

PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
UNIVERSITY MOHAMED BOUDIAF - M'SILA

FACULTY : Mathematics and Compute
Science

DEPARTMENT : Computer Science

N° :



DOMAINE : Mathematics and Computer
Science

FILIERE : Computer Science

OPTION : RTIC

Dissertation submitted for obtaining
Master degree
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SUBJECT

**Optimization Handover in Deep Learning within
LTE**

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Academic year: 2018/2019

Acknowledgments

Above all, we especially want to thank Allah

this memory would never have been realized without his blessing.

I would like to extend my sincere thanks and gratitude to Dr. Mohammed Benouis, Who has been

honored to oversee this humble work

And provided me with advice and good guidance throughout the preparation period

I also extend my thanks and gratitude to all the teachers who supervised my education throughout my studies.

Dedication

To the Spirit of my Father, the pure glory

To those who have spared no breath in raising my
affectionate mother

To my brother Idriss and my dear sisters

I also dedicate this work to all my friends at the university

To all who taught me characters in this worldly world

To all who spared no effort in helping me.

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General Introduction

The Mobile network, which is a standard tool in enabling wireless communication using mobile devices, such as mobile phones, smart phones or tablets, is one of the most important communication radio networks. This network is usually assessed by quality of services and various types of metrics. In fact, many operators have taken to improving their networks and make them more appealing to customers. One such improvement that operators can deliver to their customers is to improve reliability of the network meaning that customers' calls are less likely to be dropped by the network.

The main contribution of this study relies on mobility network and the reliability of long term evolution network where we seek to optimize the parameters used in its handovers process. The process of handover within mobile communication networks is very important and allowing for users to move around freely while still staying connected to the network. The parameters used in the handover operations are the Time-to-Trigger (TTT) and Hysteresis (hys). The latter are used to determined where a base station better than the serving base station by enough to warrant a handover taking place. The challenge in selecting the handover parameters is that there is a fine balance that needs to be struck between calls being dropped due to a handover failing and the connection switching back and forth between two base stations, unnecessarily, wasting the networks resources. This dissertation explores the use of statistical learning and machine learning for the optimizing handover process. In this context, the effectiveness of statistical algorithm for HO optimizing has been investigated. This is achieved by modeling the functional relationships between the TTT parameter and Hys. For the second approach, it taken is to use a machine learning technique known as Q-Learning to optimise the handover parameters by generating a policy that can be followed to adjust the parameters as needed. Based on the current work related to the LTE based machine learning, it was found that the reinforcement learning algorithm implemented was capable of improving the performance of the handovers and had the potential of performing even better than what is documented in this dissertation.

the dissertation is structured as follows:

Chapter 1, a wide picture of the art of the LTE mobile network is presented. Thus, is preceded by a brief presentation of LTE components that is found in LTE. A brief overview of the new LTE Advanced technology that is used Het net and self-organization network, is also described.

Chapter 2, explains the different approach for automated handover operations. A first case study of the management of mobility and the different steps of the procedures that consist of any handover scenario for a LTE is presented. After that, is a literature review of existing handover techniques, with a focus on how these methods have been applied to LTE handover process.

Chapter 3, a new handover parameter optimization algorithm for the LTE-A networks is presented. The proposed algorithm is tested on a simulation environment along with some of the important previous works.

Chapter 4, explains the different propagation and mobility models considered for use within the simulation, as well as giving accounts of how the simulation was designed and the testing done to make sure the simulation was functioning as required. A Details the development of two approaches based on handover optimization developed for LTE handover issue is described. The results from testing and analyzing these approaches are also presented. Finally, a general conclusion and perspective are consistent with our study.

1 Introduction

Long Term Evolution (LTE) provide a successful cellular network for communication tasks such as mobile communication, internet provider, and so on. Typically, LTE is a type of mobile phone network. Long Term Evolution, a new standard for 4G networks in broadband wireless communications that delivers very high data transfer speeds compared to 3G technologies.

Unlike the previous generations of mobile phone i.e., GSM, UMTS, LTE uses different radio access technologies for downlink speeds of up to 300Mbit/s and uplink (UL) speeds of 75Mbit/s with a flexible bandwidth that ranges from 1.4MHz to 20MHz. Orthogonal frequency-division multiple access (OFDMA) and Single carrier-frequency-division multiple access (SC-FDMA) is used for the downlink and the uplink, respectively. OFDMA provides high spectral efficiency which is very immune to interference and reduces computation complexity in the terminal within larger bandwidths. Many technologies operators reported that

the number of LTE subscriptions had reached 600 Million in Q4 2019. The development of faster downloads speed was driven by the consumers want for better quality images, faster Internet browsing and smoother video streaming. The LTE system offers multiple advantages [4]:

- Provides good support for cellular devices.
- High throughput – high data rates, which can be achieved in uplink and downlink.
- More than one device can connect to a single access point Improves the quality of Internet connectivity.
- by using Voice over LTE technology Smooth handover across heterogeneous networks Reduces latency time

2 LTE Architecture

The LTE SAE (System Architecture Evolution) consists of three main parts, the User Equipment (UE), the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core (EPC). The UE can simply be considered as a standard mobile phone or smartphone. The purpose of the E-UTRAN is to connect a UE to the EPC and is made up of just one component, the Evolved Node B (eNodeB) or simply put base station[22].

2.1 User Equipment (UE)

Mobile device (or mobile station) used by the subscriber or user to connect to the network

2.2 Evolved packet system (EPS) entities

Service Architecture (SAE). In other words, the combination of E-UTRAN and EPC is also called Evolved Packet System (EPS), consists of the following entities[22]:

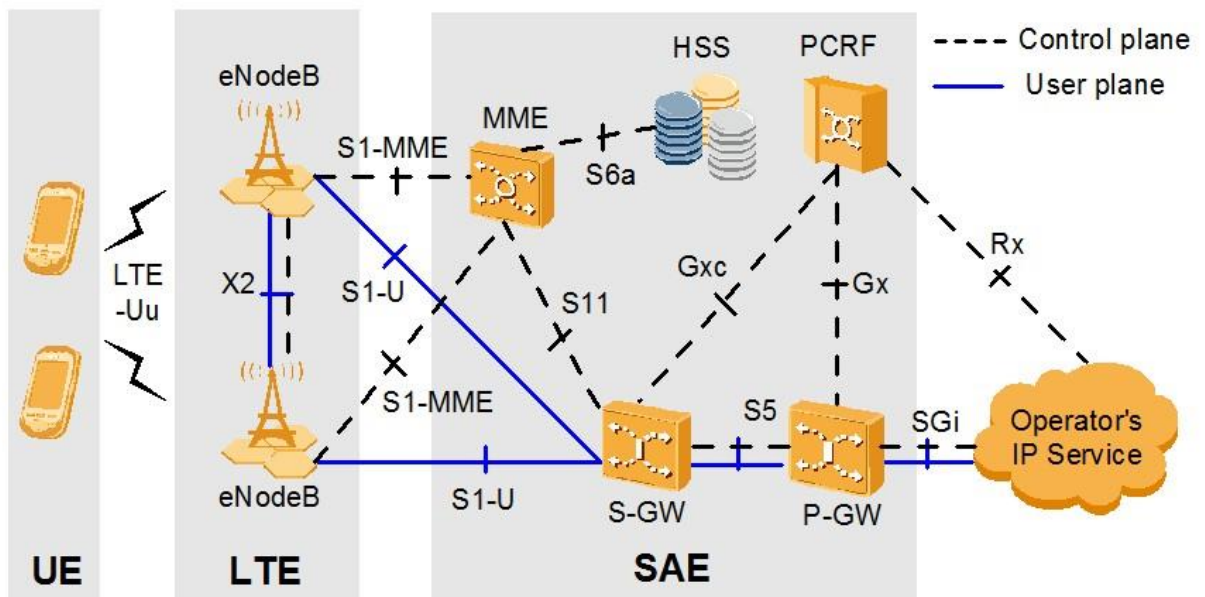


Figure 1.1 EPS system architecture

2.2.1 Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)

Enhanced version of the terrestrial radio access network in UMTS Function of this part is Lead wireless communication between the mobile and the other part of the LTE architecture Evolved Packet Core (EPC) , It also contains eNodeB . Each eNodeB station communicates with the EPC section via the S1interface and can communicate with nearby stations via the X2 interface, which is primarily used for signaling and packet forwarding functions during the delivery procedure. the eNBs can communicate to the Mobility Management Entity (MME) by means of the S1-MME interface and to the SGW (Serving Gateway) via the S1-U interface ,Data packet forwarding is an important feature of LTE It stores data during the delivery

process, through the transfer of the subscriber from one terminal to another, and then redirects this data to the subscriber when the connection becomes well within the coverage of the second station without any loss[31].

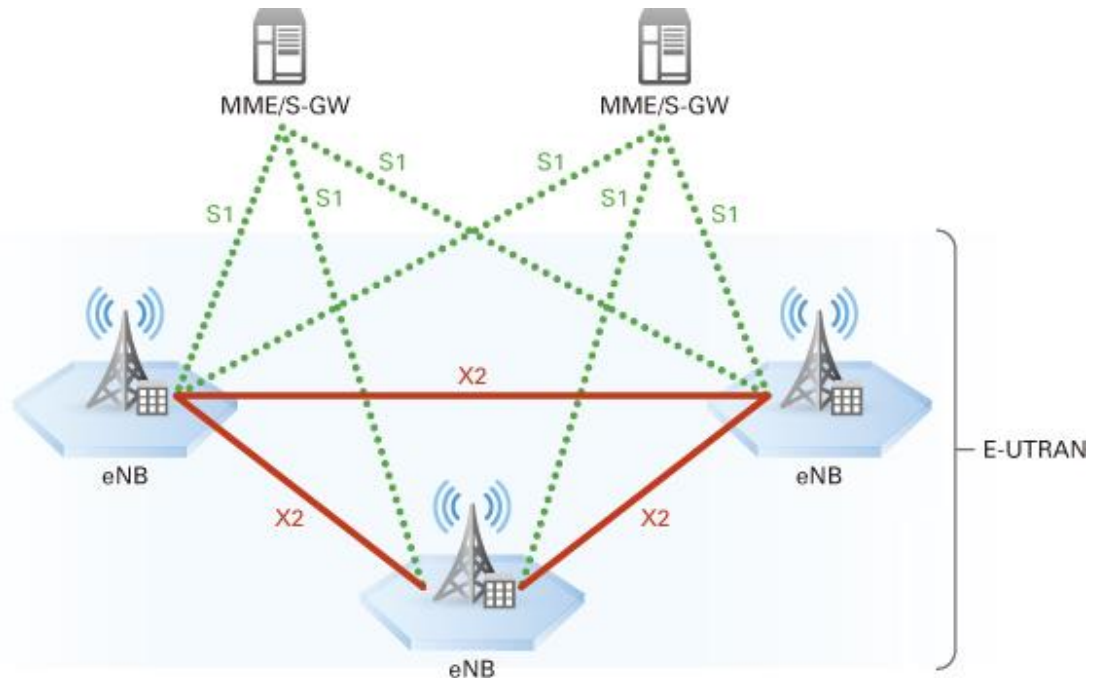


Figure 1.2 E-UTRAN Architecture

2.2.2 Evolved Packet Core (EPC)

The core network (called EPC in SAE) is responsible for the overall control of the UE and establishment of the bearers, The following figure shows the architecture of this section and its most important elements[5]:

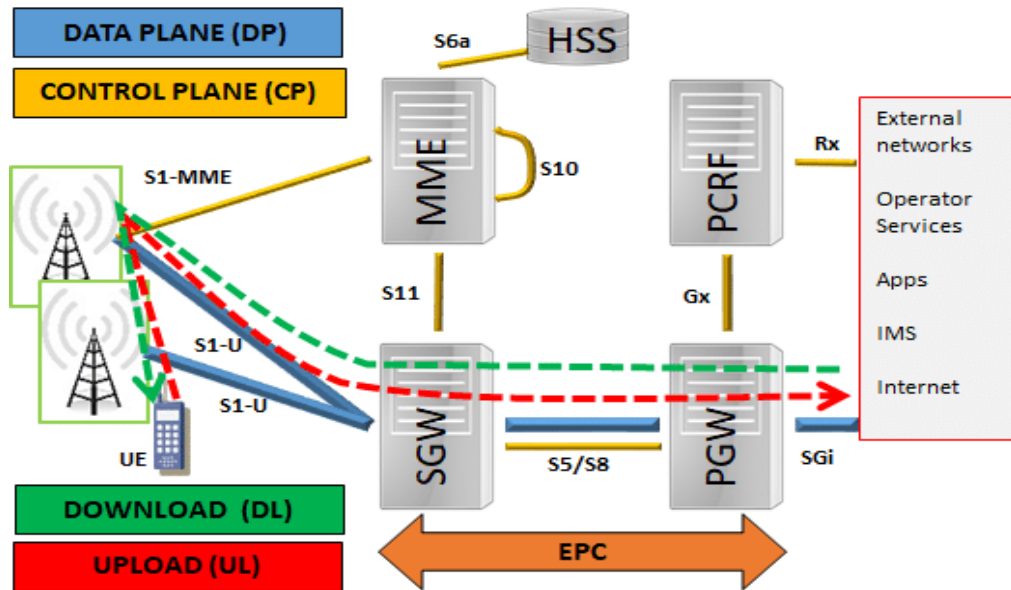


Figure 1.3 EPC core network architecture

- ❖ **Home Subscriber Server (HSS)** A central database that contains subscriber information in the network.
- ❖ **Packet Data Network (PDN) Gateway (P-GW)** Connects to the outside world such as PDN (Internet) networks via the SGI interface
- ❖ **Serving Gateway (S-GW):** It plays the role of the router, routing data between the fixed station and the PDN gateway.
- ❖ **Mobility Management Entity (MME)** : Controls the Mobility process at the high level within the mobile device , By managing the exchange of signals between the mobile device and some EPC components.
- ❖ **Policy Control and Charging Rules Function (PCRF):** Its function control freight operations and quality of service.

3 LTE e-Node B Protocol Stack

LTE is organized into different protocol layers. It is divided into control plane architecture and user plane architecture:

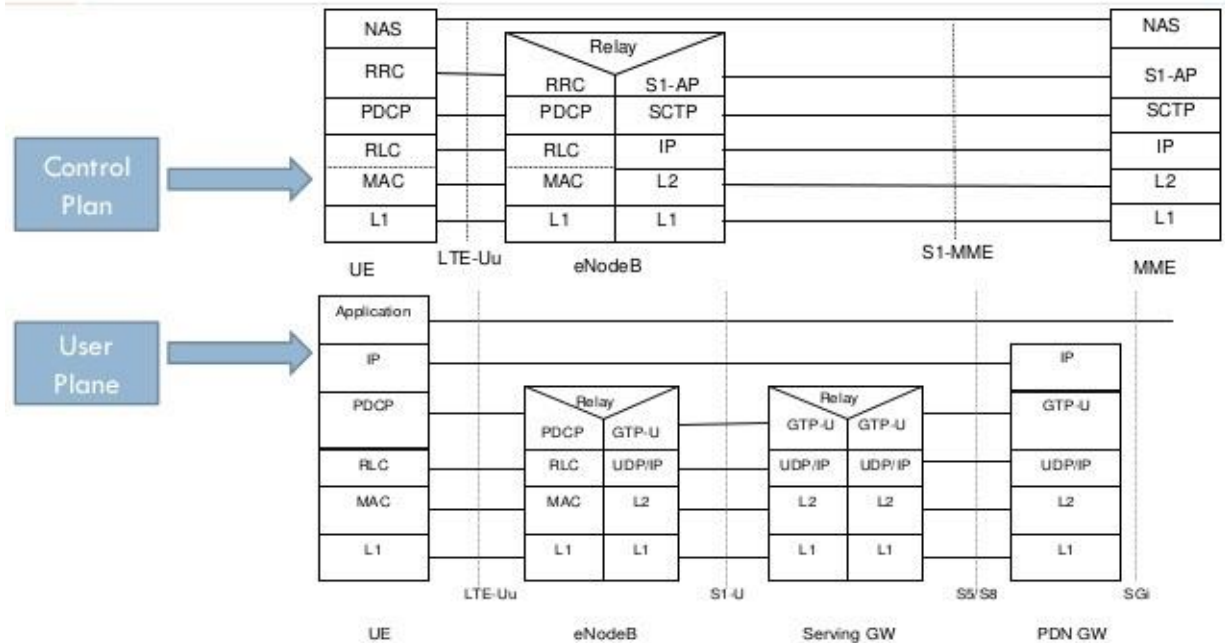


Figure 1.4 LTE e-Node B Protocol Stack

3.1 User Plane

The user plane protocol stack between the e-Node B and UE consists of the following sub-layers:

- ✓ RLC (radio Link Control): RLC is located on top of the MAC-layer and below the PDCP-layer is responsible for Concatenation, segmentation The RLC offers services to Transfer of upper layer Protocol Data Units
- ✓ Medium Access Control (MAC): The MAC layer is composed of a Hybrid Automatic Repeat request (HARQ) entity and handles hybrid-ARQ retransmissions and uplink and downlink scheduling, a multiplexing/de-multiplexing entity, and a control entity ,There are some services offered by Mac Services to RLC's in the form of logical channels.

- ✓ PDCP (Packet Data Convergence Protocol): is located above the RLC layer and below the IP layer ,PDCP provides its services to the RRC, its responsible for ciphering ,integrity protection and header compression.

3.2 Control Plane

The Control Plane depends on the state of the user equipment which includes two states: idle or connected, the control plane includes additionally :

- ✓ the Radio Resource Control layer (RRC) The main services and functions of the RRC is include connection control, measurement configuration control and reporting, transfer of UE Radio access capability information , Establishment, maintenance and release of an RRC connection between the UE and E-UTRAN, Mobility functions.
- ✓ The other protocol is called NAS Present in the UE and MME and responsible for high level signaling, including messages attach and Handover and others.

4 The Interfaces of LTE

The LTE / SAE system consists of several internal interfaces and with the others 2G / 3G systems[41]:

4.1 Interface Uu

The LTE-Uu radio interface is defined between the eNodeB and the UE.

4.2 Interface X2

X2 Interface performs the following functions:

- ✓ LTE X2-UP (User Plane): protocol tunnels end-user packets between the LTE eNodeBs, The X2-UP interface protocol stack is identical to the S1-UP protocol stack.
- ✓ LTE X2-CP (Control Plane): whose function is summarized in controlling different transmission resources, It also controls the operation of handover and responsible for controlling the connection between the UE and the network .

4.3 Interface S1

It can be split into control-plane (S1-MME) and user-plane (S1-U). The S1-MME is a signaling interface which supports a set of functions and procedures between the eNB and the MME , while the S1-U interface is designed to carry user plane data between eNodeB and the S-GW.

5 LTE Channel

Actually, LTE uses several different types of logical, transport and physical channel, which can be distinguished by the kind of information they carry and by the way in which the information is processed It is almost like 3G and split as follows[12] :

5.1 Logical Channels

define what type of information is transferred. Data and signalling messages are carried on logical channels between the RLC and MAC layers, Each logical channel type They contain the information that we want to send ,It consists of a control channel (for transferring control plane information) And traffic channel (for transferring user plane information),and Logical Channel Divided into two parts DL and UL these channels are also in both direction downlink and uplink directions ,they are carries information originating from the upper layer data or signaling[12] .

5.2 Physical Channels

is a physical time-frequency resource used for the transmission of control and user-plane messages. The physical layer maps transport channels to their corresponding physical channels. There are also physical channels that does not correspond to any transport channels. we can further classified as[16] :

- Physical Data channels (DL, UL)
- Physical Control Channels (DL,UL)

5.3 Transport channels

Define How to transfer information by specifying the type of user modulation as well as the coding that you will be working on , the method of transferring information is described in the physical channel.

the coding that you will be working on , the method of transferring information is described in the physical channel[12] .

6 The Fundamental Characteristics of the LTE

- High throughput : LTE (3GPP) supports theoretical peak data rates of 75 Mbps uplink and 300 Mbps downlink. It supports 4x4 MIMO antennas , The LTE system can operate according to multiple frequency spectra, The frequency spectrum is 800 MHz to 2.6 GHz, where the signal carries more space and thus reaches more people and is suitable for rural areas ,In fact the System should support downlink peak data rate of 100Mb/s and uplink peak data rate of 50Mb/s within a 20 MHz spectrum[42].
- Latency :The period between the stimulation of a system and the response to that stimulus. It is necessary to reduce latency or waiting time to make the response closer , LTE aims at user plane latency of less than 5 ms in low network load conditions and for small IP packets So the delay rate in the LTE is much lower than the previous generation[42].
- Mobility : It can serve the user even if he is walking at high speeds of up to 350 km / h, such as trains.
- Coverage: Covers areas of up to 100 km, , but in the conditions of interference and the existence of densely populated and also speeds of users may not be achieved after 30 km.
- Multiplexing: There are two modes of frequency multiplexing, frequency multiplexing(FDD) and time division multiplexing (TDD). In FDD (Frequency Division Duplexing) mode ,transmission and reception are at different frequencies. In TDD mode, the broadcast and reception pass at the same frequency, but at different times ,with introducing the duplex technique method, which is the separation between DL and UL. both schemes can be used on same platform[31].
- Adaptive modulation: The LTE is used more than MOD ((BPSK-QPSK - 16 QAM – 64 QAM)) According to quality of services , The higher quality then high order modulation is applied ,Which is the 64-Qam Where he has a large rate Up to 100 MbPs

But the possibility of error is large, it is therefore advisable to have good quality. The opposite in BPSK has a lower rate but a lower risk of error. This is why we use it in signaling control because we still have no knowledge where control is very accurate. Where both modulations of uplink and downlink correspond [8]:

- Modulations Downlink : QPSK, 16QAM et 64QAM.
- Modulations Uplink : QPSK et 16QAM.

7 LTE-Advanced

Is an evolution of the LTE standard that while maintaining full upward compatibility with LTE, is considered a fourth-generation standard, LTE-Advanced download rates can be greater than 1,2 Gb/s. The standardization of the first version (rel 10) was completed at the end of 2011. The features of this system are in line with ITU-4 standards and technical requirements and are therefore a true 4G system. These features include the following [6]:

- High data transfer rate : 3 Gbps downlink, and 1.5 Gbps in the uplink.
- High spectral activity : Up to 30 bps / Hz in the downlink., twice high as in LTE and 15 bps / Hz on the uplink three times higher than the LTE system.
- Voice over WiFi (VoWiFi) : In LTE networks, voice calls can be made via WiFi rather than LTE Radio if there is a WiFi network covering the area where the mobile device is located. To implement this feature, ePDG must be in the heart of the network core network, where it works as a VPN Gateway to ensure the confidentiality of calls as they pass through the Internet. The IMS network calls in the same way VoLTE but through the Internet. It can also work handover between WiFi network and LTE network [10].
- Narrow band - Internet of Things (NB-IoT) : To connect various devices such as wearable devices, self-driving cars and different sensors in different devices and devices for monitoring and measuring the Internet must be provided with the mobile interface module as a portable device, The devices supporting the NB-IoT operate at a frequency of only 180 KHz and their price is very cheap and the data rate in the direction of the downlink is almost 200 Kb / s [6].
- Cell edge : Improved performance at the ends of the cell (areas farthest from the fixed station) With twice as much output as LTE, The peak of the downlink is reached Efficiency of 0. bps/Hz. and uplink peak spectrum efficiency of 0.07 bps/Hz.

- Carrier Aggregation (CA) : uses of multiple Carrier channels or Carrier together instead of one holder , Resulting in increased data transfer rates, capacity and performance, The Carrier that can be assembled is the same Carrier LTE: (1.4, 3, 5, 10, 15, 20) MHz ,The maximum Carrier that can be assembled in theory is 5 so the highest bandwidth available is 100MHZ There are three ways to assemble a Carrier[6]:

Intra-band contiguous : the contiguous Carrier (from Carrier LTE) converges within a single operating frequency band

Intra-band non-contiguous : any carrier within the same operating frequency band can be used in aggregation

Inter-band non-contiguous : A non-contiguous spacing assembly is included within different frequency bands.

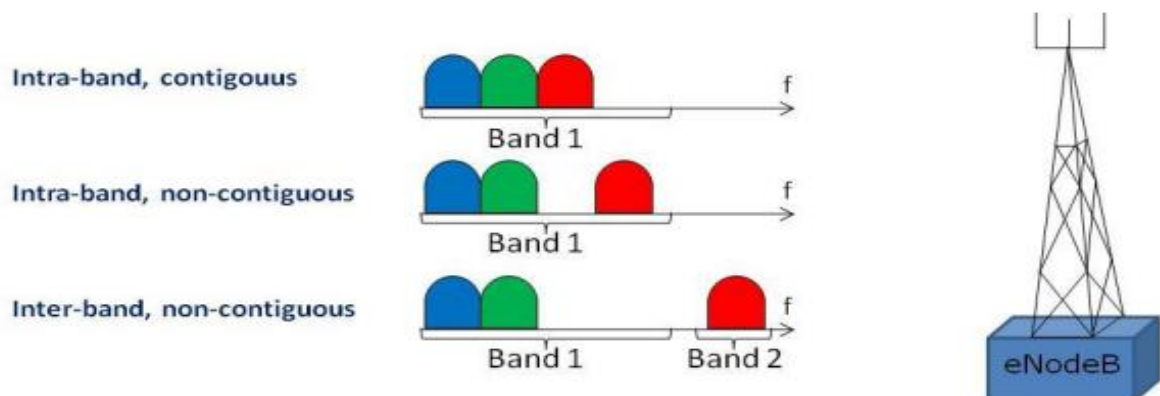


Figure 1.5 LTE-Advanced different type assemble Carrier Aggregation

- MIMO : In this system LTE-A has been re-used with the development allowed using 8 x 8 MIMO In the downlink and 4x4 MIMO on the uplink , that's Makes Enables sending different data streams with same physical time-frequency resources
- Coordinated MultiPoint (CoMP) : is technology will be available in Rel.11 version of the LTE-A system as the development of its primary goal of improving network performance at the end of the cell, Works on many TX and RX points in the downlink and uplink path to secure both sending and receiving, and synchronizing[6].

8 Heterogeneous Network (HetNet) & Small Cells

This technique uses small cells that are installed in different regions where the signal strength is expected to be weak either because of the lack of coverage or because of the large number of subscribers, technology HetNet aims to increase network capacity and capacity to accommodate the growing number of users. The function of these small cells is to increase the coverage of the basic cell and increase the ability of the network to Serving more users. As a result, by coordinating the work of these small cells, all users can get high data transfer speed and high quality of service wherever they are. Called the basic cell that provides coverage with a few miles of Macrocell, other small cells are classified according to the coverage area provided by each cell From the largest space to the smallest Microcell Picocell· Femtocell.

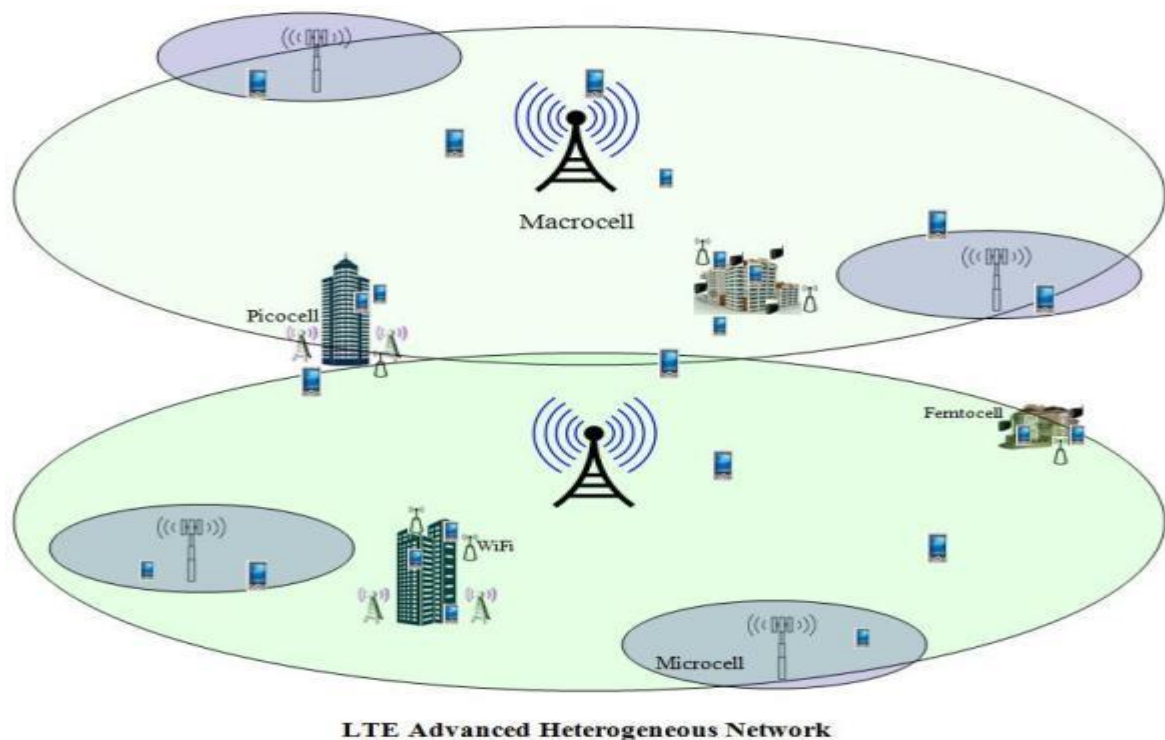


Figure 1.6 Heterogeneous Network (HetNet) & Femto-Cell

➤ Femto-Cell

Works as a mini tower for a telecom company and provides costs and improves quality of service, but it covers very limited space femtocells involves the use of a low power base station with broadband Internet access such as XDSL, cable or optical fiber (FTTH), Femto-cell is

introduced to LTE in Release 9 does not support X2 interface, It connects to the EPC with S1 interface over user's broadband connection.

9 Self Organizing Networks

This technique is used to manage and coordinate multiple small and large cells, in terms of automatic cell installation and maintenance, minimization of interference, which can simulate adjacent cells, detect areas of weakness in the network and apply appropriate solutions, It will allow rapid deployment of new BTS, Unlike previous generations detect the transport link and establish a connection with the elements of the core network, for example minimizing drop call rate, or maximizing handover success rate[40].

9.1 Architectures SON

Self-organizing networks are mainly divided into three major architectural types [40]:

9.1.1 Distributed SON

self organization functions are executed on the edge network elements, and adapts more quickly to changes in the network (agility). a distributed architecture allows for ease of deployment in multi-vendor networks and optimization on faster time scales

9.1.2 Centralized SON

self organization functions are generally executed on the element system or a separate SON server that manages the eNBs.

9.1.3 Hybrid SON

is a mix of centralized and distributed SON , it's executed in core and edge network elements, without overcoming the disadvantages.

SON Architecture

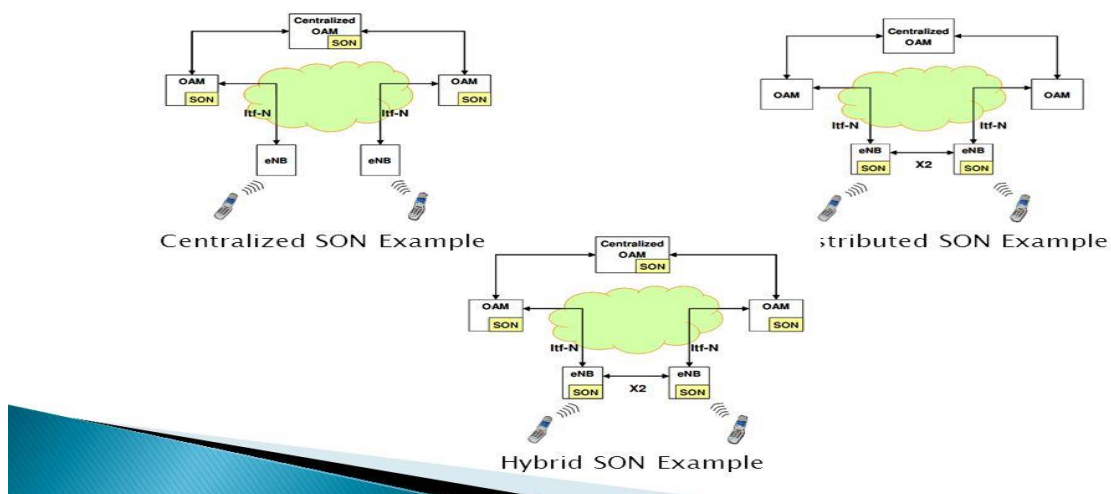


Figure 1.7 SON architectures for LTE-A networks

9.2 SON functions

The purpose of SON technologies is to adjust automatic network parameters, based on measurement reports of the UEs and the eNodeB, It improves service quality and reduce the complexity of network management , SON functions can be typically divided into three main categories Each has its own multiple functions [43]:

9.2.1 Self Configuration

Self-configuration is a concept that includes a lot of features and defined by SON properties such as Automatic Software Management, Self Test and Automatic Neighbor , The self-configuration process requires the creation of new published nodes, then merging these nodes into the network and placing them in the auto-running state [43].

9.2.2 Self Optimization

Self- Optimization explores problems faster and improves network performance where it occurs in operational mode. The self-organized network automates tasks by performing measurements on network equipment, detects service quality issues, identifies cause, and takes corrective action automatically based on OMC (Operation and Maintenance Center) performance measurement statistics One of the most important features of the mechanism of energy saving is the automatic closure of a certain percentage of the basic stations during the

night hours, where the adjacent main station to maintain the coverage of the area by re-configured parameters. It's establishes neighbor relations (ANR) as well as improve random access parameters [43].

9.2.2 Self Healing

Self-healing involves diagnosis and treatment of network failures With changing the required parameters and algorithms in the system to minimize Effect, where self-healing mechanisms aim to minimize the effects of failure, after the diagnosis of failure and reporting it comes the step of compensation procedures are trying to change the required configuration parameters on the associated Cells so that these compensation procedures can restore the affected cell from failure [43] .

10 Conclusion

This chapter has detailed the architecture of the LTE architecture. After, we have discussed the different components that involved in LTE core network. As part of the review of LTEs, the different recent technologies of LTE related to access network is introduced, followed the emerging new technology of utilizing small cells, Het-Network and Self Organizing Networks is also presented.

1 Introduction

As a result of the large increase in data transmission in the network and the huge number of users, one of the requirements of LTE technology is to provide better Quality-of-Service (QoS) to customers by allowing them to continue to use provided services even after moving out of range of the original serving base station. This is assessed by the handover mechanism which is based on statistical algorithms which are often defined by the signal to noise ratio of the radio between UE and base station. On the other hand, mobility is an important component of mobile cellular communication systems, the aim of the LTE radio network is to provide fast and smooth handover from one cell to another while maintaining a simultaneous network and simple management. In High-Speed Railway Environment, LTE technology supports high speeds such as trains up to 500 km/h while the mobile network performs a mechanism handover, even the user is still connected and also maintaining its quality of services. Through this chapter we will explain the mechanisms of Handover and mobility Between cells, therefore, Handover is considered to obtain the desired performance and an important process in LTE networks.

2 Mobility within the LTE

Continuous mobility of the user from one cell to another or the concentration of users within the cell where they are based, these mechanisms are usually based on radio measurements by the station on the source cell and neighboring cells. Based on these measurements the target cell is selected and how to convert the UE to this cell. The user performs measurements of service cell and neighbor cell attributes to enable the process.

When the user receives a signal that is in the active mode then starts supplying the cell with measurements report and then decides how the transfers are performed. The transfer is being performed in interface S1 between inter cellular or the X2 interface if there is direct connection between source and target eNBs [13].

2.1 IDLE states

A user does not need this service to be a single place but can be used anywhere and even in the

case of travel and its purpose is to maintain the battery and reduce the load on the network the IDLE mode UE is not known by the eNodeB but is known by the network and can communicate with the network when it notices any incoming call[7] [11].

2.1.1 Cell Reselection

If the user does not have an RRC connection to the radio network, the network can Use the S1 interface procedure to move the user into RRC_IDLE , E-UTRAN relies on the UE to detect adjacent cells where the user can rely on the measurements of the source cell and delete its measurements if they meet the necessary criteria and the UE will simply analyze all possible carrier frequencies (Intra-frequency- Inter-frequency) [11].

2.2 Connected States

It depends on two cases when the user decides through his measurements from the source cell and neighboring cells, then sends the report and the second case the source cell performs the handover to the target station based on user measurements where the user in the case of sending and receiving the station has full control during the user activity, The user has a black list to protect from unwanted measurements of adjacent cells [12] [20].

3 Handovers in LTE

main function of handover is the maintenance of the traffic flow, especially when the movement of the user, the user's choice of the host station depends on the strength of the received signal, the quality of the received signal through the mechanism handover and its features during a continuous user conversation or continuous flow of data the user loses signal, weakens the quality of service in the source cell. The user is connected to a nearby station with a strong signal without interruption to the call or data transmission, where the system provides mobility for users Reliably and without dropping any of their calls. the user's device makes periodic measurements and then sends a report to the source cell[19].

3.1 Good Mobile Site

The operations required to search for cells are based on signals called sync signals. There are two types:

- ✓ the primary synchronization signal (Primary Synchronization Signal, PSS).

- ✓ the secondary synchronization signal (Secondary Synchronization Signal), SSS.

These signals are known to the UE and have temporal and frequency properties optimized to allow synchronization, which typically takes place through correlation. The user uses these measurements to calculate the signal level indicator received from the RSRP, it used at idle mode to determine the best cell seen from the UE. This fundamental principle better cell governs the mobility of the terminal in idle mode, it chooses the cell target with the best signal, using regular cell measurements surrounding. The objectives are, to ensure that the user is reachable, that is to say the user will be able to correctly receive the notification messages sent on the cell (paging), to ensure the best radio conditions when the UE goes online (for example to make a call), which also minimizes his consumption [16].

3.2 Types of Handovers

The handover can be classified according to several criteria according to the frequency difference and the system as well as the processing method, Thus, Types of handovers are classified into two categories[13]:

3.2.1 Intra-LTE Handover

Implement and complete the handover process across X2 and S1 interfaces where it indicates the state where the source cell and the target cell are located In the same eNodeB then handover is completed without EPC (Evolved Packet Core) involvement , In another case, the procedure requires an Intra-MME / SGW: The handover operation is performed through the S1 interface when the target cell and the source cell are connected through the same MME / SGW[13].

3.2.2 Inter-LTE Handover

Handover happens towards other LTE nodes. (Inter-MME and Inter-SGW) This process is required both the source and target connect to the same PGW. And in Inter-MME/SGW Is similar to the Inter-MME but is here UE need To cross from MME / SGW[13] [10].

3.2.3 Inter RAT(Radio Access Technology handovers)

Happens when the UE is in CONNECTED mode ,The handover process is performed after reserving the channel resources for another mobile network In case of handover between eUTRAN to UTRAN the Source-RNC(Radio Network Controller)connects to the Source-SGSN and S-SGW , the Target-eNB connects to the Target-MME and Target-SGW, and both the source and target SGWs connect to the same PGW [13] [10].

3.3 Factors that cause Handover operations

- ✓ Signal strength
- ✓ Speed of the UE
- ✓ weaker signal from serving Base station and strong signals from N-eNB

3.4 Handover procedure

The Handover is influenced by important factors of signal strength and user speed or Interference from adjacent channels, therefore , Handover is done across several steps and generally in a system LTE is done in three distinct steps[22]:

3.4.1 Handover preparation

The data flows between the UE and the core network where the handover algorithm assumes a lot of measurements for mobile where the UE profiles are different in the network so there are different types of services.

The UE records the information and makes measurements and then send report if they satisfy the conditions of trigger ,the source cell determines if the user needs handover based on the measurements sent by the UE and then the target cell is selected, if X2 based handover, the serving cell sends Handover Request message directly to the target cell, The Handover Request message Contains various information about, service quality and security parameters, RRC configurations of the source cell[19]. if no X2 interface between the two cells, the eNodeB configured to initiate handover towards a target cell via the S1 interface. MME performs a Handover Request message sent by the source cell and sends it to the target cell. If the target cell is accepted the request, send a RRC Connection Reconfiguration message

Which contains the configurations that will be used by the UE at the target cell [16].

3.4.2 Handover Execution

This step is responsible for executing the connection with the new cell and breaking the connection with the previous cell:

The UE commanded by the source eNB to perform the HO, after UE receives the RRC Connection Reconfiguration message and transits to the RRC idle, 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.

UE Switch from the source cell to the target cell, by releases the resources of the source cell and tries to access the target cell with using the random access procedure [19] [7] .

3.4.3 Handover Confirmation

When the UE has successfully accessed the target cell, the UE sends the RRC Connection Reconfiguration Complete message (C-RNTI) to confirm the handover, the target cell sends the path switch procedure is initiated between the target eNB and the MME/S-GW. And starts to forward all the packets received from the X2 interface to the UE. The source cell receives UE Context Release message and sends UE Context Release Complete message to its MME in S1 based handover, MME responds back to signal the completion of the path switch. In this particular step the target eNodeB asks the source eNodeB to release resources for the UE[19].

3.4.4 Post-Handover

UE is attached to the target eNB, UL / DL traffic is transmitted between the new cell and UE .

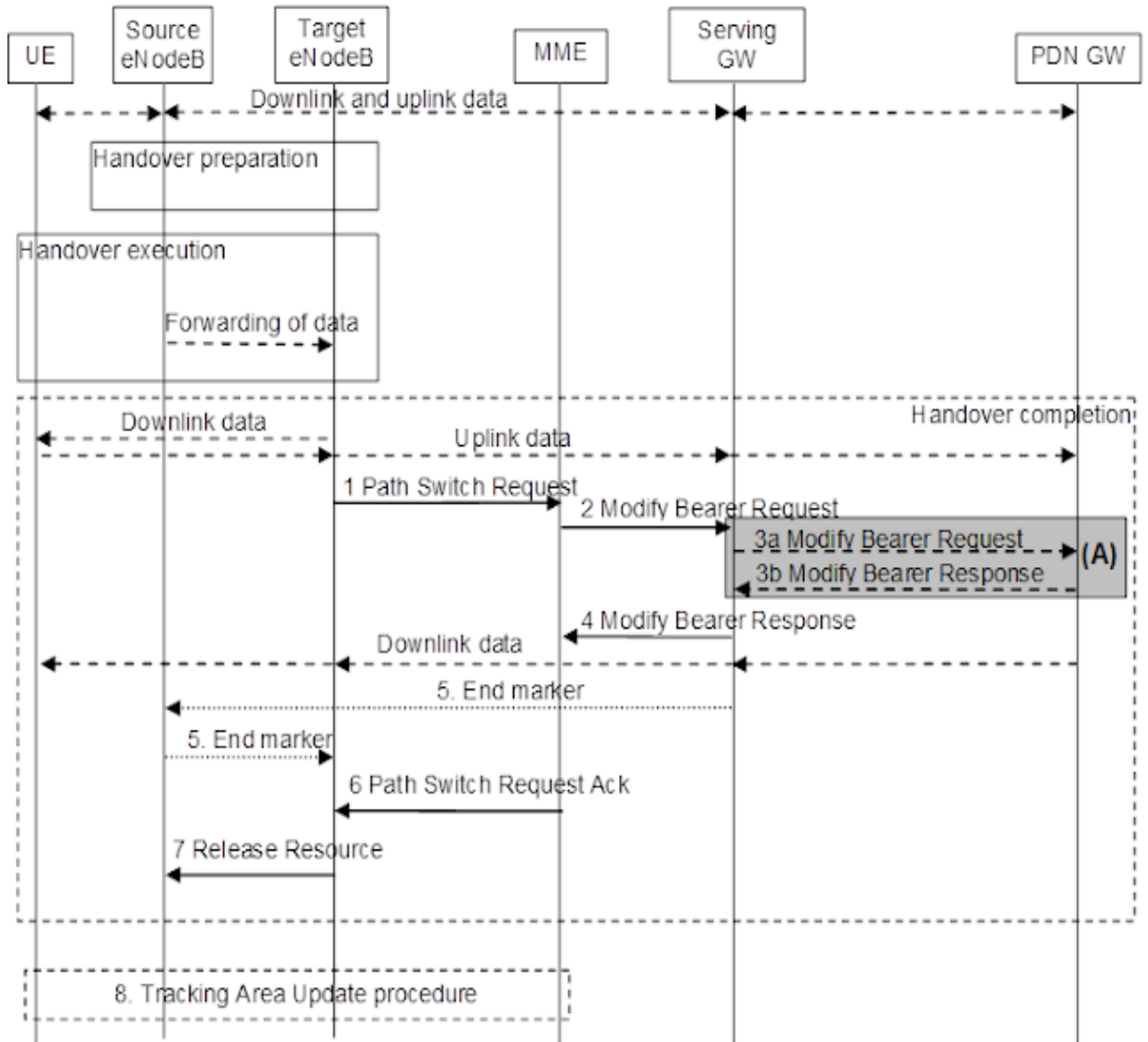


Figure 2.1 Handover Procedure

3.5 Measurement Reporting

The user performs several measurements and then sends the report to the network Which in turn decides what cell is connected to the mobile phone[9]:

3.5.1 Measurement configuration

Measurement objects: , BS defines each cell using its physical cell identity and a list of cells that the user must ignore during the measurements and contain information about the carrier and the downlink ,and also Bandwidth for use in measurement reporting.

3.5.2 List of Reporting Configurations

Include report criteria and when to send the report results and the form in which it is sent.

3.5.3 Measurement identity

Specifies the cell that triggered the report by using its physical cell identity. In response, the serving eNB can run the handover procedure.

3.5.4 Measurement Reporting

Agreement on the duration of the measurement report, measurement reports are triggered by various measurement events such as signal strength and quality of service[11]

3.5.5 Measurements gaps

During these measurements gaps, the UE can move to another carrier frequency and make a measurement, Where it cannot schedule the transmission to and from UE, measurements gaps are defined to help the UE for their inter frequency and inter-RAT measurements.

3.5.6 Quantity configurations

The quantity configurations include the quantity of the parameters used by filtering and evaluation procedures.

3.6 Handover signal measurements

3.6.1 Reference Signal Received Power (RSRP)

The RSRP is the most basic measurement made by the physical layer of the UE, to obtain an average value of the power received of all resource elements that carry cell specific reference signal within the considered bandwidth, The value ranges from -140 dBm to -44 dBm. [2].

3.6.2 Reference Signal Received Quality (RSRQ)

Describe the quality of the transmitter, RSRQ is defined as $(N \times \text{RSRP})/\text{RSSI}$, The RSSI represents the total power of the received signal, this includes the transmitted signal, noise and interference N is a number of resource blocks over which RSSI is measured, the

unit of RSRQ is dB and the value would be always negative (because RSSI value will always be larger than N x RSRP) also varies between -19.5dB and -3dB in steps of 0.5dB. [2]

3.6.3 Signal-to-interference-plus-noise ratio (SNIR)

Is a measure of Signal Quantity and Interference and Noise Quantity which compares the level of a desired signal stronger to the noise and interference level background (unwanted signal) , Its unit is dB .Mathematical it can be express as:

$$\text{SINR} = \text{Signal Power} / \text{Noise} + \text{Interference Power}$$

3.6.4 RSSI (RECEIVED SIGNAL STRENGTH INDICATOR)

The RSSI is the total power that UE observes across the whole band this includes data channels, control channels, adjacent cell power and serving cell power .

3.7 Handover Parameters

3.7.1 RSRP and RSRQ Threshold

Signal strength and signal quality are important conditions for a handover trigger, when the RSRP or RSRQ falls below the threshold the UE must choose a better cell to stay connected to the network and quickly without interruption , Where the signal is affected by UE speed and location as well as the noise.

3.7.2 Hysteresis (HO margin)

Is the key to maintaining the minimum difference between the signal received from the source eNodeB and the target eNodeB. The hysteresis values range from 0 to 30 dB

3.7.3 Time-to-Trigger (TTT)

Is the time during to trigger the event for the handover in order to send it to the cell through a measurement report , This parameter can decrease the number of unnecessary handover , the value of the TTT parameter are 0, 40, 64, 80, 100, 128, 160, 256, 320, 480, 512,640, 1024, 1280, 2560 ,5120 ms.

4 Handover Events in LTE

4.1 Intra-RAT Event-triggered Measurement Reporting

The event is triggered when the following condition is true[3].

4.1.1 Event A1

This event based On the quality of the service RSRQ is triggered when the serving quality cell becomes better than a threshold during the Time of trigger(TTT when UE detects through periodic measurements of signal quality that they meet the event A1 condition and The eNodeB stops inter-frequency or inter-RAT measurements.

The hysteresis value affects the cell decision when Hys increases, the probability of entering event A1 will be reduced ,thresh value will also increase the delay in taking the decision to start Event A1.

Entering condition:

$$M_s - Hys > Thresh$$

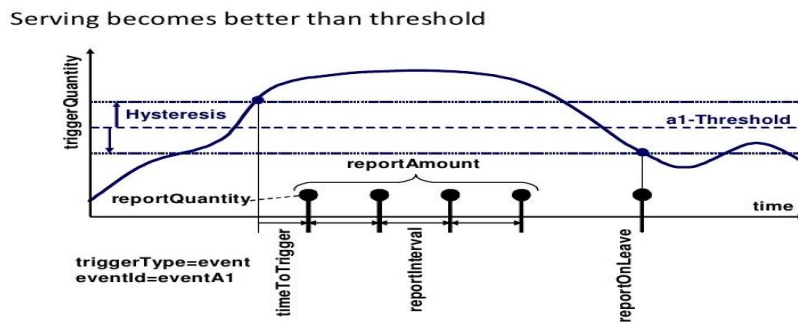
Leaving condition:

$$M_s + Hys < Thresh$$

M_s is the measurement result of the serving cell, M_s is expressed in dB in case of RSRQ.

Hys is the hysteresis parameter for this event.

$Thresh$ is the threshold parameter for this event.

Event A1**Figure 2.2** Event A1**4.1.2 Event A2**

The algorithm uses the measurement of the reference signal of the received quality RSRQ, Event A2 means the signal quality of the serving cell becomes worse than threshold, The eNodeB starts Inter-frequency or Inter-RAT measurements, The eNodeB can execute Measurement gap if it needs activation.

Entering condition:

$$Ms + Hys < Thresh$$

Leaving condition:

$$Ms - Hys > Thresh$$

The probability of trigger Event A2 will be increased if the value of Hys is lower and the threshold value is greater ,If the signal quality is weak it becomes easy to break the condition ,that Leading the UE looking for adjacent cells with better signal.

Event A2

Serving becomes worse than threshold

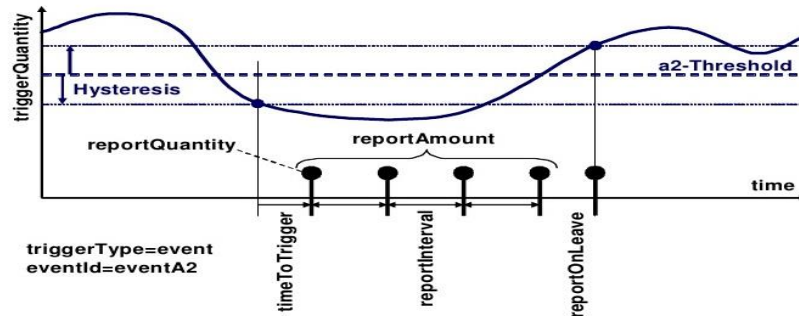


Figure 2.3 Event A2

4.1.3 Event A3

Event A3 is triggered when a neighboring cell becomes better than the serving cell by an offset, offset is a constant variable that represents the threshold for the difference in RSRP between the serving and the target cell and Event A3 depends on Parameter TTT is required for satisfying HOM(offset and Hys) condition.

Entering condition:

$$Mn + Ofn + Ocn - Hys > Ms + Ofs + Ocs + Off$$

Leaving condition:

$$Mn + Ofn + Ocn + Hys < Ms + Ofs + Ocs + Off$$

Mn is the measurement result of the neighboring cell.

Ofn is the frequency specific offset of neighboring cell.

Ocn is the cell specific offset of neighboring cell.

Ms is the measurement result of the serving cell.

Ofs is the frequency specific offset of the serving cell.

Hys is the hysteresis parameter for this event.

Off is the offset parameter for this event, It is expressed in dB.

Event A3 is cancelled or not triggered when a neighboring cell becomes worse than the serving cell by an offset during time to trigger .

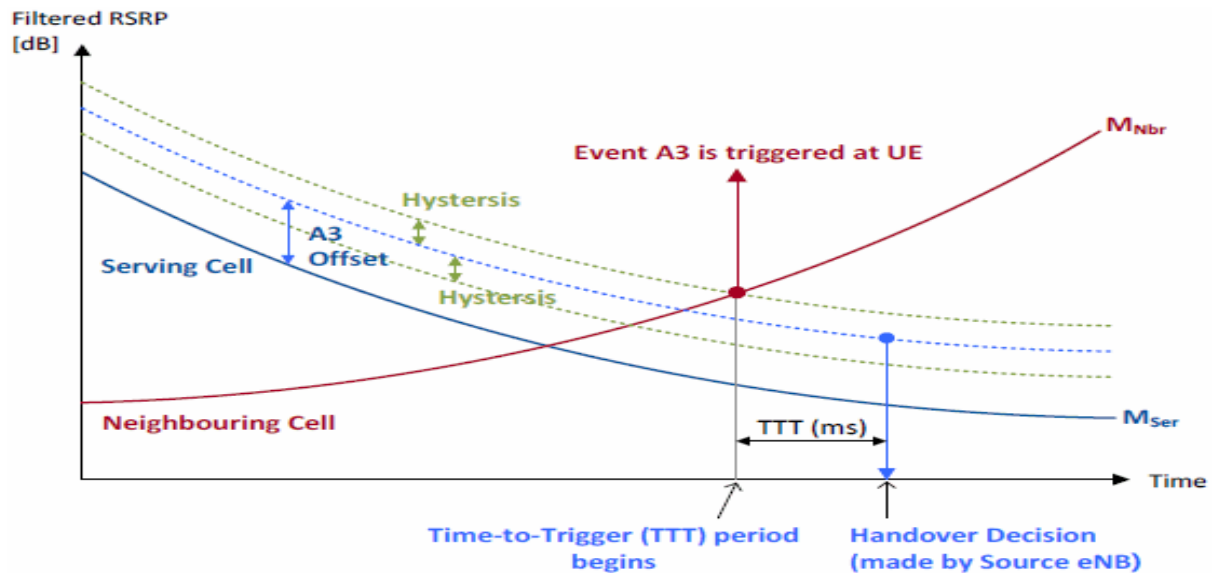


Figure 2.4 Event A3.

4.1.4 Event A4

Neighbor cell becomes better than threshold, by default the algorithm configures the A4 event with a very low threshold, so that the triggering criteria are always true, eNB may trigger handover driven by load balancing.

Entering condition:

$$M_n + Ofn + Ocn - Hys > Thresh$$

Leaving condition:

$$M_n + Ofn + Ocn + Hys < Thresh$$

Event A4

Neighbour becomes offset better than threshold

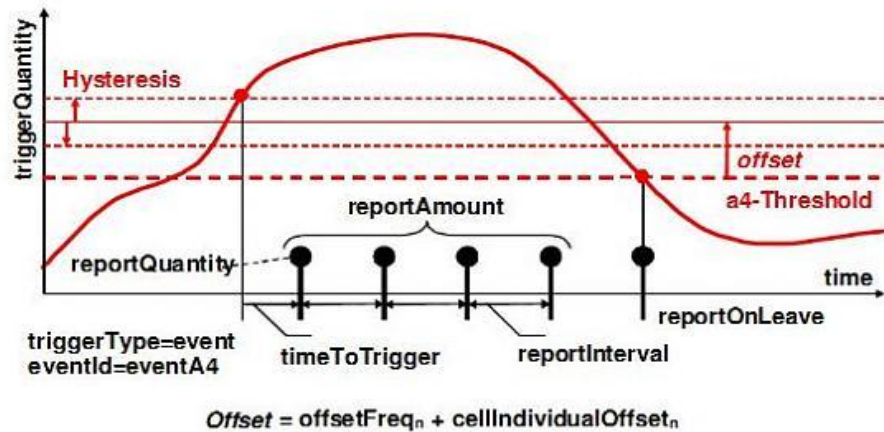


Figure 2.5 Event A4

4.1.5 Event A5

Is triggered when The quality of the signal serving cell becomes worse than threshold 1 and neighboring cell becomes better than threshold 2, The eNodeB starts Inter-frequency or Inter-RAT-measurements.

Entering condition:

$$M_s + Hys < Thresh\ 1 \quad \text{and} \quad M_n + Ofn + Ocn - Hys > Thresh\ 2$$

Leaving condition:

$$M_s - Hys > Thresh1 \quad \text{and} \quad M_n + Ofn + Ocn + Hys < Thresh2$$

The probability of event A5 triggering depends on threshold1 and threshold 2 values if Thresh1 is set too low and Thresh2 is set too high, the probability of Event A5 triggering will be decreased .

Event A5

Serving becomes worse than thr.1 and neighbour becomes better than thr.2

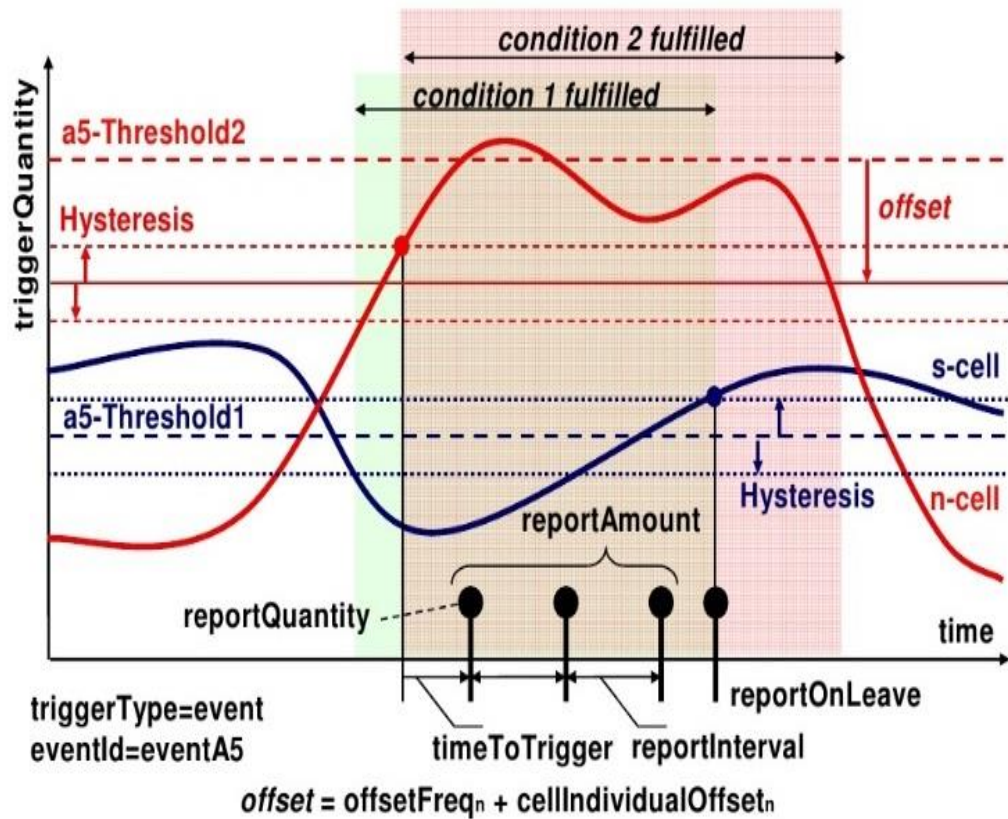


Figure 2.6 Event A5

4.2 Inter-RAT Event-triggered Measurement Reporting

4.2.1 Event B1

Inter-RAT neighbor becomes better than threshold.

Entering condition:

$$M_n + Of_n - Hys > Thresh$$

Leaving condition:

$$Mn + Ofn + Hys < Thresh$$

Event B1

Inter RAT neighbour becomes better than threshold

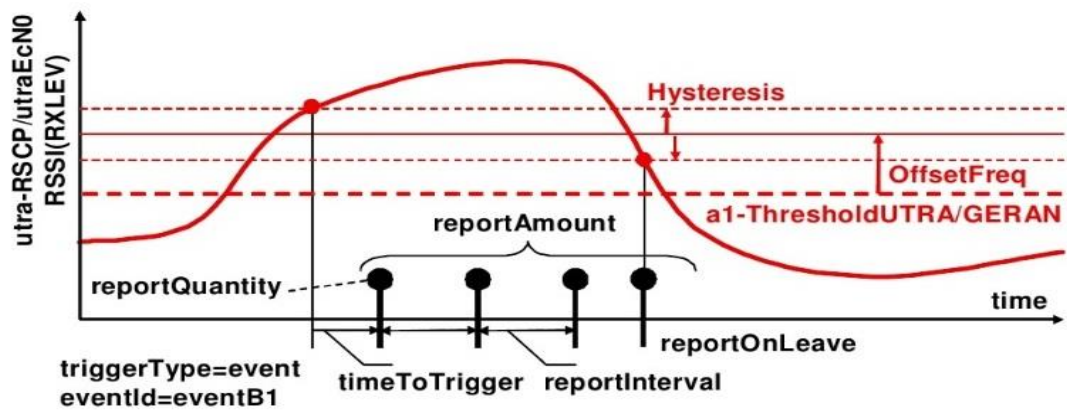


Figure 2.7 Event B1

4.2.2 Event B2

is triggered when a Serving becomes worse than one threshold and inter-RAT neighbor becomes better than another threshold.

Entering condition:

$$Ms + Hys < Thresh1 \text{ and } Mn + Ofn - Hys > Thresh2$$

Leaving condition:

$$Ms - Hys > Thresh1 \text{ and } Mn + Ofn + Hys < Thresh2.$$

Event B2

Serving becomes worse than threshold1 and inter RAT neighbour becomes better than threshold2)

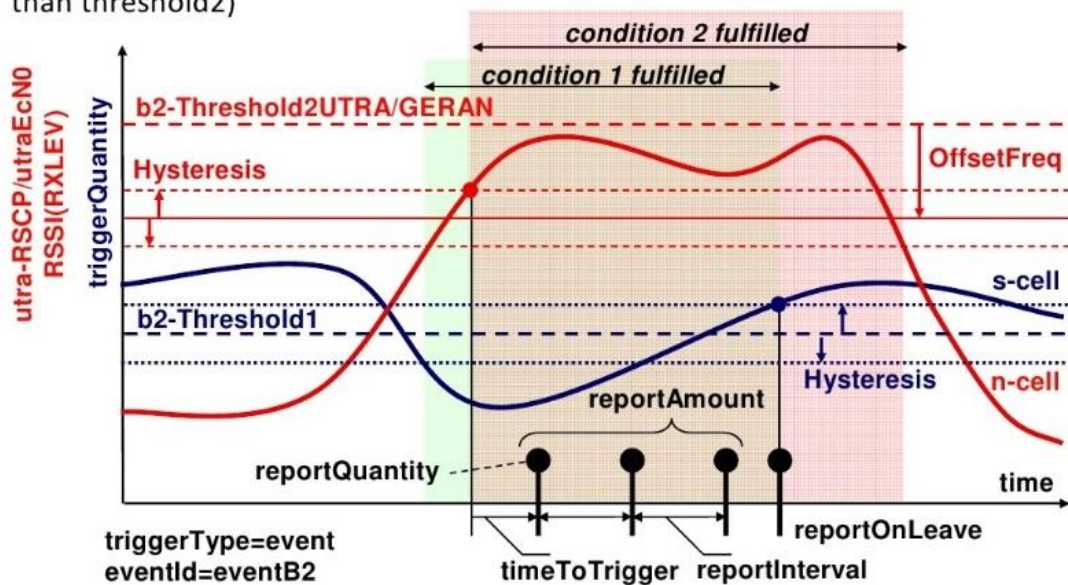


Figure 2.8 Event B2

5 NS-3 Software

The NS-3 simulator (Network Simulator 3) is a network simulator mainly for research and educational use. support for various network technologies including LTE The NS-3 project, started in 2006, First version 3.1 June 2008 and Current version 3.29 Available for Linux, OS X and Windows Cygwin Written in C ++ Simulation scripts in C ++ and also provides bindings for Python, Provides a range of useful properties for simulation, Smart pointers, Trace sources is an open-source project that strives to maintain an open environment for researchers with the contribution and sharing of their software .below are a few distinguishing features of

ns-3 in contrast to other tools[42]:

- ✓ *ns-3* is designed as a set of libraries that can be combined together and also with other external software libraries.

- ✓ While some simulation platforms offer users a single, integrated GUI environment in which all tasks are performed, NS-3 is more modular in this regard. Several animators, data analysis and visualization tools can be used with NS-3. However, users should expect to work on the line of command and with C++ and / or Python development tools.
- ✓ NS-3 is mainly used on Linux systems, although the support exists for FreeBSD, Cygwin (for Windows), and Windows Visual Studio support native is under development.

The LTE module of the ns-3 is developed by Technological Center of Telecommunication of Catalonia, Spain with LENA project, ns-3 supports various aspects of the LTE with providing support for heterogeneous networks, mobility and handover procedure. So, ns-3 is preferred as a simulation environment for this thesis work.

5.1 Model NS-3

The simulation model under NS-3 is shown in the figure 2.12:

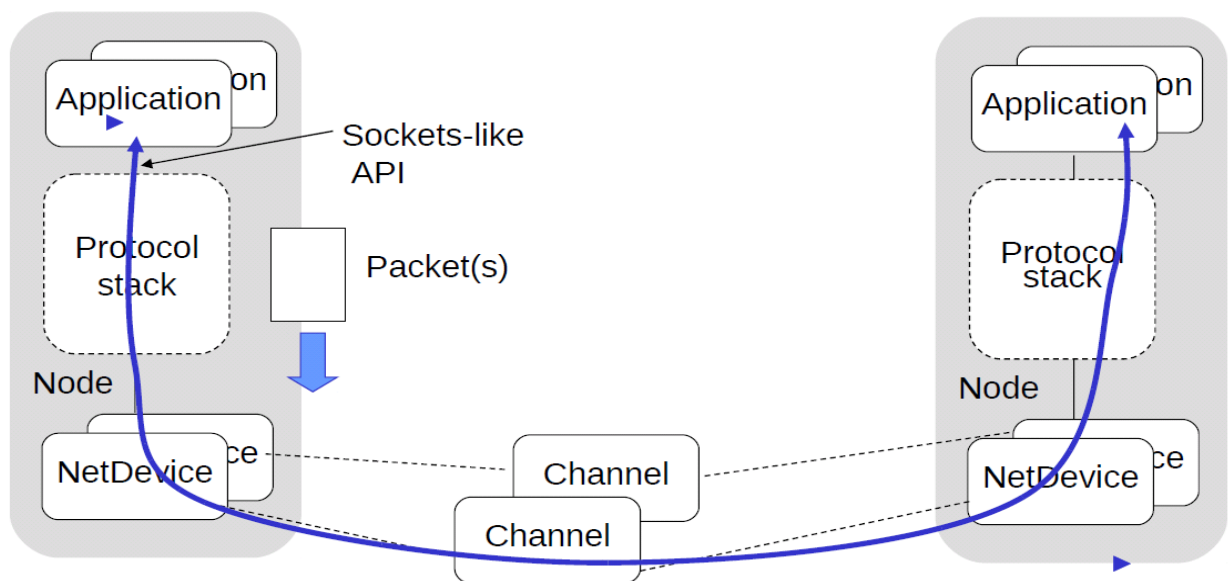


Figure 2.9 Model NS-3

- ✓ **Node:** node class represent a network element contains a list Application and a list of NetDevice It's like a computer to which we add features.
- ✓ **application:** The class Application contains a number of sockets and provide methods that generate an activity to simulate.
- ✓ **Channel:** Channel class provides methods for managing communication subnetwork objects and connecting nodes to them as a large Ethernet switch, or three-dimensional space.
- ✓ **NetDevice:** The NetDevice class provides methods for managing connections to Node and Channel objects.
- ✓ **Topology Helpers:** In ns-3 help to find Nodes with attached NetDevices In a large simulated network and make this as easy as possible.

5.2 Software Organization NS-3

Figure 2.13 describing the software architecture of NS-3:

NS3: Software Organization

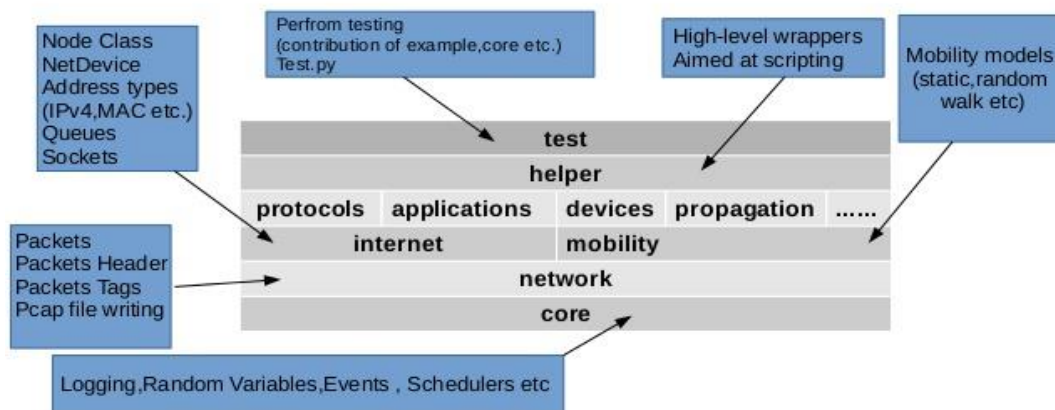


Figure 2.10 NS-3 Software Organization.

5.3 The modules of NS-3

The modules available for NS-3 are shown in Figure 2.14:

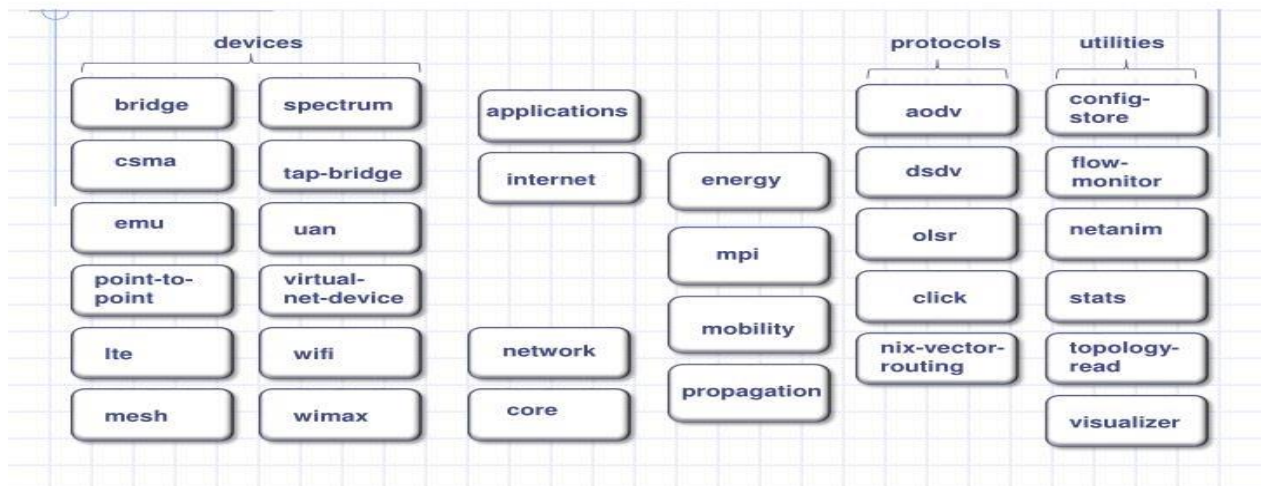


Figure 2.11 NS-3 Module

6 Conclusion

This chapter deals with the management of mobility in LTE networks which consists of two states: idle state and the connected state. Then, we described the different types of well-known algorithms used in Handover. However, the traditional A3, A2, A5 event-based HO algorithms are mainly designed for the low speed (≤ 30 m/s) networks. Then, we explored the Handover challenges that faced the handover process of mobile LTE network. So, in the next chapter, we examine the optimization of the Handover process within different effects that involved in the LTE under realistic environment condition.

1 Introduction

High speed is one of the main factors affecting Handover A3 event performance, Handover may fail due to unreliable radio link failure RLF and ping-pong.

Reduce the number of unnecessary Handover, including ping-pong, Handover too early and handover too late By tuning the Hys and the TTT HO parameters, must that our algorithm can lead greatly Better performance, such as reducing frequent Handover operations will keep the network effective while The signal load will be noticeably low and dropped call rates

The eNodeB gather the statistics of handovers HPI(handover performance indicator) , too late handovers , RLF , too early handovers , ping-pong and calculate handover rate then changes hysteresis and TTT values According to information collected from the user, These statistics constantly seek to improve network performance in an automated manner. However The trade-off must allocate the necessary resources for the distribution of the load balancing to provide the necessary services requests of the users in the network.

In this work, we study a different scenario compared to a traditional A3 HO event with new A3 Ho Algorithm of Adaptive Hys and Time To trigger for LTE network in case High speed vehicles.

2 Handover Failures

The general configuration of the HO parameters is unsuitable if the handover parameters are improperly configured , handover failure can occur when UE that fails to maintain radio connection afterwards Drop call ,The parameters related to RLF detection and recovery can be referred to Annex long-term evolution (LTE) timers An RLF is detected at the physical layer so the UE or eNodeB can detect this kind of Radio Link Failure , if UE may received signal quality is too low or Power (SINR) from UE is much lower than what eNodeB configured for the UE ,RLF will also be determined due to poor downlink conditions, the reliability of the current radio connection is evaluated to go through RRC Connection Reestablishment procedure. upon expiry of Timer T310 after the signal quality drops below threshold, N311 consecutive times is triggered when in-sync indications are received, once when the condition of N311 is fulfilled, UE won't go for RLF. Upon expiry of this Time, UE will maintains the entire radio resource configuration by finds the best neighboring eNodeB from the latest

measurement session and sends a reestablishment request to the target eNodeB to reconnect[18]. The mobility performance is not as good as in homogeneous deployments a high mobility requirements or poor mobility management will result in unnecessary HOs, HOFs, In addition Increasing the HOF rate due to the distribution of small dense cells leads to increased interference intensity, The worst Handover performance appears from a small cell to a macro cell, pico-to-macro In contrast to a homogeneous macro-cell deployment[16] [17].

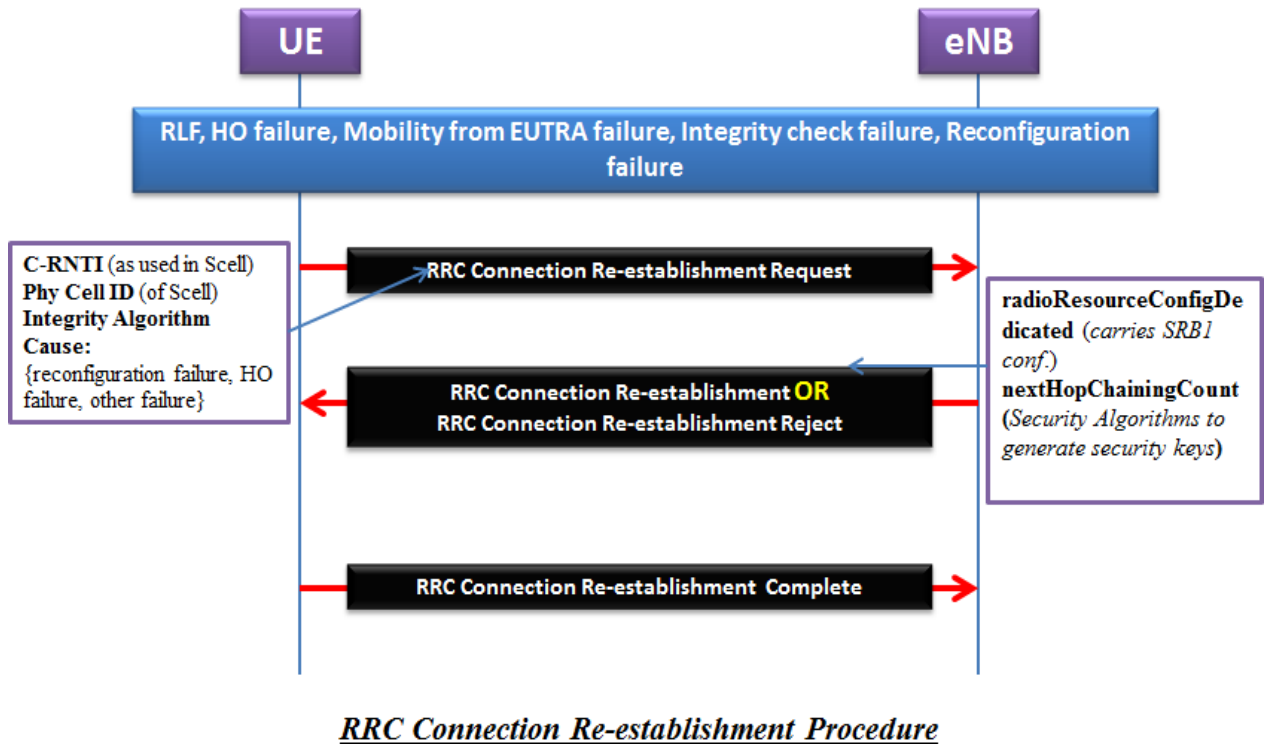


Figure 3.1 RRC Connection reestablishment Procedure.

To solve handover failures problems and improve the HO performance with regard to HOF rate can be categorized into three types:

2.1 Handover Too Early

Handover happens when a UE moves into a target cell too early, when RLF occurs between the UE and the target cell during or after the handover[18]. the connection will drop almost immediately The UE has successfully been handed over from source cell to target cell Then, the victim UE try to re-establish the connection to the previous cell since this cell Has a

stronger signal ,The serving cell itself recognizes the too-early handover and send an indication to the target cell and notification between cells is unnecessary to adjust Handover parameters.

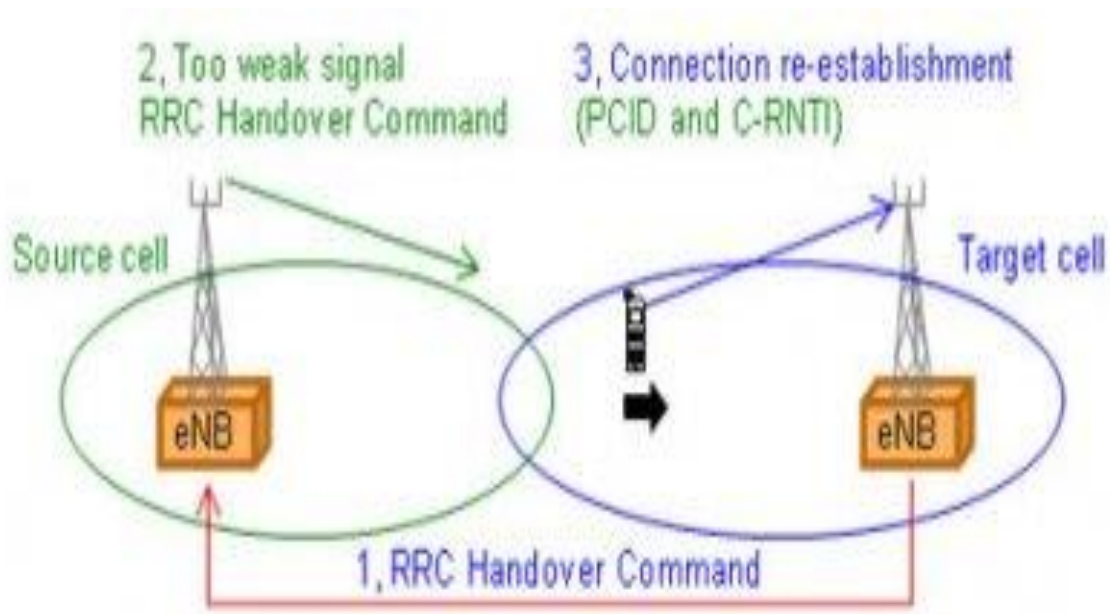


Figure 3.2 Handover too early.

2.2 Handover Too Late

happens when a UE Crossing the border faster than the handover parameter settings allow and before the HO procedure finishes , RLF occurs between the UE and the source cell because the signal strength is already too low to reach the UE or the signal quality of the serving cell is inadequate for the data communication requirement , then The UE attempts to reconnects a new cell, The original cell recognizes the handover that was too late after being notified by the target cell about the RLF , In order To reset Handover parameters[18].

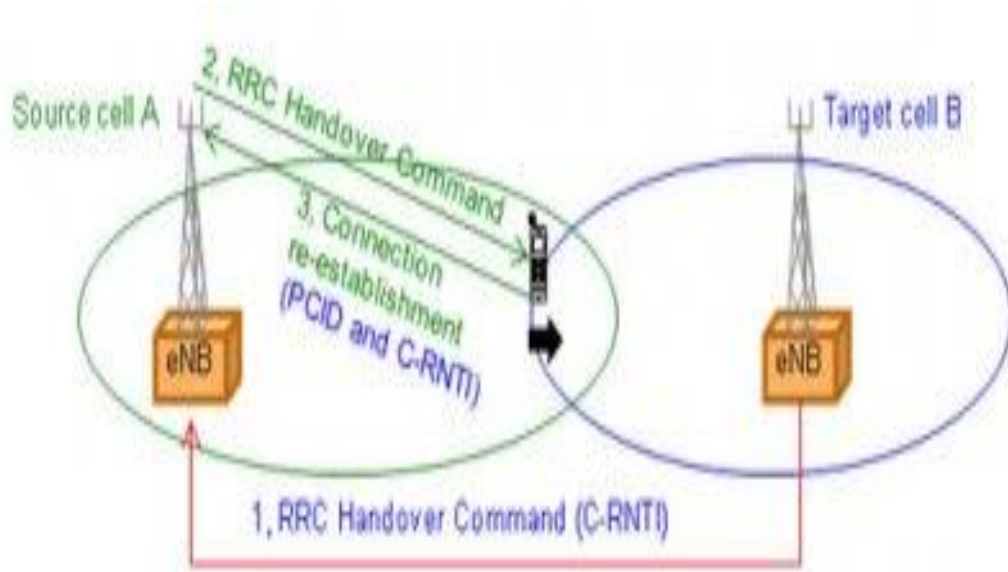


Figure 3.3 Handover too Late.

2.3 Ping-pong Handover

When Handover occur from one cell to another but is quickly handed back to the original cell then an RLF occurs shortly because high signal fluctuation at the common boundary of the eNBs [23]. the UE can send a measurement report and the new serving cell could start a handover procedure with the target cell of the UE. In A3 event, if the hysteresis and TTT values are too low, instantaneous increases in the measurements can trigger the measurement reporting and can give an indication of incorrect handover parameter setting, hence potential for dropped calls will increase and quality degradation will also increase.

3 Handover Performance Indicator HPI

The eNodeB gathers the statistics of handovers HPI (handover performance indicator) , and calculate the rate of too late handovers , too early handovers , ping-pong then changes hysteresis and TTT values According to information collected from the user, These statistics constantly seek to improve network performance in an automated manner. However, the trade-off must allocate the necessary resources for the distribution of the load balancing to provide the necessary services requests of the users in the network. In this work, we study a different scenario compared to a traditional A3 HO event with new A3 Ho Algorithm of Adaptive Hys

and Time To trigger for LTE network in case High speed vehicles. To find an appropriate set of handover parameters which is a summary Of statistics from handover failures (HOF), Ping Pong (HPP) indicators, RLF indicators, too late handover and handover too early ,HPI processes to monitor the performance of HO procedures per cell. The metrics that can be used in the optimization algorithm are:

HO_{HOF} : is the handover failure performance indicator Due to an unreliable radio link, The UE then detects a radio link failure or a handover failure event and reconnects to the network by performing RRC reestablishment or RRC establishment . HPI_{HOF} is the ratio of the number of the HO failures to the total number of the HOs (HO_{total}) [15].

HO_{RLF} : The Radio Link Reconfiguration procedure is initiated by the Controlling RNC by sending the message RADIO LINK RECONFIGURATION to the target eNodeB. The message is sent using the relevant signalling connection , In the unsuccessful case a message RLF is returned, indicating among other things the reason for failure Like the number of the HO calls that were dropped (by the network) before the HO procedure was finished. HPI_{RLF} is the ratio of $HO_{dropped-network}$ to the number of calls that were accepted in the target cell[15] :

$$HO_{RLF} = HO_{dropped-network} / HO_{accepted} \quad (1)$$

HO_{total} : signifies the total number of the HO attempts of the handover failures (HOF), and RLF indicators:

$$HO_{total} = HO_{HOF} + HO_{RLF} \quad (2)$$

3.1 Handover Ping- pong Rate

ping-pong ($HO_{ping-pong}$) that result from premature reaction to fluctuating radio resources, pose a great threat to the QoS of delay sensitive connections .

HPI is the ratio of the number of ping-pong HOs ($HO_{ping-pong}$) to the total number of HOs:

$$HPI_{HPP} = HO_{ping-pong} / HO_{total} \quad (3)$$

3.2 Handover Too Early Rate

This metric shows the ratio of the too early handover events A3 . too early handover occurs if these hysteresis and TTT values are too small. In such a case, the hysteresis and TTT values should be increased The handover failures can be detected with using the RLF Indication messages sent to the target cell.

$$HPI_{early} = (HO_{ping-pong} + HO_{early}) / HO_{total} \quad (4)$$

where $HO_{ping-pong}$ and HO_{early} are the number of ping-pong HOs and early HOs, respectively[19].

3.3 Handover Too Late Rate

This metric shows the ratio of the too late handover events for a3 event , If a large hysteresis a3 value is used for detecting the channel quality degradation of the serving cell should be decreased to avoid a too late handover and The unsuccessful HOs are added to these indicators when the procedure has failed, because of the radio link quality[19].

$$HPI_{late} = (HO_{dropped-network} + HO_{failure} + HO_{late}) / HO_{total} \quad (5)$$

where $HO_{dropped}$, $HO_{failure}$ and HO_{late} are the number of dropped HOs, failed HOs and late HOs, respectively.

4 Handover Parameter Optimization Method

A large hysteresis value is used for the Event A3 HO. if UE is at the cell boundary of the serving cell, the HO may begin late in which case, hysteresis should be decreased However, too-small values for the TTT or the hysteresis can cause too-early or wrong-cell handovers, so that a longer value for the TTT, or a greater HH(hysteresis) is required and The offset values also effects the measurement report triggering with changing the hysteresis value .

The problem that must be solved is to reduce the total number of handover failure due to the incorrect configuration of the algorithm handover parameters and finds the best combination of HH and TTT, which improves HO performance.

4.1 Adaptation of HH (Hystersis) By The Variation of Speed

$$HH_{adj} = HH_{def} - \log_{HH_{def}}((V_{max} - V_c + 1) / V_{max}) \quad (6)$$

where HH_{def} denotes the default hysteresis for all UEs, V_{max} is the maximum speed of the vehicle and V_c is the current speed of the vehicle, which includes vehicle context information , The maximum speed of a high-speed train is currently 350 km/h if the velocity of the train increases, the HH will decrease. Otherwise, if the velocity of the train decreases, HH will incur minimal changes.

4.2 Adaptation of TTT By The Variation of Speed

This is based on many simulations and previous studies where we add every speed to the time that fits them effectively to significantly reduce failed handover The values TTT are 0, 40, 64, 80, 100, 128, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560 and 5120 ms and the default value is 256ms.

UE velocity	TTT ms
V = 5 km/h	256
V = 30 km/h	100/128/160
V = 60 km/h	64/80
V = 120 km/h	40

Table 3.1 combination TTT by deferent speeds

When the speed between 5km/h and 30km/h TTT is 256ms while at high speeds 120km/h and larger, TTT takes less than values 40ms

```

Collect of context information
Collect of RLFs ,HOT,HOF.
HPIlate ← Calculate HPI Too Late Handover
HPIearly ← Calculate HPI Too Early Handover
HH ← handover hysteresis for UEs
HHadj ← calculated HH adjustment value
if HPIlate > HPIearly then
    HH ← HH - HHadj
    TTT ← Adapt TTT(v)
end if
else if HPIearly > HPIlate then
    HH ← HH + HHadj
    TTT ← Adapt TTT(v)
end if

```

Algorithm 3.1 Proposed algorithm HO A3 based HPI.

5 Improvements Over the Simulation Environment

To Applying Algorithm A3event based HPI There are some challenges to overcome , as ns-3 does not support RLF to detect the handover failures , A user can not be changed to idle state after being in RRC Connected state, The transition procedure from CONNECTED to IDLE state is created to send the RRC connection release when the appropriate connection setup timer expires , connection re-establishment attempts are failed In order to implement RLF .

The ns-3 implement two timers to detect the handover too early and too late events with Handover Leaving Time and Handover Joining Timer If timeout occurs the UE's context Destroys through cell source or cell target, With using these timers the handover failures and handover too early or too late can be detected.

6 Simulation Environment

In this section, we will try to show the difference between the traditional algorithm A3RSRP and the algorithm suggested by some indicators that evaluate the performance of the handover process. . In this section, the simulations environment is shown firstly. Then the simulation results are presented

Distance between Macrocell	2500m
eNB transmission power	46dbm
Number of UE	Random distribution
UE speed	5km/h – 350km/h.
Bandwidth	100 MHz
Handover algorithm	A3RSRP Algorithm / A3RSRP based HPI
Serving cell threshold	30
Neighbour cell offset	1

Table 3.2 Simulation Parameters

6.1 Analysis of Simulation Results

Firstly, we have studied the influence of speed on the number of Handover, in fig 3.4 show number the handover decrease with increased the speed of UE. the simulation time is 30 s and the number of UE is 30, when velocity of the UE is 5 ,30, 60, 100 km/h, the handover number of the traditionnel A3 algorithm and the handover number of the novel algorithm A3 based HPI statistic are 0, 11, 1,1 and 13, 18, 12,12 respectively.

We Note number of handover decreasing at speeds 200 km/h to 350 km/h , because the UE is unable to take Handover decision And in a new algorithm A3 based on statistics Enable users to perform handover decisions will be higher By dynamically adjusting handover parameters in different speeds and simultaneously considering the statistical HPI characteristics to trigger handover.

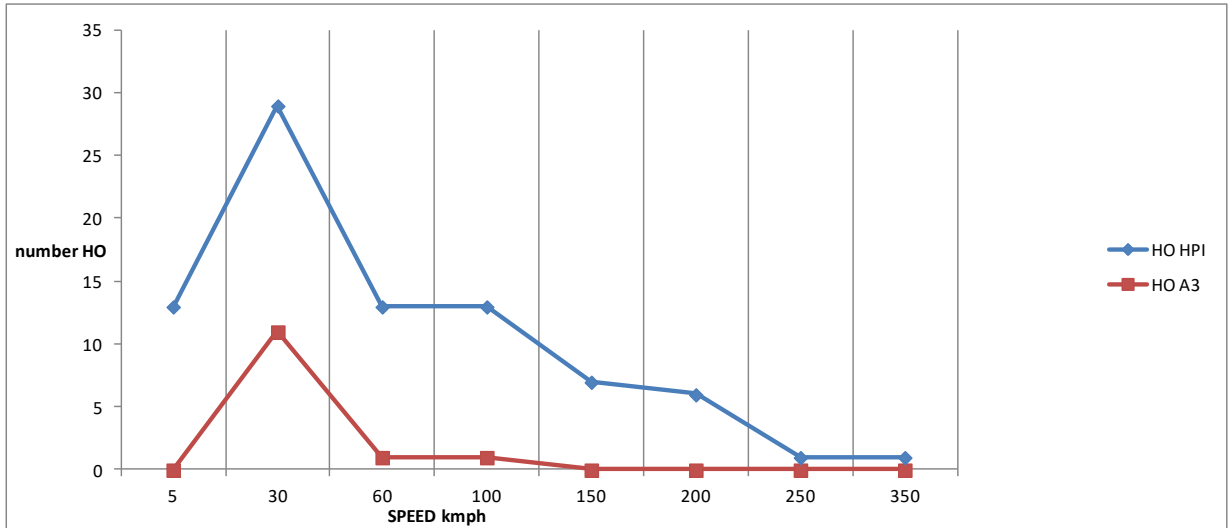


Figure 3.4 Comparison Number of Handover based HPI with HO a3 based speed

Fig. 3.5 Illustrates the number of Success handover Comparison between two algorithms The number of handover success decreases when the speed of the UE increases At slower speeds, the number handover success of A3 base HPI is greater than the conventional, while at medium speeds we see an increase in the success of the handover A3 . Then the success of number handover is increased in the algorithm A3 based HPI at speeds of 60 km/h to 250 km/h while in the old A3 algorithm decreases until becomes 0 % at speed of 100 km/h.

The proposed algorithm reduce the failure rate of handover from 72 % up to 92 % On the other hand, algorithm A3 based HPI support high speeds up to 2

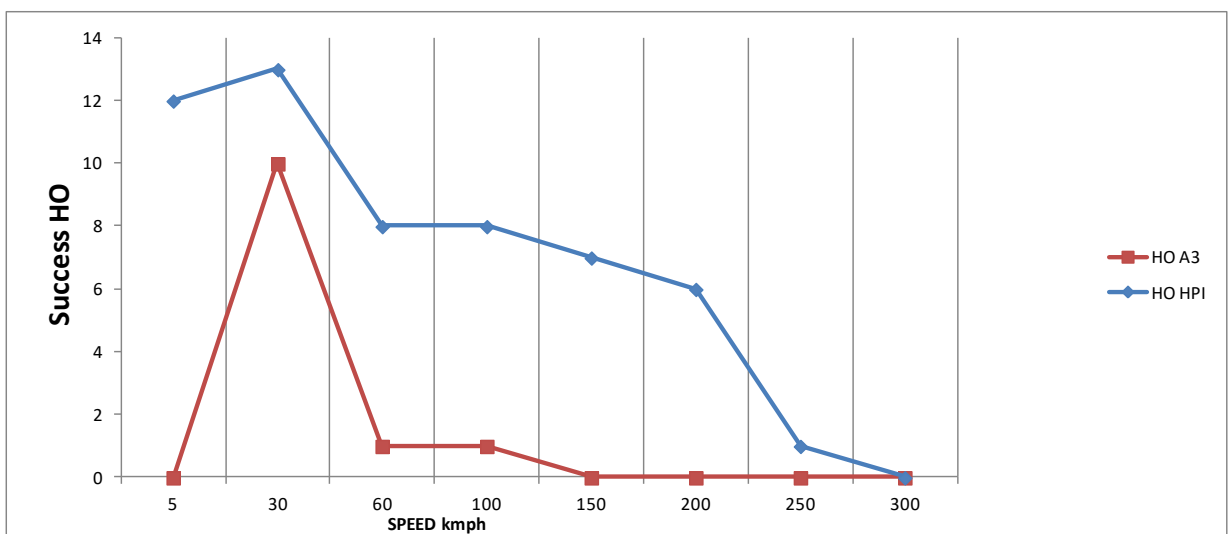


Figure 3.5 Comparison the success of number handover based HPI with HO a3 based speed

The column chart in Fig 3.6 shows the rate of handover too early within simulation of 5 users , Where they are high in an A3 algorithm starting at speed 60

There is no failure in algorithm A3 based HPI until the speed of 100, where there is a decline in the rate of handover too early compared to the old algorithm, Time to Trigger and Hys adjusted with high speeds to complete the handover process successfully. if there a heavy number of UE will be note a higher failure rate for the old algorithm compared to the proposed algorithm.

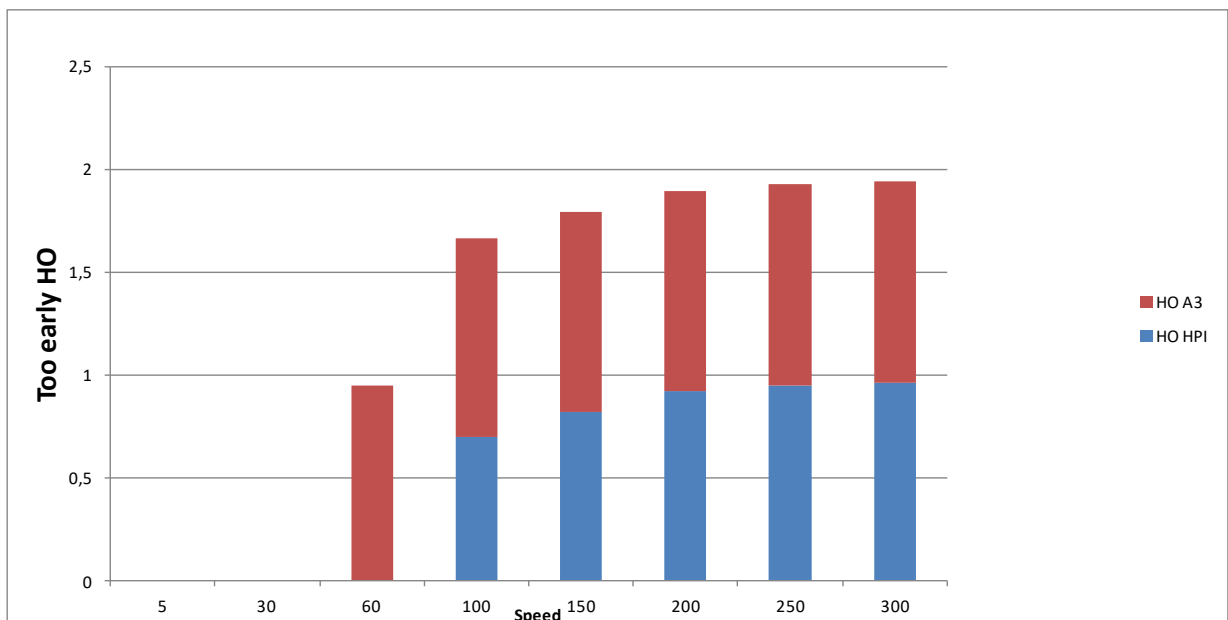


Figure 3.6 Comparison the rate of handover too early based HPI with HO a3 based speed

The column chart at Fig 3.7 illustrate the rate of too late handover , HO occurs at the cell frontier where the UE still for a longer time , A3 handover Be high rate failure starting at speeds 30 kmph which is explained by high interference levels , Conversely the algorithm A3 based HPI is absent until the speed of 60 kmph where we notice a slight difference.

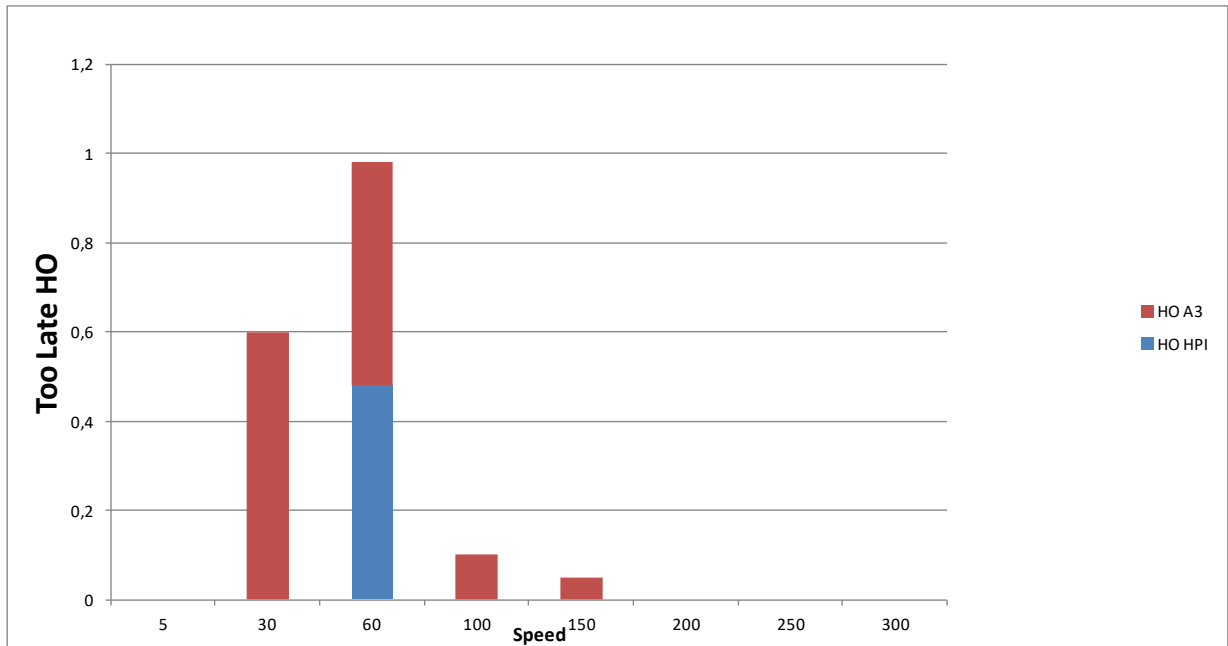


Figure 3.7 Comparison the rate of too late handover based HPI with HO a3 based speed

We note in Figure 3.8 an increase in the number of packets lost due increasing the speed of the UE ,A3 Ho based HPI Perform high efficiency by Reduced The packets lost rate, while at low speeds it is very low and is less than 60 % at 100 speed ,At high speeds the rate of packets lost reaches its peak due to increase number of handover failure .

By analyzing the results of an A3 algorithm it gets a great loss at slow speeds 30 Up to 60% packets lost rate With a difference of 55% over a proposed algorithm while the median speeds, loss rate varies from 81% to 96%. in general that causes are related to improper configuration of the radio access controller.

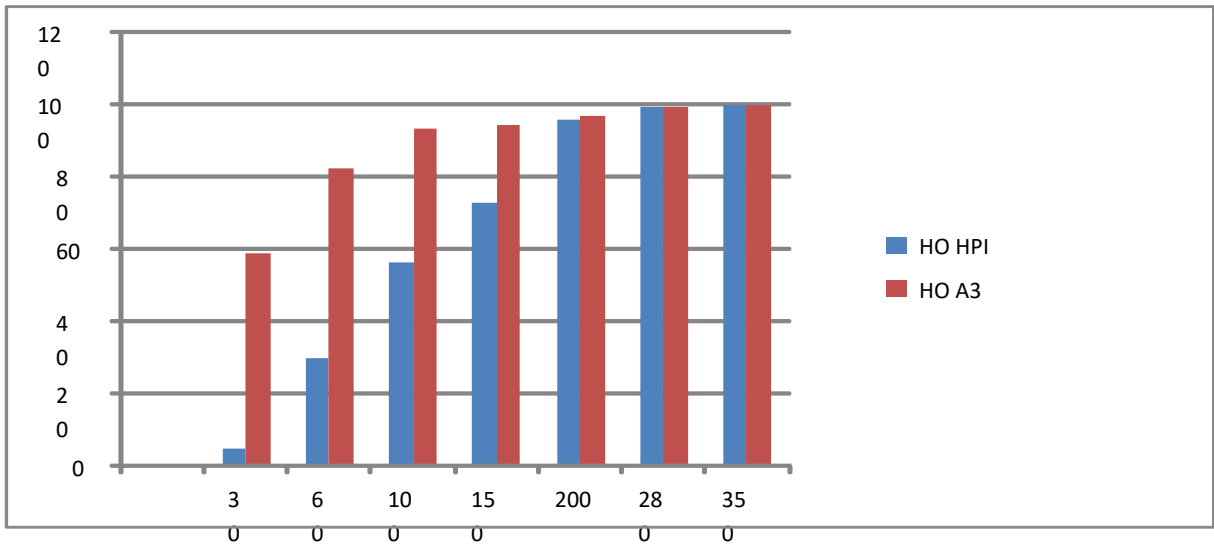


Figure 3.8 Comparison the number of packets lost HO based HPI with HO a3 based speed

The Figure 3.9 below shows the delay in the handover decision , the signaling message exchange plays an important role to quantify factor of Handover latency in order to efficiently transferring the call to new access area , We have analyzed the handover latency to compare the handover delays In a simulation environment that contains five users , By comparing between the two algorithms, the difference in the delay time starts at speeds of 30 to 200 ,The proposed algorithm allows the reduction of the delay time to 0.039 milliseconds, which is sufficient in order to avoid the handover too late by 65%.

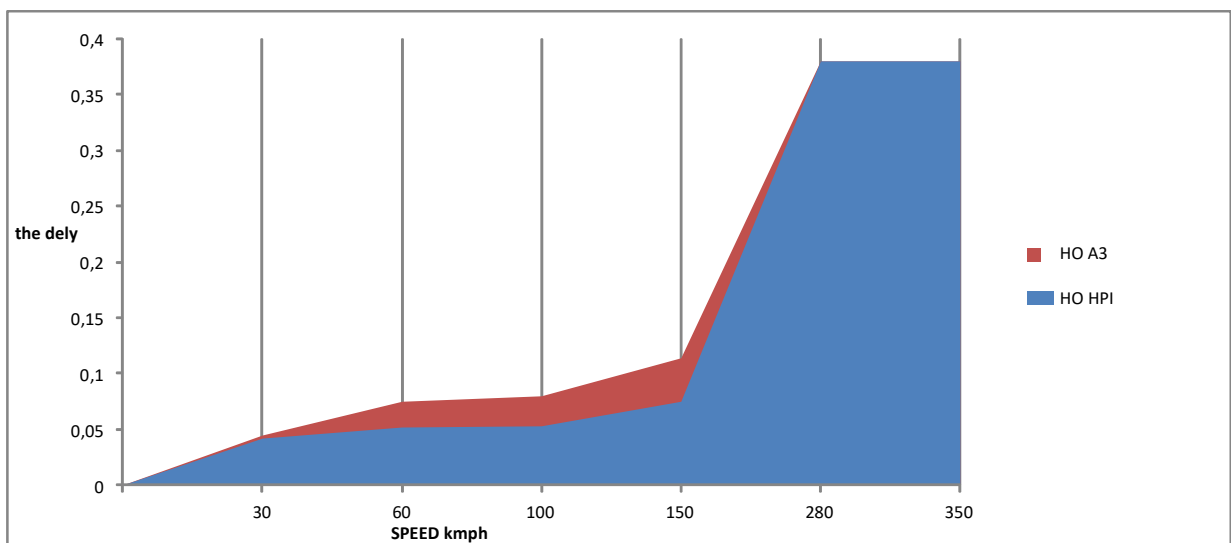


Figure 3.9 delay between handover based HPI and OLD HO a3

7 Conclusions

The purpose of this chapter was to self-improve the handover process (HO) built from the statistics collected during movement of UE to achieve the robustness of mobility. through on analyzing the performance results of the proposed algorithm A3 based HPI compared to the traditional A3 algorithm in the issue of different speeds. In this work, we intended to figure out the trade-off between Hys and TTT parameter by adjusting the HOM and adapting time to trigger with different speeds.

The simulation results proved that proposed algorithm a better performance for reducing the rate of handover too late and handover too early at slow speeds and high speeds respectively, as well have a good performance latency in handover execution, Where the delay was reached up 0.038 ms.

1 Introduction

A fundamental challenge in LTE design is to manage and allocate resources to meet traffic demands under difficult constraints. One of the most challenge, the handover which is resolved by applying sets of traditional algorithms derived from the reference power received measurements RSRP. However, this method faces increasing challenges due to today's dynamic and diverse traffic, and the complexity of network architectures and resource structures.

In LTE network, to maintain the service, the user equipment (UE) changes its serving base station (BS) as it moves, which is called handover (HO). As mentioned in the previous chapter, the HO process is designed for macro-cell systems and triggered by the event A3 of UE, when the difference between the periodically measured Reference Signal Received Power (RSRP)/Reference Signal Received Quality (RSRQ) of a candidate cell (target cell) and that of the serving cell is higher than the HO hysteresis margin (HHM). In the traditional macro-cell system, static HHM and TTT strategies are usually adoptable. However, in hostile environment, the HO rule for macro-cell systems may lead to the HO rate (i.e., Frequent HOs or increased HO) problem, where the HO process can be triggered even with a little/high movement of the UE [20]. One way to optimize the HO process is tuning the HO parameters adaptively by implementing threshold comparisons with several specific metrics [21]. The most similar work to our proposed method is given in [22], where the authors proposed some statically-based approaches to solve the decision HO problem. Similarly, in our work, an adaptive HO approach was proposed to control the number of handover, which uses a predefined TTT and HYs threshold and path loss factor to adapt the HO.

Another type of HO optimization strategies is based on IA and machine learning. The latter including traditional algorithm, reinforcement learning and deep learning, are creating paths for computing technology to perform tasks that once seemed out of reach. So far, we adopt the reinforcement learning (RL) framework to learn the optimal controller for each UE, which makes HO decisions. We incorporate the situation and exploration information of UEs into states to model the HO process, where the exploring information, i.e., the serving SBS indices for UEs, can facilitate the exploitation versus exploration tradeoff to accelerate the learning. In this study, we have investigated the reinforcement learning algorithm in the

Handover mobile LTE network. Specially, A handover optimization technique based on Q-learning technique-based agents that act in the network and use the network's feedback to learn the effects of their actions. Q-Learning algorithm is proposed to maximize the total system throughput THR and minimize the number of handovers and provides the optimal policy-how a decision maker acts in an environment that changes overtime without any prior knowledge of the environment. Here it would be attractive to have an algorithm that can learn to make good choices Each proposed approach shows significant improvements compared to traditionally designed algorithms, the result shows that delay is the important criteria for real-time applications , the direction of UEs, signal-to-interference plus noise ratio, etc., also affect the throughput THR of the system. So, these parameters need to be considered in q learning approach After getting optimal eNB, optimal triggering points such as Time-To-Trigger, hysteresis are chosen by using Q-learning approach so that, handover failure, and, handover ping-pong effect can be minimized[24].

2 Reinforcement Learning

Reinforcement Learning is a type of Machine Learning alongside supervised and unsupervised learning, though both supervised and reinforcement learning use mapping between input and output, unlike supervised learning where feedback provided to the agent is correct set of actions for performing a task, and unsupervised learning, where no feedback is given and the task is to find structure in data [25]. Elements of Reinforcement Learning: the basic elements required for reinforcement learning is as follows:

- Model (M) of the environment: This means we create a model of the behavior of the environment. in which the agent operates, Models are generally used for planning by deciding what action to take while considering future rewards.
- Reward function (R) Mapping of state action pair to reward, the Rewards are provided directly by the environment, where the reward function determines what is the good and bad state of the agent, the reward would perfectly reflect of the agent's actions, In general performance of the agent would be perfect under every state, The purpose is to increase the overall reward the agent receives, in case a reward have low values . may be changes the policy to select some other action.

- Value function: which often denoted as $V(s)$ The value function represent how good is a state in the long run for an agent to be in, the value of a state It is equal to the total of reward for an agent that begin from state, it's always yield a low value but provide a high immediate reward. The agent brings as much reward as possible then estimating values to provide more precise judgments about actions options in purpose to obtain a higher stats values.
- Policy (P): A policy is the agent's behavior, it is a map from state to best action Which must be taken when they are in those States. A policy is a function can be either deterministic or stochastic, in general Stochastic policies are better than deterministic policies While the probability is distributed to the assigned actions, the agent begins to see what the most perfect actions. Meaning they are sufficient to determine behavior in a particular state, but in case deterministic Evaluating a policy is typically high variance [25].

3 Q-Learning

Q-learning algorithm is a reinforcement learning method which is model-free Q-learning provides a practical solution to obtain the optimal policy by selecting the highest value of action in each state which applies an action $a \in A$ at time t when the environment is in state s and provide the expected reward to the agent after executing the action in the specific state [27]

$$\langle s_0, a_0, r_0, s_1 \dots \rangle \quad (1)$$

This can be described as the agent was in State 0, did Action 0, received Reward 0 and transitioned into State 1 and so on.

The main idea of the algorithm consists in evaluating the current policy $\pi(a|s)$ through a value function ($Q\pi(s, a)$)

$$Q(st,at)=\max\pi R_{t+1} \quad (2)$$

It is called Q-function, because it represents the “quality” of certain action in given state.

The agent looks for an optimal policy $\pi^*(s) = a$, which for a given state, will return the action that earns the most rewards in the long run. After convergence, the Q-learning algorithm

provides an optimal strategy $\pi^*(s)$ by choosing the action that maximizes the Q function in a given state:

$$\pi^*(s) = \operatorname{argmax}_a Q^*(s, a) \quad (3)$$

Otherwise, Q-learning algorithm specify how the agent's policy is changed as a result of its experience. Q values, therefore, are defined using temporal differences, is a method of dynamic solution that derives from TD-learning. It consists of learning the value of the actions according to the states, which makes it possible to calculate the optimal policy dynamically.

In Q-learning precisely, the agent has a function $Q: S \times A \rightarrow \mathfrak{R}$ which assigns to each state-action pair (s, a) a Q-value $Q(s, a)$, corresponding to the expected reward obtained by performing the action in state s and following an optimal policy from the next state

$$Q(s,a)=r + \gamma \max_{a'} Q(s',a') \quad (4)$$

The Q-value for that state-action pair is updated based on the reward received when selecting that action and the best Q-value for the subsequent state s' . The update rule for the state action pair (s, a) is the following:

$$Q(s, a) \leftarrow Q(s, a) + \alpha [r + \gamma \max_{a'} Q(s', a') - Q(s, a)] \quad (5)$$

In this expression, the α factor, present in the formula for updating the Q values, is called the parameter of the Step size and its values usually vary between 0 and 1. If the step size were 0 then the algorithm would ignore any rewards received and if the step size were 1 the algorithm would consider the rewards gained just as much as the previous experiences of a state-action pair.

where $\gamma \in (0,1)$ is the discount factor that balances between the immediate and future rewards. The possible future rewards ($\max_{a'} Q(s, a)$) is the maximum of the Q-Values of all possible state-action pairs from the action selected.

Q-learning uses the temporal difference error to adjust the estimation of Q-value according to the received rewards. Temporal difference is the difference between actual Q-value and its

current estimated value [25]. The agent also keeps a table of Q-Values, in which information will be added about the new states and actions that are being explored, starting state can either be chosen by random or be a pre-determined start state for the problem. The agent will then choose an action, Actions are chosen either stochastically or by a policy So, each row of it corresponds to a different state, and each column stores information about the value of the Actions [26].

Require:

S is a set of states

A is a set of actions

γ the discount reward factor

α is the learning rate

- 1: procedure Q-Learning(S, A, γ , α)
- 2: real array Q[S, A]
- 3: previous state s
- 4: previous action a
- 5: initialise Q[S, A] arbitrarily
- 6: observe current state s
- 7: repeat
- 8: select and carry out an action a
- 9: observe reward r and state s0
- 10: $Q[s, a] \leftarrow Q[s, a] + \alpha(r + \gamma \max_{a_0} Q[s_0, a_0] - Q[s, a])$
- 11: $s \leftarrow s_0$
- 12: until termination
- 13: end procedure

Algorithm 4.1 Q-Learning Procedure.

The convergence of the Q-Learning algorithm during the exploration phase is reached when the q -values becomes constant. If it explores too much it might suffer from a low q -values After a Q-Learning algorithm has finished exploring the model of the environment it explores a policy [29] [30]. The exploration policy should be such that each state-action pair will be encountered infinitely many times to solve the problem that the Q-Learning agent was exploring.

4 LTE behavior-based Q-learning

Before proceeding to describe the handover optimization based Q-learning, we have to explain the necessary frameworks that included in the LTE model.

4.1 Mobility Model

Mobility for wireless networks has become an important issue and has been the subject of several research, A number of mobility models have been proposed, proper mobility models must be generated for the mobile users.

Currently, there are two types of mobility models are the random waypoint model and the random direction model, both usually operate in a finite two-dimensional plane also The two models differ in how users choose the next part to pass. Random Waypoint. A model that break times between changes in destination and speed If no pause, the model is called "Random Walk" A random direction model that forces UE to travel to the edge of the simulation area before changing direction and speed, The two models differ in how users choose the next part to pass[33].

The Random Direction Model is defined as follows in proposed model of handover Q-learning:

- 1.Choose an initial position.
2. Select a direction randomly between 0 and 359 degrees.
3. Chooses a movement speed.
3. Moves according to the chosen parameters.
4. Arrived at an edge of the simulation zone, resumes in step 2.

4.2 Propagation Model

Cellular systems are becoming more heterogeneous where A wide variety of infrastructure will be deployed in these new networks including macro and femto base stations ,For more coverage design of modern cellular networks the signal strength measurements must be taken into consideration. The radio propagation models are mathematical formulation for the characterization of radio wave propagation as a function of distance frequency and other conditions for proper determination of the received signal strength at certain location from the

Node B Then, The propagation models can be combined to get reliable service coverage and capacity of HetNet, In general, there is a relationship between propagation models and types of environments for which they are suitable , these models are classified mainly into three types; empirical, deterministic and stochastic .

4.2.1 Stochastic Models

Combination of deterministic models and empirical models of various parameters (building heights, street width,...) on the other hand , these models use Low Resolution (LR) geographic data but require the least information about the environment and use much less processing power to generate predictions for example indoor coverage problems in dense urban areas.

4.2.2 Deterministic Models

Based on a terrain description (buildings, clutter types, streets,...) and uses a precise locations to analyses particular situations[34] , then providing realistic and correlated spatial variations of the path loss , deterministic models often require a complete 3-D map of the propagation environment[35].

4.2.3 Empirical models

are those models based on observations and measurements linked to the environment to enable a rough estimation of the number of required sites in a large area[34] [35] , these models are mainly used to predict the path loss . In this context a kind of Empirical models was proposed that fits into various environments is the ECC-33 model.

ECC-33 model :The ECC 33 path loss model, which is developed by Electronic Communication Committee (ECC),is most usable in empirical propagation model, which is based on the Okumura model , It is also give correction factors for ‘suburban’ and ‘open’ areas so that it more closely represents a fixed wireless access (FWA) system[36] . This model is designed to predict path loss at higher frequency greater than 3GHz , The path loss model is defined as:

$$L=A_{fs} +A_{bm}-G_b-G_r \quad (6)$$

where, A_{fs} are the free space attenuation , A_{bm} the basic median path loss , G_b the Base

station height gain factor and G_r , the receiver height gain factor. They are individually defined as [37] :

$$A_{fs} = 92.4 + 20 \log d + 20 \log f \quad (6)$$

$$A_{bm} = 20.41 + 9.83 \log d + 7.89 \log f + 9.56 [\log f]^2 \quad (7)$$

Transmitter antenna height gain factor:

$$G_b = \log(h_b/200)(13.958 + 5.8 \log(d)) \quad (8)$$

The receiver antenna height gain factor, G_r for medium cities is expressed as:

$$G_r = [42.57 + 13.7 \log_{10}(f)][\log_{10}(h_r) - 0.585] \quad (9)$$

and for the large city [42] :

$$G_r = 0.759 h_r - 1.862. \quad (10)$$

f is the frequency in GHz.

d is the distance between base station and mobile antenna in km.

h_b is the base station antenna height in meters

h_r is the mobile antenna height in meters.

MODELS	FREQUENCY BAND	TERRAIN
SUI	Below 11GHz	Hilly Terrain
HATA	150MHz to 1500MHz	Urban, Suburban & Rural
OKUMUR A	Up to 3GHz	Urban, Suburban & Rural
COST-231	500MHz to 2000MHz	Urban, Suburban & Rural
ECC-33	Up to 3.5GHz	Urban, Suburban & Rural
COST-231 W- 1	800 to 2000MHZ	Buildings in the vertical place

Table 4.1 Comparison of various outdoor propagation models.

Among the different categories of propagation models, The comparison results in table 4.1 show that the

ECC-33 model gives in general a better prediction for suburban environment [38] , whereas the other model underestimate the path loss in all three terrain ,ECC-33 models seem to be the best suited to cope with the new challenges brought by HetNets (various topologies , 3D

environments, etc.), The ECC-33 model shows the closest agreement with the measurement results. It is highly recommended for urban environments If well implemented [37] , small and large propagation ranges are all addressed in a coherent way, However, the model provide a correction factors for suburban or rural environments, So ECC-33 model would be the one used in the simulation .

5 Problem Formulation

In our problem, improving handover performance uses a Q-Learning algorithm it is required to find the HOM and TTT to provide the best performance the model of the environment has a state for every combination of TTT and hys which clarify the proposed Q-learning optimization technique. An action within the model can move to any other state that is different by one of the following changes to the handover parameters:

1. A single value increase of TTT.
2. A single value increase of hys.
3. A single value increase of both TTT and hys.
4. A single value decrease of TTT.
5. A single value decrease of hys.
6. A single value decrease of both TTT and hys.
7. A single value increase of TTT and a single value decrease of hys.
8. A single value increase of hys and a single value decrease of TTT.

achieve the goal state which is giving a total number of 336 states .

The immediate response of the algorithm after an action, a , is to estimate the new reward value, however, there is no direct relation between the performance metrics and The system throughput which is defined as the rate of successful messages delivered over a communication channel that are sent by all users per second. The cell throughput is measured at the eNB and is expressed as THR, handover failure (HOF) ratio and ping-pong handover (HPP) are calculated and used to get the reward value in the end of each iteration by using the reward function ,it's defined by following equation:

$$\text{Reward} = w_{\text{THR}} * \text{THR} + w_{\text{HOF}} * \text{HOF} + w_{\text{HPP}} * \text{HPP} \quad (11)$$

The coefficients in Equation.11 are given the values of which metrics is more important. For $w_{THR} = 2$, $w_{HOF} = 1$ and $w_{HPP} = 0.5$ for ping-pongs , giving a higher priority to THRs compared to HOFs and accepting HPPs .

THRs are twice as important as HOFs and four times more important than HPPs In every time step the handover performance metrics are collected [39].

The reward value is used to get the new Q-value which updates the element of the Q-matrix that corresponds to such HOM & TTT combination. This simulation is repeated to ensure that the final Q-values converge in the matrix. At the end, the maximum Q-value in the matrix corresponds to the HOM and TTT values combination that achieves the best performance. The values of triggering points are determined by considering the speed and direction of the UE with take up his location in the area.

6 Evaluation

A 4 macro-cell and 254 pico-cell in network has been used, where in all environment there are 600 users .as shown in Fig. 4.1. All results depend on the downlink channel only.

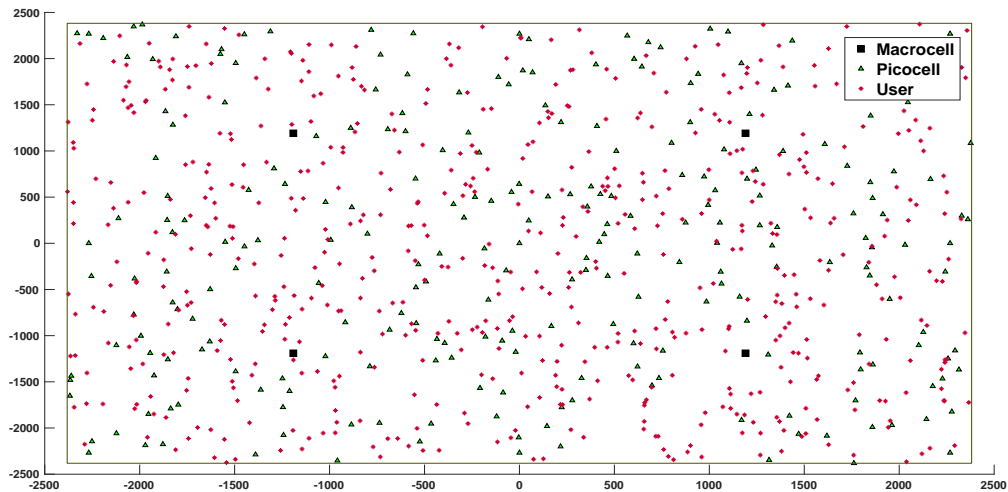


Figure 4.1 Illustration of cell layout, geographical distribution of UE .

In figure 4.2 and figure 4.3 shows how the optimisation system performed against the throughput performance , In this Q-learning algorithm, the users move at speed 0.5 m/s to 2 m/s randomly , the simulation started with the TTT being 0 seconds and the hys being 0 dB. It can be seen that the optimisation process and the throughput performance performed very similar. The figures demonstrates that optimisation process has the highest throughput this is because it prevents the network from making radio link failure RLF that results in dropping in packets This means that the optimisation system would be expected to perform better the majority of the time.

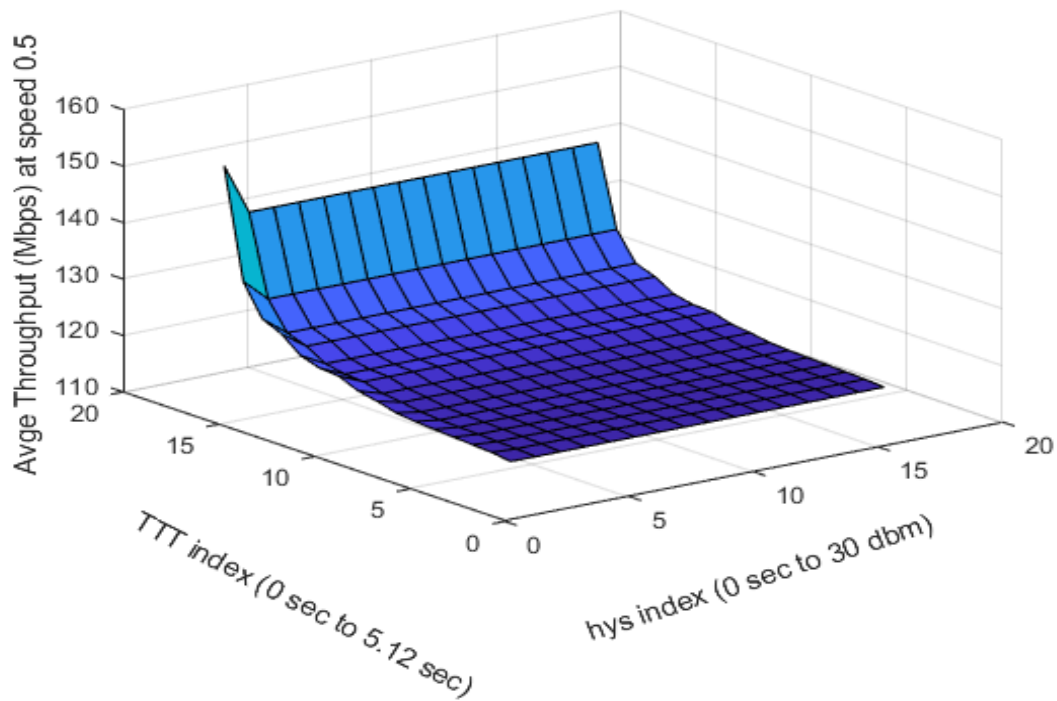


Figure 4.2 Illustration average throughput at speed 0.5 m/s of users .

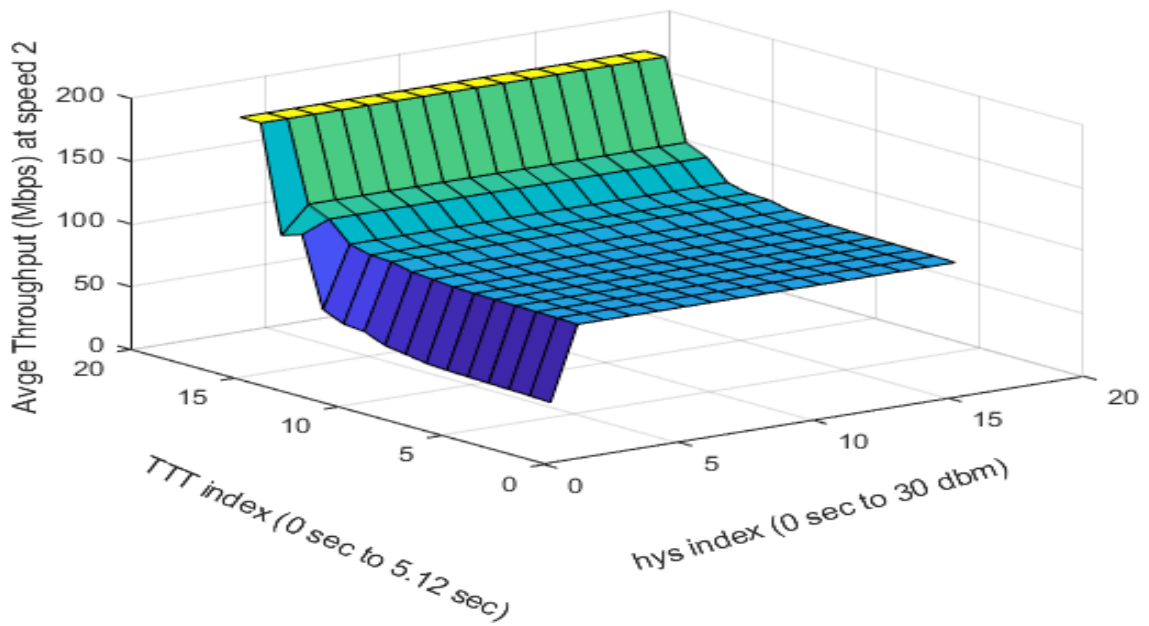


Figure 4.3 Illustration average throughput at speed 2 m/s of users .

In this algorithm We divided handover failures by cell type where handover occurred between macro cell M2M or when happen between picocell P2P ,then the system gather the total failures in each type of cells .

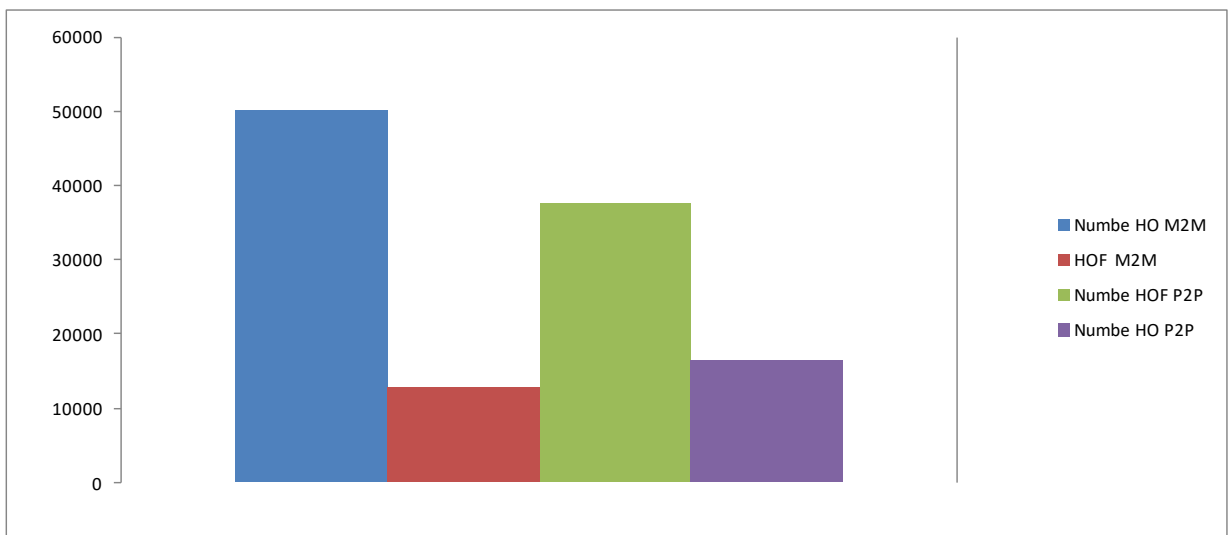


Figure 4.4 number of HO attempts and HO failure at macro and pico cells

In order to see how good the learning performs . Compared to the results shown in the Figure 4.4 above , where we note that failure in Macro cells is very small for pico cells , because the reward function is estimated based on the cell throughput (THR) of Macro cell only. The THR value is one of the main components that constructs the reward function as shown in Eq. 11.

7 Conclusions

The proposed algorithms based on Q-learning of Macro cell-throughput the algorithm monitors any degradation in the performance metrics of Macro cell , The proposed handover optimization technique is evaluated and compared to previous work. Q-learning achieves minimum average number of handover per user and also has maximum throughput.

General Conclusion

General Conclusion

Through our study of all the handover event algorithms we observed that the A3 algorithm at high speeds has lower performance and high failure handover than low velocity where the ping-pong occurs more and more especially when the user is within the edge of cells, due improper configuration of parameters time to trigger and hys.

In this context, the handover optimization algorithm in LTE HetNets were mainly investigated under two aspects. First, handover decision based of statistics to improve handover performance for LTE.

Secondly we proposed technique based on Q-learning that learns the best HOM and TTT values with taken into account a model of a HetNets scenario, such propagation model and user mobility with his location specifically in border cell we showed that our algorithm can effectively find the optimum handover parameters algorithms were proposed in order to achieve better throughput performance.

via simulation results are compared with the old handover A3 event under different UE speed scenarios. Results show that the proposed Q-learning algorithm and the statistics technique effectively improves network performance, which can significantly reduce the probability of unnecessary handovers in the system., maximize the throughput, and minimize the system delay.

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ملخص

يعتبر نظام تطور طويل مدى في الاتصالات اللاسلكية الخلفية الناجحة للأجيال السابقة بحيث تصل السرعة النظرية للتدفق 100 ميغابايت في ثانية .

الهدف من هذه المذكرة هو تطبيق خوارزمية التعلم العميق باستخدام برنامج ماتلاب من اجل تحسين خوارزمية التسليم ضمن نطاق الشبكات الغير متجانسة تحد اداة محاكاة الشبكات

كلمات مفتاحية: LTE ,Hetnet , Handover, Q-learning , NS-3.

Abstract

A LTE system in wireless communications is the successful successor to the second and third generations. It provides a rapid flow of information so that the theoretical speed of the flow reaches 100 Mbps.

The purpose of this dissertation is to implement a deep learning algorithm using MATLAB to improve delivery algorithms in the context of long-range evolution networks and to adapt them within the architecture and scope of heterogeneous networks under Network Simulation3 Tool.

Key words: LTE ,Hetnet , Handover, Q-learning , NS-3.

Résumé

Un système LTE dans les communications sans fil est le successeur de succès des deuxième et troisième générations. Il fournit un flux d'informations rapide pour que la vitesse théorique du flux atteigne 100 Mbps.

L'objectif de cette thèse est de mettre en œuvre un algorithme d'apprentissage approfondi utilisant MATLAB pour améliorer les algorithmes de diffusion dans le contexte de réseaux évolutifs à longue portée et de les adapter à l'architecture et à la portée des réseaux hétérogènes sous Network Simulation3 Tool.

Mots clés: LTE, Hetnet, Handover, Q-learning, NS-3.