Mobility Management in LTE Heterogenous Networks

A Project Report

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THESIS CERTIFICATE

This is to certify that the thesis titled Mobility Mangement in LTE Heterogenous Networks, submitted by **J Manoj Vikram(EE10B018)**, to the Indian Institute of Technology, Madras, for the award of the degree of **Bachelor of Technology**, is a bona fide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

This thesis aims to look at various mobility improvements such that these improvements tend to provide robust mobility of users in Long Term Evolution Heterogenous networks. Mobility improvements is gained through setting parameters dynamically, based on the speed of the User-Equipment(UE). Estimating the speed of the User-Equipment is done by using a basic Mobility State Estimation(MSE) algorithm based on the number of cell changes. The basic MSE algorithm has some flaw in estimating the speed, especially at low speeds. This could be overcome by using the technique of relative weights.This thesis also include studying various key performance indicators of mobility like ping-pong rate, short Time of Stay(sTos) rate and Handover Failure(HOF) rate with parameters like offsets and Time To Trigger(TTT). This thesis also includes a new algorithm to reduce short Time of Stay count by estimating time of stay inside a pico cell and avoiding it by through manipulation of mobility parameters.

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ABBREVIATIONS

eNB	eNodeB
FC	K-Filter Coefficient
LTE	Long-Term Evolution
HetNet	Heterogenous Networks
HO	Handover
HO_CMD	Handover Command
HOF	HandOver Failure
MSE	Mobility State Estimation
MTS	Minimum Time Of Stay
RLF	Radio Link Failure
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
sTos	short Time Of Stay
Tos	Time Of Stay
TTT	Time To Trigger
UE	User Equipment

NOTATION

M_n	Neighbour cell RSRP value
M_p	serving cell RSRP value
Oc_n	cell specific offset of neighbour cell
Oc_p	cell specific offset of serving cell
Of_n	frequency offset of neighbour cell
Of_p	frequency offset of serving cell
T310	RLF timer
N310	parameter assigned for number out of syncs
N311	parameter assigned for number of in-syncs
off	A3 offset
Hyst	Hysterisis
sin	sine function
cos	cosine function

Mobility Management in LTE Heterogenous Networks

CHAPTER 1

Introduction

In this chapter, LTE overview, Self-Organisisng Networks will be presented.

1.1 LTE Overview

LTE or Long-Term Evloution encompasses a set of aggressive requirements that aim at improving the end-user throughput and cell capacity. These along with full mobility, will bring high standard benefits to user experience. LTE is designed to support all kind of IP data traffic and voice is supported as Voice over IP (VoIP) for better integration with multimedia services. LTE aggressive requirements lead to the definition of a new Network Architecture, the Evolved Packet System (EPS), which comprises the Enhanced RAN (E-UTRAN or LTE) and the Evolved Packet Core(EPC). LTE paved the way to a new standardisation approach with buitin SON features. LTE is based on Orthogonal Frequency Division Multiplexing (OFDM) for downlink radio transmission and data are carried simultaneously by narrow-band subcarriers, where as in uplink due to power constraint on UE, single carrier FDMA is used.
The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multicast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD).

1.2 Self Organising Networks

Self organising networks automate the procedure involved in planning, deployment, management, optmisation and healing. Self organizing network functionalities are commonly divided into three major sub-functional groups, each containing a wide range of decomposed use cases.

1. Self configuration functions
2. Self optimization functions
3. Self healing functions

Self configuration: Also known as "plug and play", it involves process of bringing a new network element or network element parts into service with minimal human operator intervention.

The process encompasses three phases

1. Auto connectivity setup
2. Auto commissioning
3. Dynamic radio configuration

Self optimisation functions: These functions optimizes certain parameters and ensure reliability through the following functions

1. Mobility Robust Optimisation
2. Mobility load Balancing

Self healing functions These functions aims at reducing the failure due to non-cooperative or failing nodes. For example if a node is failing then the adjacent nodes can support its users through some algorithms.

CHAPTER 2

Mobility Management

In this chapter goals of Mobility Robust Optimisation, mobility relevant parameters, mobility related problems, and generic solutions are presented.

Mobility Robust Optimisation: The task of Mobility Robust Optimisation is to ensure that there is full mobility, that is proper handovers and cell reselections. The main goals of MRO are

1.Minimise call drops

2.Minimise Radio Link failure

3.Minimise unnecessary handovers

2.1 Mobility relevant parameters

The following parameters have significant impact on key performance indicators of mobility.

Time To Trigger(TTT): A report is not sent immediately after the corresponding condition is met. Instead, the condition has to be fulfilled for a certain period indicated by Time To Trigger(TTT).

Filter Coefficient: A UE has to apply a recursive averager to its Layer 1 measurements, and the time constant is configured by the eNB via a filter coefficient index.

A3 Event threshold A3 event is triggered if neighbouring cell RSRP/RSRQ is above certain offset as shown in Figure 2.1 for a certain amount of time(TTT). This offset is called A3 offset.

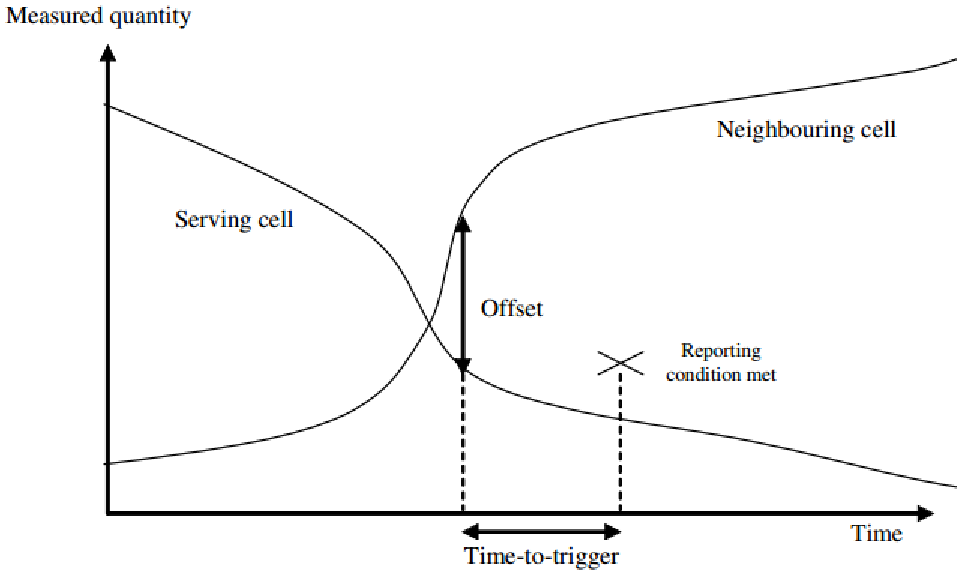

Figure 2.1: A3 Event

2.2 Mobility related problems and generic solutions

Too Late handover: Too late handover is caused if a handover initiation is delayed or not started at all. In any one of the case it suffers RLF.

Too Early handover: It is caused if handover is initiated towards a cell whose connection is not stable enough yet.

Wrong handover: If handover is aimed to particular cell, however due to some reasons if it is initiated to another cell, then this failure is termed as wrong handover.

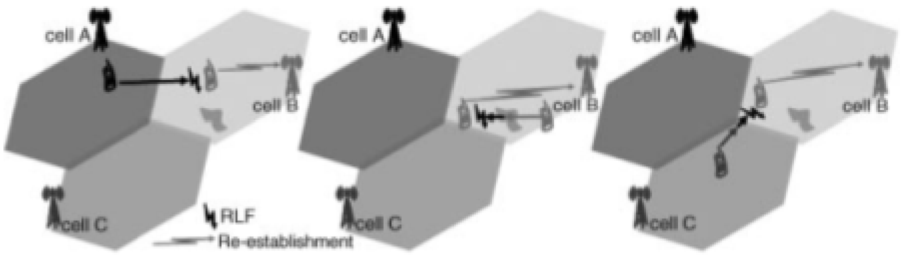

Figure 2.2: Too late handover (left), Too early handover (middle) and handover to wrong cell (right)

Below table is a generic solution for the above mentioned problems

Handover problem	Action	Parameters to be changed
Early Handover	Postpone handover	Large A3 offset,TTT/FC
Late handover	Prepone handover	smaller A3 offset,TTT/FC

CHAPTER 3

Handover Performance

In this chapter we study how RLF's occur, modelling of handovers, ping-pong rate and sTos rate. We also study how various parameters affect the ping-pong rate, sTos rate, handover failure rate and Radio Link Failure.

Radio link failure:

Radio link monitoring function in UE enables UE to check whether it is in *in-sync* or *out-of-sync* with respect to its serving cell. In case of a certain number of consecutive *out-of-sync* indications (called 'N310'), the UE starts a network-configured radio link failure timer 'T310'. The timer is stopped if a number 'N311' of consecutive *in-sync* indications are reported by the UE's physical layer. Both the *out-of-sync* and *in-sync* counters (N310 and N311) are configurable by the network. Upon expiry of the timer T310, Radio Link Failure (RLF) occurs.

3.1 Modelling of various parameters

Handover Modelling:

The figure 3.1 describes the handover procedure. For the purpose of modelling, this handover procedure is divided into three states.

State 1: Before the event A3 entering condition is satisfied.

State 2: After the event A3 entering condition is satisfied and before handover command is successfully received by the UE.

State 3: After the handover command is successfully received by the UE, but before the handover complete is successfully sent by the UE.

Handover failure can happen only in state 2 and state 3.

In state 2, handover failure can happen in two ways-

1.When HO_CMD is received when timer T310 is running or just started.

2. When RLF occurs

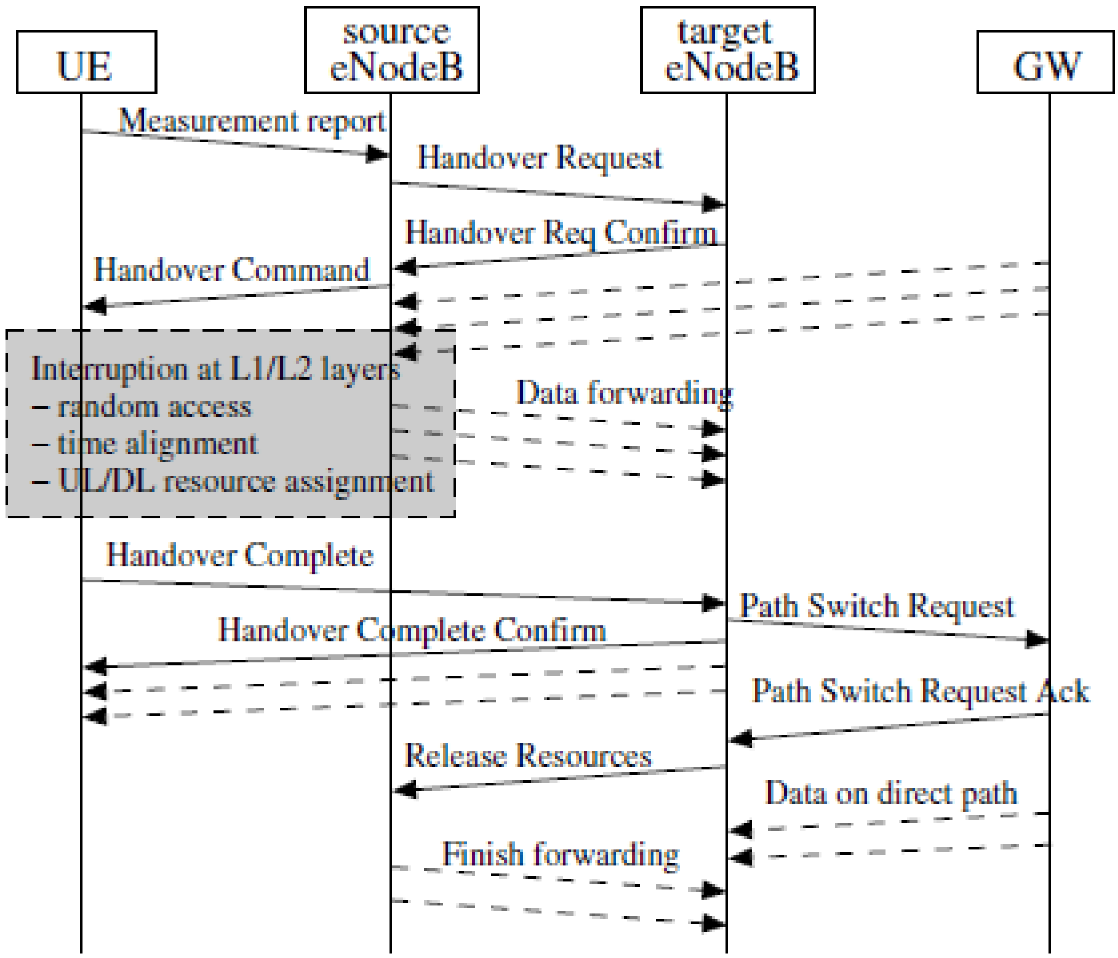

Figure 3.1: Handover procedure

In state 3 only due to RLF's, HOF's will happen.

HOF's, both in state 2 and state 3 are logged separately for studying performance, however overall handover failure rate i.e HOF rate =(Total number(both in state 2 and state 3) of handover failures) / (Total number of handover attempts).

Ping-pongs: A handover from cell B to cell A and then handover back to cell B is defined as a ping-pong, if the time-of-stay connected in cell A is less than a pre-determined minimum time-of-stay parameter (MTS).

Ping-pong rate is defined as (number of ping-pongs)/(total number of successful handovers).

Short-Time of Stay(sTos): A sToS is counted when a UE time-of-stay in a cell is less than a predetermined minimum time-of-stay parameter (MTS), i.e. a UE with ToS < MTS.

sToS rate = (number of Short ToS occurrences)/(total number of successful handovers)

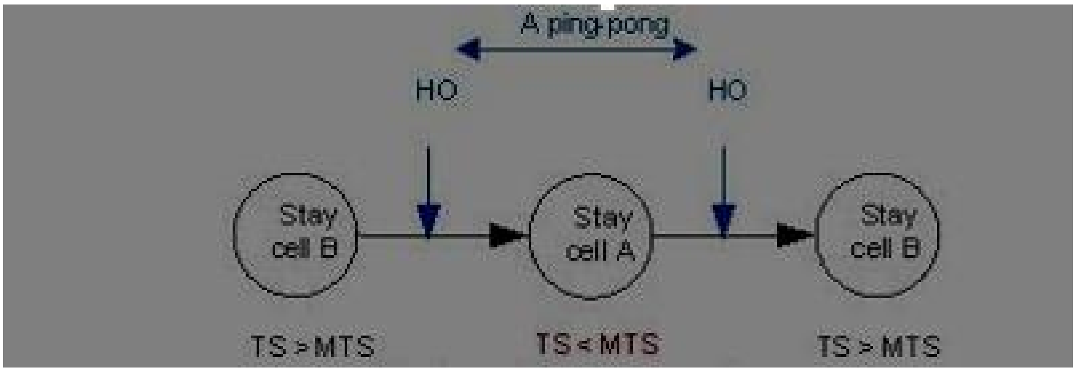

Figure 3.2: ping-pong condition

3.2 Analysis of Handover Performance for different offsets

Below table specify the three configurations for which handover performance is studied.

Key parameters	1st configuration	2nd configuration	3rd configuration
Neighbour offset[Macro pico] in db	[0 0]	[0 4]	[0 5]
A3 offset in db	0	1	1
Hysterisis in db	0	1	2.5
TTT in ms	480	480	480

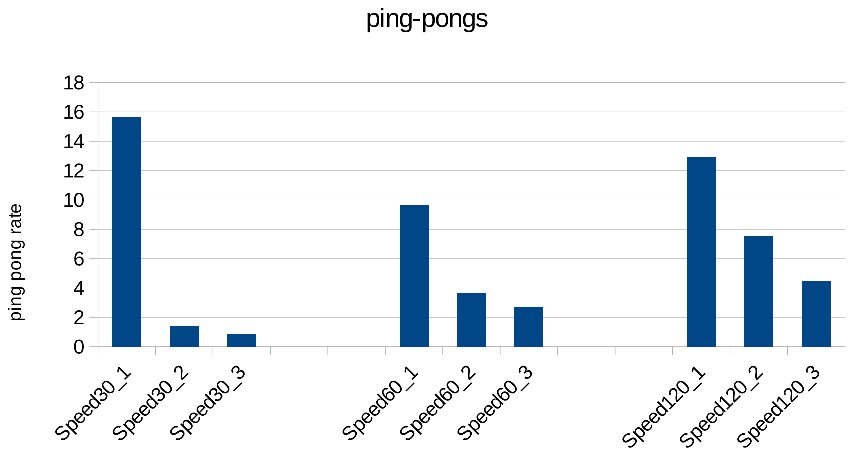

Figure 3.3: Ping-pong rate for different configurations at speeds 30,60 and 120

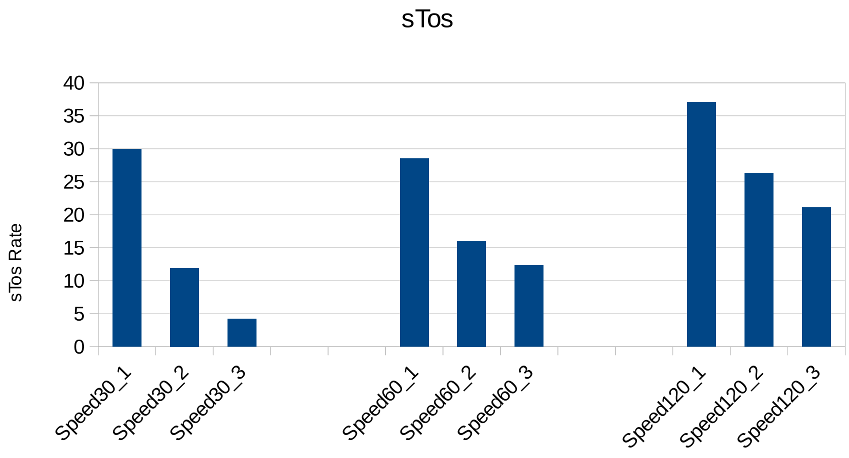

Figure 3.4: sTos rate for different configurations at speeds 30,60 and 120

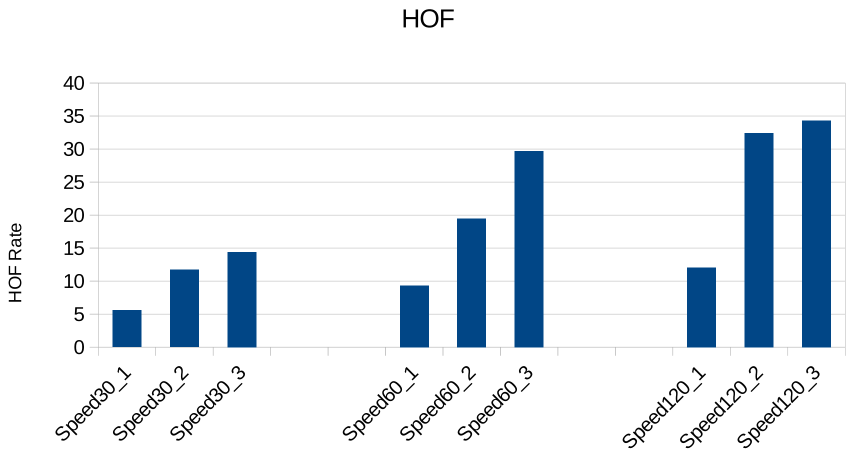

Figure 3.5: Handover failure rate for different configurations at speeds 30,60 and 120

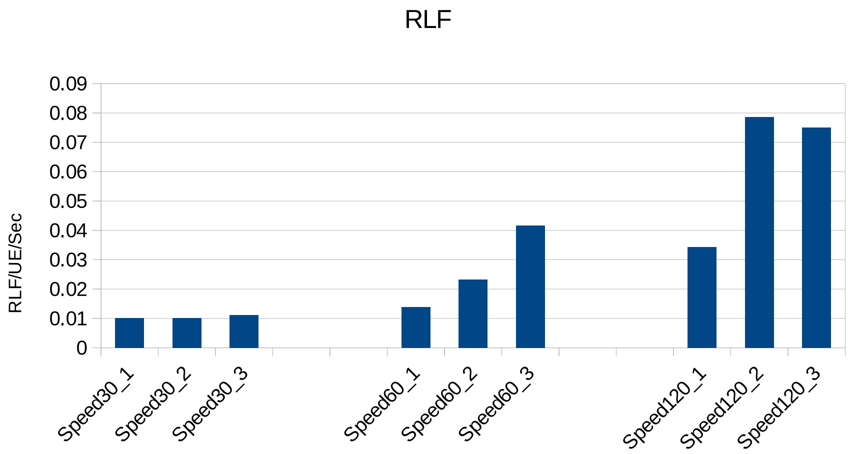

Figure 3.6: RLF/UE/Sec for different configurations at speeds 30,60 and 120

Here it can be seen that ping-pong rate and sTos rate are decreasing with 1st, 2nd,3rd configurations where A3 offset and hysterisys are increased. Generally in all the HOF's, Pico-Macro(P-M) HOF is the major contributer in determining the total number of HOF's, as majority of HOF's happen in P-M.
We have following equation as entering condition for A3 event.

$$M_n + Of_n + Oc_n - Hys > M_p + Of_p + Oc_p + Off \tag{3.1}$$

Consider P-M HOF in different configurations

$$Of_p = Of_n = Oc_p = 0 \tag{3.2}$$

$$M_n + Oc_n - Hys - Off > M_p \tag{3.3}$$

1st configuration:

$$M_n + 0 - 0 - 0 > M_p \tag{3.4}$$

$$M_n > M_p \tag{3.5}$$

2nd configuration:

$$M_n + 0 - 1 - 1 > M_p \tag{3.6}$$

$$M_n - 2 > M_p \tag{3.7}$$

3rd configuration:

$$M_n - 1 - 2.5 > M_p \tag{3.8}$$

$$M_n - 3.5 > M_p \tag{3.9}$$

In 1st 2nd and 3rd configurations from the above equation's it can be seen that M_n is 0, 2, 3.5 units more than serving cell for 1st, 2nd and 3rd configurations respectively when A3 event entering condition is satisfied. That implies A3 is met at a distance very close to pico in 1st configuration than in 2nd. Similarly A3 is met more closely to Pico in 2nd configuration than in 3rd configuration.

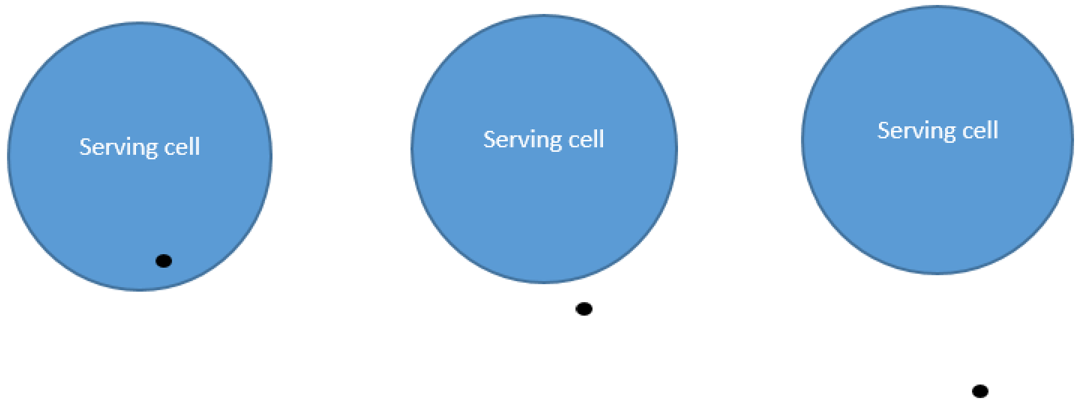

Figure 3.7: Scenario for three different configurations, black dot indiactes point where HO is initiated

Since pico power is less, compared to macro, the number of HOF's will increase if A3 is met at a farther distance. The reason being when A3 is delayed it implies HO is delayed that means there is a high probability of RLF happening in state 2 which will cause HOF as per definition. So the aforesaid explains why HOF's will increase in 1^{st},2^{nd} and 3^{rd} configurations.

3.3 Analysis of HO Performace for different TTT

Here as expected the ping-pong rate is decreasing with increasing TTT as seen in figure 3.8, similarly sTos rate also follows similar trend as seen in figure 3.9 and HOF's increase with TTT as seen in figure 3.10.

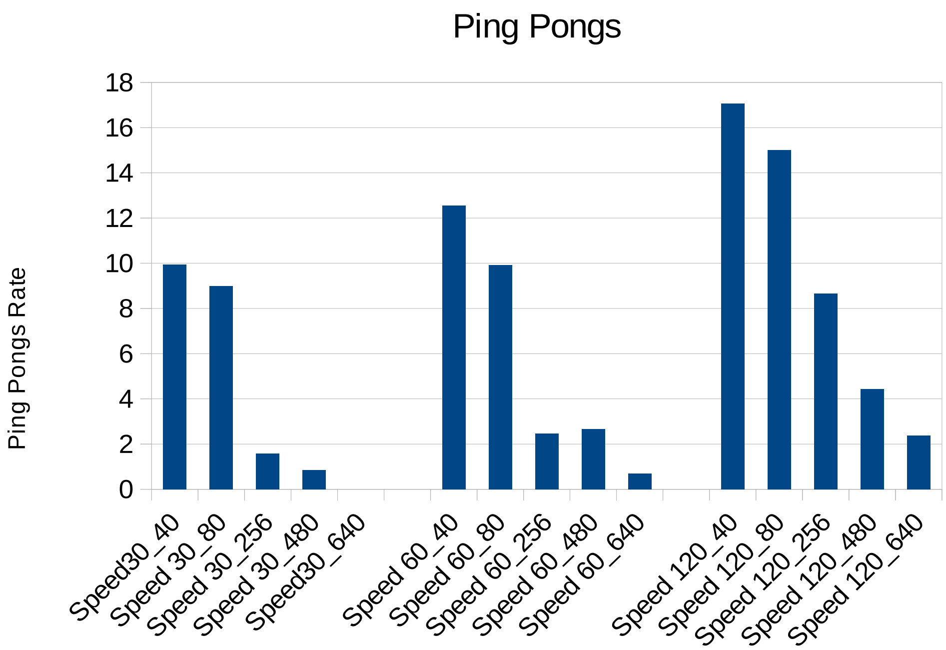

Figure 3.8: Ping-pong rate for TTT values of 40,80,256,480 and 640 at speeds 30,60 and 120

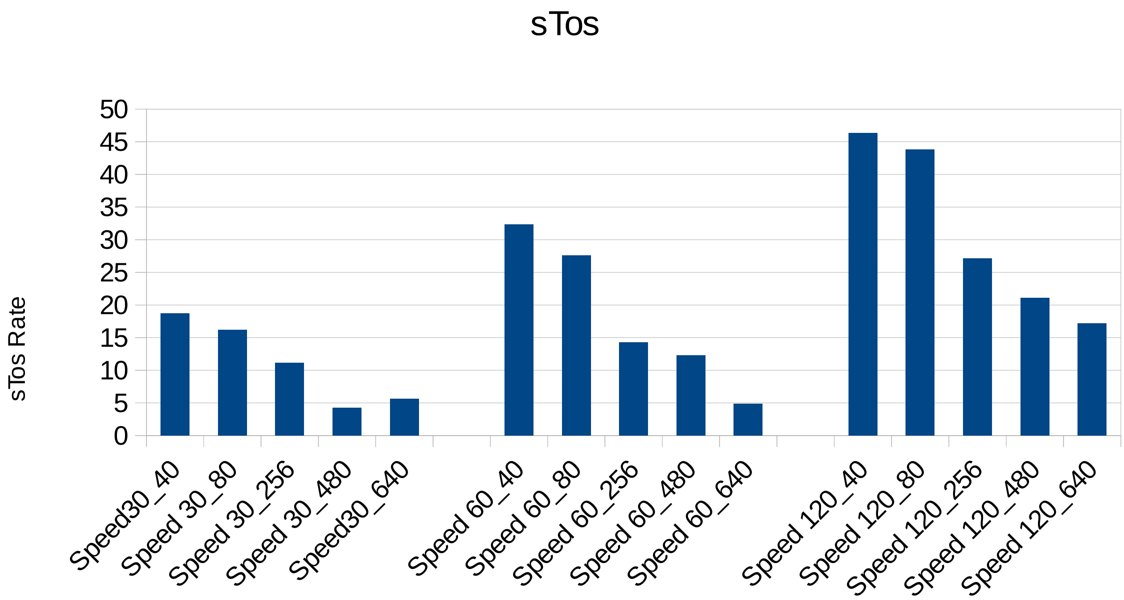

Figure 3.9: sTos rate for TTT values of 40,80,256,480 and 640 at speeds 30,60 and 120

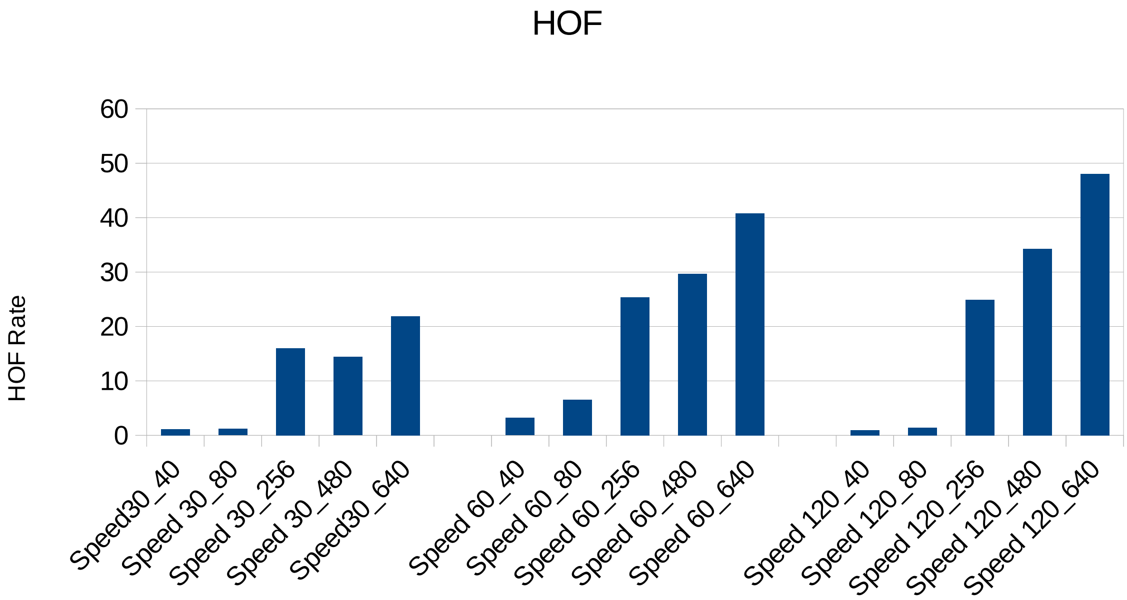

Figure 3.10: Handover failure rate for TTT values of 40,80,256,480 and 640 at speeds 30,60 and 120

CHAPTER 4

Mobility State Estimation

4.1 Introduction

Mobility state estimation aims at estimating the state of the UE for a certain period of time.
Basically there are three states.
1. Normal
2. Medium
3. High
UE could be in any of the three states.

4.2 Algorithm

Algorithm used here is a simple, which is based on number of cell changes. The logic is very trivial, if the speed is very high then the number of cell changes in a time period is more when compared to cell changes when speed is very low.

we calculate the cell changes as below

$$cellchanges = Totalcellchanges - 2 * pingpongs - cellReselections \tag{4.1}$$

Now there are two thresholds known as medium threshold and high threshold.
If the number of cell changes is less than medium threshold then it is in Normal state.
If it is above medium threshold and less than high threshold then it is in Medium state.
If it is above high threshold then it is said to be in High state.
Now data will be acquired once in 30 seconds. The above algorithm will operate on the latest data and estimate the state of the UE and set corresponding parameters like TTT, K-filter etc accordingly which aid in increasing efficiency.

4.3 Results of MSE comparing with different TTT values

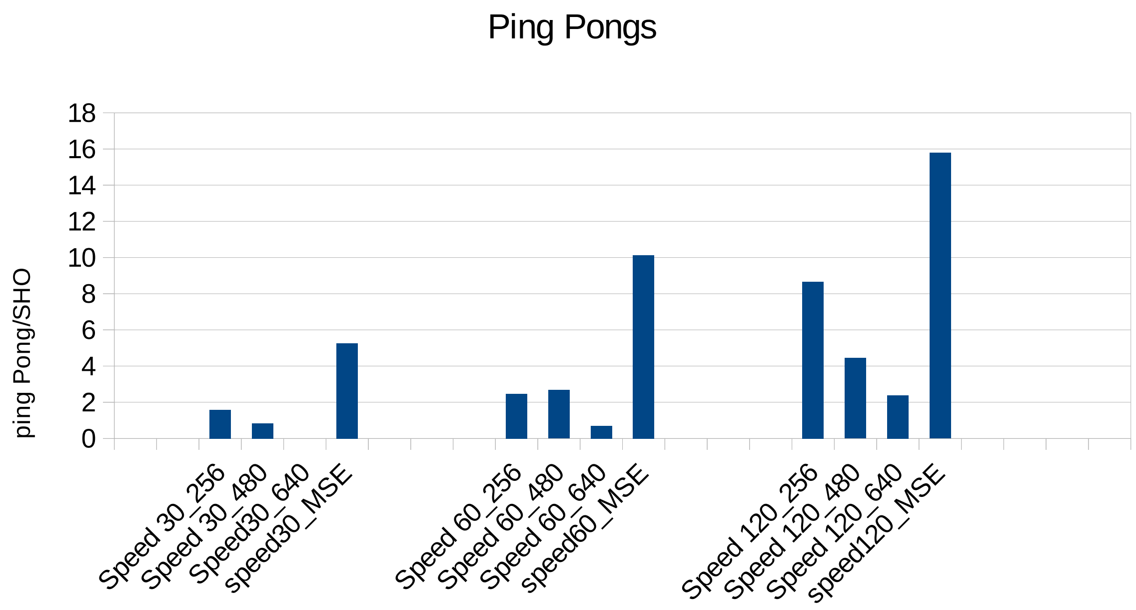

Figure 4.1: Ping-pong rate for MSE and TTT values of 256,480,640 at speeds 30,60 and 120

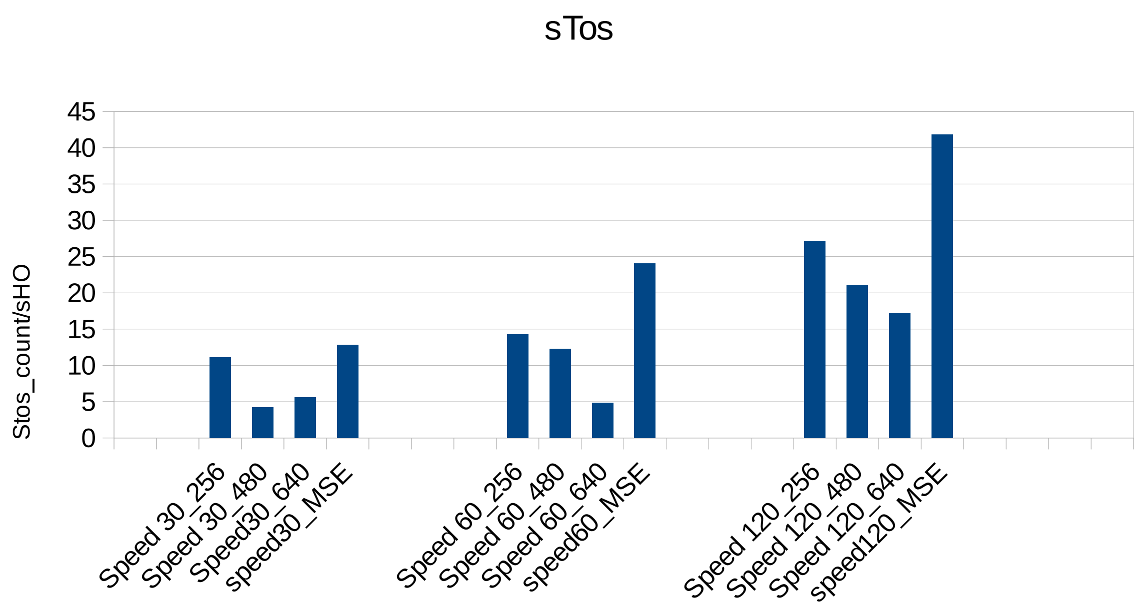

Figure 4.2: sTos rate for MSE and TTT values of 256,480,640 at speeds 30,60 and 120

conclusion: Here it can be seen that HOF rate and RLF is optimised as seen in figure 4.3 and 4.4, while ping-pong rate and sTos rate is increasing as seen in figure 4.1 and

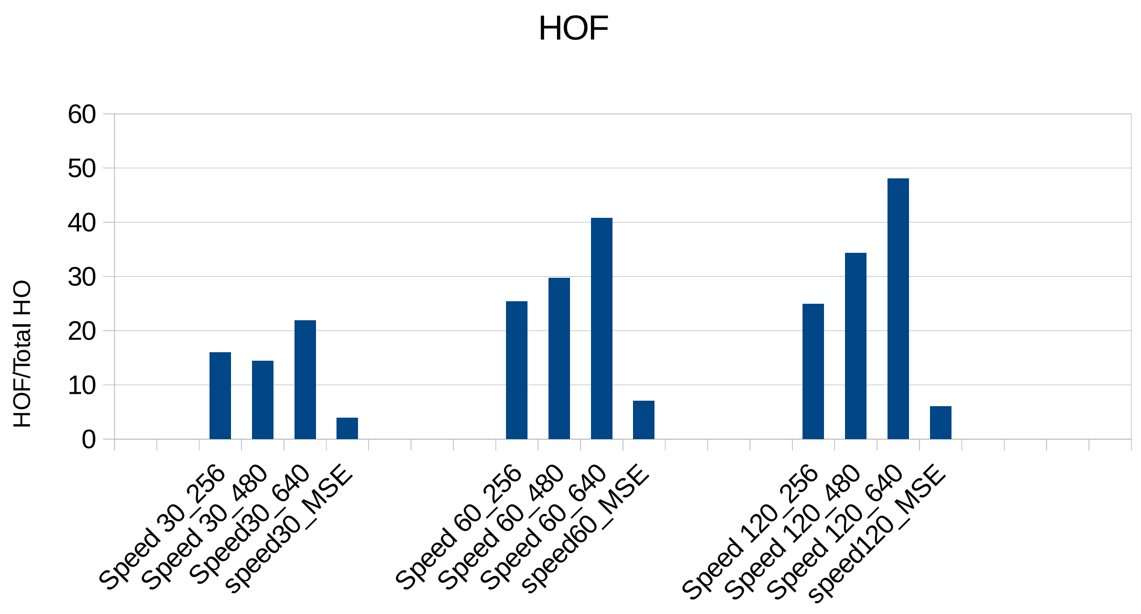

Figure 4.3: Handover failure rate for MSE and TTT values of 256,480,640 at speeds 30,60 and 120

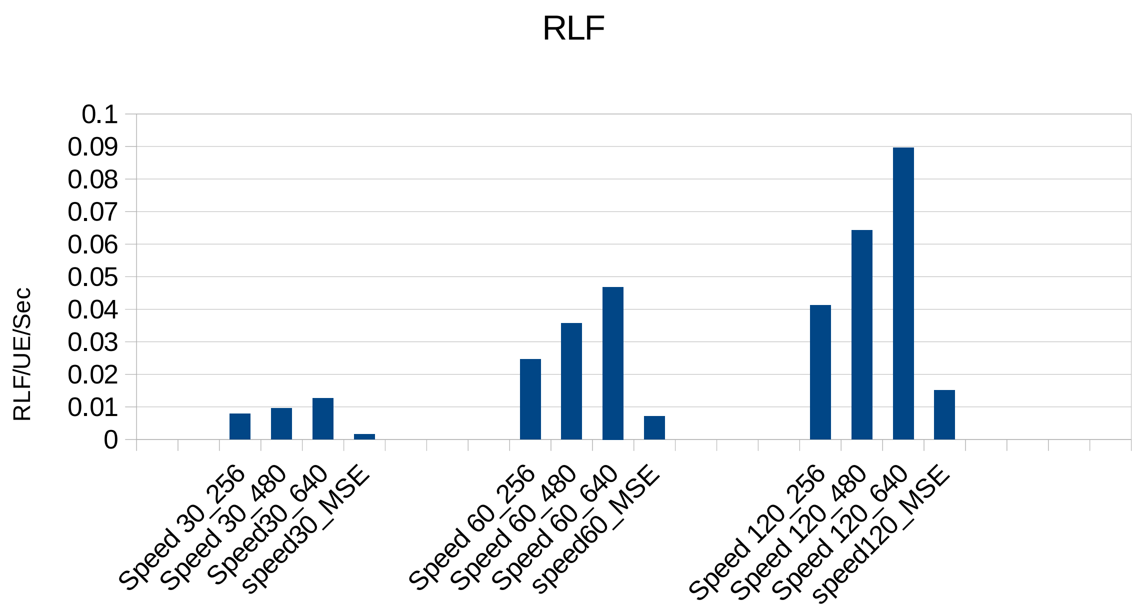

Figure 4.4: RLF/UE/sec for MSE and TTT values of 256,480,640 at speeds 30,60 and 120

4.2, this is because the algorithm we used is simple and basic one, so there is some flaw in estimating the state of the UE.

4.4 Problems with cell change Algorithm

Cell change algorithm will work perfectly in homogenous networks, however in heterogenous networks this is not efficient. In heterogenous networks we find pico cells along with macro cells. Suppose there are high number of pico deployment near a macro, then there is high probability that there will be high number of cell changes even though speed of the UE is very low. This may lead to wrong estimation of the state of the UE and inturn degrades the performance of the system.

The below figure 4.5 shows the distribution of percentage of time in each state for speeds 30, 60 and 120. Here it can be clearly seen that estimation is not appropriate.

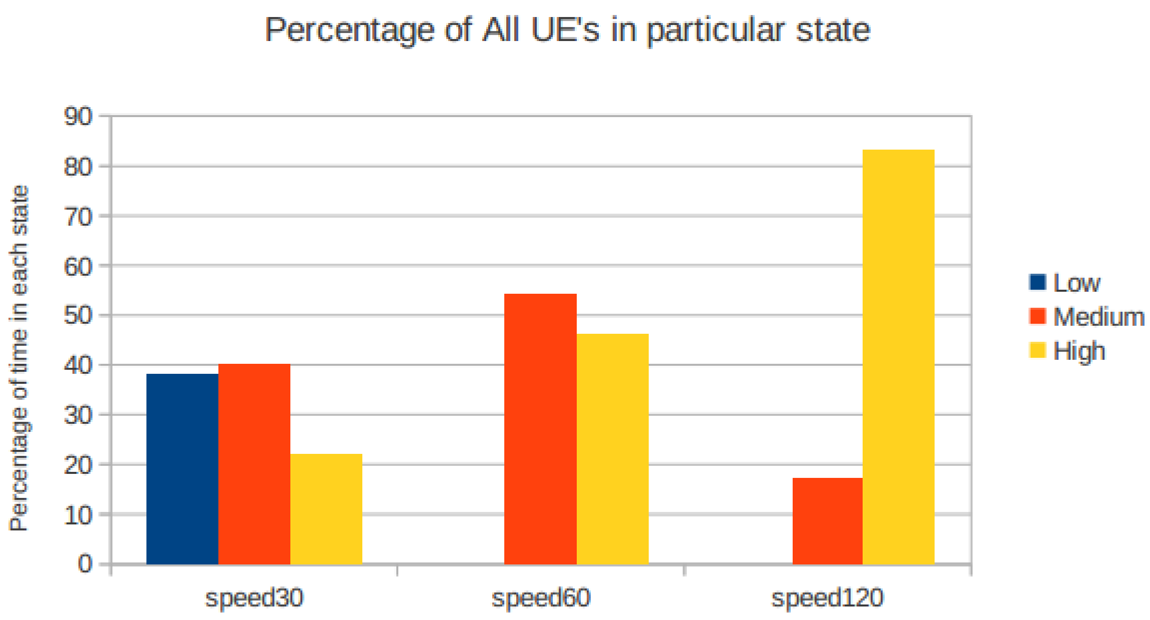

Figure 4.5: Percentage of time each state for speeds 30,60 and 120

4.5 Solutions by relative weights

Estimation through cell changes is hindered by the pico cells in between leading to Macro-Pico(M-P), Pico-Macro(P-M), Pico-Pico(P-P) Handovers which overstimate cellchanges. It is M-M Handovers which plays an important role in determining the number of cell changes. Hence we use the concept of relative weights to decrease the effect of M-P, P-M and P-P Handovers in cell changes.

P-P is mainly responsible for over estimation of cell changes we give relative weight as low as 0.2

Similarly M-P and P-M are given relative weight of 0.4

where as M-M is given a relative weight of 1

Even ping-pongs can be of 4-types, similarly ping-pongs are also assigned relative weights to avoid negative value of cell changes as below

1. Macro-Pico-Macro

ping-pong is counted as 0.4

2. Pico-Macro-Pico

ping-pong is counted as 0.4

3.Pico-Pico-Pico

ping-pong is counted as 0.2

4.Macro-Macro-Macro

ping-pong is counted as 1

cell change is calculated as below

$$cellchange = Totalcellchange - 2 * pingpongs - cellreselections \tag{4.2}$$

Note the cell change we get here may not be a perfect integer, so we ceil the value and make it a perfect integer.

Figure 4.6 tells us that using relative weights we are able to estimate correctly upto 60% where as earlier estimation was not even close to 40%

4.6 Reducing sTos count

The new algorithm proposed below will try to reduce sTos count by following method.

Assumption: basic assumption is that by different RSRP methods with very high probability one could estimate the position and velocity of UE.

In the figure 4.7 from RSRP methods if we know the position and velocity then chord AB length could be found out by simple geometry Apply sine rule in triangle OAB

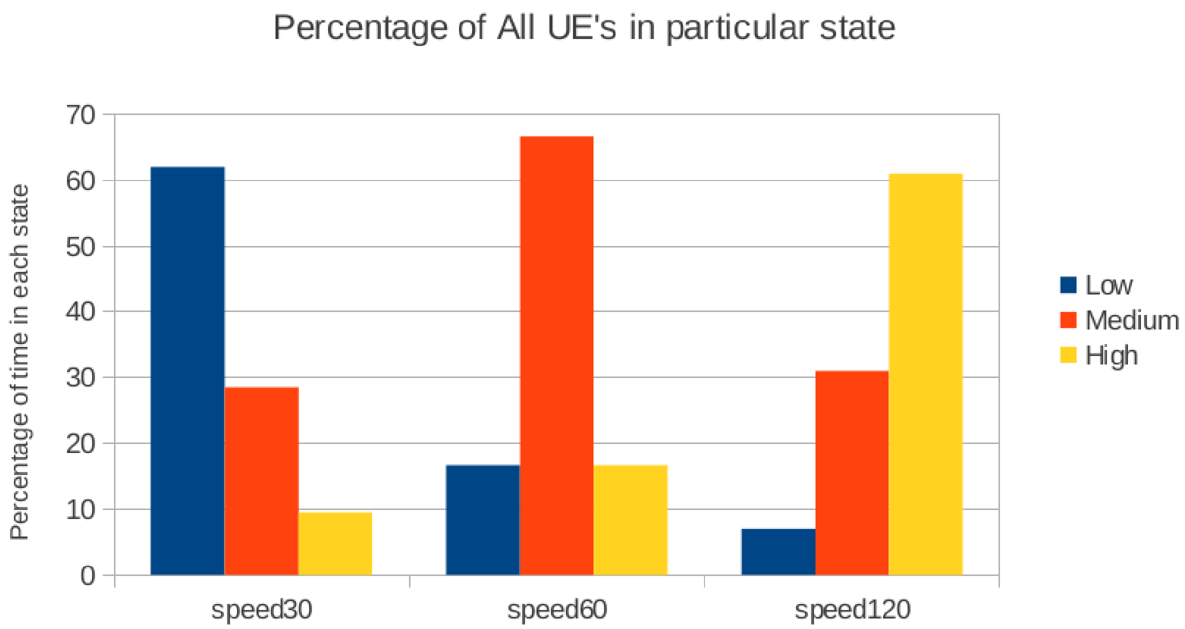

Figure 4.6: Percentage of time in each state after applying relative weights

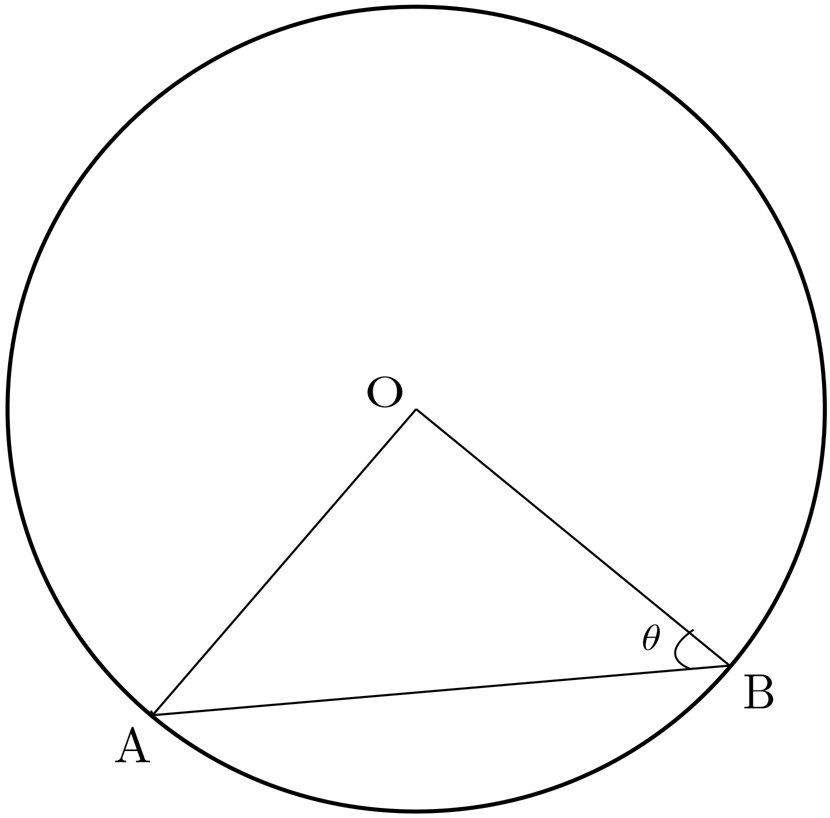

Figure 4.7: pico cell with estimation of UE travelling along chord AB

$$\frac{OA}{\sin(\theta)} = \frac{AB}{\sin(180 - 2 * \theta)}$$

$$AB = 2 * OA * \cos(\theta)$$

$$\theta = \theta_1 - \theta_2$$

where θ_1 is angle made by the position vector with the horizontal and θ_2 is angle made by AB with the horizontal. since we know position vector and velocity vector finding out θ is quite simple.

Time taken to travel that distance is $time = distance \div velocity$. so roughly we know the amount of time a UE spends inside a pico cell. If this time is less than MTS then there will be a sTos count, but if somehow it is ensured that HO is not happening to this pico, then this sTos count could be reduced which can be achieved by setting TTT value greater than the time it is inside pico. If HO is not taking place in first case then there is no scope for sTos.

CHAPTER 5

Future work

So far we have seen the most basic algorithm to find out the mobility state, but there is a big scope to find new algorithms to find out the MSE. Along with cell changes if we could some extra constraints to make a tighter estimation then it may result in tremendous increase in performance.

Similarly the relative weights used here are more generic, one could actually work on to find out for what values we get maximum estimation.