Efficient Handover Scheme for LTE Networks

Niranjan Rathod

A Thesis Submitted to

Indian Institute of Technology Hyderabad

In Partial Fulfillment of the Requirements for

The Degree of Master of Technology

Department of Computer Science Engineering

July 2013

Declaration

I declare that this written submission represents my ideas in my own words, and where ideas or words of others have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited, or from whom proper permission has not been taken when needed.

(Signature)

(Niranjan Rathod)

CS11M05

(Roll No.)

Approval Sheet

This Thesis entitled Efficient Handover Scheme for LTE Networks by Niranjan Rathod is approved for the degree of Master of Technology from IIT Hyderabad

15th July 2013 (KIRAN KUCHI)

(————) Examiner
Dept. of Electrical Engineering
IIT Hyderabad

Kotaro Kataoka July 10th, 2013

(————) Examiner
Dept. of Computer Science Engineering
IIT Hyderabad

10/7/13

(Dr.Bheemarjuna Reddy Tamma) Adviser
Dept. of Computer Science Engineering
IIT Hyderabad

C. Krishna Mohan 10/7/2013

(————) Chairman
Dept. of Computer Science Engineering
IIT Hyderabad

Acknowledgements

Many individuals contributed in many different ways to the completion of this thesis. I am deeply grateful for their support, and thankful for the unique chances they offered me.

I am greatly thankful to my supervisor Dr. Bheemarjuna Reddy Tamma for his valuable guidance, constant encouragement and timely suggestions. I would like to make a special mention of the excellent facility provided to me by IIT Hyderabad.

I am also thankful to the support provided by Mr. Chaganti Ramaraju and Mr. Vanlin Satya.

More than to anyone else, I owe to the love and support of my family. My father Ramarao Rathod, my mother Parvathi Rathod and my Elder brother Shivaji Rathod and my Younger sister Vandana Rathod.

Abstract

The conventional mobile networks consists of macrocells or Evolved NodeB (eNB) which provide good coverage but reduces bandwidth available for a given area. The problem of coverage and limitation of bandwidth in a mobile network system is solved by using femtocells or Home Evolved NodeB (HeNB).

In this thesis various handover scenarios have been considered for a LTE network having both femtocells (HeNB) and macrocells (eNB). Three handover scenarios: hand-in, hand-out and inter-femtocell and two different handover strategies: reactive and proactive handover are considered and analyzed. The mobility of the User Equipment (UE) has also been taken into consideration to achieve an optimal handover procedure. An algorithm has been proposed, which is used to dynamically decide upon the handover policy to be used based on the UE mobility and signal strength from the various available cells. The signaling and latency in handovers is studied using X2 interface between macrocells and femtocells. The proposed algorithm has been studied using the NS-3 simulator.

Contents

Chapter 1

Introduction

In a broad geographic area to serve UEs without costly infrastructure wireless systems are used. The main disadvantage with wireless systems is its bandwidth and coverage. In order to provide better services without bandwidth and coverage problems, 3GPP specified femtocell deployment as a solution. Femtocells are small base stations covering a small region to provide better services in homes and office buildings. The deployment of femtocells was at early stage even though there was an enormous enthusiasm over their services. The experiments on evaluating femtocells are done in labs by many operators, most of them are in early stage but only a few services are currently supported in commercial femtocells.

1.1 Femtocells

A femtocell or femto Access Point is a small cell that has a radio as in a cellular tower of a cellular operator network. Femtocells are designed for small coverage, which is suitable for homes, enterprise buildings and apartments without radiating much outside that region. It looks as a WiFi access point in shape and size. It is designed with self-configuring and self-optimizing functionality which reduces the burden of operator and consumer. Femtocell operates through Ethernet connection using a DSL or cable modem to backhaul data and voice calls through the UE's Internet connection to the mobile operator network. Thus the cellular operators can extend their mobile network with femtocells to indoor environments.

Because of poor coverage in certain regions femtocells are deployed. Cellular operators with their collected statistics, estimated that perhaps 10% of UEs do not get good cellular coverage at residential regions, and more over 70% of U.S. residents have a broadband connection to their home, so femtocells are well fitted to fill the gap of cellular coverage. But some operators suggests that someday technology becomes so cheap that next generation cellular networks may have more deployments of femtocells with lower macrocell deployments.

The mobile operator controls the radio in the femtocell from core network, and it will operate with standard mobile terminals without additional modifications. When a subscriber arrives home, his/her mobile terminal will perceive low signal strength from macrocell and makes a handover to femtocell automatically. It is designed to improve indoor coverage of 4G LTE and future mobile communication systems. The Micro cell range is typically less than 2 kilometers wide, a Picocell range is 200 meters or less, and a femtocell range is of the order of 10 meters. There are two main places where it is used, namely residential setting and enterprise setting. Residential settings generally support 1 to 4 mobile terminals whereas enterprise settings supports 16 to 32 active mobile terminals.

1.2 Applications of Femtocells

A femtocell's job is that it allows the service operators to extend service coverage in indoor regions, especially in the areas where access is almost negligible or where the access is limited or unavailable. Femtocells can also be used in the areas where there is very high traffic of mobile UEs, thus reducing the burden on the macrocell.

It is very much attractive and popular because femtocell is the improvement to both coverage and capacity, especially indoors. Not only it increases coverage capacity but also it provides better voice quality and battery life. And also sometimes they are provided different attractive tariffs or offers such as discounted calls from home. The most important application of femtocells is that they are used to give coverage even in smaller regions like rural areas. It increases the reception of mobile signals in the area. Some places which have no reception of macrocell network i.e., in the coverage hole, femtocells can be used to guarantee the service of mobile Users.

1.3 Femtocells deployment

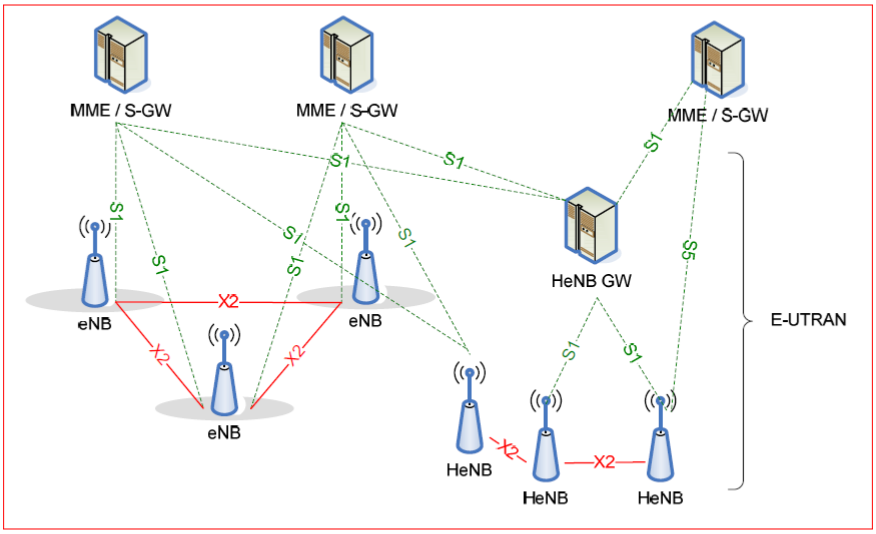

Figure 1.1: Overall E-UTRAN Architecture with deployed Femto-GateWay (HeNB-GW)

Femtocell holds the same functionalities as that of a macrocell and the Femto-Gateway provides the functionality of Mobility Management Entity (MME) to femtocells. The logical architecture and interfaces between these entities are shown in Fig 1.1.

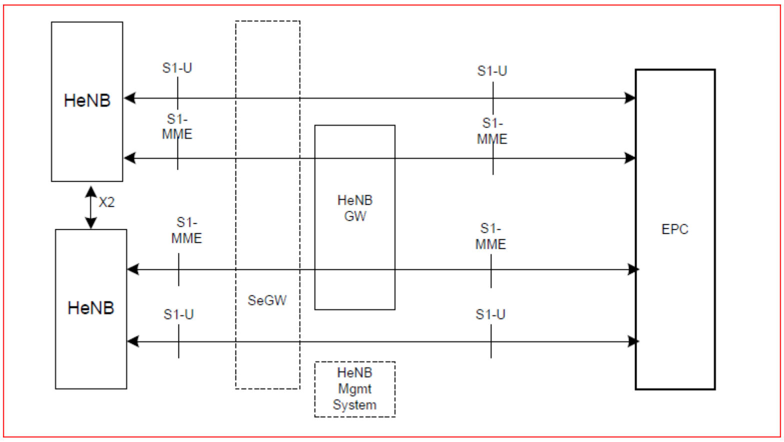

Figure 1.2: Overall E-UTRAN - Femto-Gateway (HeNB-GW) operating in LIPA mode - Logical Architecture

The HeNB-GW (Femto-Gateway) as in Fig 1.2, allows the S1 interface between femtocell (HeNB) and to EPC through Femto-Gateway for supporting a large number of femtocells in a scalable manner. The Femto-GW is a concentrator for the control plane (C-Plane), especially as the S1-MME interface. S1 user plane (S1-U) interface of the Femto will be terminated at the femto-GW or a logical User-Plane connection can be used between Femto and Signal-GW (S-GW).

S1 interface is used as the interface:

- Between the EPC and Femto-GW,
- Between the femtocell and Femto-GW,
- Between the femtocell and EPC,
- Between the macrocell and EPC.

The Femto-GW appears as macrocell to the MME. The Femto-GW appears to the femtocell as a MME. The S1 interface between the femtocell and the core network is the same, regardless whether the femtocell is connected to the core network through a Femto-GW or not. Femto-GW has to connect to the core network for serving UEs mobility between cells, which does not require inter MME handovers.

1.4 Review of Previous work

Earlier work on femtocells included the description of the procedure of handovers, mobility support and the deployment of femtocell in LTE [1]. Along with these, mobility management problems such as handover between cells, procedure for cell search, cell reselection and parameters for handover decision have been described. It has been shown that the UE has to scan the entire femtocell radio spectrum when it switches from macrocell to femtocell [2]. To integrate femtocell network into macrocell network, some changes on existing protocols and network architecture of Universal Mobile Telecommunications System (UMTS) networks has been proposed [3]. Handover rules based on varying speeds and Signal Strength are suggested in [4], for reducing the handovers in a macro-femto cell network. The rules proposed will lead to increase in throughput of UE at high speed and will reduce the chances of a handover happening. The authors in [5] propose an adaptive HHM method, where the HHM is calculated based on the distance of UE from target cell. The distance of UE is estimated by using measurements of signal strength and Signal to Interference and Noise Ratio (SINR) values. It was proved that a larger HHM value reduces the number of unnecessary handovers, but it leads to throughput degradation. In [6], authors proposed two HO mechanisms in two-tier macro-femto cell network, (a) the proactive HO, where the HO decision policy is taken as in [7], and (b) the reactive strategy, where a macrocell-femtocell handover was done, when it reaches a RSS threshold for continuity of service. The reactive strategy was used when the traffic used by UE is real-time, for non-real traffic the proactive approach is preferred. The initial results of the proposed approach reduces the number of unnecessary handovers in the network, but throughput degradation and reducing control messages are not investigated. The authors in [8], by assuming that UE speed is known, proposed a handover scheme in femtocell. For handover decision in macro-macro and femto-femto cells, the proposed algorithm uses a handover policy which has a measurement report that includes the signal strength, max capacity, number of UEs connected to the target cell. Optimization of mixed measurement and acquiring required handover decision parameters are not thoroughly investigated at the serving LTE cell.

In this thesis, the focus is on reducing the control messages and latency during handovers. A new handover approach is proposed based on the UEs speed and its standard LTE measurement reports. Two varying velocities have been considered: low speed (0-10 kmph) and speed ($>$ 10kmph). X2 interface has been used between the macrocells or femtocells for reducing the control messages. The results show that the proposed algorithm with proactive and reactive strategies has a better performance in reducing handover latency. The proposed algorithm uses handover hysteresis margin (HHM) for reducing the unnecessary handovers.

Chapter 2

Handovers

2.1 Introduction

Handover refers to the process of disconnecting from the source cell (currently attached) and connecting to a target cell while maintaining ongoing call and data sessions. Handover has become a mainstay in cellular wireless networks as it allows UEs to be mobile without losing connectivity. Although handover allows one to maintain continuous connection, it also involves a lot of overhead and causes delay for the packets to be delivered to the destination UE. There are two types of handovers based on the when the connection to new cell is established. They are

- Hard Handovers
- Soft Handovers

2.1.1 Hard Handover

In hard handover, the connection to the target cell is established after the connection to the source cell is broken. Hence this handover is also called the ”break-before-make” handover.

2.1.2 Soft Handover

In soft handover, the connection to the target cell is established before the connection to the source cell is broken. Hence this handover is also called the ”make-before-break” handover.

2.2 Handovers in LTE Network

2.2.1 Macrocell Handovers

The handover procedure and mechanism as specified by 3GPP LTE consists of the following steps:

- UE measures signal strength in downlink
- Measurement reports are prepared at the UE

- UE sends these reports to the serving cell
- Handover decision is made at serving cell using measurement reports of the UE.

Sequence of message passing between source and target cells in handover procedure of LTE is depicted in Fig 2.1
The handover process takes place in 3 phases:

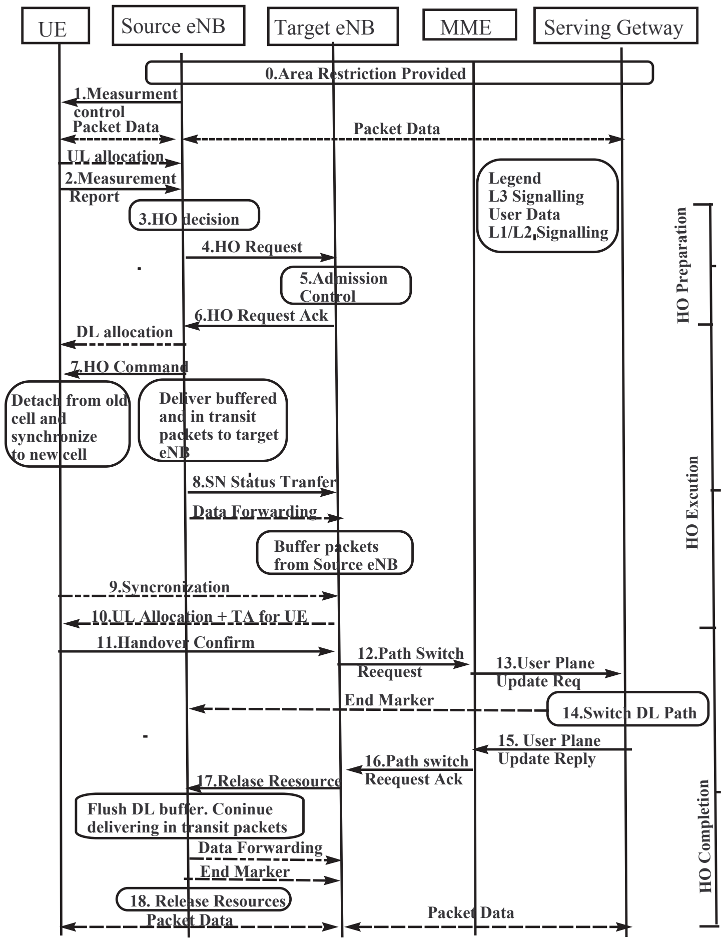

Figure 2.1: LTE Handover procedure sequence diagram

- **Handover preparation:** This phase consists of the source eNB and target eNB preparing themselves before the handover takes place. The main message and process are as follows:
  1. Measurement control - The source eNB configures the UE measurement procedures.
  2. Measurement report - The UE periodically sends measurement report message to serving eNB.
  3. Handover decision - The serving eNB makes the handover decision based on the UE measurement reports.
  4. Handover request - Once a decision is made to handover then this message is sent to the

target eNB asking it to prepare itself for the soon arrival of UE.
5. Admission control - The target eNB checks if it can admit the handover request based on the QoS requirements.
6. Handover Request Acknowledge - If admission control is successful, then the target eNB notifies the serving eNB with this message. It will contain certain parameters required for the UE to attach to the target eNB.
7.Handover command - This message is sent to the UE by the serving eNB to trigger the handover.

- **Handover execution:**This phase consists of the actual handover process. The process is as follows:
8. SN Status Transfer - This is used to convey the uplink PDCP SN receiver status and the downlink PDCP SN transmitter status of E-RABs
9. Synchronization - This involves the UE attaching itself with the target eNB.
10. UL Allocation + TA - The target eNB sends the timing advance (TA) to the UE and allocates it uplink resources.

- **Handover completion:** This phase involves notifying the nodes in EPC about the handover and cleanup of resources which will no longer be used. The process is as follows:
11. Handover confirm - The UE indicates the confirmation of the handover.
12. Path switch request - The MME is notified of UE's change of cell.
13. User plane update request - The MME informs the S-GW about the change of cell by the UE.
14. Switch downlink path - The S-GW notes this change.
15. User plane update reply - The S-GW then responds to the MME after the change is incorporated.
16. Path switch response - The MME responds to the target eNB once the path has been switched in the S-GW.
17. Release resource - This is sent to inform the source eNB to release resources reserved for the UE.
18. Release resources - The serving eNB releases related radio and control resources.

2.2.2 Femtocell Handovers

With the advent of femtocells, there are a lot of challenges in the handover decision. femtocells are introduced to provide better coverage for indoor environments (residential, commercial and office environments) and also to reduce the load on the macrocell. With high deployment of femtocells, there could be a lot of cells within a particular area. This situation has introduced new challenges in the handover decision procedure. One of those challenges would be reducing unnecessary and frequent handovers.

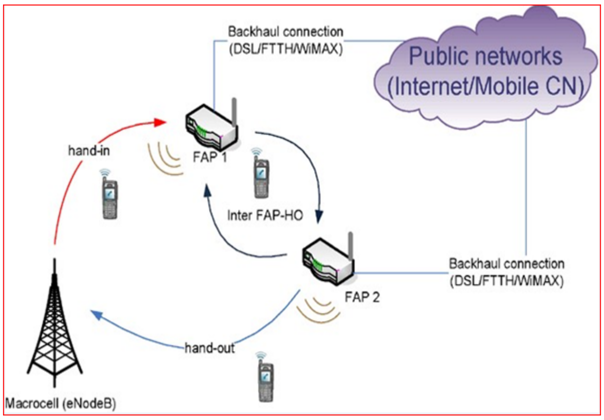

Figure 2.2: Handover scenario in femtocell network

Three handover scenarios can be possible in femtocells as depicted in Fig 2.2.

- HandIn: When UE switches from macrocell to femtocell, this handover is performed.
- HandOut:When UE switches from femtocell to macrocell, this handover is performed.
- Femtocell to femtocell (Inter-FAP) handover: The scenario where a handover takes place between one femtocell to other femtocell.

2.3 Femto-Gateway

Femto-Gateway is the concentrator for the control plane between femtocells and the Mobility Management Entity. It is deployed at operator side. All femtocells are connected to this gateway for protocol conversation to core network. Femto-Gateway appears as an eNB to the MME and as MME to femtocells. S1 handovers are used for macrocell to femtocell via Femto-Gateway. According to 3GPP TS 23.401 specification where ever X2 interface is not possible there we need to go with S1 handover. Inter FAP handover is done without intervention of MME as femto-Gateway appears as MME to the femtocells.

2.4 Handovers with S1 and X2 interface

As shown in the Fig 2.3 , while preparing for handover, the source eNB sets up a tunnel between source eNB and Serving-Gateway (S-GW) using S1 bearer and also there is one more tunnel between S-GW and target eNB. S1 interface is used for uplink setup between target eNB and S-GW. In case of handover execution, UE is detached from source eNB and the packet forwarding for downlink is done through target eNB. In handover completion there is no need of path switch request by MME, as MME knows about the handover event. S1 interface is released between source eNB and S-GW and also between S-GW and target eNB.

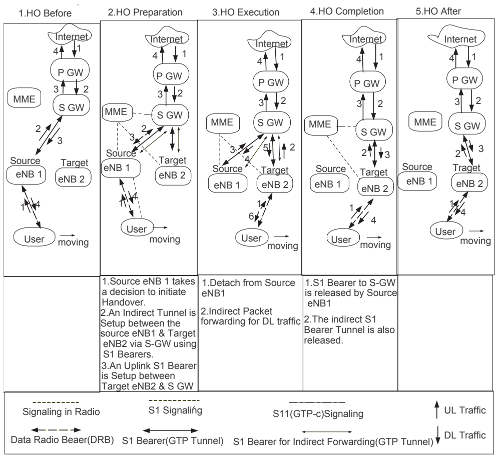

Figure 2.3: S1 Handovers

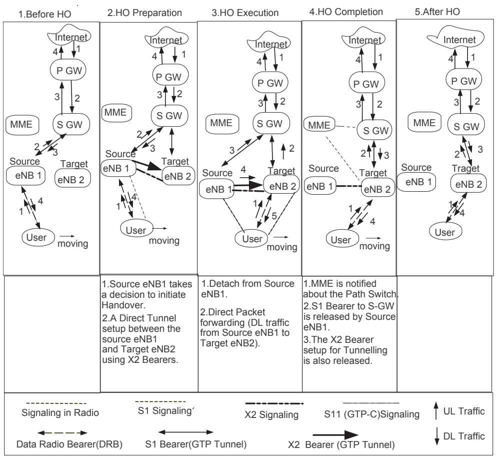

Figure 2.4: X2 Handovers

As shown in the Fig 2.4 , while preparing for handover the source eNB sets up a direct tunnel between source eNB and target eNB using X2 bearer. In case of handover execution, UE is detached from source eNB and packet forwarding is done to target eNB through X2 bearer. In handover completion, as MME is not aware of handover event, it requests the S-GW to switch the UE path from source eNB to target eNB.

2.5 Proactive and Reactive Handovers

The serving cell can perform handover using two handover approaches i.e. proactive and reactive handover, which differ in triggering handover.

a) Proactive Handover: In this strategy, handover can take place at any time before the signal strength of serving eNB reaches threshold. This handover strategy estimates UE position before UE reaches that position. Whenever the UE has found a new target eNB signal (or HeNBs SINR), the serving eNB calculates the time left to trigger the normal handover, based on certain threshold on time left, it performs handover. This handover mechanism seems to reduce packet drop.

b) Reactive Handover: Femtocells have a small coverage due to lower power. Because high density of femtocells, the UE in femtocell network encounters frequent and unnecessary handover. To reduce the unnecessary and frequent handovers overhead in the network, the reactive handover approach is used. In this handover mechanism, it tends to delay the handover as long as possible, even though it has discovered the good signal strength from other cells. The handover is taken place only when the UE almost loses its signal strength from serving cell.

2.6 Mobility Models

Mobility of the UE is an important factor in the handover decision. So, in this thesis we have used speed of the UE as one of the parameter for handover decision. By knowing the velocity and current position of an UE, we can estimate where the UE is heading towards, so that handover decision can be taken earlier or later. In this mechanism of handover, it was assumed that the UE sends periodical (example: every 1 ms) measurement reports to the source cell (either eNB or HeNB) during its motion. The UE measurement reports will contains the standard measurements used for calculating signal strength, based on these measurement report serving cell takes the handover decision.

In simulation, we have used constant velocity mobility model for Macro-UEs and building mobility model for Femto-UEs.

2.7 Handover Decision Parameters

SINR is calculated as P / (I + N) where P is received signal power, I is interference and N is noise power. The Radio frequency conditions can be classified as follows

Table 2.1: Radio frequency conditions

Status	RSRP(dBm)	RSRQ(dB)	SINR(dB)
Excellent	>=-80	<=-10	>=20
Good	-80 to -90	-10 to -15	13 to 20
Mid cell	-90 to -100	-15 to -20	0 to 13
Cell Edge	<=-100	>-20	<=0

In Handover scenario, the UE has to send periodic measurement reports. The common measurements for handover decision mechanism include Reference signal received quality (RSRQ), Reference signal received power (RSRP), signal to interference plus noise ratio (SINR), Receive Signal Strength Indicator (RSSI) and Quality of Service (QoS) parameters.

In this thesis, we have chosen SINR measurement of UE as handover decision criteria as it gives the channel quality information. If channel quality is good, UE will have better quality of service for real time traffic (voice). The Fig 2.5 depicts the range of SINR values in a scenario where 3 macrocells (with cosine Antenna model) and 20 femtocells are deployed.

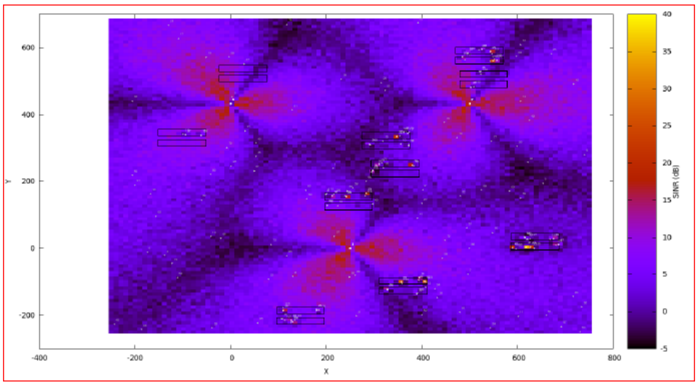

Figure 2.5: SINR measurement of UE as handover decision criteria

In the Fig 2.5 each and every pixel represents a position (x,y) with corresponding SINR value. When UE position matches with the pixel position, we can get the associated SINR value of the UE.

Chapter 3

Proposed Work

3.1 Proposed Algorithm

The inter-femtocell and hand-in handovers involve more complexity than the hand-out handover. The problem that we experience is the selection of target femtocell, which leads to increase in handover interruption time. Another problem is reducing the unnecessary handovers due to high density of femtocells. With these constraints, we propose a prediction mechanism for UE movement. If we know the UE movement, towards where it is heading, we can decide whether to take proactive or reactive approach. The mobility prediction uses UE's physical movement and estimates it's next position. If we know the next position, the system can decide how to make a hand over. The unnecessary handovers are mitigated by using reactive handover mechanism, where the handover is postponed until the UE reaches to a threshold signal strength of the target cell.
The input values to the algorithm are SINR, UE velocity and handover hysteresis margin (HHM). There are 4 scenarios considered for handover in the algorithm:

- Macro-Macro Handover: This scenario is triggered when the SINR of the target eNB is better than that of the serving eNB plus the HHM. When UE is moving from one macrocell region to another macrocell region with more speed (velocity greater than 10kmph), target macrocell is predicted based on the euclidean distance between UE and neighbor macrocells. After deciding target cell, we need to check for the type of application the UE is using. If UE is using real time traffic (voice), then perform proactive handover mechanism. If UE is using non-real traffic then perform reactive handover mechanism. In case the UE is moving with a velocity less than 10kmph then no mobility prediction is used. The type of handover is decided based on the type of application, i.e. proactive handover for real time traffic or reactive handover for non-real time traffic.

- Hand-In: This scenario is triggered when the SINR of the target HeNB is better than that of the serving eNB plus the HHM. If UE is moving with more speed (velocity greater than 10kmph), then don't perform the handover from macrocell to femtocell, as UE may quickly move out of femtocell coverage region, which may lead to an unnecessary handover. If the UE moves with less speed (velocity lesss than 10kmph) then perform the handover, as UE is expected to stay for some period within the femtocell coverage region. The handover performed

Algorithm 1 Handover Algorithm

Input: SINR *value of serving cell*
Input: V *speed of the UE*
Input: HHM *Handover Hysteresis Margin*

```
if (SINR(Target-eNB) > SINR(Serving-eNB) + HHM) then
  if (V > 10) then
    PREDICT USER MOBILITY;
    if (TRAFFIC-USED = REAL-TIME) then
      DO PROACTIVE HANDOVER;
    else
      DO REACTIVE HANDOVER;
    end if
  else
    if (TRAFFIC-USED = REAL-TIME) then
      DO PROACTIVE HANDOVER;
    else
      DO REACTIVE HANDOVER;
    end if
  end if
end if
if (SINR(Target-HeNB) > SINR(Serving-eNB) + HHM) then
  if (V > 10) then
    DON'T PRFORM HAND-IN;
  else
    if (TRAFFIC-USED = REAL-TIME) then
      DO PROACTIVE HAND-IN;
    else
      DO REACTIVE HAND-IN;
    end if
  end if
end if
if (SINR(Target-HeNB) > SINR(Serving-HeNB) + HHM) then
  if (TRAFFIC-USED = REAL-TIME) then
    DO PROACTIVE HANDOVER;
  else
    DO REACTIVE HANDOVER;
  end if
end if
if (SINR(Target-eNB) > SINR(Serving-HeNB) + HHM) then
  if (TRAFFIC-USED = REAL-TIME) then
    DO PROACTIVE HAND-OUT;
  else
    DO REACTIVE HAND-OUT;
  end if
end if
```

is based on the type of application as in the previous case.

- Femto-Femto Handover: In this scenario, we need to check for handover threshold value between source and target femtocell and type of application UE is using. Based on type of application UE is using we perform the handovers as in the previous cases.

- Hand-out: In this scenario, perform the handover when UE experiences signal strength from macrocell which is greater than signal strength of the femtocell by a margin of HHM. The exact type of handover is again based on the type of application.

3.2 Simulation Parameters

In this thesis, we have investigated the two tier LTE network handovers and evaluated the handover performance in ns-3 simulator. We have used X2 interface between macrocells and femtocells for reducing signaling cost. Hand-in and Hand-out procedure is performed via Femto-Gateway. The UE's mobility prediction is done by using euclidean distance between target cell and UE. The various other parameters used in simulation are listed below.

Table 3.1: Parameters used in simulation

Parameter	Value
Transmission range of Macrocell	800 meters
Transmission range of Femtocell	50 meters
Velocity of UserEquipment	0-30 km/h
Number of Macrocells	4
Number of Femtocells	2 to 12
Number of UEs	20
Simulation time	100 secs

3.3 Results

To evaluate the performance of handovers, the proposed algorithm is implemented and tested. The random mobility model has been used for the UE, when it is outside the building. Number of femtocells are varied from 2 to 12. Number of macrocells used is fixed to 4. The coverage shape of macrocell and femtocell is assumed as circular.

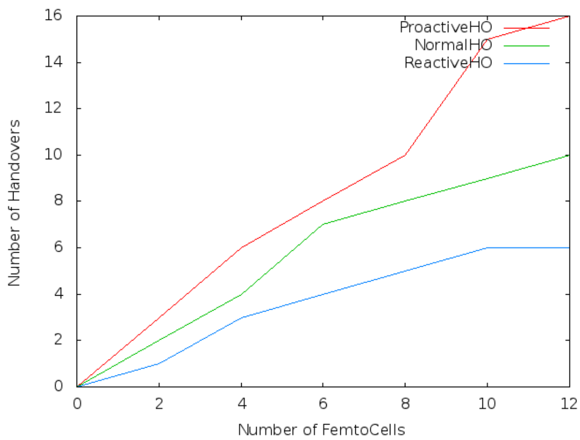

Figure 3.1: Handovers

From Fig 3.1, we can observe that the number of handover are increasing with increase in the number of femtocells. The lowest number of handovers are reactive handovers as compared to proactive and normal handover scheme because of delay in handover decision. Thus, it was proposed that the reactive handover mechanism is better in mitigating the unnecessary handover. From Fig 3.2, we can observe that the latency of handover is lower for reactive handover strategy because of less number of handovers.

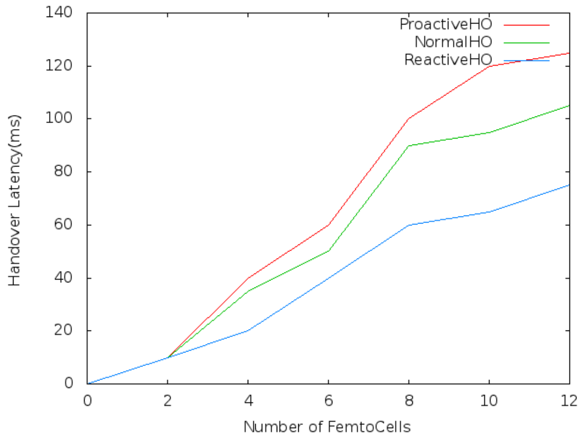

Figure 3.2: Handover Latency

Chapter 4

Conclusion and Future work

4.1 Conclusion

- The reactive handovers mechanism has more potential to mitigate unnecessary handovers compared to other handover mechanisms.
- Signaling overhead in handovers can be reduced by using X2 interface between Macro cells or Femto cells. Reducing signaling overhead results in reducing handover latency, which leads to an efficient handover.

4.2 Future Work

- Comparing handover latency of X2 interface with S1 interface.
- Considering load balancing factor in handover decision.

References

[1] H. Kwak, P. Lee, Y. Kim, N. Saxena, and J. Shin. Mobility management survey for home-e-NB based 3GPP LTE systems. *Journal of Information Processing Systems* 4(4), (2008) 145–152.

[2] H. Lee and Y. B. Lin. A cache scheme for femtocell reselection. *IEEE Communications Letters* 14(1), (2010) 27–29.

[3] M. Z. Chowdury, W. Ryu, E. Rhee, and Y. M. Jang. Handover between macrocell and femtocell for UMTS based networks. *In Proceeding of 11th international conference on advanced communication technology, Gangwon-Do, South Korea* ISBN: 978-89-5519-139-4, (2009).

[4] W. Shaohong, Z. Xin, Z. Ruiming, Y. Zhiwei, F. Yinglong, and Y. Dacheng. Handover study concerning mobility in the two-hierarchy network. *IEEE 69th Vehicular Technology Conference* 1, (2009) 1–5.

[5] Z. Becvar and P. Mach. Adaptive hysteresis margin for handover in femtocell networks. *6th International Conference on Wireless and Mobile Communications* Sept, (2010) 256–261.

[6] A. Ulvan, R. Bestak, and M. Ulvan. Handover scenario and procedure in LTE-based femtocell networks. *4th International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies* Oct 2010.

[7] S. Sesia, I. Toufik, and M. Baker. *LTE The UMTS Long Term Evolution: From Theory to Practice, John Wiley and Sons* ISBN: 978-0-470-69716-0.

[8] H. Zhang, X. Wen, B. Wang, W. Zheng, and Y. Sun. A novel handover mechanism between femtocell and macrocell for LTE based networks. *In Proceeding of 2nd international conference on communication software and networks,Los Alamitos: IEEE Computer Society* ISBN: 978-0-7695-3961-4/10, (2010) 228–231.