radio access systems;

• Cell spectral efficiency, ranging from the 3 bits/Hz/cell in the indoor downlink scenario, to the 0.7 bits/Hz/cell in the high speed uplink scenario;

• Peak spectral efficiency, ranging up to 15 bits/s/Hz;
• Bandwidth scalability up to and including 40MHz, up to 100 MHz should also be considered;
• Latency requirements for control plane to achieve 100 ms transition time between idle and active state, and respectively to enable 10 ms user plane latency (in unloaded conditions)
• Mobility support up to 350 km/h

Many of these demands were already met by LTE Release 8. For that reason, 3GPP also defined its own requirements for LTE-Advanced that, in some areas, exceed the ones issued by the ITU-R, especially in terms of peak and cell-edge spectral efficiency [14]. This ensures an incremental step of performance and capabilities between the successive releases. More detailed information about LTE-A requirements can be found in [15].

The performance improvement brought by LTE-A is mainly achieved thanks to the introduction of new features. As seen in [16], some of these are:
• Intra and Inter-band Carrier aggregation (CA)
• Enhanced MIMO
• Coordinated multipoint transmission and reception (CoMP)

Apart from these, LTE-A also introduces the eICIC functionality for co-channel deployment of HetNets and also, relay nodes for backhauling the base stations via LTE radio interface.

These two features aim at enhancing the network capacity and coverage.
The most relevant features that are related to this work will be further described along this chapter. More detailed information can be found in [17].

2.2.1 Network Architecture

Both the Radio-Access Network (RAN) and the core network were modified in order to obtain a much more simplified network. This process led to what is called System Architecture Evolution (SAE) which consists of a flat architecture that comprises a new core network referred as the Evolved Packet Core (EPC), as well as a new RAN named Evolved-Universal Terrestrial Radio Access Network (E-UTRAN). Figure 2.1 depicts a simple LTE architecture example including the main standardized interfaces.

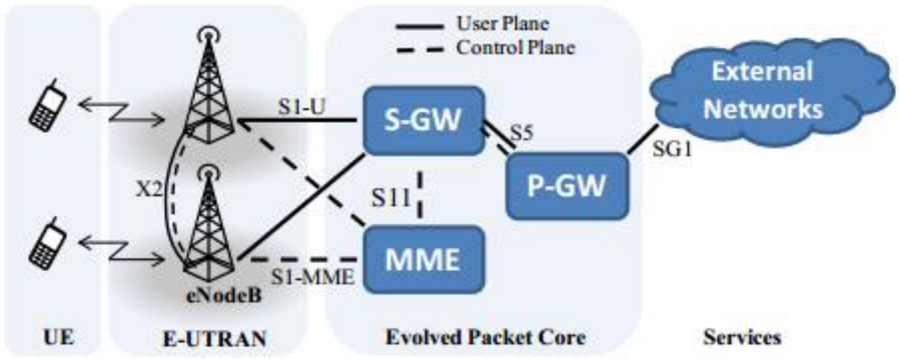

Figure 2.1: LTE Network Architecture

Evolved Packet Core Overview

LTE packet core network assumes a full Internet Protocol (IP) network architecture and is designed to support voice in the packet domain. It includes support for multiple access networks, including 3GPP legacy e.g. GSM and UMTS, and some others non-3GPP systems (for example WiMAX or cdma2000).

The main components and functionalities of the EPC are the following:

• **Mobility Management Entity (MME):** is the main control element in the EPC. The MME is in charge of user mobility, bearer set-up, and some security functions such as authentication and temporary identification of the user.

• **Serving Gateway (S-GW):** is responsible for routing and forwarding user data packets among different LTE nodes. It is also a key part in inter-eNodeB mobility events.

• **Packet Data Network Gateway (P-GW):** is the termination node of the EPC and provides to the UE access to external packet data networks (e.g. Internet).

E-UTRAN Overview [9]

The E-UTRAN consists of base stations (called evolved Node B in LTE) that are interconnected with each other via the X2 interface.

The LTE evolved Node B (**eNodeB)** is the only node in the E-UTRAN and is in control of all Layer 1 and Layer 2 radio related functionalities. The eNodeB acts as a bridge between UE and

the EPC, relaying data between the radio interface and the EPC through the S1 interface. Other

functionalities of the eNodeB are:

• Channel coding and de-coding.

• Radio Resource Control: this relates to the allocation, modification and release of resources for the transmission over the radio interface between the user terminal and the eNodeB.

• Radio Mobility management: this refers to a measurement processing and handover decision.

• Radio Resource Management (RRM): administrates the usage of the radio resources.

Additionally, the **X2 interface** is also a new element introduced in the E-UTRAN that gives the possibility to connect eNodeBs with each other. The main purpose of this interface is to allow the exchange of signaling information [18] making possible some of the features described above, especially those related to user mobility and RRM. The X2 interface is a logical interface, this means that the eNodeB are not necessarily connected together with a physical direct connection, in fact, it is usually routed in the same transport connection as the S1 interface [17].

Since most of the contributions of this project are closely related to E-UTRAN functionalities, a special emphasis will be put on the E-UTRAN functions that are most relevant in this study.

These include some of the layer 1 to layer 3 features such as: MIMO, RRM algorithms, carrier aggregation, among others.

A home eNB (HeNB) is a base station that has been purchased by a user to provide femto cell coverage within the home. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

2.3 Heterogeneous Networks

Traditionally, mobile broadband networks are deployed as homogeneous networks consisting of macro cells. The placement of the macro base stations is carefully planned in order to allow the maximum coverage and manage the interference amongst them. In these networks all the base stations have similar transmit power levels, antenna patterns, backhaul connectivity and receive noise limit. Besides, all cells grant unrestricted access to the UEs in the network [4]. An example of a traditional network deployment can be seen in Figure 2.2.

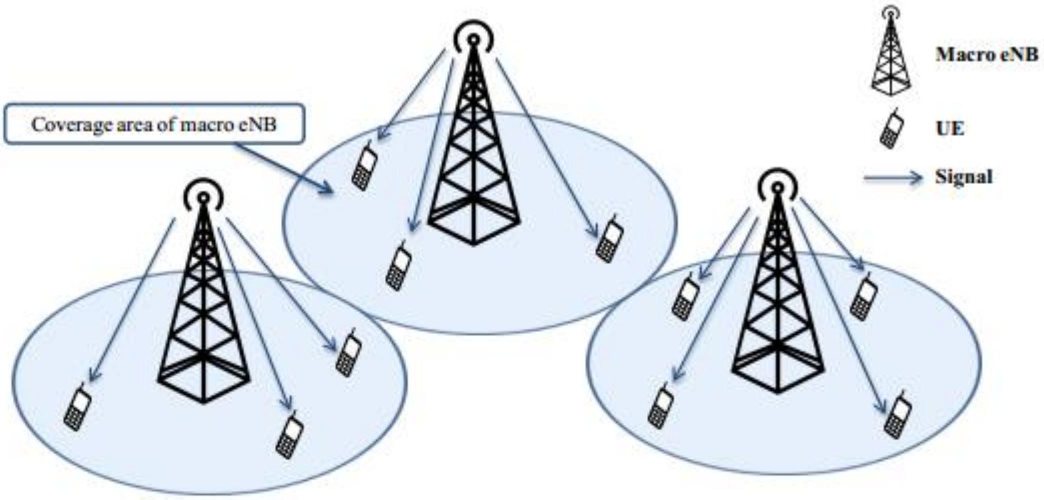

Figure 2.2: Homogeneous Network Deployment

A Heterogeneous Network (HetNet) consists of a series of low-power nodes that are distributed throughout the existing macro cell network. The LPNs (also called small cells) transmit at significantly lower power levels. This deployment allows to improve the spectral efficiency per unit area, as the low-power cells make possible to remove coverage holes in the macro-only network and increase the capacity in zones with very high traffic volume (usually called hotspots) [4]. Therefore, Heterogeneous Networks are envisioned as the major performance improvement enablers of LTEAdvanced [28]. A possible HetNet deployment is shown in Figure 2.3.

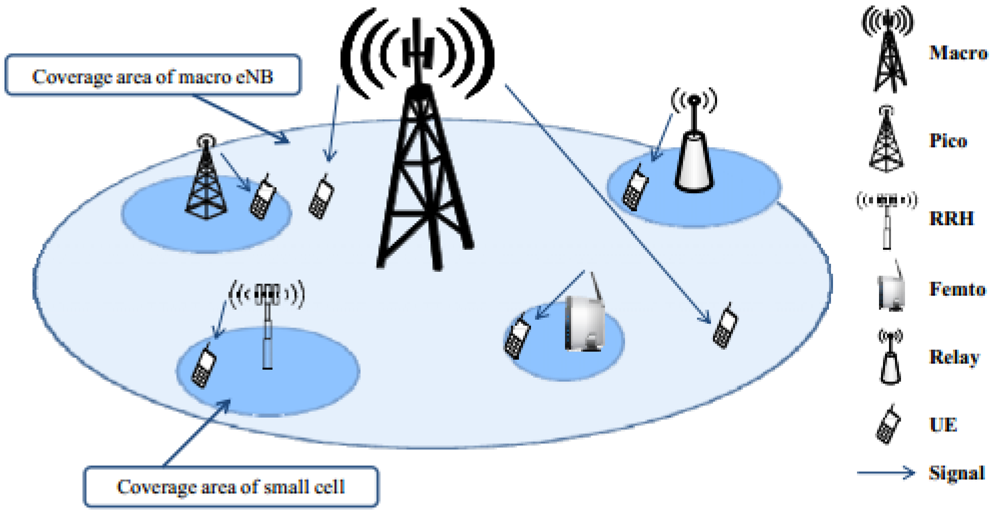

Figure 2.3: Heterogeneous Network Deployment

There are different types of small cells that can be deployed in a HetNet. Small cells can not only be operator deployed as macro cells, but also user deployed. Some of them can be coexisting in the same area. A summary of macro and small cells characteristics can be seen in Table 2.1 [19] A detailed description of the different small cell types can be found in [2] [4] [20]

Table 2.1: Different types of cell in Heterogeneous Network

Types of nodes	Transmit power	Coverage	Placement	Access
Macrocell	46 dBm	Few km	Outdoors	Open to all UEs
Microcell	30 - 37 dBm	< 2 km	Outdoors	Open to all UEs
Picocell	23 - 30 dBm	< 300 m	Indoors or outdoors	Open to all UEs
Femtocell	< 23 dBm	< 50 m	Indoors	Open or restricted (CSG)
Relay	30 dBm	300 m	Outdoors	Open to all UEs
RRH	30 dBm	300 m	Indoors or outdoors	Open to all UEs

Macro cells and most small cells are connected via S1 or X2 interface. These interfaces introduce some delay in the transmission. On the other hand, RRH nodes use a fiber fronthaul, which has nearly zero delay and, therefore, it can be considered as an ideal backhaul.

It is worth noticing that an ideal backhaul is considered thorough this study. However, for the sake of simplicity, we will refer to the small cells as pico cells. Two different kinds of deployments can be used in a HetNet, as explained in [2]: cochannel deployment and dedicated carrier deployment. Following sections explain the main design features of each one.

Macro and Small Cell Description

Below a brief description of the main characteristics of macro cells and the different types of small cells [2] [4] [20]:

• **Macro** nodes cover a wide area, usually a few kilometers, transmitting typically at 46 dBm power. They are installed by the operators, and serve openly thousands of users, using a dedicated backhaul. They are also known as enhanced NodeBs (eNBs) in LTE.

• **Pico** nodes are regular base stations but with lower transmit power, usually between 23 and 30 dBm. They typically cover areas of 300 meters or less. Their placement is planned by the operators so as to increase capacity in hotspots and enhance coverage in areas with poor macro penetration (like malls or office buildings). They can be placed indoors or outdoors, and usually have omni-directional antennas. The access is open to all users.

• **Micro** nodes are similar to pico nodes, but their coverage area is bigger, usually around 2 kilometers, and they are deployed outdoors.

• **Femto** cells, also known as home eNBs (HeNBs) are user deployed. They have low transmit power, typically less than 23 dBm, and they cover a small area, like a house (less than 50 meters). The backhaul connectivity is facilitated by the user's home digital subscriber line (DSL) or cable modem. They are placed indoors in an unplanned manner, and have omni-directional antennas. Femtos are classified as open or closed depending on whether they allow access to all users or just to a closed subscriber group (CSG).

It is worth noticing that closed femtos are a source of interference for the users to which they refuse access. Thus, closed femtos cause coverage holes in co-channel deployments.

• **Relay** nodes have transmit power and coverage area similar to picos, and are also deployed by the operators, but they possess a wireless backhaul. They are used to improve the signal strength and the coverage in deadspots (like tunnels or new areas). Relays can be in-band, if they use the same frequency for backhaul operation and communication with the UE, or out-of-band, if they use a different frequency for the backhaul.

Radio Access Technology Section

In-band relays have been the focus of studies as they do not need additional dedicated spectrum, contrary to out-of-band relays.

• **RRH** (Remote Radio Head) nodes have similar transmit power and coverage area than relays. They are compact and have light weight. RRHs allow more flexibility to operators in deployments with physical limitations or site acquisition problems as they are connected to a conventional macro base station and release it from some radio circuitry, thus decreasing power losses and consumption. Besides, they are very useful in the deployment of centralized architectures, as they connect to the macro through fiber, which allows for nearly ideal transmission (no delays). That allows the possibility of having all the processing at the macro site

Chapter 3

Handover in LTE Heterogeneous Network

3.1 Introduction

LTE pays a large emphasis on providing fast and seamless handover form a source cell to the target cell. Handover is one of the most important factors that may degrade the performance of system connections in wireless data networks. Handovers are used to keep mobile user connected to their network, even when these users move from one network access point to the other network access point. The main goal of the handover process is to maximize overall network utilization and provide the user best connectivity during their communication.

3.2 Overview

Handover is the procedure for changing the assignment of a mobile unit from one BS to another as the mobile unit moves from one cell to another. Handover is handled in different ways in different systems and involves a number of factors. There are two main handover technologies in wireless communication systems, hard handover and soft handover. Hard handover is a break-before-make method [21]. It means that a new wireless link connection with the target eNodeB should be set up after the release of the connection with the source eNodeB. Soft handover is a make-before-break method. It means that a new wireless link connection is established with the target eNodeB while the connection with source eNodeB is maintained [21]. The principal parameter used to make the handoff decision is measurement signal strength from the mobile unit at the base station.

3.3 Reason for Handover

To maintain the connection, a handover mechanism constantly scans the area. When a better network is found or the mobile unit is moving to another cell, then a handover procedure is started. In LTE eNodeB is responsible for handover decisions. The eNodeB contains all the Radio Network Controller (RNC) which makes EUTRAN flat network architecture.

3.4 Handover Parameters

The HO process can be controlled by various parameters such as HO hysteresis (HYST), Time to Trigger (TTT) etc. [23]

3.4.1 Hysteresis

The role of the hysteresis is to make the measured neighbor look worse than measured to ensure it is really stronger before the UE decides to send a measurement report to initiate a handover. The IE specifies the value of hysteresis, which is used for the determination of the entering condition of leaving condition for particular event-triggered measurement reporting. The value of hysteresis is calculated as (the IE value 0.5) db, where the IE value can be any integer up to 30.

3.4.2 Time to Trigger (TTT)

The role of time to trigger is to avoid a ping-pong effect. This field specifies the period during which the specific criteria for a particular event need to be met in order to trigger the measurement reporting. Its value can be 0, 40 , 64, 80, 100, 128, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560 or 5120 ms.

3.4.3 Threshold

This IE gives the threshold value for a particular event-triggerd measurement reporting as follows:[22]

- A1 Threshold: The Value of Threshold for event A1
- A2 Threshold: The Value of Threshold for event A2
- A3 Threshold: The Value of Threshold for event A3
- A4 Threshold: The Value of Threshold for event A4
- A5 Threshold: The Value of Threshold 1 for event A5
- A5 Threshold: The Value of Threshold 2 for event A5

3.4.4 A3- Offset

This parameter can be found in 3GPP 36.331. It configures the RRC IE a3-Offset included in the IE reportConfigEUTRA in the MeasurementConfiguration IE. The value sent over the RRC interface is twice the value configured, that is, the UE has to divide the received value by 2.The role of the offset in Event A3 is to make the serving cell look better than its current measurement in comparison to the neighbor.

3.5 Handover Triggering Events

LTE Events A1, A2, A3, A4 and A5 are based upon either RSRP or RSRQ messages.[24]

3.5.1 Event A1

The LTE Event A1 is triggered when the serving cell becomes better than a threshold. The event is triggered when the following condition is true:

MEAsserv - Hyst > Threshold

Triggering of the event is subsequently cancelled when the following condition is true:

MEAsserv + Hyst < Threshold

The hysteresis can be configured with a value between 0 and 30 dB.

3.5.2 Event A2

The LTE Event A2 is triggered when the serving cell becomes worse than a threshold. The event is triggered when the following condition is true:

MEAsserv + Hyst < Threshold

Triggering of the event is subsequently cancelled when the following condition is true.

MEAsserv - Hyst > Threshold

The hysteresis can be configured with a value between 0 and 30 dB.

3.5.3 Event A3

The LTE Event A3 is triggered when a neighbouring cell becomes better than the serving cell by an offset. The offset can be either positive or negative. The event is triggered when the following condition is true:

MEASneigh + Oneigh,freq + Oneigh,cell - Hyst > MEASserv + Oserv,freq + Oserv,cell + Offset

MEASneigh + Oneigh,freq + Oneigh,cell + Hyst < MEASserv + Oserv,freq + Oserv,cell + Offset

3.5.4 Event A4

The LTE Event A4 is triggered when a neighbouring cell becomes better than a threshold.

MEASneigh + Oneigh,freq + Oneigh,cell - Hyst > Threshold

Triggering of the event is subsequently cancelled when the following condition is true:

MEASneigh + Oneigh,freq + Oneigh,cell + Hyst <Threshold

3.5.5 Event A5

LTE Event A5 is triggered when the serving cell becomes worse than threshold-1 while a neighbouring cell becomes better than threshold-2. The event is triggered when both of the following consitions are true:

MEASserv + Hyst < Threshold-1

MEASneigh + Oneigh,freq + Oneigh,cell - Hyst >Threshold-2

Triggering of the event is subsequently cancelled when either of the following conditions are true:

MEASserv - Hyst > Threshold-1

MEASneigh + Oneigh,freq + Oneigh,cell + Hyst <Threshold-2

3.5.6 Event B1

The LTE Event B1 is triggered when a neighbouring inter-system cell becomes better than a threshold. The event is triggered when the following condition is true:

MEASneigh + Oneigh,freq - Hyst > Threshold

Triggering of the event is subsequently cancelled when the following condition is true:

MEASneigh + Oneigh,freq + Hyst < Threshold

3.5.7 Event B2

The LTE Event B2 is triggered when the serving cell becomes worse than threshold-1 while a neighbouring inter-system cell becomes better than threshold-2. The event is triggered when,

MEASserv + Hyst < Threshold-1

MEASneigh + Oneigh,freq - Hyst > Threshold-2

Triggering of the event is subsequently cancelled when either of the following conditions are true:

MEASserv - Hyst > Threshold-1

3.6 Types of Handover Procedure

Handover is handled in different ways in different systems and involves a number of factors.[22]

Based on the involvement of a change of RAT Handover is classified as;

3.6.1 Intra E-UTRAN handover:

This handover takes place between two E-UTRAN cells.

3.6.2 Inter-RAT handover:

Handover between different radio technologies. For example handover from LTE to WCDMA. This handover takes place between an E-UTRAN cell and a cell of RAT other than LTE.

Based on the interface between the source eNodeB and the target eNodeB there are X2-Based handover and S1-Based handover.

3.6.3 X2 Based Handover

If there is an X2 interface interconnecting the source eNodeB and the target eNodeB, then the handover procedure typically uses the X2 interface. In this case, the source eNodeB and the target eNodeB belong to the same MME. The X2-based handover procedure differs slightly in the two following cases:

- The handover does not change the serving GW.
- The handover changes the serving GW.

3.6.4 S1 Based Handover

The handover between E-UTRAN cells takes place using the S1 interfaces that interconnect the source eNodeB and the target eNodeB with their MMEs, typically when the X2 interface cannot be used. This may happen in the following cases:

- The X2 interface does not exist between the source eNodeB and the target eNodeB
- A change of MME or a change of the serving GW is required and the source eNodeB is configured to use the S1 interface because of the change.

- The target eNodeB rejects the attempt of the source eNodeB to initiate handover using the X2 interface

The handover procedure can also be classified based on the scenario for handover as follows:

3.6.5 Backward Handover

Backward handover can be described **as** network-controlled/UE-assisted mobility. Handover related information is exchanged between the UE and the source eNB via the old radio path thus, the usage of the term ‘backward’. Specifically, the radio conditions need to be good enough for the source eNB to be able to decode the Measurement Report from the UE and subsequently prepare the target cell for handover. The radio conditions also need to be good enough for the UE to be able to decode the Handover Command from the source eNB. There is a short interruption in service between the time that the UE decodes the Handover Command from the source eNB and the time that the target eNB decodes the Handover Confirm from the UE. However, data forwarding and in-order delivery ensures that none of the data buffered in the source eNB is lost.

3.6.6 Forward Handover

Forward handover can be described as UE-based mobility. Handover related information is exchanged between the UE and target eNB via the new radio path after the UE context is fetched by the target eNB from the source eNB hence the term ‘forward’ is used. Forward handover is successful even if the radio conditions are not good enough for the source eNB to be able to decode the Measurement Report from the UE and prepare the target cell. The success of the handover procedure even with complete failure of signaling with the source eNB makes forward handover robust to rapidly changing signal strength conditions. This will still incur an additional delay versus the backward handover procedure and, consequently, a longer interruption in service.

3.6.7 Blind Handover

The network makes a decision of handover without depending on any measurement reports from the UE. The blind handover can be quickly performed due to the avoidance of any measurement, so it can be used when the delay in handover is undesired. However the radio link quality at the new cell is uncertain. The blind handover typically occurs to move a user from a heavily loaded cell to a lightly loaded cell for the purpose of load balancing.

3.7 Handover Procedure Scheme

Generally X2 based backward handover between E-UTRAN cells are expected to take place. In most of the cases, both source and target eNBs are connected to the same MME and are located in the same tracking area (TA) [23]. The measurement reports cover the handover between two cells supporting the X2 interface between the eNBs.

The X2 procedure can be described in three steps as follows [24]:

3.7.1 Handover Preparation

Handover measurements and processing are performed by the UE. Handover measurements are usually based on downlink reference signal received power (RSRP) estimations [25]. This measurement reports contain information about the neighboring cells. Then UE sends the periodical measurement reports to the source eNB. When eNB decides that handover is necessary based on the measurement report, it triggers the handover. Depending upon the events (A1-A5) it chooses the best reported target cell for upcoming handover. Usually, a handover event is A3 event [26].

Then, the source eNB sends an X2 handover request to the target eNB. This message contains the information needed to perform the handover such as UE context information, Radio Access Bearer (RAB) context, Target Cell ID. The target eNB performs call admission control and if it is able to provide the requested resources for the new UE, it sends a handover (HO) request acknowledgment (ACK) to the source through the X2 connection. The source eNB receives this message that includes the RRC Connection Reconfiguration message in a transparent container that the source eNB has to forward to the UE. In the RRC message, L1/L2 parameters are provided to the UE in order to be synchronized with the target eNB. Finally, the source eNB sends the HO command message that encloses the RRC Connection Reconfiguration message to the UE. If the target eNB cannot accept the Ho request, it responds to the source eNB with an X2 negative acknowledgement message. During this step, the UE states remain unchanged.

3.7.2 Handover Execution

UE receives the RRC Connection Reconfiguration message and transits to the RRC idle state triggering the detachment from the source eNB. The source eNB sends the Sequence Number (SN) status transfer message that contains the Packet Data Convergence Protocol (PDCP) sequence numbers to the target eNB through X2 interface. For UL the first missing data unit is included and for DL the next sequence number to be allocated. Then, UE is synchronized with the target based on the given parameters and send the HO Confirm message that encloses the RRC Connection Reconfiguration Complete to acknowledge the successful handover to the target eNB. As a result, the UE transits to the RRC connected state with respect to the target eNB. Concerning the UE synchronization, if a dedicated random access preamble has been received in the RRC Connection Reconfiguration message, the UE does not need to perform the random access procedure, i.e., contention free Random Access Channel (RACH) process. If this is not the case, the UE performs the normal random access procedure [26].

3.7.3 Handover Completion

The target eNB receives the RRC Connection Reconfiguration Complete message and the path switch procedure is initiated between the target eNB and the MME/S-GW. The target eNB starts to forward all the packets received from the X2 interface to the UE before any new ones coming from the Serving Gateway (S-GW). The target eNB receives the end-marker from the old path switch and starts transmitting packets from the new path switch. Afterwards, the source eNB UE context is released via receiving UE release context message from the target eNB. Finally, the S1 bearer that was initially established between source eNB and UE is also released.

All the steps are illustrated at the figure 3.1 which shows inter-eNB X2 based backward handover procedures in LTE Heterogeneous networks.

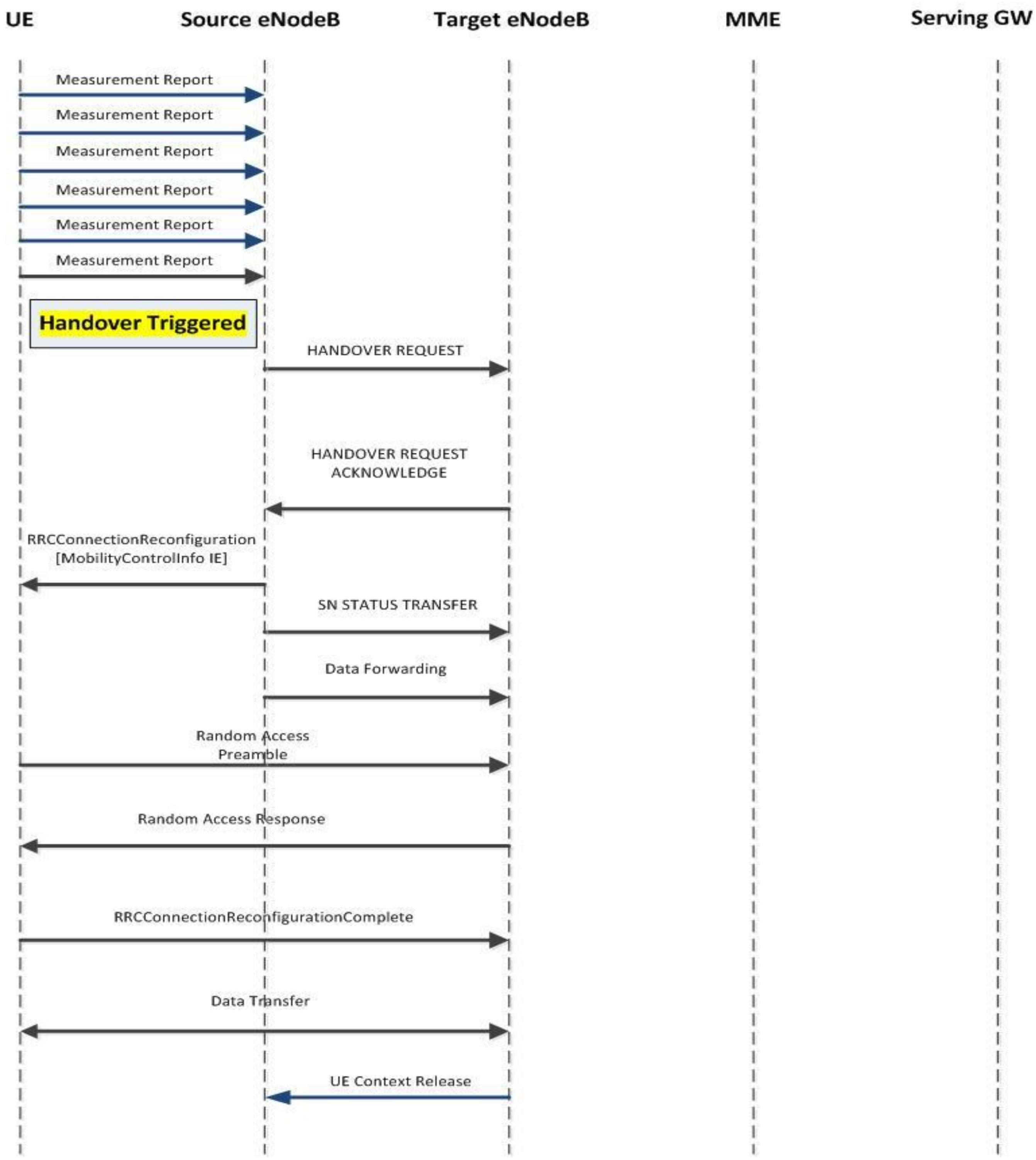

Figure 3.1: Inter-eNB X2 based backward handover procedures in LTE Het-Net.

Chapter 4

Het-Net Handover Problems

4.1 Introduction

In order to meet the mobile data traffic explosion, the most straightforward approach is to deploy more base stations. With more base stations, radio resources can be reused more often per area, effectively increasing the spectral efficiency per area. In this context, HetNets, which are comprised of coexisting macro cells and low power nodes (LPNs) such as pico cells, femto cells, and relay nodes, have been attracted as the most promising solution to provide a major capacity booster. However, in order to realize the potential coverage and capacity benefits of HetNets, operators are facing new technical challenges in, for example, mobility management, interference management, and backhaul provisioning.

4.2 Mobility Management

Mobility management is a major challenge in the Het-Net where the main difference from macro only networks is that the link connection to an LPN degrades quickly when moving out of the LPN coverage. Furthermore, very limited LPN coverage and densely deployed LPNs may lead to frequent handovers and increased handover failures [28]

Due to its capital importance, mobility management challenges in HetNets have attracted much interest from the 3rd Generation Partnership Project (3GPP). In Release-11 study item, detailed simulation has been carried out to assess HO performance in HetNet with the radio link failure rate and ping-pong rate as the metrics.

4.2.1 Radio link Failure

Radio link failure (RLF) is a common phenomenon in LTE HetNet when the radio channel signal strength is weak to continue with the application. RLF is a local event detected by UE immediately and network nodes come to know later. It is also difficult to recover for the UE due to low signal. Hence, RLF has to be dealt locally by the UE.

Radio link failure (RLF) occurs in a mobile handset when it experiences interference and/or poor signal strength leading to disconnection with the base station. This leads to discontinuation of the Handover procedure. Radio link failure results in the sudden increase of SINR. For Hysteresis and TTT delay (large) Radio link reaches PDCCH outage. Radio link failure occurs due to loss of radio coverage or unacceptable level of interference in the air interface between the mobile and network.[29]

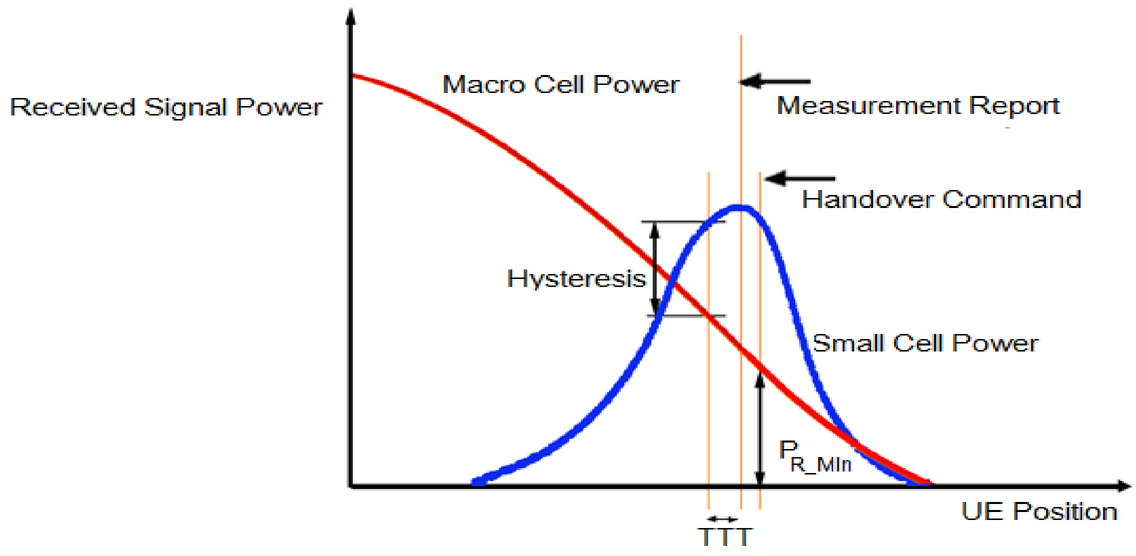

Figure 4.1: Radio Link Failure (Received Signal Power vs. UE position)

4.2.2 Ping Pong Effect

Handover decision mechanisms generate a ping pong effect caused by the inefficiency of the network handover metrics which do not consider the required end user performance. The ping-pong movement in LTE HetNet is one of the most crucial problems which reduce the quality of the connection and degrade the performance of the handover.

Example:

Cell A handovers a user to Cell B and Cell B handovers the same user back to Cell A shortly after. In most of the cases, those two successful handovers can be avoided, for example, by a larger handover hysteresis. The left plot in Figure 4.2 shows two ping-pong situations.[29]

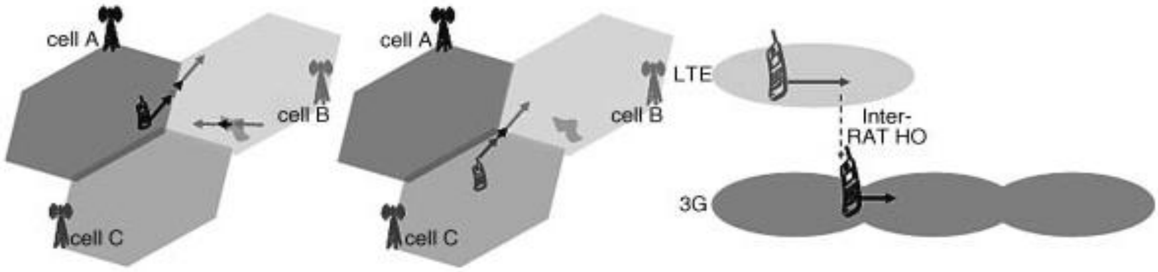

Figure 4.2: Unnecessary handovers ping-pong

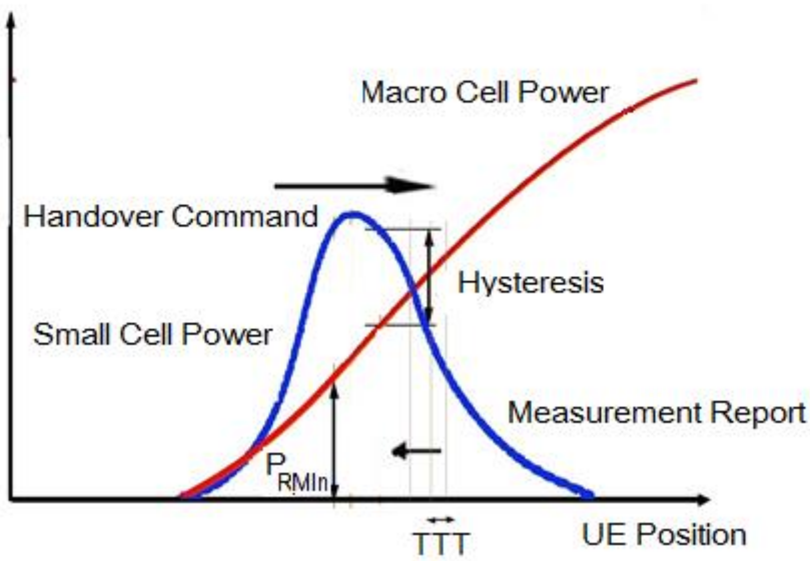

Figure 4.3: Ping-Pong Effect (Received Signal Power vs. UE position)

4.3 HetNet Handover Failure

The HO performance was not as good as in pure macro deployment. Of the different HO types, Pico-to-Macro (P-M) handover shows the worst performance while Macro-to-Pico (M-P) handover shows only a little better. The UE speed has a significant impact on the HO performance. The trend of simulation results indicated that high speed UEs suffer much higher HOF rate than low speed UEs. [26]**.** In a recent simulation result, without UE's speed dependent HO parameter optimization, a HOF rate is about 50% in P-M HO case and about

36% in M-P HO case. With UE's speed dependent HO parameter optimization, a HOF rate is about 35% in P-M HO case and about 21% in M-P HO case [30].

In conventional macro-only homogeneous networks, the UE typically use the same set of handover parameters such as handover margin (HOM) and time to trigger (TTT) throughout the network. To suppress the impact of fading, TTT is introduced to make the measurement results reported by UE with sufficient stability. However, in HetNet environment, where macro cells, pico cells, femto cells, and relay nodes have different coverage area sizes, using the same set of handover parameters for all cells and/or for all UEs may degrade mobility performance. Therefore, in HetNets, there is a need for cell-specific or UE-specific handover parameter optimization. Moreover, when high-speed UE moves from pico cell to macro cell, it may run deep inside LPN coverage areas before the TTT optimized for macro cells expires, thus incurring handover failure due to degraded downlink signal.

Compared to the HO region between the same type of source cell and target cell, the HO region between different type of source cell and target cell in HetNet is much smaller as shown in Fig. 4.4. In [31], with 500m inter-site distance (ISD) between macro cells and 125m ISD between macro cell and Pico cell, it says the size of HO region of Macro to Macro (MM) HO is 22.5m, but the size of HO region of M-P HO is only 2.375m.

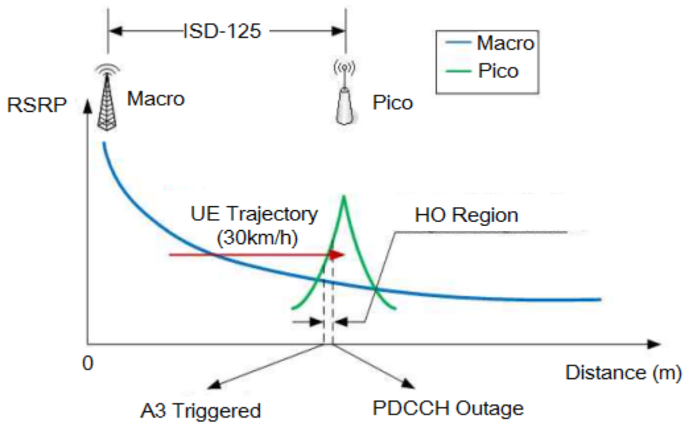

Figure 4.4: HetNet handover region

Table 4.1 shows elapsed time during the UE will pass through the HO region of M-P HO and required TTT for successful HO per UE speed with assumption of the handover preparation delay of 50ms. If TTT is set 256ms to all UEs without consideration of UE speed, then the HO will fail with UE speed of more than 30Km/h. If TTT is set 80ms to all UEs, then the HO will fail with UE speed of more than 120Km/h. Therefore the UE mobility speed estimation (MSE)-based TTT scaling algorithm is adopted in LTE from Release-8 [26]. But the MSE is not as accurate in HetNet environments as in macro only deployments since it does not take into account cell sizes.

Table 4.1 ELAPSED TIME & REQUIRED TTT PER UE SPEED

UE speed (Km/h)	Elapsed time (ms)	MAX TTT (ms)
3	2850	2800
30	285	235
60	142.5	92.5
120	71.25	21.25

The LTE HO timing is shown in Fig. 4.5. If the event A3 condition is satisfied throughout the TTT, the UE send a MR to serving eNB. After HO preparation delay, the UE can receive a HC from serving eNB which instructs to execute HO. In high speed UE case, the UE moves closer to PDCCH outage during TTT and HO preparation delay. The UE will overpass PDCCH outage boundary and fail to receive the HC from serving eNB which incur HOF.[25]

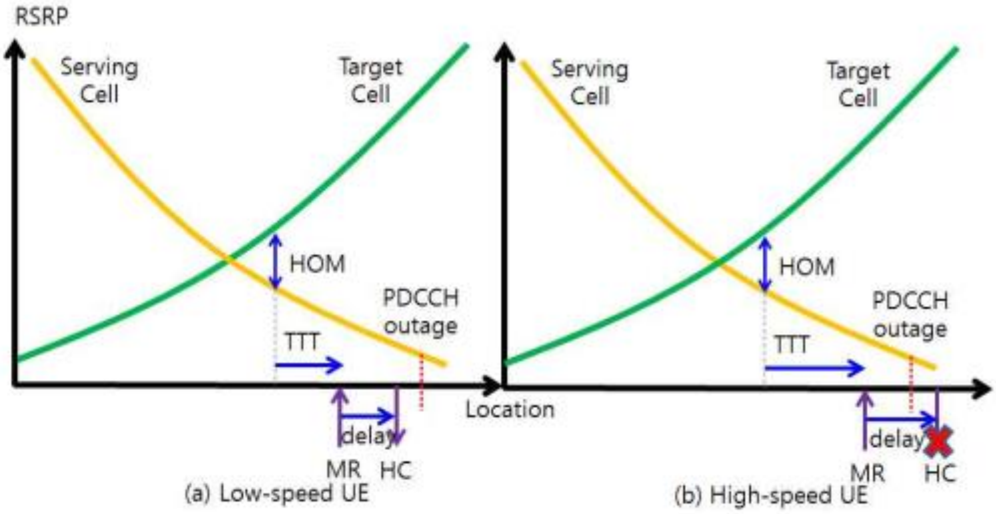

Figure 4.5: LTE Handover Timing

To determine a more accurate handover triggering point is a critical issue greatly reduces the failure probability of handover. Too early handover triggering will cause ping-pong effect problems because the UE tries to switch to the source cell again shortly after a successful handover to the target cell. Too early handover triggering occurs because of a failure in the target cell radio link after a handover has been finished. The UE tries to re-establish its radio link with the source cell. Another reason for too early handover is radio link failure in the target cell during the handover process. The UE tries to re-establish its radio link in the source cell.

Similarly, too late handover triggering will also lead to handover failure. In this situation, the handover procedure in the source cell is initialized too late since the UE is moving faster than the handover (HO) parameter settings. Hence, when the HO command from the serving cell is transmitted, the signal strength is too weak to reach the UE which is located now in the target cell. Hence, connection is lost. How to find an exact handover triggering point to increase the success probability of handover and to decrease handover overheads is a critical issue and many researches were targeted this point.

Chapter 5

Proposed Handover Scheme

5.1 Introduction

Many Handover Procedure has been proposed to improve overall HO performance with regard to HOF rate and [32]. There are three main directions [33]. Solution Direction 1 builds on current speed based mechanisms and tries to enhance these mechanisms. Solution Direction 2 tries to look at the radio conditions themselves. Solution Direction 3 assumes there is no serious problem and considers only small enhancements. And after RAN2#82 meeting, 18 solutions from 12 companies are proposed to further discuss the solution for mobility performance improvement [34]. From our point of view, we think handover mechanism solely based on the radio conditions themselves will be versatile and future-proof. So we propose a solution solely based on modified forward handover.

5.2 Forward Handover vs. Backward Handover

In classical handover for LTE HetNet, mobility support for User Equipment in connected-state is Backward Handover. For backward handover to complete, the radio conditions need to be good enough for the source eNB to be able to decode the Measurement Report from the UE and subsequently prepare the target cell for handover. The radio conditions also need to be good enough for the UE to be able to decode the Handover Command from the source eNB.

For Forward Handover, Handover related information is exchanged between the UE and target eNB via the new radio path after the UE context is fetched by the target eNB from the source eNB. Forward handover is successful even if the radio conditions are not good enough for the source eNB to be able to decode the Measurement Report from the UE and prepare the target cell. The success of the handover procedure even with complete failure of signaling with the source eNB makes forward handover robust to rapidly changing signal strength conditions.[35]

5.3 Proposed Handover Scheme

We propose a modified X2 based forward handover scheme that improves HO performance with regard to HOF rate in a HetNet. Here the classical A3 handover triggering event is adapted by taking into consideration the distance between the UE and the base stations. This procedure reduces the number of measurement procedures which improves the system performance by decreasing the total processing power over distance.

5.3.1 Handover Preparation

When a HO preparation event is triggered, the source eNB sends X2 Handover Request message which contains the information needed to perform the handover operation to more than one potential eNBs with handover resources whereas previously it chose only one potential target eNB. Here the measurement report is not important as for forward handover; the handover does not depend on the measurement of neighboring cells. After receiving the Handover request through X2 interface the target eNBs perform call admission control. The target eNBs with resources to allocate the UE send a Handover request acknowledgment to the source eNB through X2 interface and if some are unable to receive the upcoming UE they send a negative acknowledgement (NAK). . The source eNB receives this message that includes the RRC Connection Reconfiguration message in a transparent container that the source eNB has to forward to the UE. Finally, the source eNB sends the HO command message that encloses the RRC Connection Reconfiguration message to the UE.

5.3.2 Handover Execution

After receiving a RRC Connection Reconfiguration message, the UE does not execute HO immediately and performs measurement continuously. The UE decides an optimal HO time and an optimal target eNB based on the measurement of the parameters. Because the UE has the best knowledge of its radio conditions in a timely manner, its decision can be the best optimum. The UE transits to the RRC idle state triggering from the source eNB. The RRC connection reconfiguration message contains L1/L2 parameters for the UE in order to be synchronized with the target eNB. In previous method, the source eNB calculated the suitable target eNB. For uplink the first missing data units is included and for downlink the next sequence number to be allocated. Then, UE is synchronized with the target based on the given parameters and send the HO Confirm message that encloses the RRC Connection Reconfiguration Complete to acknowledge the successful handover to the target eNB. As a result, the UE transits to the RRC connected state with respect to the target eNB. Concerning the UE synchronization, if a dedicated random access preamble has been received in the RRC Connection. In return the selected target eNB sends back a random access response to the UE. The UE sends the Sequence Number (SN) status transfer message that contains the Packet Data Convergence Protocol (PDCP) sequence numbers to the target eNB through X2 interface.

5.3.3 Handover Completion

After sending the Sequence Number (SN) status transfer message, a RRC Connection Reconfiguration Complete message is transmitted to the target eNB by the UE. Then the path switch procedure is initiated between the target eNB and the MME/S-GW through the X2 interface. The target eNB starts to forward all the packets received from the X2 interface to the UE before any new ones coming from the Serving Gateway (S-GW). The target eNB receives the end-marker from the old path switch and starts transmitting packets from the new path switch. The source eNB performs data forwarding to the selected target eNB after receiving a HI. The UE disconnects from the source eNB and connects to the target eNB concurrently. And the source eNB sends a resource release message to other potential target eNBs if necessary after receiving notification of handover completion.

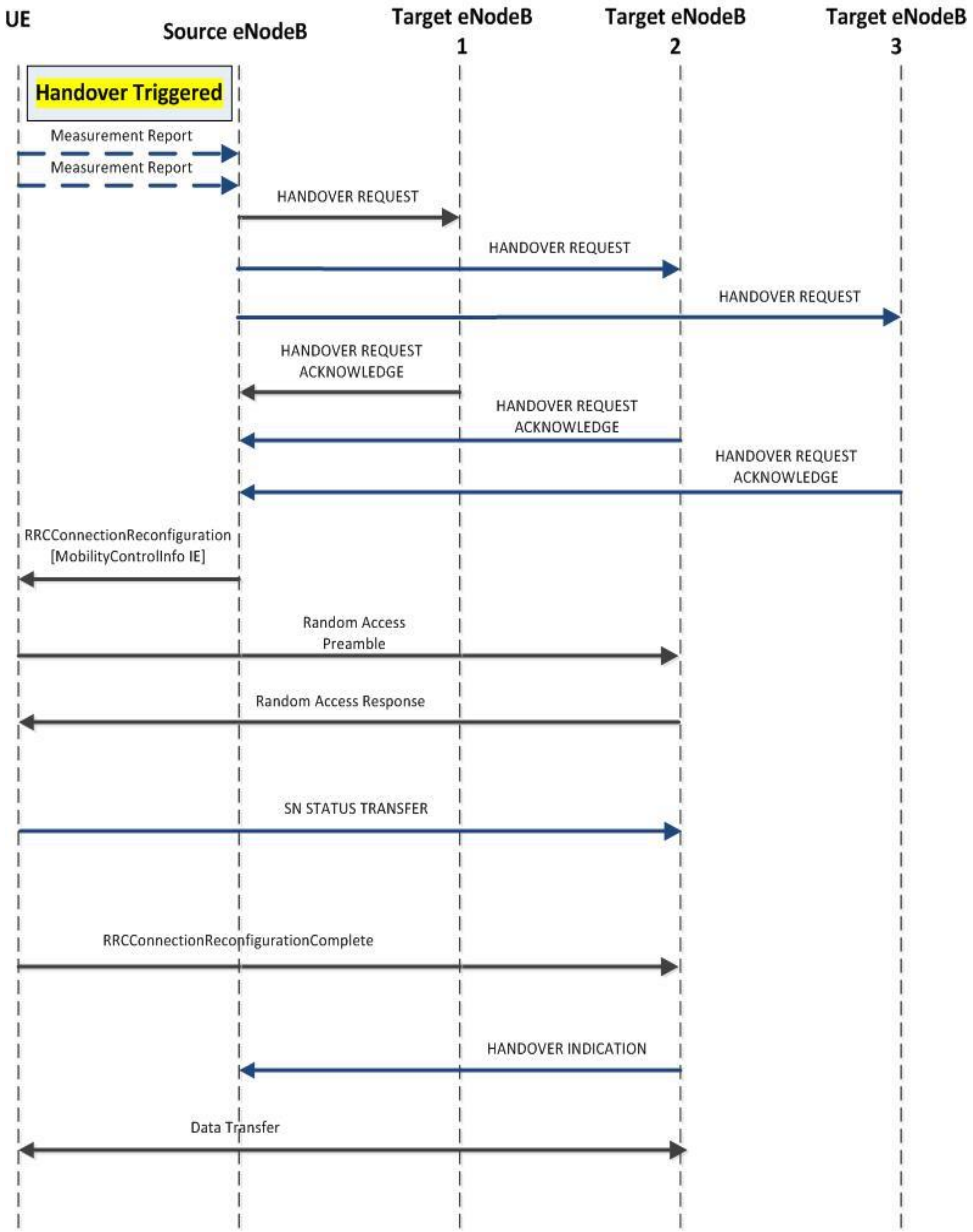

Figure 5.1: Proposed X2 based Modified Forward Handover

Chapter 6

Simulation of Forward Handover

6.1 Introduction

The purpose of the simulation is to prove whether our proposed Handover scheme is performing better than the existing backward scheme or not. To prove it we need to show the improvement of Minimum Received Power in case of proposed handover scheme while handover procedure going on from Pico cell to Macro cell.

6.2 Handover Simulation Scenario

To simulate and compare between backward existing Handover and Proposed Handover we built a scenario consisting one Pico Cell, one Macro Cell and one UE (user). In this scenario UE starts moving in a constant speed from Pico Cell area to Macro Cell area in 1-D motion. The starting position of UE is (0, 0, 0). The Inter Site Distance (ISD) is 500 meter which means the Macro eNodeB is 500 meters away from Pico eNodeB and Macro eNodeB position vector is (500, 0, 0). As UE starts moving towards Macro eNodeB , the received power keep decreasing because of the path loss and interference of the Macro Cell eNodeB. At some point in the middle the serving Pico Cell received power will be less the received power from Macro Cell by A hysteresis. At that point Handover will start and after a time TTT (Time-to-Trigger) the handover messages will go on as stated earlier. After TTT time passed the UE will send numbers of Measurement Reports to the serving eNodeB according to the existing Handover Scheme. The interval between sending each measurement report is called Reporting Interval. Both TTT and Reporting Interval is important parameters for this simulation.

With the increment of TTT and Reporting Interval the minimum received power will be lower and in our scheme as there is no need to send measurement report. We will get benefit from in terms of user movement at different speeds. More the speed less the minimum received power.

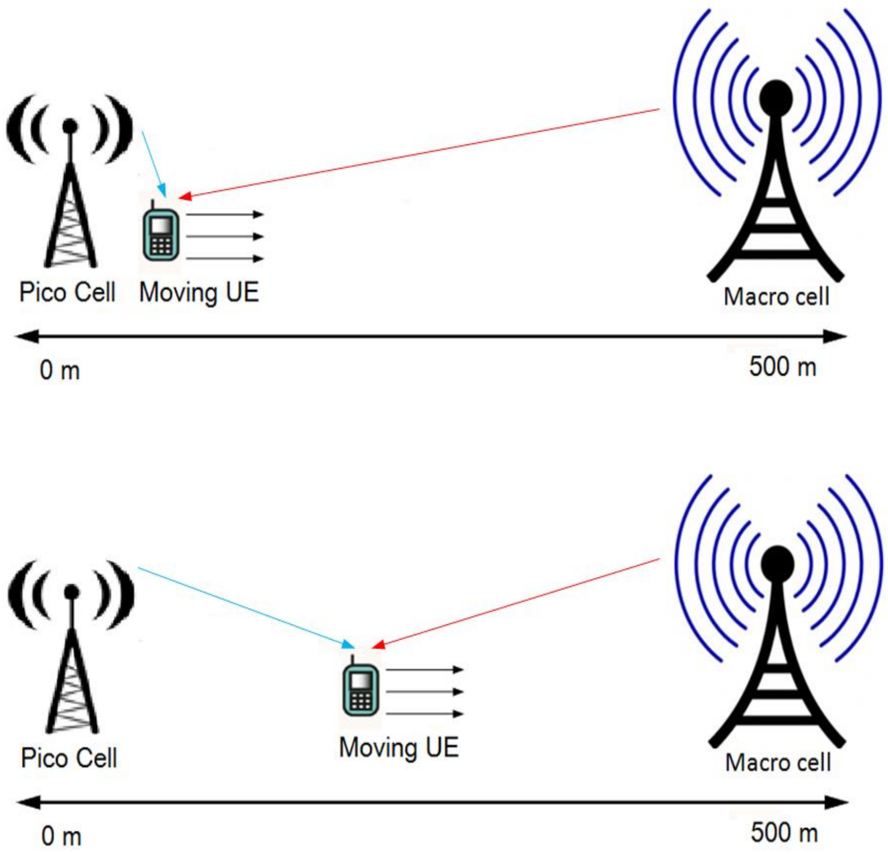

Figure 6.1: Handover Scenario

In figure 6.1 the scenario is stated. As user moving from Pico cell to Macro cell environment there will be a point where handover will take place. We are calling that particular locations power is minimum received power (**P_{rmin}**).

6.3 Handover Parameters

The most important part of the simulation is choosing the parameters to show the improvement in terms of minimum received power. We will pick some parameters to carry on our simulations.

The parameters we choose is –

- TTT (Time to Trigger)

- Reporting Time Interval
- Number of Measurement Report sent

As per 3GPP technical report [*] the simulation parameters for LTE HetNet are given. From those parameters values we choose the following parameters for simulation purpose. To

Table 6.1: Handover Parameters

SET	TTT (ms)	Reporting Interval (ms)
1	40	120
2	80	480
3	160	1024
4	480	5120

From the table we can say that, SET 1 parameters are the best case scenario for the current Handover Scheme. And for SET 4 it will be worst case scenario. The UE will require most time to complete a handover in case of SET 4 parameters and for SET 1 case it will require least time.

The objective to set the parameters in this fashion is to compare between the worst case and best case performance of our proposed scheme and existing backward handover.

Now we need to set up the physical parameters of the scenario such as Macro Pico transmission power, path loss model etc. The parameters were chosen in following table shown

Table 6.2 Handover Physical Parameters

Simulation Parameters	***Macro Cell***	***Pico Cell***
No. of Cell	*1*	*1*
Hysteresis	-	*5 dB*
Tx Power	*46 dBm*	*23 dBm*
Distance	*500 m*	*500 m*
Path loss model	*128.1+(37.6*log10(d)) , d in kilometer*	*140.7+(36.7*log10(d)) , d in kilometer*
No. Reports	*{5 , 7 , 10 }*	*{5 , 7 , 10 }*

Here No. of reports was chosen among the given list of values.

6.4 MATLAB Simulation

We've simulated the Prmin vs UE velocity by numerical solution. By using above mentioned pathless formula we created MATLAB function to calculate the Received power which has input argument of Tx power and distance travelled. The Rx power is in the output. Distance travelled is calculated with the

$$d' = velocity \times ((TTT + (Report\ Interval \times No.\ of\ Reports))$$

$$d = d' + dmin$$

$$RxPower = power\_pico(d)$$

The received power than is than plotted in graph of both the existing and proposed handover. Velocity values were { 0 , 10 ,20 , 30 , 40 , 50 , 60 ,70 , 80 ,90 , 100} kilometer per Hour. And received power in dBm values.

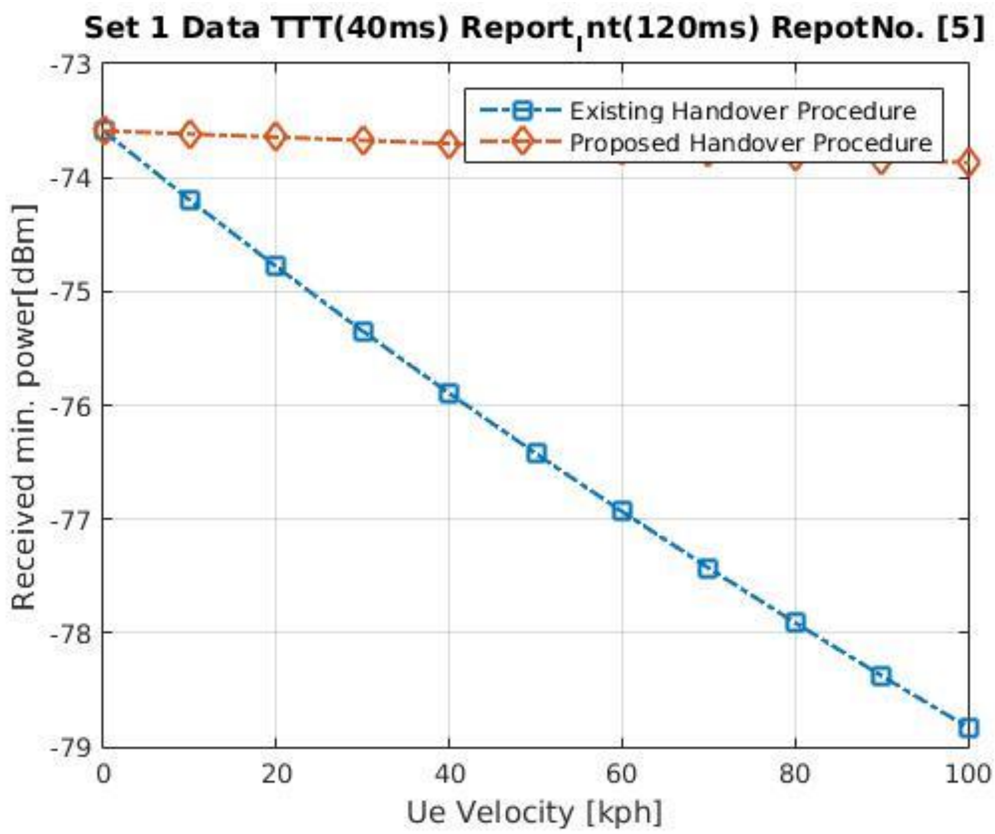

Figure 6.2: Set1 Data Comparison Report Number.5

In this figure we calculated for SET 1 data and found out that the proposed method severs better Prmin than the existing method in terms of Pico – Macro Handover. The number of report here is 5.

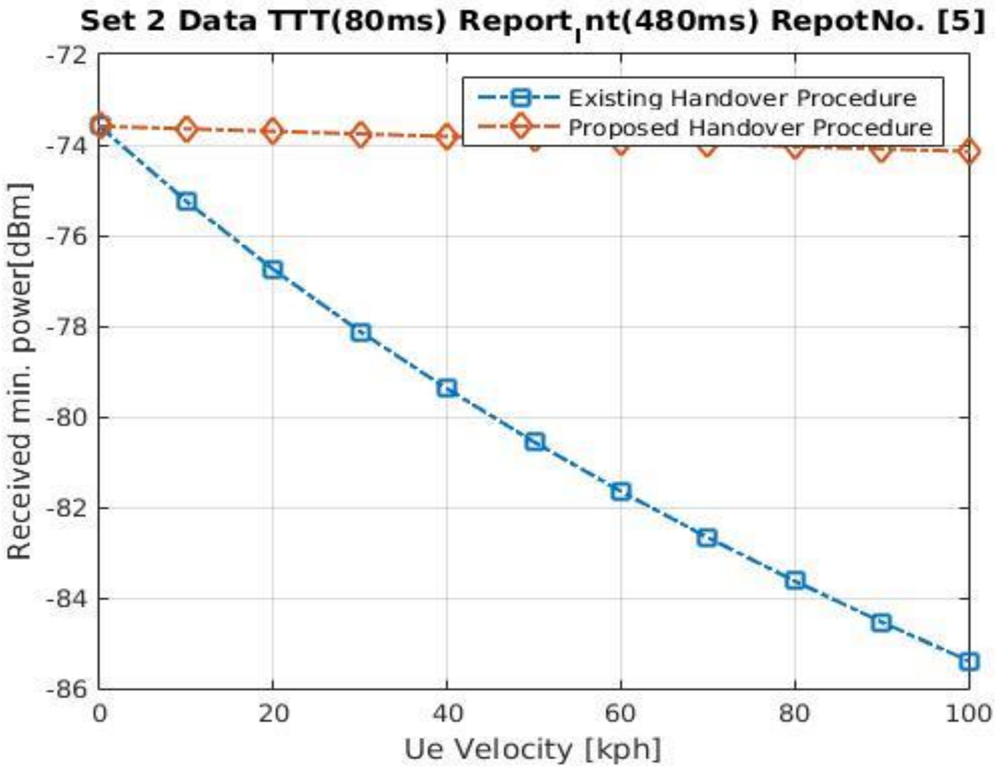

Figure 6.3: Set2 Data Comparison Report Number.5

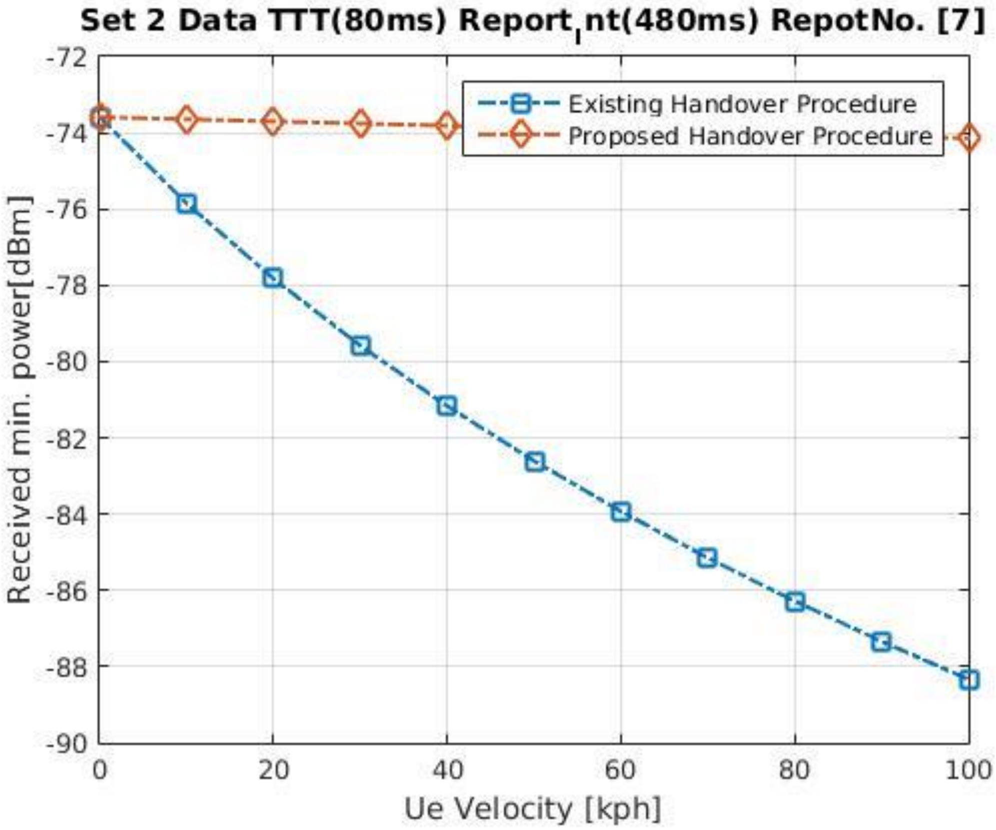

Figure 6.4: Set2 Data Comparison Report Number.7

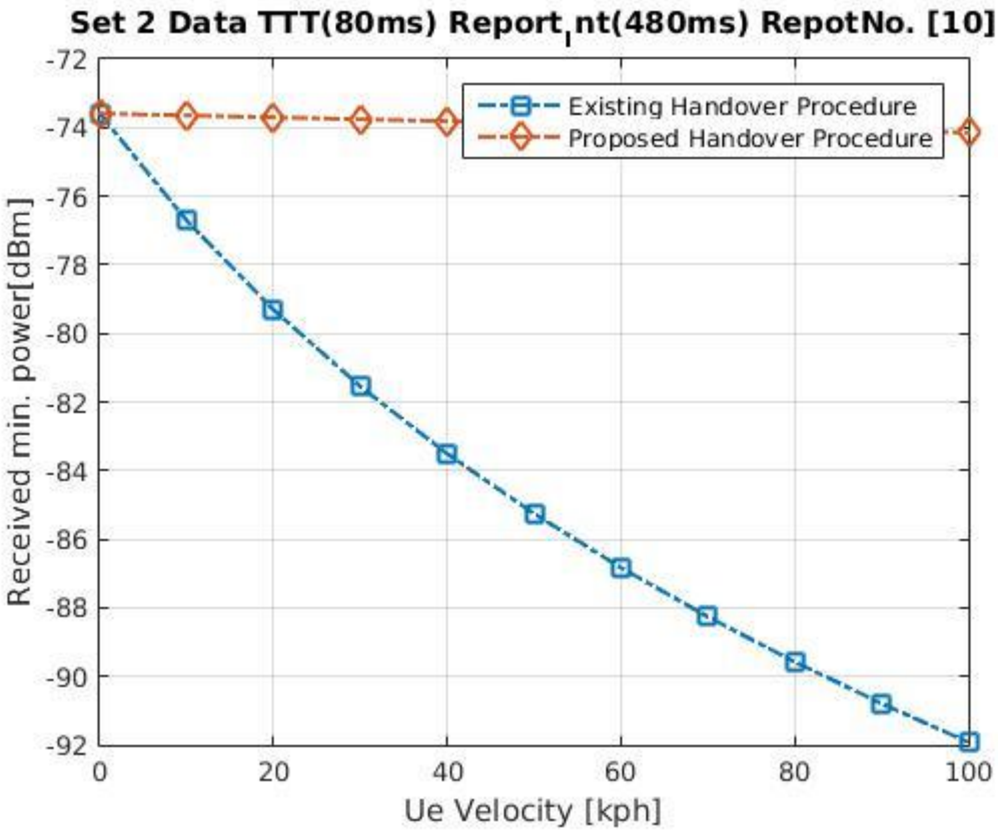

Figure 6.5: Set2 Data Comparison Report Number.10

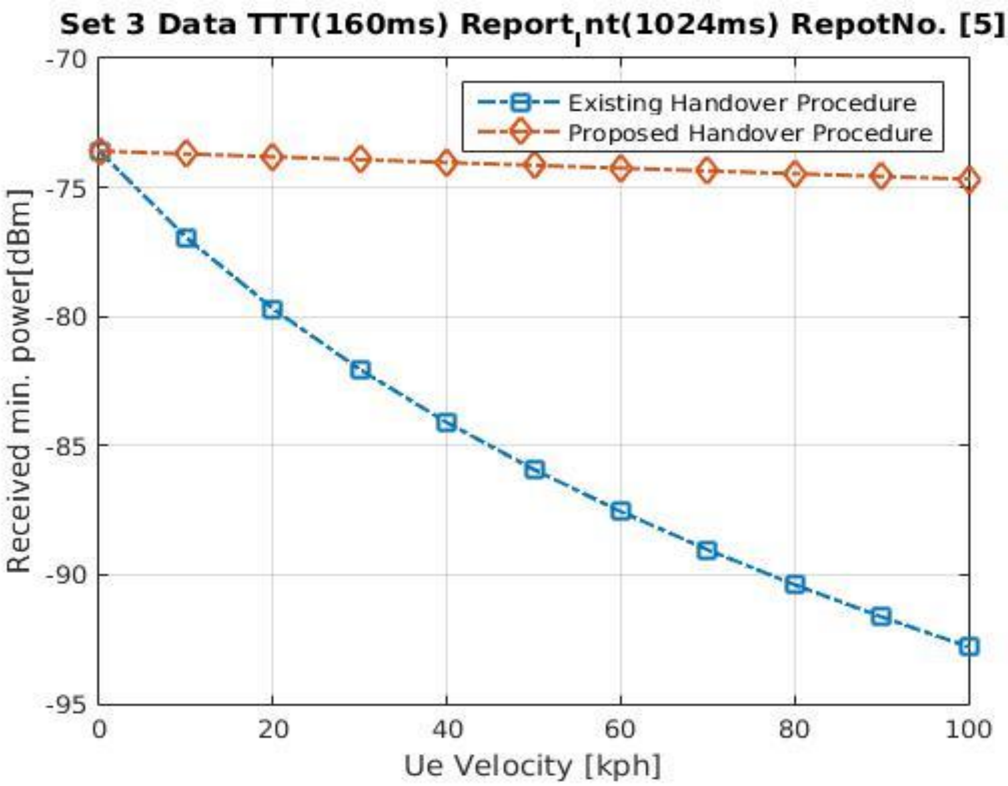

Figure 6.6: Set3 Data Comparison Report Number.5

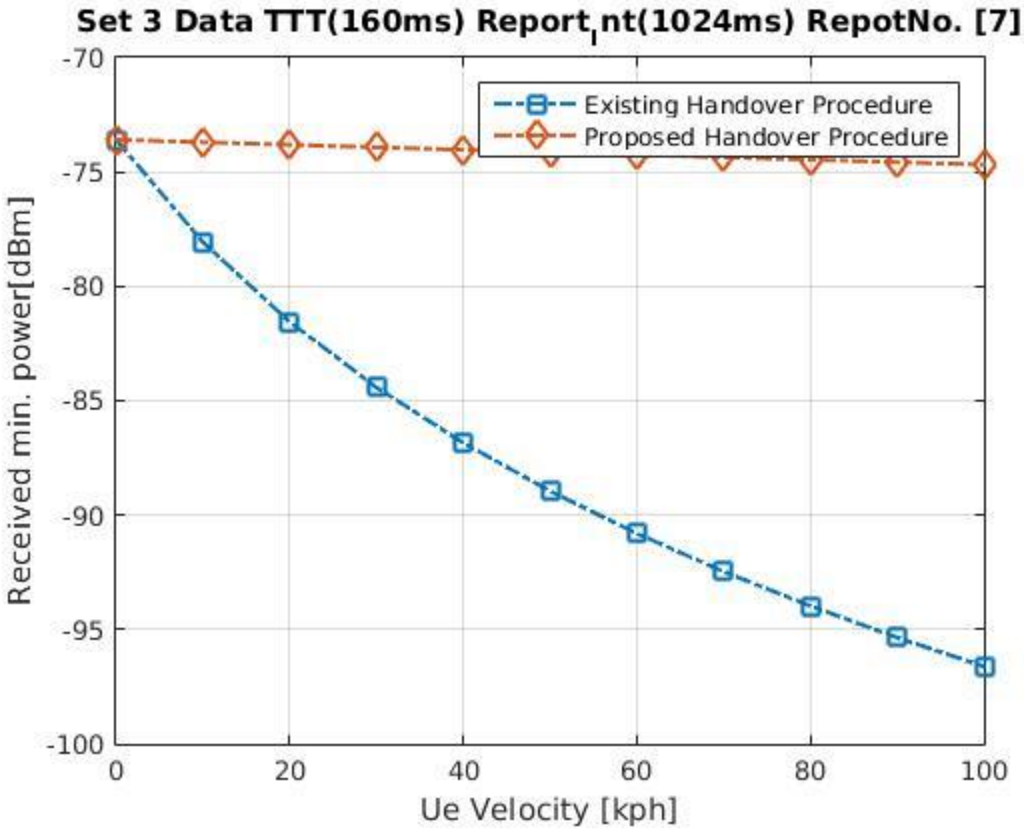

Figure 6.7: Set3 Data Comparison Report Number.7

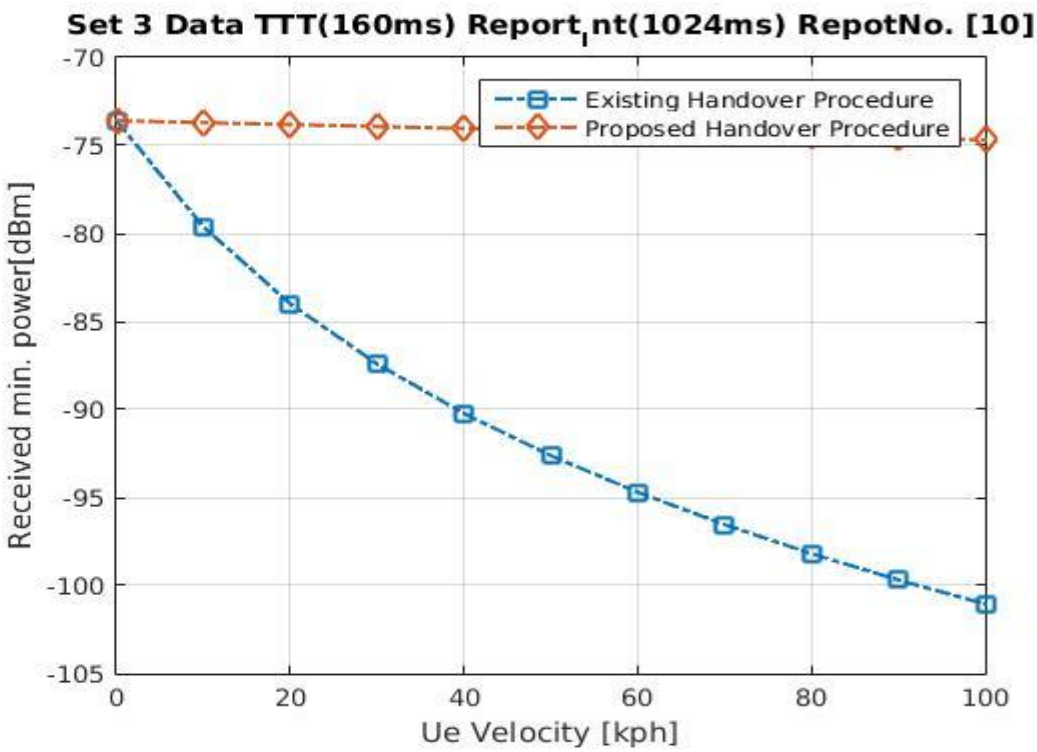

Figure 6.8: Set3 Data Comparison Report Number.1

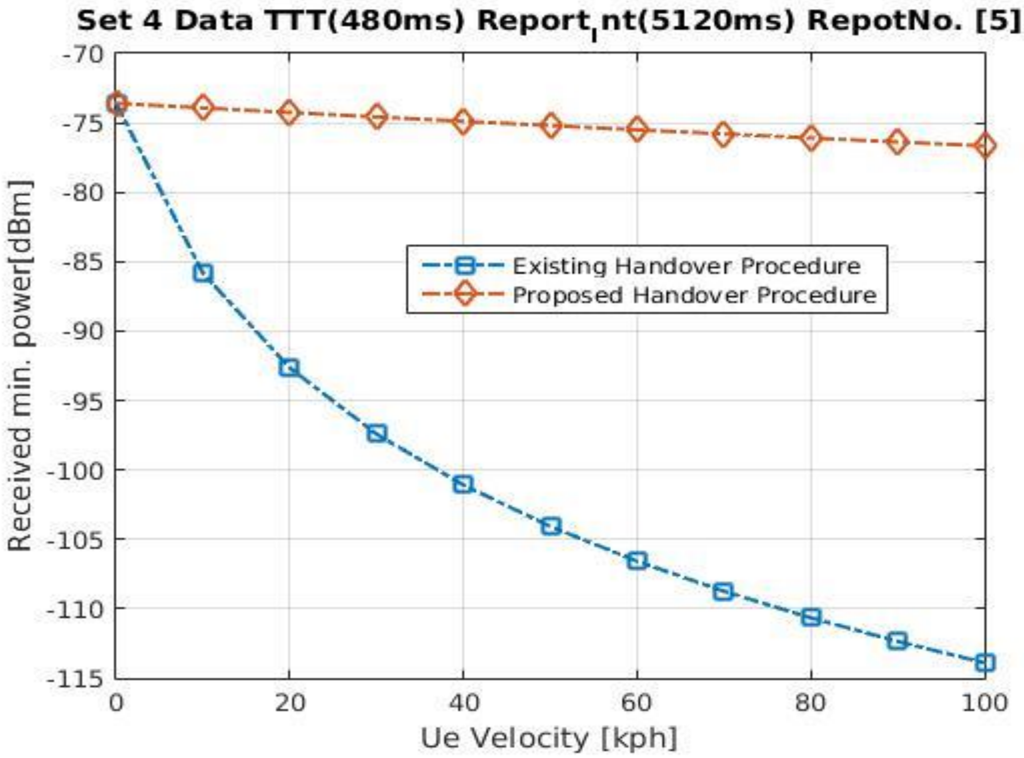

Figure 6.9: Set4 Data Comparison Report Number.5

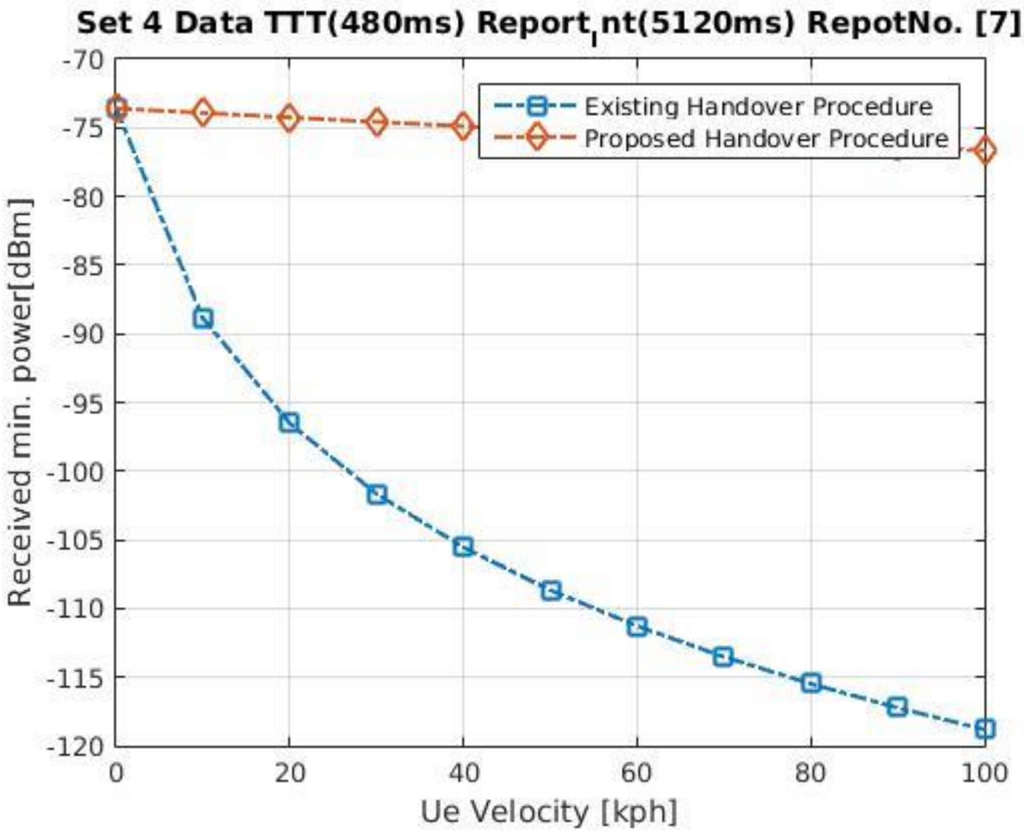

Figure 6.10: Set4 Data Comparison Report Number.7

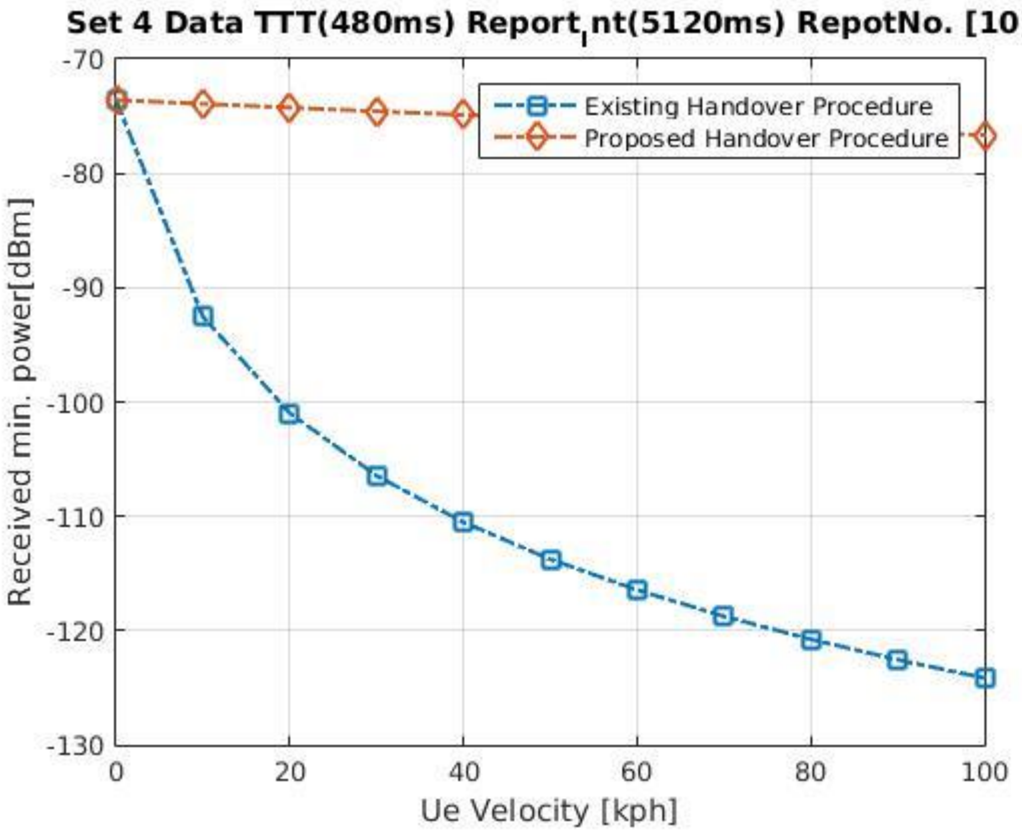

Figure 6.11: Set4 Data Comparison Report Number.10

6.5 NS-3 Simulation

NS-3 is a discrete-event network simulator for Internet systems, targeted primarily for research and educational use. NS-3 is free software, licensed under the GNU GPLv2 license, and is publicly available for research, development, and use. [N.Baldo]

We implemented X2 based handover in NS-3 detailed explained in baldo2013 [16]. As this literature suggest how X2 interface was implemented in the simulation scenario. Also there are some given example simulation of X2 based handover.

6.5.1 Simulation Scenario for NS-3

We used similar simulation scenario for NS-3 implantation as we used earlier for MATLAB numerical simulation (3.3). Our Objective of the simulation is also same. In this simulation we curved out the result in a graph velocity vs Minimum received power from serving cell.

The data set for TTT and Reporting Interval time was chosen from Table 6.2 . In this case we only showed SETs data result only for reporting number of 5 case. That would be enough for proving our improvement in minimum received power.

6.5.2 Simulation Parameters

We chose the higher velocity only for this time. As the problem of received power reduction is in the higher velocity region. The values we chosen is for {60 80 100} kilometer per hour. Following table contains the adjustments made to simulate our scenario in NS-3 LTE module. We curved out the parameters from {reference} which is a 3GPP technical paper.

Table 6.3: NS-3 Simulation Scenario

ITEMS	MACROCELL	PICOCELL
ISD	500m	500m
Path loss Model	Friss Two Ray Model	Friss Two Ray Model
No of Cell	1	1
Antenna pattern	Omnidirectional	Omnidirectional
Carrier BW	2.1 GHz	1.9 GHz
Tx Power	46 dBm	23 dBm

6.5.3 Simulation Results

The following figures are obtained from the values generated from NS-3 simulation output file *uestats.txt.* We got the least received power from the file just before the handover took place. Plotting of the results shown in next page:

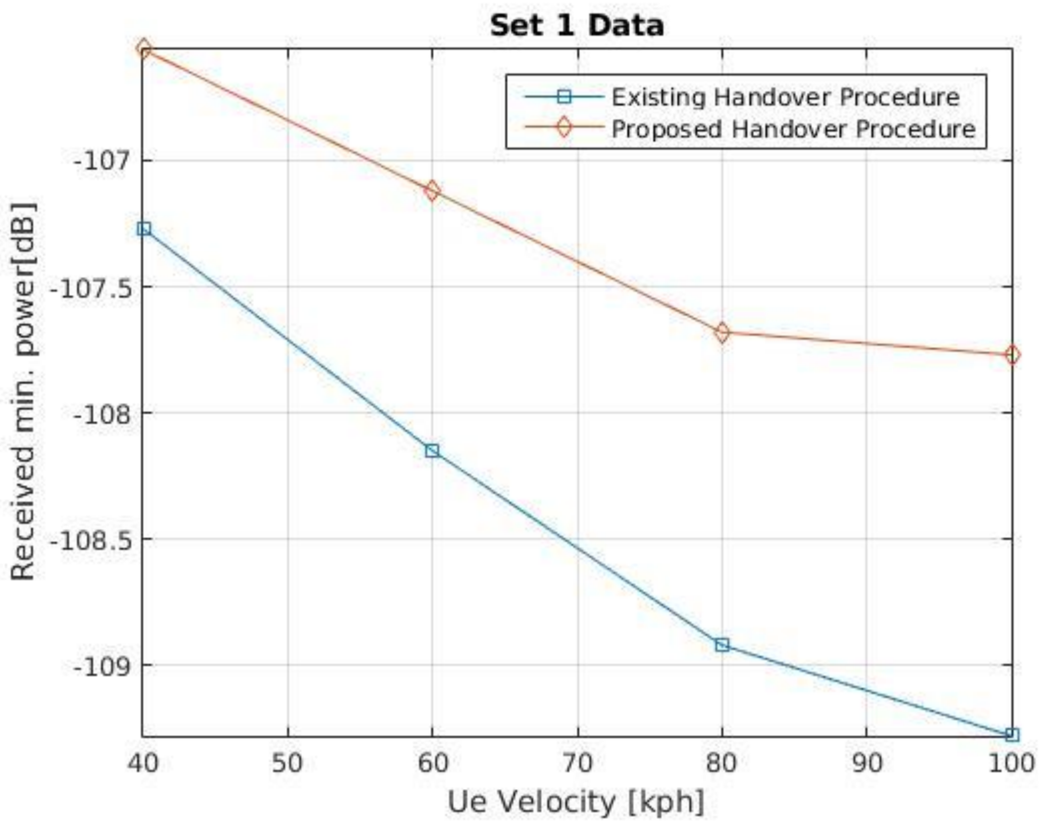

Figure 6.12: Set1 Data Comparison Report Number.5

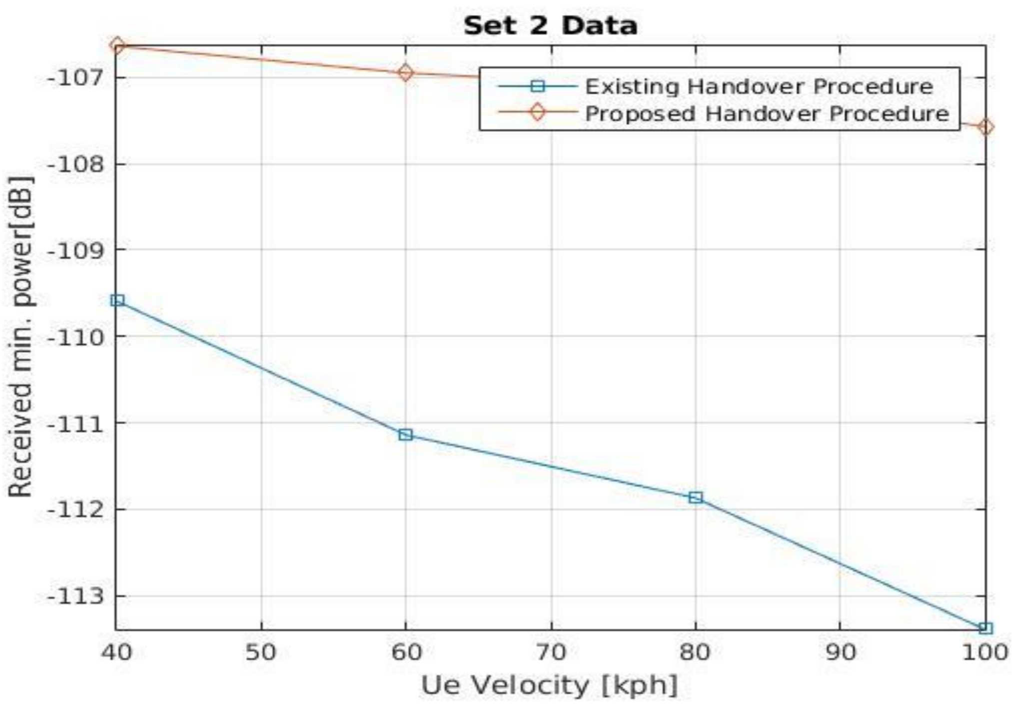

Figure 6.13: Set2 Data Comparison Report Number.5

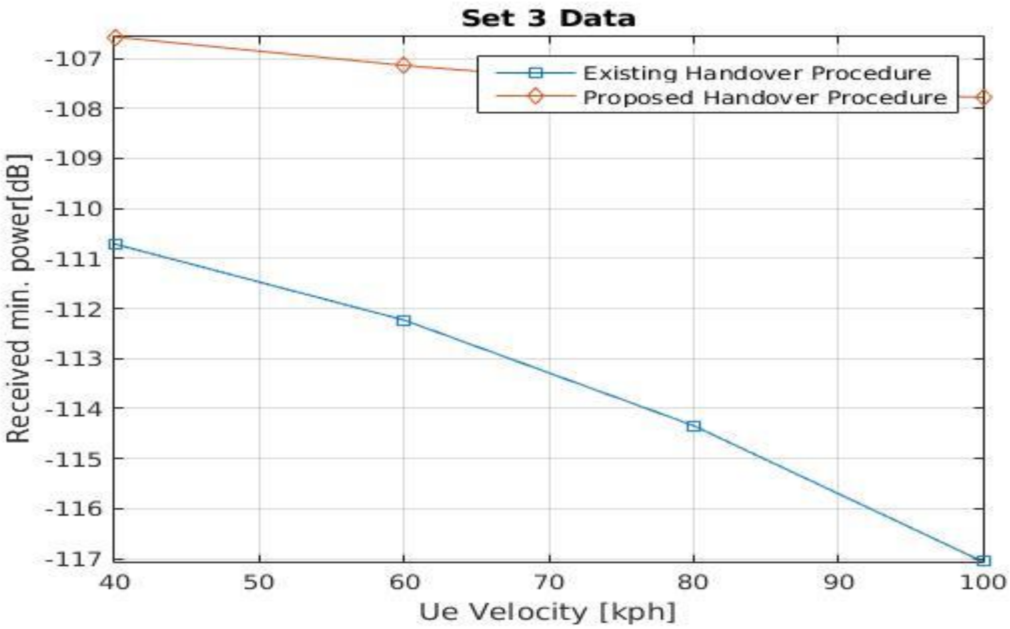

Figure 6.14: Set3 Data Comparison Report Number.5

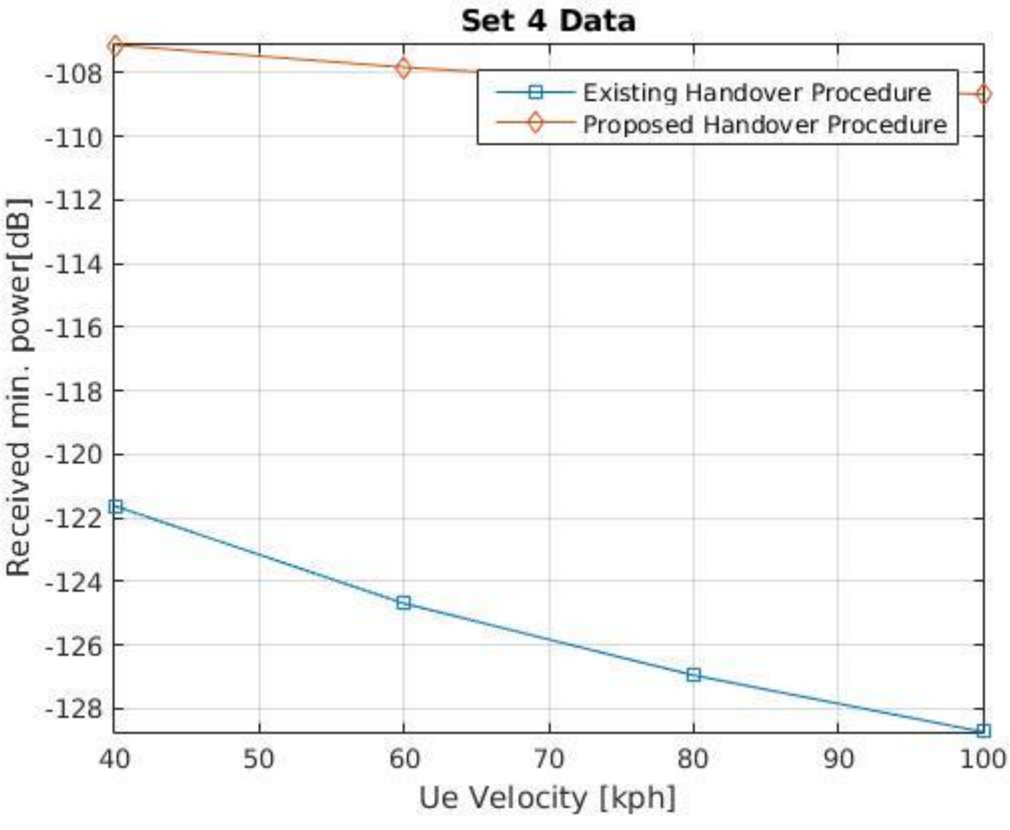

Figure 6.15: Set4 Data Comparison Report Number.5

6.6 Improvement of received power achieved

We got received power improvement in both simulations (MATLAB and NS-3). For MATLAB case we got improvement which is illustrated in the following figures.

Figure 6.16: Improvement of P_{min} for Set1 Parameters

This is showing improvement of Prmin in case of SET 1 data at different velocities is from 4.26% to 6.45%. This is showing higher the velocity higher the improvement.

In case of SET 4 which is worst case for Handover it even shows much better improvement yielding 31.53% to 36.59% for velocities chosen earlier. And in case of

Figure 6.17: Improvement of P_{min} for Set2 Parameters

In case of NS-3 simulation we get almost similar result in terms of best case and worst case scenario. The SET 1 data shows improvement of 3.92% to 5.48%. In case of SET 4(worst case) data it shows 31.57 % to 37.12% minimum received power.

Figure 6.18: Improvement of P_{min} for Set3 Parameters

Figure 6.19: Improvement of P_{min} for Set4 Parameter

Chapter 7

Conclusion

In this thesis paper we proposed a fast and efficient handover scheme for handover between Low Power Cell to Macro cell. We introduced forward handover scheme for heterogeneous network. The proposed handover scheme is more robust against radio link failure (RLF) than the existing X2 based and S1 based handover scheme. Our proposed method shows a decent performance, which proves it will allow low latency during handover and reduce RLF and HO failure efficiently in terms of LTE HetNet scenario.

Still there are some issues that need to be solved to impose our scheme over current backward HO scheme. In case of Macro cell to Pico cell HO current version of our scheme doesn't show enough improvement in Minimum received power of serving cell. In case of fault information is recovered with more difficulty and it is more difficult to have encryption continuity because the key needed to be transferred to new BTS efficiently.

Our future work will be inspired by these problems, and we will try to look for more solutions in this matter. The robust and efficient Macro to Pico HO procedure establishment will be our next goal.

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