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Efficient Mobility Management in LTE Femtocell Network

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Thesis Proposal

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Abstract

The future network architecture towards heterogeneous, it would be converged many different types of network, such as cellular network, femtocell network, ad-hoc network, MANET, VANET and wireless sensor network. With new network service type and service demanding are emerging, it would cause the huge number of mobile terminal accesses to network. Hence, it makes big trouble for managing mobility, and brings forward challenge.The handover is the most important part in the mobility management, because the handover is frequently occurred when UE is moving, hence the handover number directly affects the system performance, and network QoS. A sophisticated HO decision algorithm can improve the performance of system, although in current literature there are many HO decision algorithms proposed and every algorithm owns dramatical advantages, but they also have limitations or drawbacks. In this report, we will survey the HO decision algorithms, and summarise them. Based on some current algorithms propose a new HO decision algorithm.

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Chapter 1

Introduction to LTE and LTE femtocell network

1.1 Introduction to LTE

1.1.1 LTE network system

LTE, an acronym for Long-Term Evolution, it is considered to be the mainstream technology of the mobile telecommunication system which is evolution of 2G/3G. Because of it adopted emerging technology such as OFDM, MIMO to be used as core technology, it is evolutionally changed comparing 3G technology, regardless of the wireless access technology and the network architecture. Therefore it is named "Long Term evolution", also called 3.9G.

Since 3GPP proposed the concept of LTE at Toronto conference in 2004, the LTE standard has been investigated through two phase which is Study item and Work Item. Release 8 document of LTE was specified in December of 2009, In release 10 described LTE-Advanced first standard.Currently,the LTE Advanced standard formally satisfies the ITU-R (ITU Radiocommunication Sector)requirements to be considered IMT-Advanced. And ITU-R defined it as "true 4G".

1.1.2 LTE Advanced network system

LTE Advanced(LTE-A) network is evolution release of LTE, aiming to meet wireless network marketing more demand and application, as well as to meet or exceed the requirement from IMT-Advanced in near future. Meanwhile, LTE-A remain the backward comparability for LTE. The new wilreless technology such as Carrier Aggregation, enhanced UL/DL MIMO,Coordinated Multi-point Tx&Rx,Relay and Enhanced Inter-cell Interference Coordination for Heterogeneous Network ect. are adopted in LTE-A network system. It greatly increases system capability of peak transmitting data rate,average spectral efficiency,average spectral of cell efficiency and edge user, as well as increases the efficiency of networking, therefore LTE- A will become the most potential communication technology.

Following points describes new features are introduced in LTE-A comparing LTE:

1. Flexible spectrum usage: High frequency band optimised system is used in scenario of small coverage of hotspot, indoor environment and HeNB(Home NodeB). Low frequency band compensate the coverage of high frequency band system lost, also serving the high-speed UE.

2. Carrier Aggregation: Using LTE Advanced carrier aggregation, it is possible to utilise more than one carrier and in this way increase the overall transmission bandwidth.

3. Relay node base Station: This technology aims to improve the received signal to inter-cell interference plus noise power ratio and enhance throughput. In this way, radio waves can be propagated more efficiently, coverage extended and throughput improved at cell edge.

4. Coordinative Multiple Point (CoMP): CoMP enable the dynamic coordination of transmission and reception over a variety of different base stations. It is aiming to improve overall quality for the user as well as improving the utilisation of the network.

5. Interference management and suppression?Uses multiple receiver antennas on the mobile terminal to sup- press interference arriving from adjacent cells. The aim is to improves throughput performance, mainly near cell bound- aries.

6. Home NodeB(HeNB): The aim is to improve cellular coverage, enhancing system capacity and supporting the plethora of emerging home/enterprise applications.

1.2 Introduction to LTE femtocell network

At present, we are living in the commercial era of 4G using LTE, however, there still exists a challenge for frequency resource constrained. This issue leads to higher frequency is operated in the new communication network system, normally they operates in the frequency higher than 2GHz. Due to attenuation of electromagnetic wave propagation, the wave strength suffered in various degree of attenuation in different environments such as propagating through wall, window etcetera. Particularly higher than the frequency of 2GHz, when wave propagated through wall of building, the attenuation is more serious. As a result, this issue makes trouble for indoor network efficiency of coverage using.

In order to solve this issue, femtocell network has been proposed in LTE. and grew up in LTE- Advanced. it is not only aiming to solve that the network for indoor, edge coverage poor using problem, but also to efficiently avoid the issues of the interference between cells and enhance handover quality.

In early period, the femtocell network developed very tough. The business giant company NOKIA and MOTOROLA has developed Nanocell and Picocell technology in 90s of last centry, and push these new technology to the market. Unfortunately, at that moment they are not widely accepted by consumer. In 1999, Bell labs and Alcatel has proposed definition of the "home base station", soon afterwards this definition was widely accepted by people. In 2006, people called this kind of technology "femtocell".

In 2008, Home NodeB of WCDMA and Home NodeB of LTE has been included research plan to aim standardising Femtocell network. Comparing picocell, femtocell is more successful in the market, and developed very fast, since it was pushed market. Because Picocell has obvious inefficiency, reversely there is many disadvantage for femtocell relating Picocell.Table 1.1 describes the comparison with Picocell and Femtocell.

Parameter and Arbitrary	*Picocell*	*Femtocell*
Coverage radius	< 100	< 50
Number of user	10∼100	4∼64
Connection with core network	Coaxial-cable, Fiber	Coaxial-cable,Fiber,ADSL
Installation	Installed by operator	Installed by user
Installation complexity and flexibility	Easy	Easy and Flexible
Transmitting power	High	Low
Volume	Big	Small

Table 1.1: Comparison with Picocell and Femtocell

As result the femtocell came into being because of demand of efficient indoor coverage, its function continuously improved, Due to ifs plug-and-play feature, femtocell is not only used in indoor environments,but also it perform very well in case of edge coverage of network. For instance, macrocell is distributed according the population intensity, the low intensity of population area normally located at edge of cellular networks,in this case this area is able to use femtocell. Because using femtocell is not necessary to increase transmitting power from macrocell, thereby to achieve the aim of saving quite number of resource.

So far, we can summarise few features about femtocell as below:

1. Femtocell provide high QoS, it connects to core network through IP network, as well as provide high quality of VoIP(Voice over IP) and data service.

2. User in Femtocell has connection with user in macrocell, in other words, the user device standard for macrocell is same to femtocell.

3. Easily install, femtocell is able to play and play, once it was activated by operator.

4. Reduce the traffic load of macrocell or other femtocell, increase network capacities.

5. Low CAPEX and OPEX, femtocell does not require change the framework of network.

6. Low costs.

Although there are many advantages in femtocell, it still has some issues to be solved. We describe the issues as following:

1. Interference management: Femtocell distributed inside macrocell, its interference may make lower the capability of macrocell handover, causes macrocell and femtocell throughput lower or disconnection. This issue is a problem of handover control procedure, if we efficiently managed the handover between two-tier macro-femtocell LTE network or between cross-tier, to avoid unnecessary handover, this issue would be solved.

2. Mobility management: The key of mobility management is handover. The hanover between macrocell and femtocell or between femtocells has limitation of time. This issue is not only related to system frequency and transmuting power, but also related to completed handover mechanism. For this point, it is the core research of report.

3. Admission control: Because of femtocell owns three modes of access control, which are open access, hybrid access and closed access. UE is authenticated whenever it accesses to Femtocell. In Chapter 2 will describe the function for each mode, and this report is focus on hybrid access mode.

In this report we are concentrating to solve efficient mobility management issue, in other words, the key is how to manage efficiently handover procedure. In order to avoid unnecessary handover occurs and reduce handover failure.

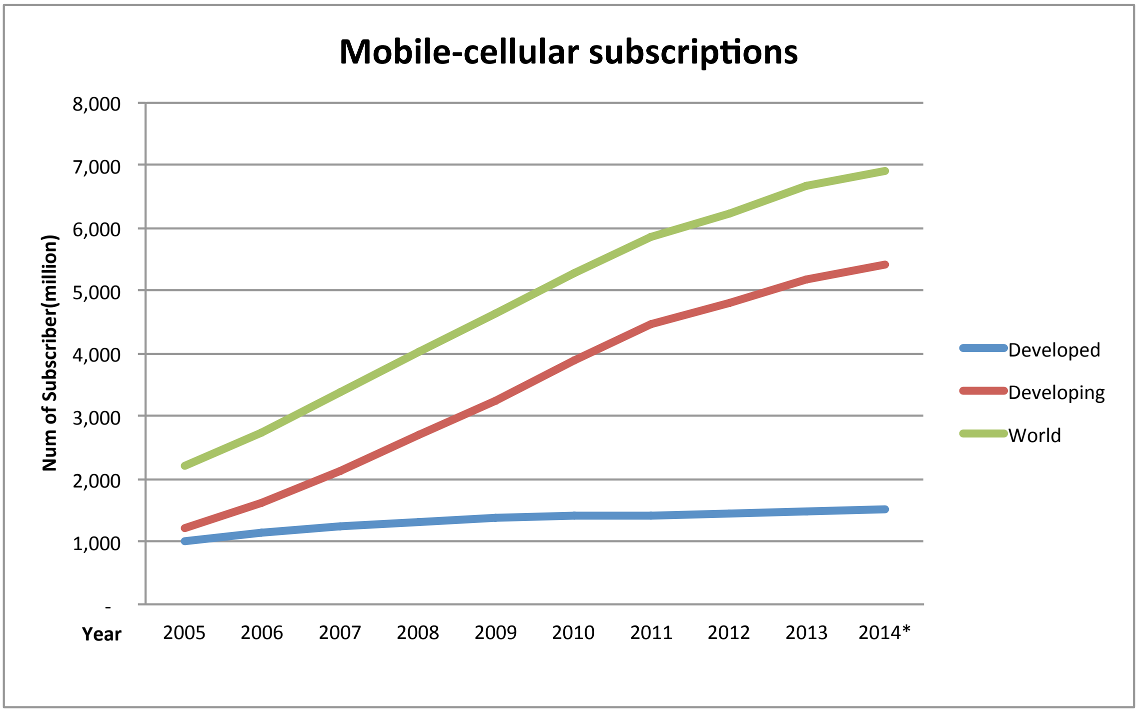

Figure 1.1: Mobile-cellular subscriptions

1.3 Necessity of research of efficient mobility management in LTE femtocell network

1.3.1 Introduction to mobility management

At present, we are entering age of mobile communication, because of mobile device function is more and more near to computer, people's habits is changed to use mobile device. Until 2014, number of mobile phones in use is more than 69 billion, in Fig.1.1 describes number of mobile phones growth, it has increased as much as triple times from 2005 to 2014. The smart phone share is almost occupies the complete market. So huge number of mobile phone and many emerging application for smartphone demand LTE system more efficient mobility management. Therefore Mobility Management play a key role in LTE network, also is a challenge for LTE.

Currently, International Organisation for Standardisation such as ITU-T,IETF,3GPP consider Mobility Management to be key research plan. Mobility Management is derived from cellular network, the network architecture in future enable to integrate various of network such as ad-hoc network, femtocell network, sensor network,internet and cellar network, to meet new type of service, as well as to efficiently manage huge number of mobile device access to serving cell. All these challenges need the support from mobility management. In other words mobility management is not solution for only one dedicated network, but also it plays a key role in many different type of wireless technology and emerging service. in addition, it needs to meet various type of mobile terminal. As a result, it is considered as important technology to be studied. The mobility management function is described detailedly in Chapter 2.

1.3.2 Mobility management in LTE Femtocell network issue

Currently, the majority of data traffic occurs at the indoor environments.Over 35% of mobile voice services and more than 40% of mobile data traffic occurs at home or at the office and maintained a increasing trend.Thus it can be seen that there is huge number of mobile terminal is used at indoor environments. Using femtocell is excellent way to mitigate traffic load of macrocell. But we image that so many terminal is randomly moving, accessing to cell and leaving, it makes a challenge to femtocell mobility management. How to efficiently manage the mobility of terminal is directly affect the performance of wireless performance.

Basically, mobility management is divided into two patterns.: Location Management and Handover Management.

Location Management is important part for mobile communication system. It simultaneously tracks UE, temporally report the new UE location to system, in order to let system knows the new location when system intended to establish connection with UE.

Handover Management performs when UE or system discovered connection status was changed, is that, the serving cell signal strength decreased to the threshold which is not met the connection quality. in this moment the network system searches new cell which is fit for ongoing connection requirement for UE as target cell, remaining the ongoing connection and handover to target cell. In order to keep the seamless connection, the handover protocol is required to consider the handover failure and handover time. These two factor is crucial issues affect the femtocell performance. Handover procedure for LTE network can be spliced into four steps: measurement control, measurement report,HO decision,HO Execution. In [9] discussed the HO decision is handover procedure impacts directly the system performance, a more sophisticated HO decision algorithm can mitigate the negative impact of user mobility and cross-tier interference on the Quality of Experience (QoE) and Signal to Interference plus Noise Ratio (SINR) performance at the UEs. Attaining a low service interruption probability for medium to high speed users is another challenging issue for the HO decision phase.

Therefore the handover management is core point to be discussed in this theses report.

1.4 Objectives of this MsC Thesis

In the last subsection has mentioned the core point for thesis report which is handover management. A sophisticated HO decision algorithm can improve the performance of system, although in current literature there are many HO decision algorithms proposed and every algorithm owns dramatical advantages, but they also have limitations or drawbacks. In this report, we will survey the HO decision algorithms, and summarise them. Based on some current algorithms propose a new HO decision algorithm. In this report, we organised as following: in Chapter 2 we describes LTE femtocell network architecture, basically introduces the entities of network and their function. The femtocell network protocol is discussed in this chapter too. In chapter 3, we describe the surrey of HO decision algorithms, then proposed new algorithm. Chapter 4 is aim to analysis and evaluate the new proposed algorithm, we simulate it, and analysis the simulation result. Charpter 5 conclude this report and talk about the further work about mobility management.

Chapter 2

LTE Femtocell architecture and capabilities

In oder to studied handover management, first of all, it is necessary to know the support of femtocell in LTE network architecture.Besides, we must understand each entities functions and the protocol. In additional, the procedure of HO is also to be known. Finally, we can accurately proposed the new HO decision algorithm, based on these fundamental acknowledgement.

2.1 LTE femtocell network architecture and functions

Fig 2.1 shows the LTE network architecture supporting femtocell and the key network elements, EPS an acronym for Evolved Packet System is consists of EPC(Evolved Packet Core), eNB(HeNB is other name for femtocell using in network protocol.) and UE(User Equipment). EPC is core network based on IP network architecture. The EPC signalling is managed by Mobility Management Entity, and data traffic is controlled by S-GW(Serving-Gateway). The eNB or HeNB and HeNB GW implements the access management, also named E-UTRAN (evolved UMTS Terrestrial Radio Access Network). The eNB and HeNB connect with MME and S-GW through S1 interface. Whereas eNBs and HeNBs interconnect with each other through X1

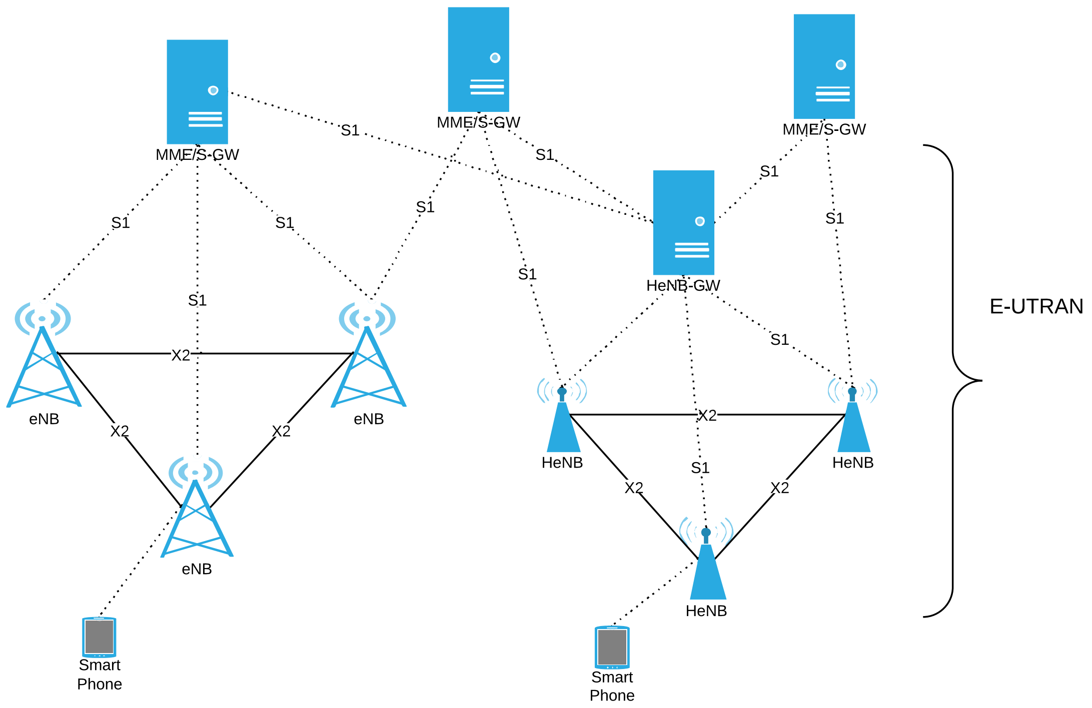

Figure 2.1: Support of femtocell in LTE network architecture

interface. Both S1 and X2 interface are logical interfaces, they support transfer the signalling in the logical layer.Comparing S1, the procedure of transferring signalling for X2 is easier than S1, because the signalling is directly transferred between eNBs or HeNBs, not necessary trough MME. This advantage is very fit for hard handover. As well as HeNB enable to be connected with S-GW and MME indirectly through HeNB-GW.

As we know S1 is a logical interface interconnected the eNBs or HeNB to MME and S-GW, and separated E-UTRAN and EPC, it is consists of control plane and user plane. S1 Control plane is interface between eNB and MME in EPC. S1 user plane is the interface between eNB and UPE function in EPC.The X2 interface is between (H)eNBs. The X2 is same to S1, it also consists of two parts which are control plane and user plane. X2 control plane is interface between (H)eNBs. X2 user plane is shortcut interface between (H)eNBs. Moreover, they support the function of X2-based handover and radio resource management. In addition, the X2 is open logical interface, it provides logical indirect end-to-end connectivity between eNB and HeNB in E-, in case of that there no exist the physical interface between them. Currently, X2-based logical interface function is more and more important in new 3GPP release, the handover between femtocells or between femtocell and macrocell is based on X2 interface. It is introduce detailedly in following of this Chapter.

The eNB function includes Radio Resource Management, IP header compression, user packet data flow encryption, paging coordination, MME selection for UE, broadcast information coordination and measurement configuration and providing. It is a director to deal with UE accessing to network system, to archive that UE connected to core network. The network system performance is depending on eNB functions. Between LTE network and 3G network, there is large difference. First of all, LTE is partial to make the system to be hierarchical, it abandoned the Circuit Switch(CS) Service, and combined the NodeB and RNC that are used in 3G network. Additionally, the air interface is changed to OFDMA and SC-FDMA physical wireless access technology. Due to the new physical wireless access technology, LTE network system proposed new function in physical layer.

HeNB function is very similar to eNB, the main difference is about the number of accessing UE, normally eNB cell is 3, whereas HeNB is 1. Therefore according this reason and the short range feature for HeNB,its transmission power is much less than eNB. Certainly the accessing number of UE and transmission power enable to be configured by environment requiring. In other words, the key feature of HeNB is more flexible than eNB. Another very important feature is HeNB owns CSG which is Closed Subscriber Group. This definition is described in section 2.3 of this Chapter.

Mobility Management Entity is key control node that manage the mobility of UE, its function is shown in Fig 2.2. Its function is changed with developing of LTE/SAE, and describer for more detail as following.

Tracking Management is to manage Tracking Area. Tracking Area is designed for UE location management, its function is similar to Location Area (LA) and Routing Area(RA) in 3G network system. TA is designed for meeting to following points.

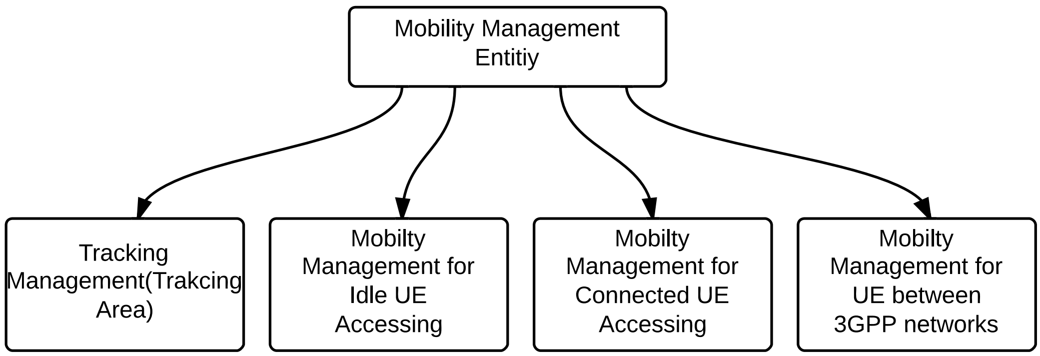

Figure 2.2: Mobility Management Entity Function

1. Synchronised the location information of UE with E-UTRAN control node and LTE/SAE control node.
2. When UE status is idle, the LTE/SAE control node is necessary to know UE in which tracking area.
3. When core network is intending to page UE, it is necessary to page all tracking areas that UE have been registered.
4. Reduced the signalling produced by UE location changed.

Mobility Management for Idle UE Accessing The idle status means the status of UE is idle in the ECM(EPS Connectivity Management). The status feature is below points:

1. There is no signalling between terminal and network, E-UTRAN does not allocate to terminal any wireless resource and the context between them is not established yet.
2. There is no connectivity of S1-MME and S1-U between terminal and network.
3. When UE initialises, it establish a RRC connection to network , and transit to ECM-CONNETED state . Then UE attached to core network and MME knows UE.

4. MME knows UE location that is within accuracy of TA level.
5. When UE leaved serving cell, and accessing other cell, it is necessary to update location information of UE.
6. When UE accessed to cell which unregistered in TA, it is necessary to update TA.
7. When UE is moving, it enable to select the cell to be serving cell.
8. E-UTRAN enable to restrict cell to be selected by UE.
9. Saving powering.

The TA of LTE/SAE is equivalent to its adjacent Routing Area of 2G/3G. When UE accessed to a type of network, it register and updates information as normal procedure. The network allocate the temporal identifier and location area identifier to them. Once UE moving to other type of cell, the other network is doing same thing, allocated new temporal identifier and location area identifier for this type of network system. In this moment, the access point of core network for UE is necessary to register to HSS, as well as to serve for UE, therefore when UE moving between these two type of network systems is not necessary to register and update again.Because of they already owns the matching relationship of UE information.

Mobility Management for Connected UE Accessing The connected status means the status of UE is connected in the ECM(EPS Connectivity Management). The status feature is below points:

1. MME knows UE location that is within accuracy of serving eNode ID level.
2. This status of UE mobility management is controlled by handover.
3. The S1 release procedure changes the state at both UE and MME from ECM-CONNECTED to ECM-IDLE.

In E-UTRAN, the UE mobility management for connected status implements the access point of core network relocation for UE, the terminal handover procedure, serving node handover decision policy, resource reservation and serving node resource release. The handover is usually triggered by serving node side. The serving node enable to decide the handover execution according to measurement and cell restricted. The handover signalling is implemented in E-UTRAN, the target cell is necessary to reserve resource for UE handover. When the handover is completed , the eNB allocates the reserved resource to UE. As well as UE is necessary to synchronise with eNB, after that, the eNB releases the resource. Additionally, Mobility Management for Connected UE Accessing enable to be classified: one is Inter-eNB mobility handover management relating the EPC relocation, other one is Inter-eNB mobility handover management not relating the EPC relocation. The main different about these two types is whether the handover is based on X2 interface to complete the handover and resource reservation.

Mobility Management for UE between 3GPP networks indicates mobility management between UMTS/3GPP and LTE. Between 3GPP network systems, the handover is always necessary to reserve resource for target eNB.

The Serving-GW is also key part of core network, its function mainly is to routing and transmit the packet data.

2.2 LTE femtocell network protocol stack

EPC consist of two parts: Control Plane and User Plane [6]. It is shown in Fig 2.3. Control plane is controlled by MME and S/P GW. User Plane is controlled by S-GW and P-GW.

The Fig 2.4 and Fig 2.5 are described the stack protocol between UE and (H)eNB with left side. This part is called radio protocol stack. We can take example to explain the work procedure of protocol stack. We image when we starts our mobile phone, first of all, it is necessary to register to adjacent base station, through transfer signalling the mobile phone enable to connect with service network. Once the connection is established, the user can enjoy the network service by using mobile phone. The

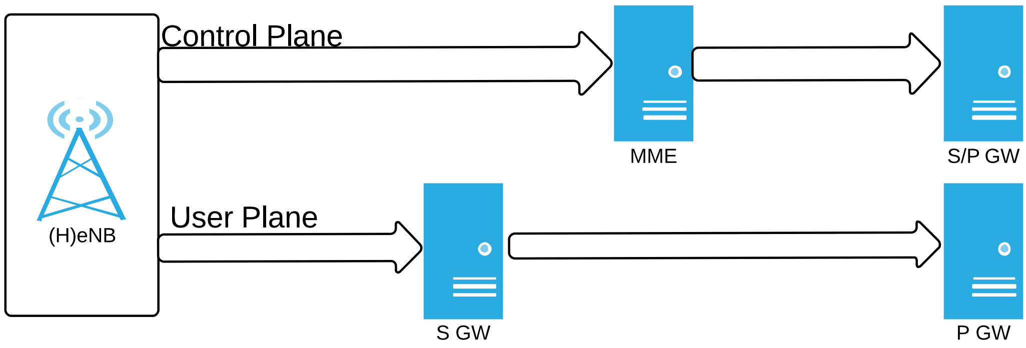

Figure 2.3: LTE EPC Architecture

network service connection is established by signalling. For instance, the voice service, when UE intending to call to another UE, at first it is necessary to send request to establish communication, during this procedure, the layer of RRC(Radio Resource Control) send the paging signal, the paging signal is transited to MME at base station through S1 interface, then MME pages the target UE also through S1 interface. Once the target UE is answered, the connection is completed and the data is transited in data plane. The conversation is to started.

LTE radio interface protocol includes that Physical layer, MAC(Media Access Control) layer, RLC(Radio Link Control) layer, PDCP(Packet Data Convergence Protocol) layer.

- Physical layer: LTE defines a number of downlink physical channels to carry information blocks received from the MAC and higher layers.

- MAC layer: MAC layer is responsible for Mapping between logical channels and transport channels, Multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels, de multiplexing of MAC SDUs from one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels, Scheduling information reporting, Error correction through

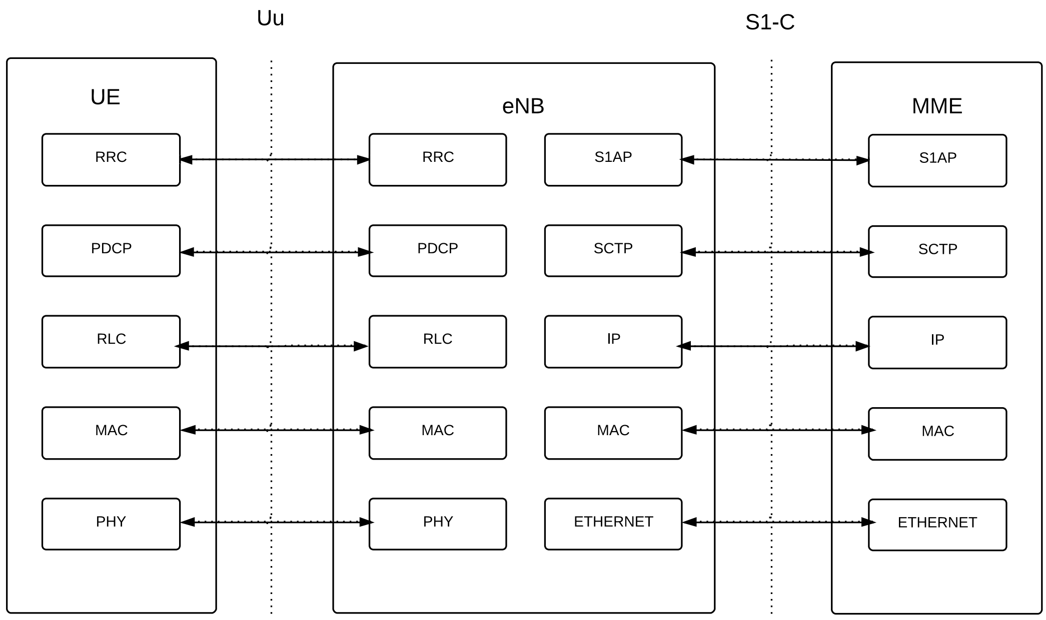

Figure 2.4: U-plane Protocol Stack on Uu (UE/eNB) and S1-U (eNB/MME)

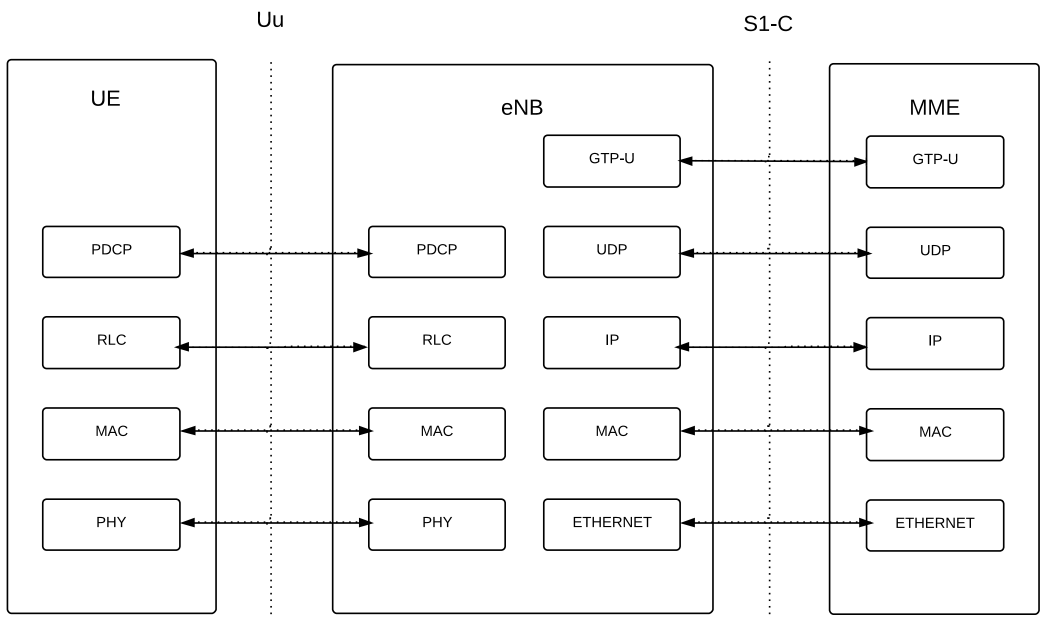

Figure 2.5: C-plane Protocol Stack on Uu (UE/eNB) and S1-C (eNB/MME)) and S1-U (eNB/MME)

HARQ, Priority handling between UEs by means of dynamic scheduling, Priority handling between logical channels of one UE, Logical Channel prioritisation.

- RLC layer: RLC Layer is responsible for transfer of upper layer PDUs, error correction through ARQ (Only for AM data transfer), Concatenation, segmentation and reassembly of RLC SDUs (Only for UM and AM data transfer).

- PDCP layer: PDCP Layer is responsible for Header compression and decompression of IP data, Transfer of data (user plane or control plane).

- RRC: RRC owns many functions, the main functions are radio resource control and mobility management and MBMS. RRC is very important for handover, the measurement is early procedure of handover, whereas the measurement is implemented through RRC-reconfiguraion. At the end procedure of handover, the (H)eNB received RRC-reconfiguraion complete message from UE, in order to achieve fast handover to target cell successfully.

The above of this section is introduced about radio protocol stack of LTE, however, S1 based interface protocol is aim to make connectivity between (H)eNB and core network. S1 interface consists two parts: Control Plane(S1-C) and User Plane(S1-U).

S1-U is shown in Fig. 2.4, the right part is S1-U protocol stack. It is provide the unreliable transmission to EPC elements by using UDP, the network layer is based on Internet Protocol. GTU-P on the top of S1-U protocol stack, it is implemented to transfer PDUs to core network in user plane.

S1-C protocol stack is shown in the right side of Fig. 2.5. In order to guarantee reliability of signalling, S1AP(S1 Application Protocol) provides the signalling service between E-UTRAN and the evolved packet core (EPC) implemented on application layer. SCTP(Stream Control Transmission Protocol) is supported as the transport layer of S1-C signalling bearer.The eNB establishes the SCTP association,there is only one SCTP association established between one MME and eNB pair.

2.3 CSG provisioning functions

Closed Subscriber Group is new definition produced by femtocell developing.The usual application is home eNBs intended to offload traffic from the public network and/or improve indoor coverage, It was proposed and specified by 3GPP Release 8. It restricts UE to access femtocell, only those UEs included in access control list are allowed to use femtocell resource. There three modes in CSG which are open mode, closed mode and hybrid mode. The femtocell or macrocell can be configured by these there modes.

- Open mode: H(e)NB is allowed any UE to access.
- Closed mode: H(e)NB is allowed only UE that is associated CSG member to access.
- Hybrid mode: H(e)NB is allowed UE that is associated CSG members or non-members to access, but associated CSG member owns the priority to use the femtocell resources.

The CSG provisioning owns two main functions[4]

- First is to manage the list of subscribers for a CSG, the CSG list can be hosted by operators or the third party.All the HNBs and HeNBs is managed in a single CSG list, i.e. all HNBs and HeNBs only have unique CSG identifier and single list for users in the same PLMN.
- Second is managing how the CSG information is stored in the UE and the network. H(e)NB is allowed only UE that is associated CSG member to access. It is avoid the non-CSG member used the resourced of HNBs and HeNBs according to allowed CSG list and the Operator CSG list. And manage the storage of the CSG subscription information in the network.

In LTE femtocell network system, hybrid mode is the most popular in uses, because of they prioritise the CSG user and non-CSG user to use the cell resources, i.e. it is guaranteed to meet the CSG user first, then serve to non-CSG user as much as possible. In other words, it is the most logical of theses three modes. Therefore the proposed algorithm of this thesis is certainly based on hybrid access mode.

2.4 Home NodeB subsystem hanover mechanism

In the Section 1.3 was simply introduced the handover and its importance. In this section, it is detailedly described the handover mechanism.Currently, there are two main type of handover technologies in wireless network system, hard handover and soft handover. In LTE system, it is purely used hard handover. Because of HHO has lower complexity than soft handover as well as in LTE, it is necessary very fast handover for real time services.Hence, it is challenging to coordinate between different cells to do soft handover. The handover can be decided into four phases according [3], measurement control, measurement report, handover decision and handover execution. The completed procedure of handover is shown in Fig 2.6.

- Measurement Control and Measurement report: These two phases are actually inseparable, it is completed by UE and H(e)NB simultaneously, measurement control is to measure the network connectivity between UE and base station. There are many factors to trigger handover, for example the received signal strength is reduced continuously to the threshold not guarantee the service quality, the source node's resource is too congested to need offload and so on. Hence the UE periodically monitors the connectivity of network, once the measurement is met to handover condition, UE send the measurement report to H(e)NB. The measurement configuration is provided by source node.The measurement report also includes the measurement information of other adjacent cell, in order to select the best selection of cell for UE.

- HO decision: The handover is triggered by UE, then UE send the measurement to source node. The source node make the handover decision based on he Measurement Report and the Radio Resource Management (RRM). As we discussed

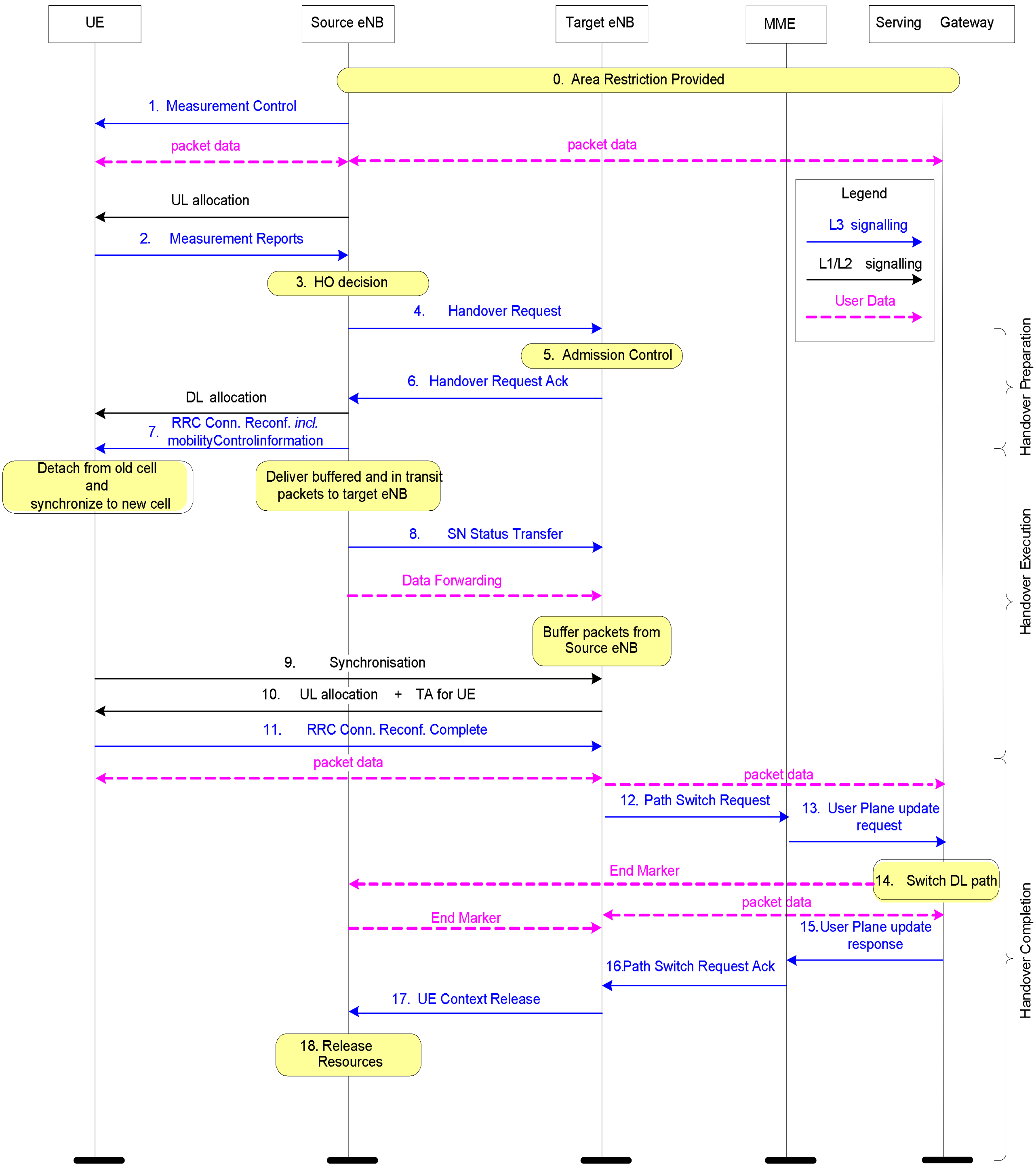

Figure 2.6: Handover Procedure for LTE femtocell network)

above, the handover play as a key role in the completed handover procedure, a excellent handover decision algorithm can lead to the whole system performance. Hence, there many types of handover decision algorithm in current literature. According various demand in real life, the algorithm is necessary to be considered the different factors. In next chapter will discus what factor is to trigger handover. Additionally, admission control is performed at target node during this phase, once source node has selected the target cell, UE is necessary to send request of handover to target cell. Target node will decide whether UE is allowed to access, according the status of target node, CSG configurations.

- HO execution: In this phase, it is necessary to completed all the signalling when UE has done the handover decision. To achieve signalling for hanover to target node, UE register, location updating, source node resource release, and so on. The signalling is carried on through S1 and X2 interface, the X2 interface can be used to exchange the HO request/commands between the serving and the target HeNB in order to reduce the required signalling and delay overheads. S1 is to complete the request for MME and S-GW.

Chapter 3

Analysis of the State of the Art and Proposal of a Handover Decision Algorithm

3.1 Survey of Handover decision algorithms

3.1.1 Handover classification

According network type, handover can be categorised by inter-network handover and intra-network handover. Inter-network handover is occurred between different systems of network, such as handover between LTE and UMTS. Inner-network handover is triggered by inner network such as handover in same system. In this theses report, we are focus on researching intra-network handover in LTE system.

In the intra-network handover, it is also divided into two types, S1 handover and X2 handover. Because there is X2 interface between eNBs or HeNBs, in case of MME does not necessary to be changed, the handover of them enable to use the X2 interface. X2 handover is more convenient than S1 handover, because of that during the X2 handover procedure, signalling is not necessary to through MME, MME is unchangeable. Additionally, to complete the handover of X2, is also necessary to use S1-C(MME) interface which is between eNode and MME, in order to releases resource at the source node. When the handover is unable to use X2 interface and MME is

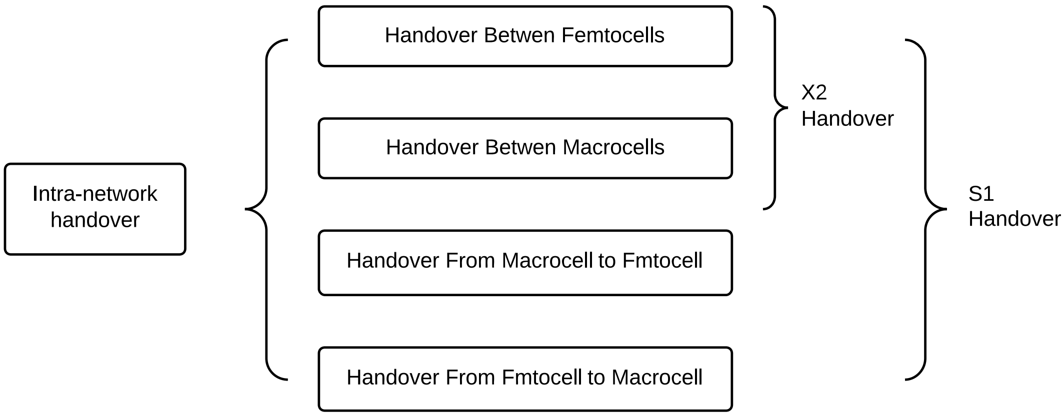

Figure 3.1: Intranetwork Handover Classification

changed, then S1 is to be implemented. S1 handover performs that source MME choose the target MME and S-GW. Normally, the handover between eNBs is not necessary to changed MME, only in case of that UE moves to the providing service area of other MME. As well as MME also selects the new target S-GW for UE. The Fig 3.1 is shown the intra-network handover classification.

3.1.2 Handover decision criteria

Fist of all, we should discuss some factors are considered in handover decision. According different network environments,the handover decision is necessary to make the best decision by considering the current status, as we know, there are many factors are considered in system. Also these factors are considered to be parameters to trigger handover. We describe the most wildly used as below.

- Received Signal Strength (RSS): RSS includes pathloss, antenna gain, log-normal shadowing and fast fading averaged over all the reference symbols (pilot). It is referred to the received power by specific cell. It main parameter for handover decision algorithm.

$$RSS = RS\_transmit\_power \times path\_loss$$

- Received interference power (RIP): It is referred to received power from cells or user in proximity. It includes the thermal noise power and is a set of UL received interference powers. RIP measurement is usually refer to as the Received Signal Strength Indicator (RSSI) for UE. RSSI parameter is according to the UE received power from all interfering cells in proximity.

- Received Signal Quality (RSQ): It refers to the ratio of RSS from a target cell to the total RIP at the UE. It is corresponding to the Reference Signal Received Quality(RSRQ) measurement.

- UE speed: UE speed refers to UE moving speed, and is widely to be considered in handover algorithm. Because of when UE speed is too high, it can lead to too much unnecessary handover.

- Energy-efficiency: It refers to UE battery, the mean UE transmit power, and the UE power consumption.

- Path loss: It refers to many factors leading to the path loss, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss,absorption and environment, It is a challenge for estimating.

- Traffic type: The traffic type is considered to guarantee the service QoS, UE handover to target cell, the target cell is necessary to check which type is UE using. The traffic type corresponds to real time or non-real time service, and video, voice, data traffic.

- Available bandwidth: This parameter is to offload the congested cell. Also, the congested cell need to implement the access control to reject new UE accessing.

- UE residence time: This parameter is to solve the UE fast access and fast leave to the cell. This issue can lead to unnecessary handover. To avoid this issue, it is necessary to set an appreciate residence time to trigger handover.
- UE membership: it refers to CSG.

3.1.3 Handover decision algorithms classification

In previous subsection, we described many parameter should be considered in the handover decision algorithm in current literatue. According to them, the handover decision algorithm enable to be classified by Received signal strength based algorithms,Speed based algorithms,Cost-function based algorithms,Interference-aware algorithms,Energy-efficient algorithms five types [9].

1. Received signal strength based algorithms: The majority of this kind of algorithm set the Hysteresis HO Margin(HHM), it aims to reduce the unnecessary handover and avoid the ping-pong handover. The general idea is to compare the RRS of serving and target cell, the RRS of target cell includes HHM. One of representative algorithm for this class algorithm is introduced in [5]. The main idea of [5] is to combine the RSS of the macrocell and the femtocell stations in order to compensate the uneven RS power transmissions between them.

2. Speed based algorithms The handover decision algorithm based on UE speed is aims to reduce unnecessary handovers cause of UE speed. The UE speed parameter is set absolute threshold, the main idea is that if UE speed is exceed to the threshold speed value, it is keeping on the serving node to search new target cell, the target candidate cell is required to be macrocell. However, this kind of algorithm is always incorporated with other parameters in target cell, such as traffic type, available bandwidth and RSS. [8] is an example of this type of algorithms, it combine UE speed with traffic type. It is according to the UE speed to control the traffic type service, moreover this algorithm uses the mobility prediction to predict the UE movement.

3. Cost-function based algorithms: The Cost-function is the core in this class of algorithm, it is combined wide range of parameters of handover decision, aiming to enhance the mobility to femtocells. The main idea is to compare the result of const function of serving cell to the hysteresis result. [11] proposed the cost-function for the users state, this function include user speed and traffic type, and SINR. The handover to completed is necessary to satisfy the Cost-function is greater than value 0;

4. Interference-aware algorithms: This class of algorithm is aim to reduce the unnecessary handover between two tier network(Macrocell and Femtocell), the main idea is to account the interference two tier of network and co-tier network by using the parameter such as RSRQ,RSRP, RSQ. These parameters are used for assessing the status of interference of UE level or cell level depended not the algorithm demand. The handover is triggered when the evaluation of interference satisfied with the hysteresis threshold. [1] proposed an adaptive HHM that is to be easily implemented to the networks and also to modify the procedure of HM adaptation to be applicable in networks with femtocells. HHM used conventionally measurement parameters such as RSSI (Received Signal Strength Indicator) or CINR (Carrier to Interference plus Noise Ratio) for the dynamic adaptation of an actual value of HM.

5. Energy-efficient algorithms: It is aiming to utilise the energy saving potential provided by the low-power operation of femtocells and for saving UE transmitting power. It uses the energy-efficiency as the primary HO decision criterion.[10] described a handover policy which is UPCM(UE Power Consumption Minimisation) focusing on minimising the UE power consumption in the integrated LTE macrocell?femtocell network. Th UPCM includes adaptive HHM which is considering the UE power consumption function. This function is the outcome of many measurement parameters such as the RS transmit power of the target cells, the RIP at the target cell sites, the operating frequency, the bandwidth availability, the UE membership status, the UE power class, and the interference

limitation at the target cells.

As above part of this section, we surveyed the handover decision algorithms, and classified the algorithms based on the handover decision criteria.All the algorithms are based on two tier macro-femtocell network, and the assumption model is single macrocell and single femtocell. We found RSS, UE speed and available bandwidth these three parameters are frequently used. Besides it, HHM is key functions in the handover decision algorithm, the use of HHM during compassion of RSS/RSQ is important way to mitigate the ping-pong handover affect. All the algorithm is not depend on only one parameter or handover decision criteria, hence, the algorithm classification is ambiguous.

3.2 New proposed handover decision algorithms

As previous subsection discussed, there is numerous handover decision algorithm in current literature, according the surveying, we found there are some challenges for them. The one is the majority of these algorithm is based on the single macrocell and single femtocell. The other challenge is there is few algorithm considering UE fast enter cell then fast leave this issue. In order to solve both two issues, we proposed a new handover decision algorithm.

Fig 3.3 is to explain the first issue: UE is moving from a cell to the target cell, when UE enter the boundary of target cell, we assume that if the RSS of UE is met to the conditions for handover, hence, the handover is triggered. when system is doing hanover procedure, UE decided to leave this cell coverage, so it is possible to lead the handover failure. Even though the handover is completed, UE leaves immediately, it is also to lead unnecessary handover happened. In order to solve this issue, we can use some parameters, for instance UE speed, if the speed is high, it is very possible to result in handover failure. and we can set a Time To Trigger (TTT) combined with RSS, the idea of this is the handover is triggered when UE stay in the coverage of target cell more than a short time and UE's RSS is greater the threshold.

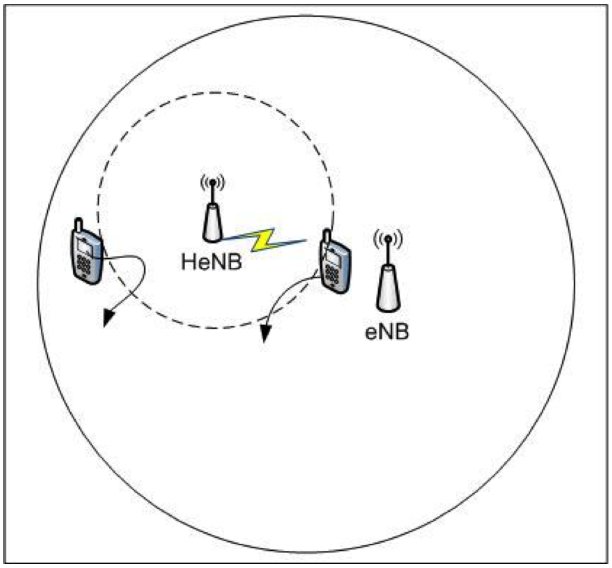

Figure 3.2: The issue of handover decision algorithm (1)

Fig 3.3 is the second issuer. As previous section mentioned, the majority of handover decision algorithm for femtocell is based on the scenario of single macrocell and single femtocell. In this thesis, we proposed a scenario which is a macrocell with multiple femtocell. For this issue, it is challenge for how to manage mobility between femtocells. To address this issuer, we can use CSG and NCL (Neighbour Cell List) to efficiently manage the handover.

Fig 3.4 is shown the completed procedure for the proposed handover decision algorithm. It is enable to divide into two part, the first part is handover from femtocell to other adjacent femtocell or handout to macrocell. The second part is handover from macrocell to femtocell.

In the first part, primarily HO executed should be satisfied two conditions which are UE velocity is greater than the velocity threshold, and the UE RSS from serving HeNB is continuously decreasing. If two conditions of HO are satisfied, then the UE should check the NCL(Neighbour Cell List) to find out those cells which their RSS are greater than the threshold as the candidate femtocell. After that UE filter the candidate cells who is belonging to the CSG, if there is not any cell of CSG, handover to Macrocell. In contrast, UE select the maximum value of RSS of CSG candidate

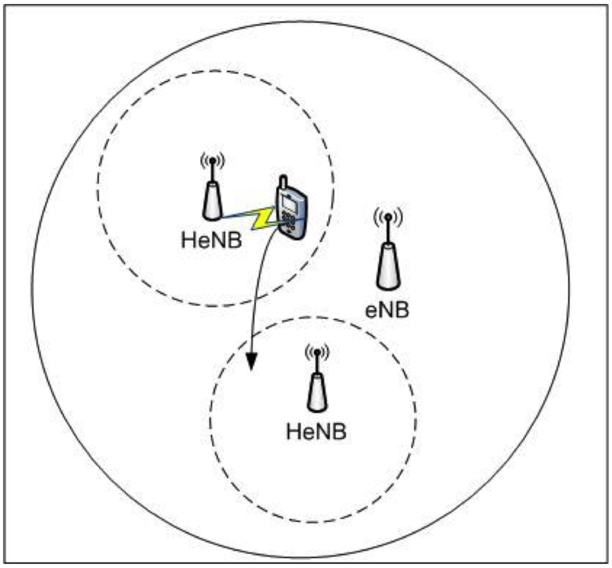

Figure 3.3: The issue of handover decision algorithm (2)

femtocell as the target cell. Finally Handover to target femtocell. Note that, due to the femtocell is allowed to be randomly managed by customer, when UE is intending to handover to femtocell, it could there be many candidate cells are satisfied the Handover condition, hence, the UE must select the best one as target cell.

The second part, in order to avoid UE fast enter and fast leave leading to the unnecessary HO, the interval time 'T' is proposed. The idea is when UE is non-CSG arrives the boundary of HeNB, handover execution should be satisfied if the RSS of UE is greater than the threshold of RSS($RSS_{th,2}$) during the interval time 'T'.Note that the $RSS_{th,2}$ is different from $RSS_{th,1}$, in addition $RSS_{th,2}$ should be less than $RSS_{th,1}$,because the non-CSG has more restricted service. Moreover, we suppose that the CSG UE do not need to wait to handover, because we could consider the majority of CSG UE as frequent user working in this coverage. On the other hand, the CSG UE handover from macrocell to femtocell should be satisfied both conditions which are its speed less than threshold value and there is available bandwidth in target HeNB.

In next chapter we will simulate the proposed algorithm, and analysis the simulation result.

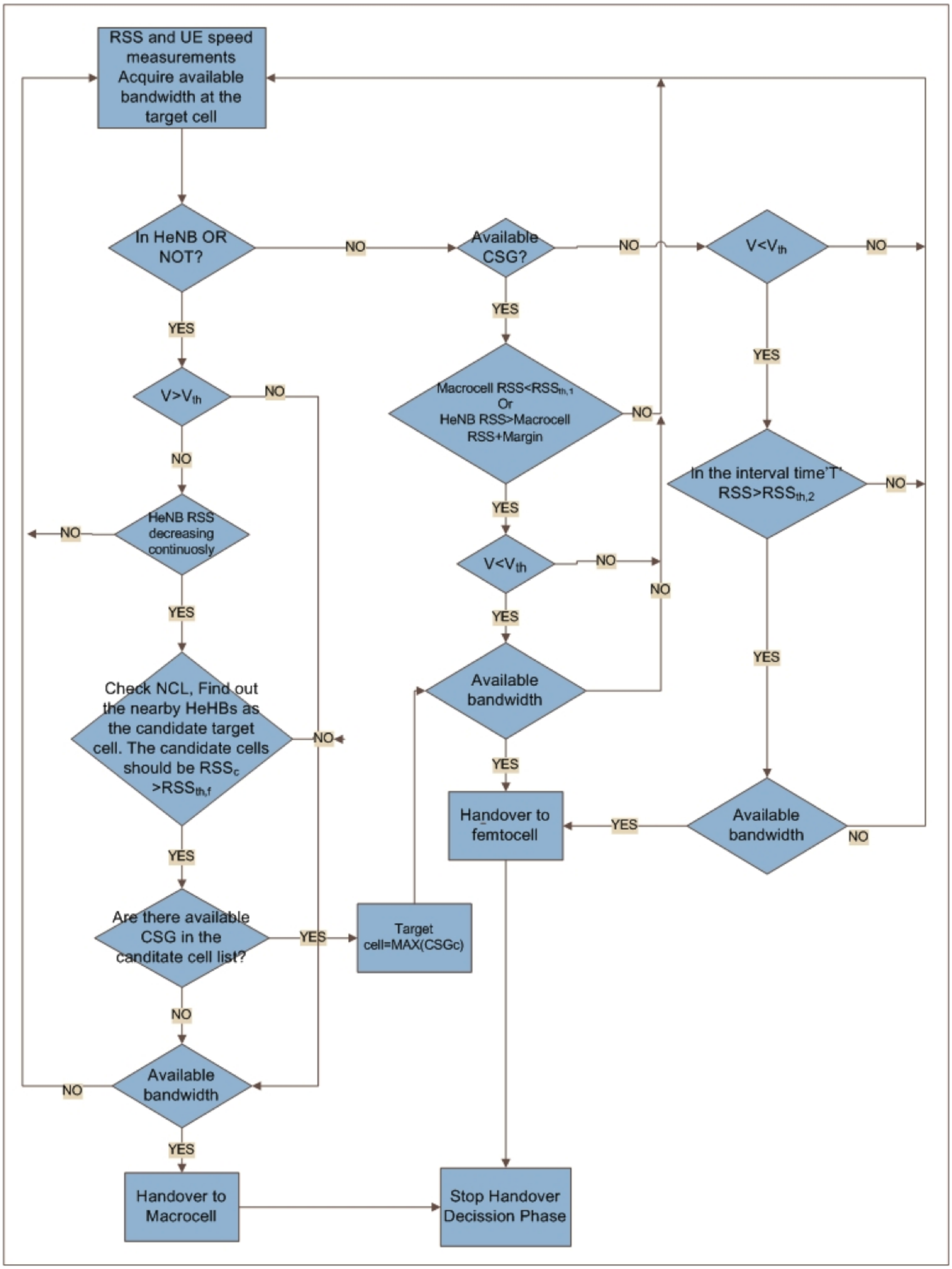

Figure 3.4: The flowchart of proposed handover decision algorithm

Chapter 4

Simulation for new proposed handover decision algorithm and simulation result analysis

4.1 Introduction to simulation system

With LTE developed rapidly, for both the industry and academic research group keep on investigating, in order to optimise the LTE system performance according the simulation evaluation. Because, currently there is limited number of open source simulator of LTE based on a system level, particularly for LTE femtocell are very few. To bridge this gap, LTE-Sim is proposed by G. Piro and F.Capozzi at Polytechnic University of Bari. LTE-Sim is an open resource framework simulator [7], it is exclusively developed for LTE network by programming C++ language, and free to use.

LTE-Sim framework is based on the system level, it is focusing on the feature of LTE networks, its function includes the models of both the E-UTRAN and the evolved packet system, downlink and uplink transmissions, single and multi-cell environments, QoS management, multiple users environment, user mobility, handover procedures, and frequency reuse techniques. Moreover the LTE network entities are implemented in this simulator, such as MME/S-GW, eNB, and UE. Besides them, it provide function which is the traffic generator is supported at the application layer

Component	Functionalities	Important Methods	Method description
Simulator	- Creates/Handles/Ends an event	Schedule()	Creates a new event and insert it into the calendar.
		RunOneEvent()	Executes an event.
		Run() / Stop()	Starts / ends the simulation.
FrameManager	- Defines LTE frame structure - Schedules frames and sub-frames	StartFrame() and StopFrame()	Handles the start and the end of the LTE frame.
		StartSubFrame() and StopSubFrame()	Handles the start and the end of the LTE sub-frame.
FlowsManager	- Handles applications	CreateApplication()	Creates an application
NetworkManager	- Creates devices - Handles UE position - Manages the hand over - Implements frequency reuse techniques	CreateUserEquipment()	Creates an UE device
		CreateCell()	Creates an LTE Cell
		UpdateUserPosition()	Updates the UE position
		HandOverProcedure()	Handles the hand over procedure
		RunFrequecyReuse()	Implements frequency reuse techniques

Figure 4.1: Main components of LTE-Sim

and manage the radio bearer. Finally, the scheduling algorithm is also included, such as PF, M-LWDF, and EXP. In the physical layer it supports AMC scheme, CQI feedback, frequency reuse techniques, and models.

The above we described is the function for running the simulation. Moreover, LTE-Sim simulator not only provided network topology scenario such as multi-cell, single-cell, but also the system evaluation function such as mobility test, SINR test and channel quality test.

For the design of LTE-Sim, it is basically divided into four components: the Simulator, the NetworkManager, the FlowsManager,the FrameManager. Fig 4.1 shows the function of each components. Each component is programmed by a dedicated class. When simulation starts, only one object for each of the aforementioned components is created.

Furthermore, in order to simulate the femtocell, some function are added in the LTE-Sim Release 5 [2]. In this new release, its outstanding contribution is related to the heterogeneous scenario with both macrocell and femtocell, taking into account the spectrum allocation techniques, user mobility, femtocell access policies and other emerging feature from femtocell, hence some new classes is created to accurately simulate for femtocell. These classes is described as below:

- Network devices: HeNB is defined as new class, to achieve HeNB function, in this class defined the unique ID, distributed the position according the Cartesian System. Besides, it provide the function for access policy to realise the CSG implementation. And the physical interface different from eNB is configured to attach it. On the other hand, UE is also necessary to add some functions for femtocell, for example the UE needs to know it is located in HeNB or eNB. Moreover, UE is necessary to know it is inside or outside in order to recognise the signal attenuation due to the wall.

- New handover management: In the handover management, it proposed two handover decision algorithms for the hetergenerous network. First one is Power Based Handover algorithm, it compares the RSS of target node and serving node, if RSS of target node is greater than serving node, the handover is executed. The second is Position Based Handover algorithm, it compares the the distance of UE, if the current distance to target node is closer than serving node, then the handover is triggered. Also both algorithms considered the access policy.

- New topology objects: There are three new network topology objects have been introduced: Femtocell, Building, and Street.

- New channel models: The channel module is charger of handling the transmission packet loss and modelling the path loss. It is implemented two new indoor propagation loss models.

  First path loss model is

  $$P_L\{dB\} = 127 + 30 * \log_{10}(R/1000)$$

  It evaluates the path loss, P_L, considering only the distance, R, between the transmitter and the receiver expressed in meters.

  Second path loss model is

  $$P_L\{dB\} = A * \log_{10}(10) + B + C * log\log_{10}(\frac{f_c}{5}) + X;)$$

It provides a high accuracy at the cost of an increased computational complexity, where R is indicates meters; the central frequency f_c is indicates in GHz; the values of other parameters A, B, and C depend on the number of walls and floors between the transmitter and the receiver.

4.2 Simulation environment introduction

According the introduction from last subsection, the LTE-Sim is the most fit for simulating the proposed algorithm. This subsection is to introduce the simulation environment of proposed algorithm.

First of all, Table 4.1 is shown the simulation parameters in used. We are using LTE-Sim scenario of Single-Cell-with-femto, which is consisted of 1 macrocell, 1 building,there is a number of HeNBs are installed in the building. Note that HeNB transmission power is lower than eNB. We assume that UE number in macrocell is 30. The simulation is implemented by using femtocell UE number by 1,3,5 and 10. UE moves as the speed as 3km/h,30km/h,120km/h, in LTE-Sim provide some UE mobility modules, we used the random direction mode, Fig 4.2 is an example for random direction movement.

Parameter	*Environment*
Total bandwidth	20MHz
eNB power transmission	40dBm
HeNB power transmission	20dBm
Apartment size	100^2
Number of apartments in a building	40
Nmber of Buildings	1
Radius of the macrocell	500m
Number of per in macrocell	30
Number of user in per femtocell	1,3,5,10
UE speed	3km/h,30km/h,120km/h
Traffic	Infinite buffer
Active Factor	1

Table 4.1: Simulation Parameters

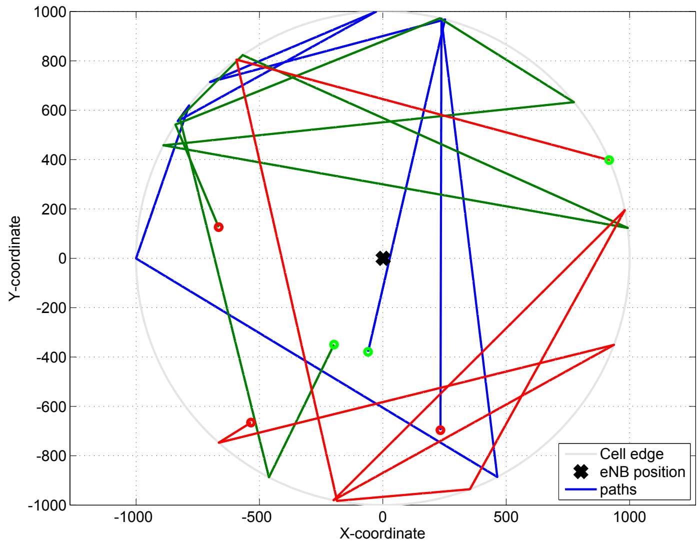

Figure 4.2: An example for random direction movement

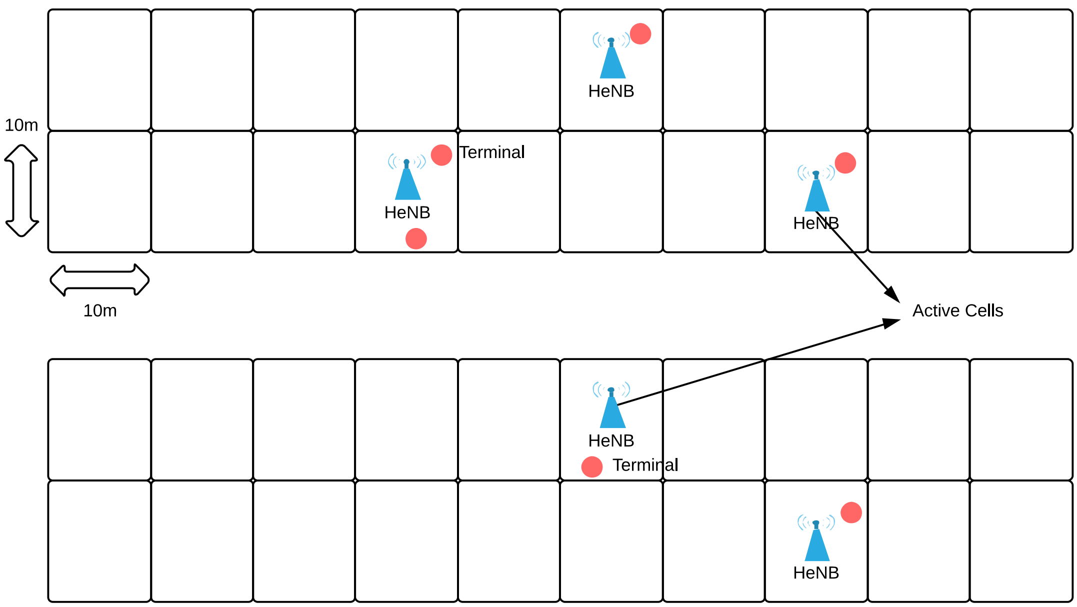

Figure 4.3: Network Topology for Building: Dual Stripe blocks

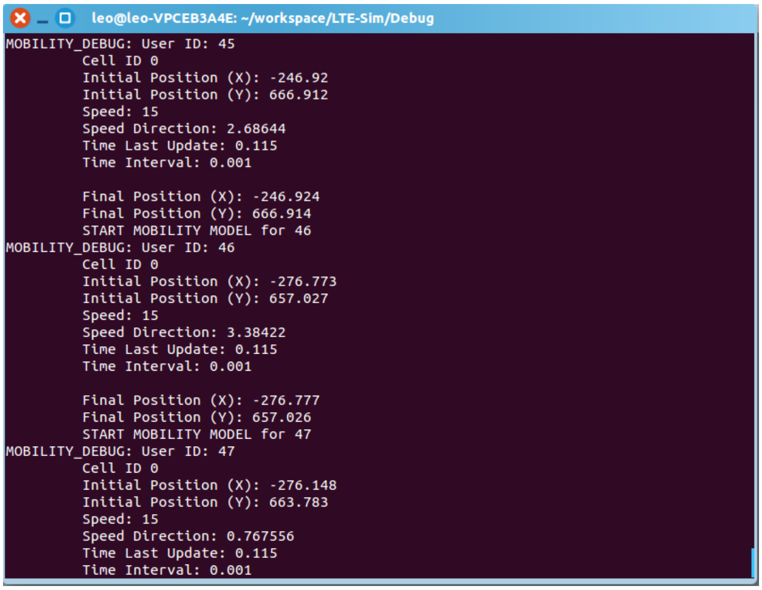

Figure 4.4: UE movement trace in smulator

There are two types for the building type in LTE-Sim. We selected the Dual Stripe blocks(Fig:4.3) to simulate. The parameter of active factor is 1, means that all the HeNB is active for running. Hence, there are 40 HeNBs in topology, all of them is working.

Additionally, in our simulation we also considered the CSG function to implemented, because of LTE-Sim does not support CSG function, we simply consider one of tenth UEs is Non-CSG. We assume those Non-CSG UEs are more restricted to access, the handover for them executed when it is satisfied the both two conditions which are waited until to 3 seconds and RSS value is greater than -70dBm during this time. For CSG UEs, the threshold value to trigger handover is -72dBm.

4.3 Simulation result analysis

In order to simulate the UE mobility,when simulation starts, the simulator generates identifier for each UE and each cell, meanwhile it initiate its position and distribute each UE to every cell acceding the configuration, Then it traces each UE

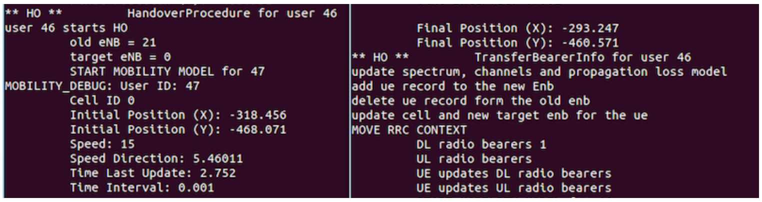

Figure 4.5: Handover management in simulator

movement every 1ms(Fig4.4), and records UE position, UE ID, the serving cell ID. When handover occurred, simulator records the handover information such as old eNB ID and target eNB ID, once handover completed, it release resource for old eNB, andnew eNB allocates the resource for UE 4.5 .

According the parameters as configured in Table 4.1, the simulation result is shown in the Fig 4.6,Fig 4.7, Fig 4.8 and Fig 4.9, respectively simulated the UE speed as 3Km/h,30Km/h and 120Km/h, and the UE number is based on 1,3,5,10. Through these three figures, it is obviously found that the HO number is greatly increased when the UE speed is higher, regardless of both HO algorithms. The growth of HO number lasted by increasing of UE number. We found that HO number in scenario of 30Km/h and 120Km/h is similar, the handover quality can not guarantee when the speed is higher than 30Km/h.

For Power-based HO algorithm, when UE speed performed 30Km/h and120Km/h, it produced huge number of HO, due to the speed is too high. In this huge of number, the majority number of HO is unnecessary, because of the high speed leads to very frequent Handover. According the UE movement trace record of simulation, the UE moves cross many HeNBs coverage and finally handover to the eNB(macrocell bases station), when it accessed each eNB coverage, the handover was triggered immediately, so these handovers are unnecessary.

For the proposed algorithm, in the scenario the number of HO is dramatically dropped comparing the Power-Based algorithm. It is efficiently avoided the unnecessary HO occurred. According the UE movement record of simulation, we found UE in the femtocell directly handover to macrocell, it avoids the unnecessary HO triggered between HeNBs.

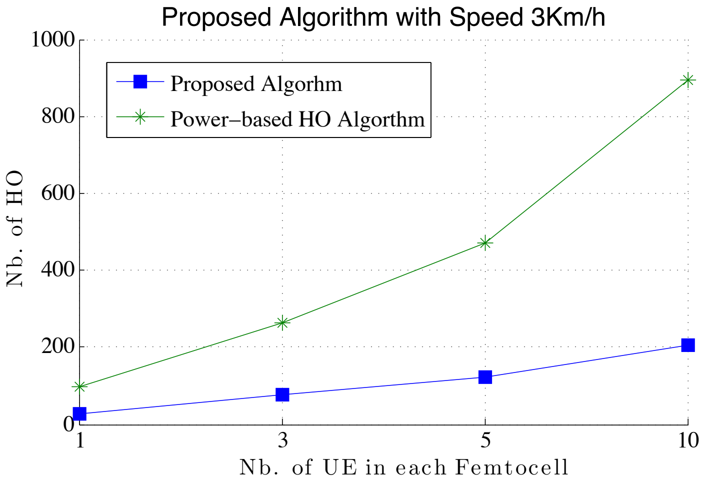

Figure 4.6: Proposed Algorithm with speed 3Km/h

In the scenario of 3Km/h and15Km/h, we found the reason of handover reduction cause the the non-CSG UE is we restrict the access condition. These two velocities are normal in real life, the handover performance is also enhanced.

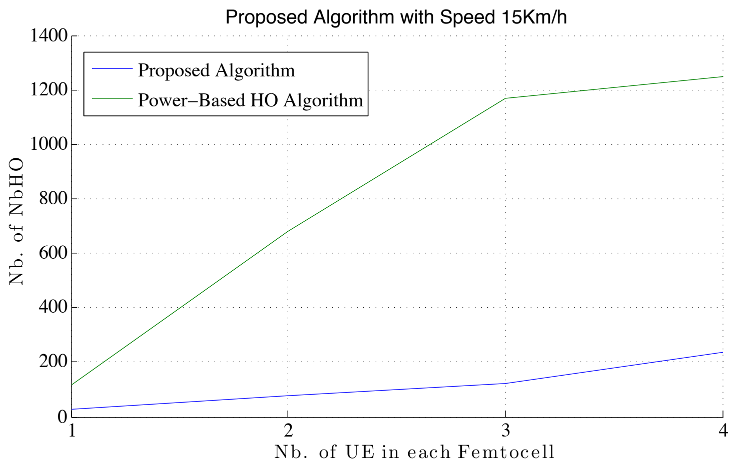

Figure 4.7: Proposed Algorithm with speed 15Km/h

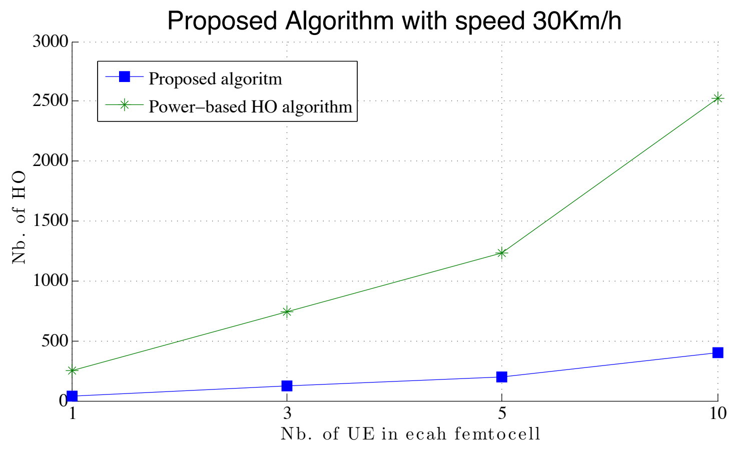

Figure 4.8: Proposed Algorithm with speed 30Km/h

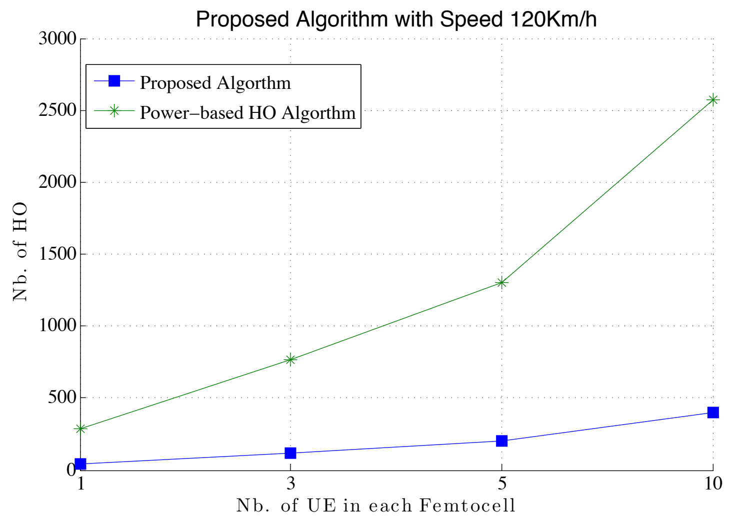

Figure 4.9: Proposed Algorithm with speed 120Km/h

Chapter 5

Conclusion and further work

5.1 Conclussion

In this thesis report, it is introduced LTE network and the statement of femtocell network, meanwhile we researched why do we need the femtocell and to researching for mobility management, the main reason of that is huge number of mobile device is increased rapidly recently, the network is more and more congested, as well as lower the network system performance. LTE network system proposed the femtocell to offload the macrocell traffic, solve network edge cover problem. With femtocell proposing, it brings mobility management issue caused by the huge number of mobile devices moving. The handover is the most important part in the mobility management, because the handover is frequently occurred when UE is moving, hence the handover number directly affects the system performance, and network QoS. Then we found that the a sophisticated handover decision algorithm can improve the mobility management. In order to well kwon the principle of hangover, we studied the integrated LTE network architecture and each functions of its elements. The signalling of handover transmission is based on both X2 and S1 network interface. The contribution of this thesis report is to design a new efficient handover decision algorithm. Hence we surveyed this handover technology in current literature, and we studied the existed handover decision algorithm. Through the survey, we found two issues needed to improve, the first is the majority of current handover algorithms is lack to consider the co-layer handover in femtocell, and the second issue is in case of UE fast enter fast leave problem. In order to solve that, we proposed a new handover decision algorithm depending on these algorithms, it is based on the UE velocity. In this algorithm, we limited access according the UE velocity for first issue, moreover we proposed a time to trigger the handover. Through the simulation for proposed algorithm, we obtained the desirable outcome, the handover is dramatically reduced comparing the conventional algorithm.

5.2 Further Work

For the further work about proposed algorithm, we need to study the UE velocity affecting the handover performance, the velocity range for different handover execution is to mere precise. The time to trigger handover is same to UE velocity to studied more.

Moreover, the future network architecture towards heterogeneous, it would be converged many different types of network, such as cellular network, femtocell network, ad-hoc network, MANET, VANET and wireless sensor network. With new network service type and service demanding are emerging, it would cause the huge number of mobile terminal accesses to network. Hence, it makes big trouble for managing mobility, and brings forward challenge. The current technology can not satisfy the emerging network requirements, particularly demanding for the terminal mobility and session mobility management. Moreover,the mobility management is not only implemented inside the dedicated network, but also the mobility management is necessary to work well for heterogeneous network, as well as the mobility management technology is integrated technology containing network architecture, network service, mobile terminal. Hence, we are necessary for continuing to investigate.

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