

***SPECTRUM ACCESS AND HANDOVER STRATEGY IN FEMTOCELL NETWORK***

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF

**Bachelor of Technology  
In  
Electronics and Communication Engineering**

**By**

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2012**

## ACKNOWLEDGEMENT

It would not have been possible to complete and write this project thesis without the help and encouragement of certain people whom we would like to deeply honour and value their gratefulness.

We would like to highly appreciate the constant motivation and encouragement shown by our supervisor and guide, **Prof. Poonam Singh**, Department of Electronics and Communication Engineering during the project and writing of the thesis. Without her guidance and help, it would not have been possible to bring out this thesis and complete the project.

We also express our gratitude towards **Prof. Sukadev Meher**, HOD, Department of Electronics and Communication, for his selfless support and help offered whenever needed, especially for the usage of laboratories. Other professors of the department equally have a space for respect in this thesis for their support. Also, our deep gratitude towards the M.Tech students and Research scholars who when asked provided with lots of project materials selflessly.

Last but not the least, our sincere thanks to all the friends who have directly or indirectly helped us in all the respect regarding the thesis and project. Also, we are indebted to our institute, NIT Rourkela to have provided the platform for gaining the precious knowledge and framing the paths of glory for our future.

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## **CERTIFICATE**

*This is to certify that the thesis entitled “SPECTRUM ACCESS AND HANDOVER STRATEGY IN FEMTOCELL NETWORK” submitted by Mr.Kundan Kumar Das & Mr. Prasant Kumar Behera, Roll Nos.108EC036 and 108EI013 respectively, in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Electronics & Communication Engineering at the National Institute of Technology , Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.*

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

**(Prof. POONAM SINGH)**

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## ABSTRACT

*The femtocell concept is a modern approach in solving the ever increasing demand of mobile communication all over the world. The spectrum Access algorithm used in this project is based on dynamic spectrum allocation approach. This minimizes the interference suffered by Primary and secondary users by allocating proper channel.*

*In this project , a handover algorithm is used including the different access modes of femtocell. Since the femtocell may be operated in various setups ,hence different modes. The algorithm is analyzed for increasing number of users with the handover decision taken and how the algorithm is effective in minimization of unnecessary handovers.*

*CHAPTER 1*

**1. INTRODUCTION**



### 1.1 Femtocell Definition

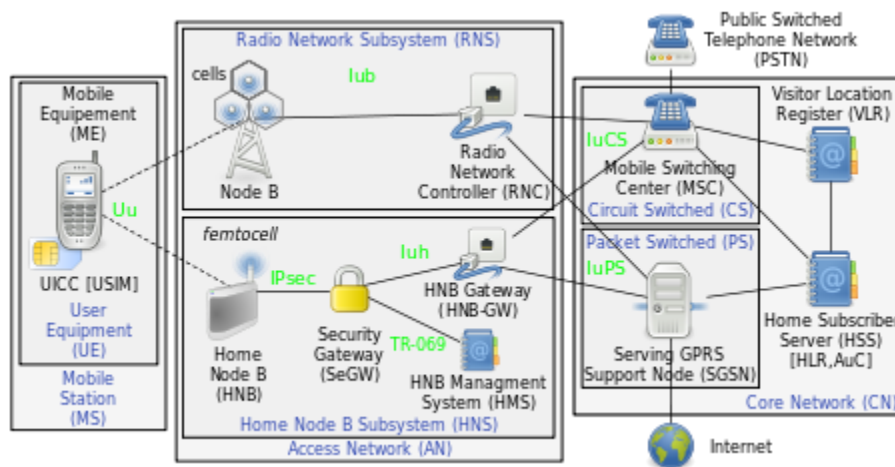
Femtocell is basically a small cellular base station, which is mostly used in a home or small business. It is designed to improve indoor coverage of 3G and future mobile communication systems.

The range of a micro cell is less than two kilometers wide, a [picocell](#) is 200 meters or less, and a femtocell is on the order of 10 meters.

A femtocell generally connects to the service provider’s network through a broadband such as DSL or CABLE. There are two main places where it is used, namely residential setting and enterprise setting. Residential settings generally support 2 to 4 mobile phones whereas enterprise settings support 8 to 16 active mobile phones.

### 1.2 Applications of Femtocells

A femtocell’s job is that it allows the service providers to extend the service coverage indoors, especially in the areas where the access is almost negligible or where the access is limited or unavailable.



**Fig1:** A traditional Node B and Home Node B (3G femtocell) in 3G architecture

In today's world it is used in 3GPP terminology where a Home Node B (HNB) is a 3G femtocell. A Home eNodeB (HeNB) is a [LTE](#) femtocell.

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.

### ***1.3 Benefits of using Femtocells***

Main benefit is that it is an alternative method to deliver the benefits of fixed mobile convergence(FMC). The difference is that FMC architecture uses a new dual-mode handset which works with the existing unlicensed spectrum wireless access points such as home/enterprise whereas the femtocell based systems will work with the existing handsets but it requires installation of a new access point that uses only the licensed spectrum.

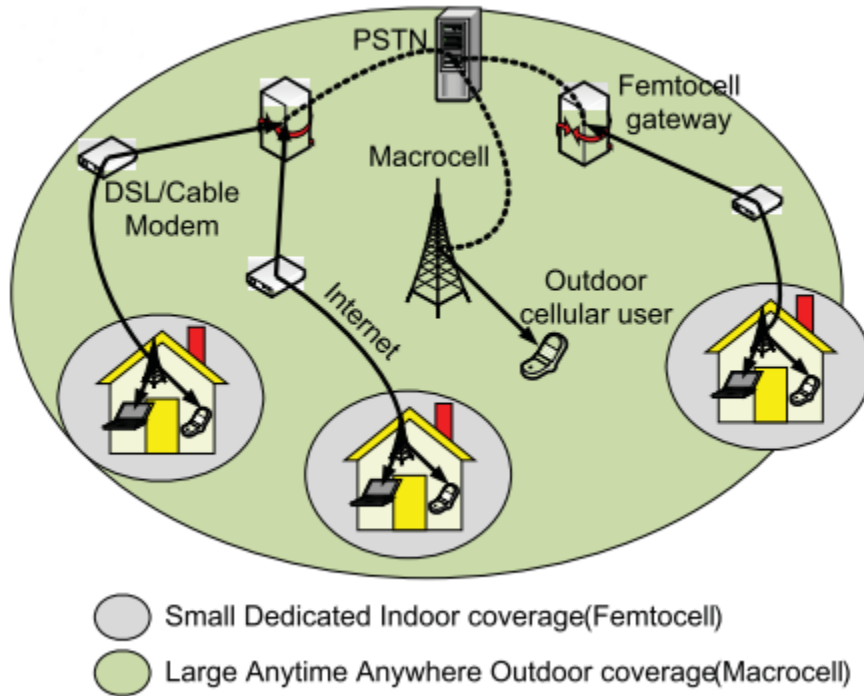
Most important application of femtocells is that they can be used to give coverage even in rural areas.

There is 5 bar" coverage when there is no existing signal or poor coverage.

For the enterprise users, having femtocells instead of DCET phones enables them to have a single phone, so a single contact list.

It increases the reception of mobile signals in the area. Some places which has no reception of Macrocell network i. e . in the coverage hole, femtocells can be used to guarantee the service of Mobile Users.

Femtocells can also be used in the areas where there is very high traffic of mobile users, thus reducing the burden of Macrocell Base Station



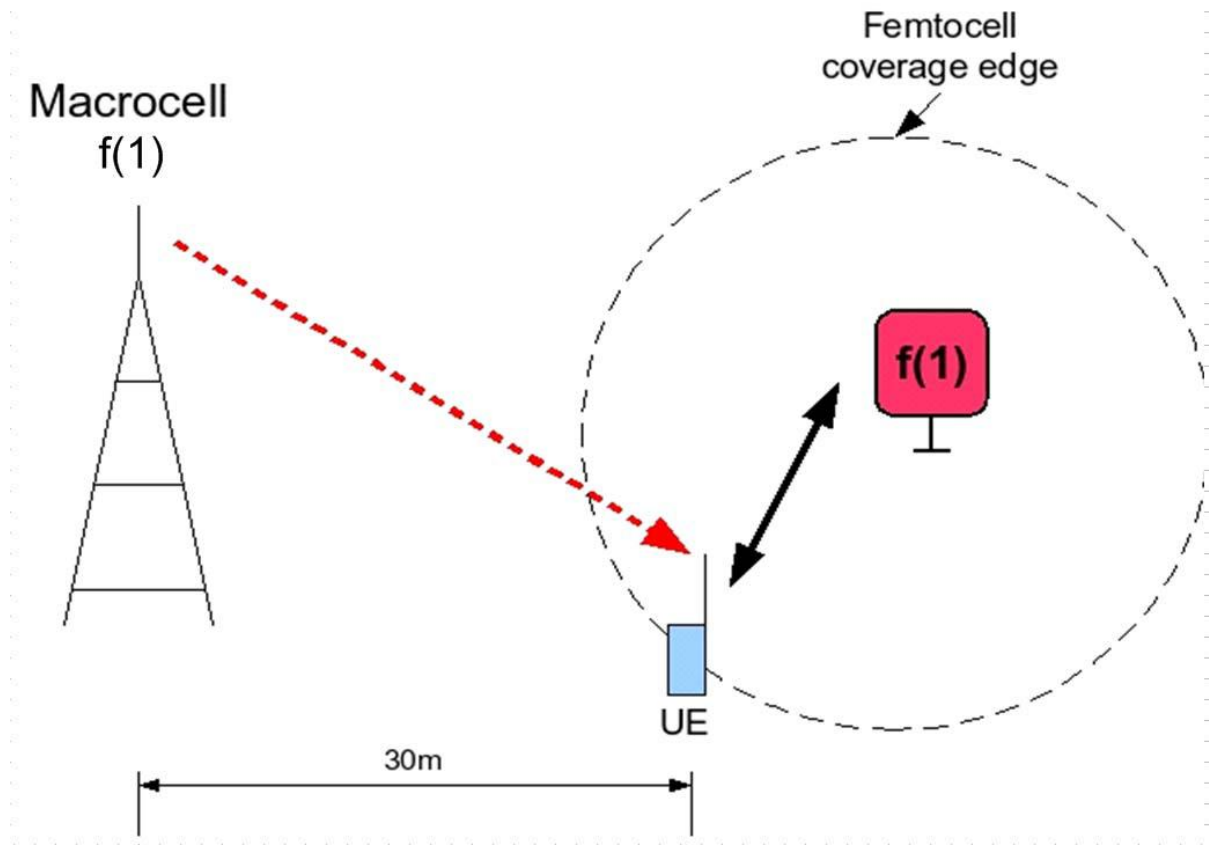
**Fig2 : A general femtocell deployment scenario.**

#### ***1.4 Issues in use of Femtocells along with Macrocells***

The macrocell and the femtocell can share the same the same frequency spectrum, thereby increasing the system capacity. But however a strong interference among the femtocells and macrocell are induced due to this spectrum sharing .

There is very less probability of interference problem among macrocell and femtocells in the areas where there is poor coverage or no coverage.

Basically this intereferece problem occurs when femtocells share networks with macrocell. But the best thing is that by the use of some interference mitigation techniques this problem can be very easily reduced.



**Fig3: Basic picture of femtocell and macrocell(two-tier network)**

### ***1.5 Aim of our work***

Basically our whole aim is to reduce interference that is caused due to the spectrum sharing between the femtocells (secondary users) and the macrocell(primary user). So for this purpose here we use the Distributed Dynamic Spectrum Access(DDSA) and Power Allocation (PA) algorithm.

And we aim to deduce a method for the process of handover between macrocell and femtocell using different access modes.

Thus ,by using above algorithms, the required simulations are obtained so that the algorithms can be analyzed. Finally, conclusions are deduced.

## **CHAPTER-2**

### ***Spectrum Access***

## 2.1 Definitions

**Two-tier network:** A network that is formed by a macrocell and a number of femtocells is called as two-tier network. This is a typical or general application scenario of spectrum sharing, which has been attracting more and more attention in recent modern years.

**Primary users(PU):** Here, the base station (BS) or the macrocell and the user equipments attached to the BS (primary user equipment, PUE) are primary users.

**Secondary users(SU):** And the Femtocell access points (APs) and the user equipments(secondary user equipment, SUE) are secondary users.

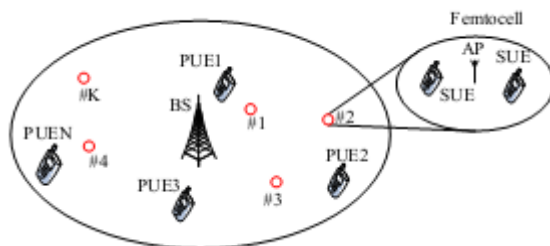
## 2.2 Optimization Model

In the centralized dynamic spectrum access algorithm , a control centre collects the overall network information and then it determines the access channels and powers that are transmitted for every secondary user equipments to maximize the utility function.

An optimization model for the special two-tier Femtocell networks is established, which minimizes the interference suffered by primary users and guarantees the received signal to noise ratio and interference necessities.

This method of spectrum access can increase the number of Femtocells and also the benefit is that it requires only a little information exchange between base station and primary user equipments as well as between base station and access points.

The Femtocell and Macrocell two-tier network is shown in this figure. This network has two main characteristics.



**Fig4:** The illustration of Co-existing Femtocell and Macrocell network

1. The coverage radius of a Femtocell is far smaller than that of the Macrocell and is almost about 10m .

2. Femtocells are usually fixed indoors and connected to the core network by the user's IP networks, e.g. ADSL.

M is denoted as the number of channels and N as the number of active PUEs in a Macrocell, where  $N \leq M$ , and consider the PUE occupying the  $i$ th channel as the  $i$ th PUE (the  $i$ th and  $j$ th PUE ( $i \neq j$ ) may represent the same PUE). The channel access matrix of Femtocells is denoted as  $\mathbf{C}$ , whose element in the  $k$ th row and  $m$ th column is  $c_{km}$ ,  $k = 1, 2, \dots, K$ ,  $m = 1, 2, \dots, M$ . If the  $k$ th Femtocell occupies the  $m$ th channel, then  $c_{km} = 1$ ; otherwise,  $c_{km} = 0$ .

### **2.3 Algorithm:**

The algorithm for Distributed Dynamic Spectrum Access used is given below:

1) The value of current Lagrange multiplier  $\lambda$  is broadcasted to all the Femtocells in the Macrocell, and the initial value of  $\lambda$  is set to be  $\mathbf{0}$ ;

Here,  $\lambda = [\lambda_1, \lambda_2, \dots, \lambda_N]^T \geq 0$ .

2) After getting the current value of  $\lambda$ , each Femtocell's AP determine its channel access vector  $\mathbf{C}_k$  according to the equation,

$$\begin{aligned} \mathbf{C}_k(\lambda) &= \arg \min_{\mathbf{C}_k \in \mathcal{C}_k} L_k(\mathbf{C}_k, \lambda) \\ &= \arg \min_{\mathbf{C}_k \in \mathcal{C}_k} \sum_{n=1}^N 1 \cdot ((1 + \lambda_n)(1 + I_{kn})c_{kn}) / L_{kn}^{sp} \text{ . individually.} \end{aligned}$$

$$\begin{aligned} \text{Where, } I_{kn} &= L_n^{pp} S_n^p / L_{nk}^{ps} \quad \text{for } n \leq N. \\ &= 0 \quad \text{for } n > N \end{aligned}$$

3) The transmitting power of each Femtocell's AP is determined according to the equation,

$$P_k^s = L_{kk}^{ss} S_k^s P_N \sum_{m=1}^M 1 \cdot (1 + I_{km})c_{km} \quad \text{independently;}$$

4) The interference intensity suffered from Femtocells,  $I_n^{sp}$  is measured by each PUE and reported to the BS;

5) The subgradient  $D(\lambda)$  is calculated by the BS according to equation,

$$D(\lambda) = [I_1^{sp} - \gamma_1 P_N, I_2^{sp} - \gamma_2 P_N, \dots, I_N^{sp} - \gamma_N P_N]^T$$

and updates the value of Lagrange multiplier  $\lambda$  using the equation,

$$\lambda(\tau+1) = \max[\{\lambda(\tau) + \Delta s_1 \cdot D(\lambda(\tau))\}, 0].$$

Where,  $\Delta s_1$  is the step size vector. Small step size gives better convergence but takes long time.

6) Go to step 1. until convergence.

**Following are the meaning of equations used here:**

$L_{kn}^{sp}$  : path loss between  $k^{th}$  SUE to  $n^{th}$  PUE.

$I_n^{sp}$ : Interference suffered by  $n^{th}$  PUE from femtocells.

$P_k^s$ : Power generated by  $k^{th}$  Femtocell BS.

### 2.4 Simulation:

The interference suffered by primary users were obtained and plotted against secondary user number.

**Following formulae were used:**

Interference suffered by PUE due to SUE.

$$I_n^{sp} = \sum P_k^s \times c_{kn} / L_k^{sp}$$

Propagation Loss Model used in simulation

$$L(d) = 15.3 + 37.6 \log(d) + nL_{wall}$$

where 'd' is distance between two users or BS.

Power Transmitted by  $k^{th}$  Femtocell.

$$P_k^s = L_k^{ss} S_k^s P_N \sum_{m=1}^M (I_{km} + 1) c_{km}$$

Where  $I_{km} = L_m^{pp} S_m^p / L_{mk}^{ps}$



**Following assumptions were made for the simulation :**

$$S_n^p = S_k^s = 10$$

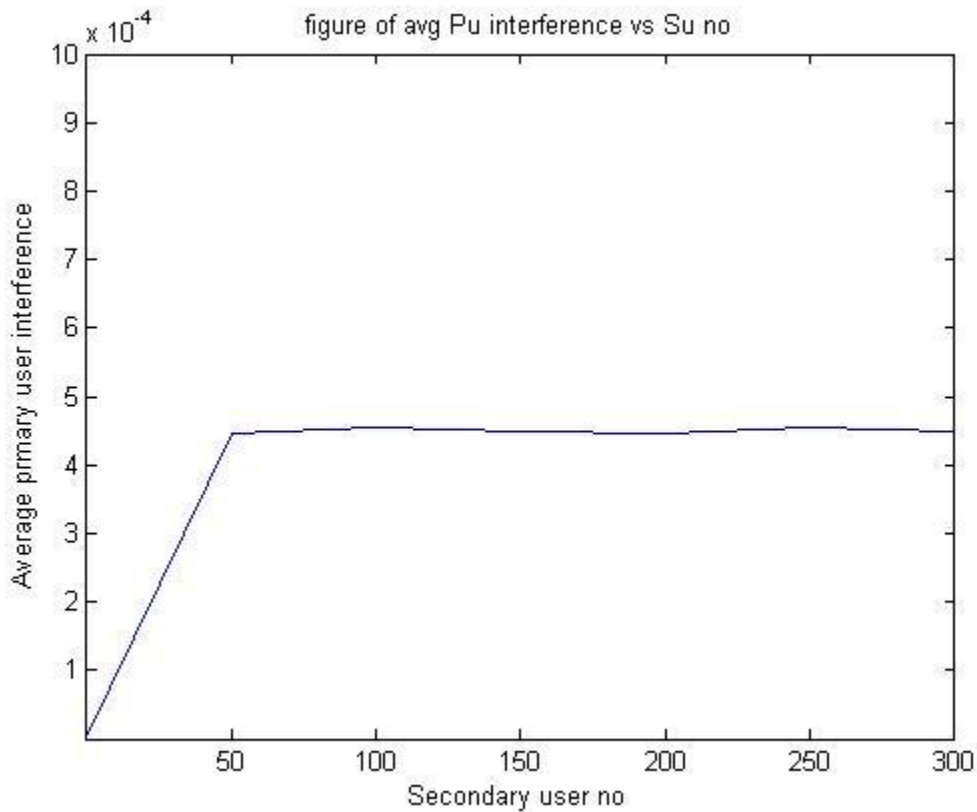
$$L_{\text{wall}} = 15$$

$$M = N = 3$$

PUE1 , PUE2, PUE3 are at distance of 50m, 200m and 400m from BS respectively.

## **2.5 RESULT AND INFERENCE:**

### **2.5.1 Result:**



**Fig5: Plot of Secondary User number Vs. Average primary user interference**

### **2.5.2 Inferences:**

- ◆ The Interference suffered by Primary User increases almost linearly for small number of femtocells within the macrocell.
- ◆ After a certain number of femtocells, the average interference suffered by the Primary User becomes steady and gets saturated and is least affected by increase in number of femtocells.

## **CHAPTER 3**

### **Handover Strategy in Femtocells**

### ***3.1 Accessing Modes in Femtocells.***

Femtocells being a network used for private, enterprise or service providers purpose needs to operate on different Accessing modes so as to provide the service for targeted user. Following accessing modes can be used for doing so.

#### **3.1.1 Types of Femtocell Accessing modes:**

- Open Access mode
- Closed Access mode
- Hybrid Access mode

#### **Open Access Mode:**

In Open Access Mode any mobile user trying to access the femtocell service is allowed to do so without any discrimination or extra charge similar to the macrocell.

Mostly these type of femtocells are deployed by Network Service Provider to enhance their coverage area and QoS.

#### **Closed Access Mode:**

In Closed Access Mode the mobile user who is registered to the Femtocell is only allowed to access the service of these Femtocell. Other users are forced to use service of macrocell even if it is of poor service.

These type of Femtocell are deployed by Organizations, Offices for their use and good reception of the mobile service.

#### **Hybrid Access Mode:**

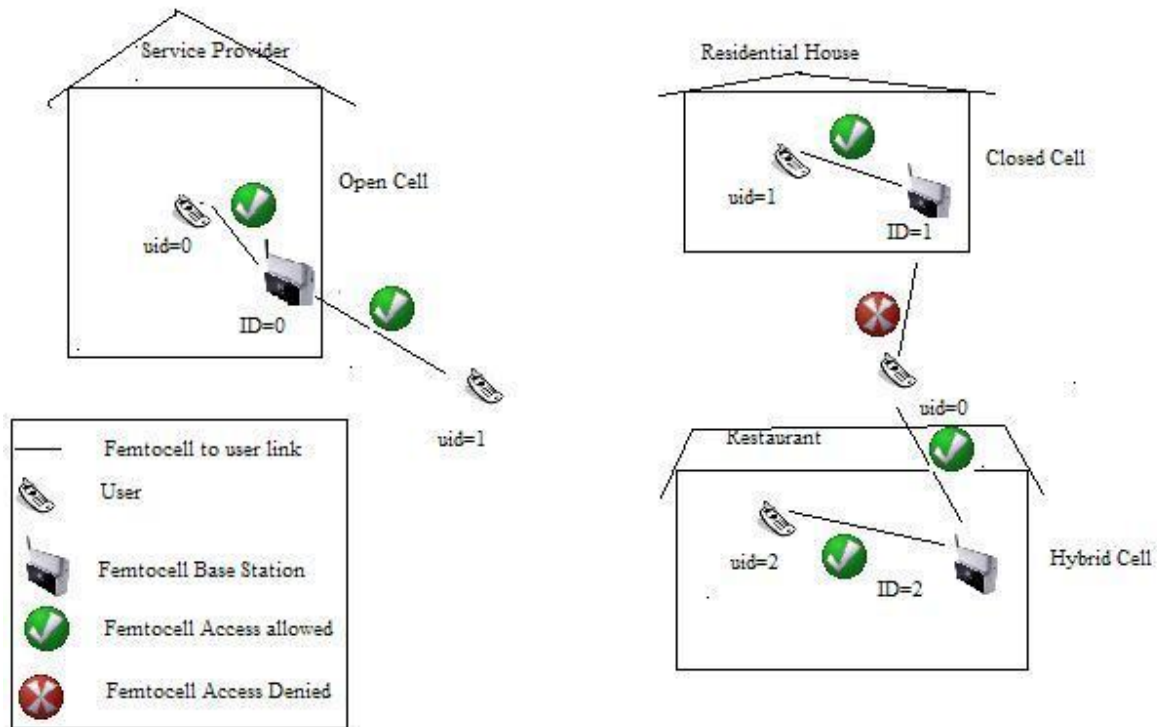
It is a Combination of Open and Closed Access Modes. In this mode the preference is given to the registered user in terms of priority and charging.

The unregistered user trying to access the femtocell may be allowed to avail partial service depending on availability of Bandwidth after giving preference to registered user and also he may be charged for the service.

**3.1.2 Identification of Femtocell type:**

In case of Closed and Hybrid mode of Access the Femtocell Base Station stores the ID of registered mobile users and so does the mobile user for its registered Femtocell group.

The FBSs of different group also has type code for identifying whether it is Open, Closed or Hybrid mode of femtocell. This enables the unregistered user or User with no access permit to identify the femtocell type and avoid unnecessary camping on the femtocell thus ensuring reduction of unnecessary battery loss.



**Fig6. Service Access permission scenarios in Femtocell**

In the above figure, it is shown three femtocells with different access modes. Here, Femtocell IDs are 0,1 and 2 for Open, Closed and Hybrid Access Modes respectively. The users also have user ID (uid) for their accessing permit to the femtocells. For Open Access Femtocell, all users are allowed to access irrespective of their uid. For Closed Access Femtocell, only user

with corresponding uid are allowed to access and for Hybrid access Femtocell other users are allowed with extra charging with preference given to registered users.

### ***3.2 Handovers in Mobile Telecommunication:***

When a mobile user moves from coverage area of one Base Station to the coverage area of another while engaging in active call then the transfer of call from one Base Station to the other or from one channel to other is known as Handover. In US it is also called Handoff. It is used interchangeably.

#### ***3.2.1 Classifications of Handovers:***

##### **Classification I:**

In 2G and 3G systems the Handover procedure is classified into following categories depending on the network structure.

- Hard Handoff
- Soft Handoff

##### **Hard Handoff:**

If the handoff is between two Base Stations which operates on different channel sets then the handoff is called Hard handoff.

It is the handoff procedure primary in GSM network but also occurs in CDMA network.

##### **Soft Handoff:**

If the handoff is between two base stations but operating channel of the call remains the same then this type of handoff is called soft handoff. In this type of Handoff, only the Mobile Base station handling the call changes but the operating channel remains same. This type of handover is found in CDMA network.

**Classification II:** Another Classification of the Handover is given below:

- Intra-system Handover
- Inter-system Handover

### **Intra-system Handover:**

If the handover is between two Base Station of the same system then it is called Intra-system Handover. This is most frequent Handover procedure.

### **Inter-system Handover:**

If the handover procedure is initiated and there is no other Base Station for the Transfer of Call belonging to the same system then Inter-system Handover occurs where the call is transferred to the Base station of other system. This type of Handover is less frequent and may incur extra cost to the user.

### ***3.2.2 Handoff Procedure in General:***

Several factors are considered before initiating handoff procedure viz. signal strength, velocity of the user, interference, type of radio network. These handoff can be done entirely by the Mobile switching Center or by assistance of Mobile stations. The latter case is also known as MAHO(Mobile Assisted Handover) and is mostly used in 2G and later systems.

MAHO is better option as it releases the pressure from Mobile Switching Centre . Also, it enables the call to be handed over between base stations at a much faster rate than in 1G analog systems. It is because the measurements are made by each mobile.

The handoff procedure includes identification of new channel belonging to new base station where the call is to be transferred and transfer of voice and control channels that must be allocated to channels associated to new base station. Also, the handoff is to be prioritized before call initiation process.

At first, optimum signal level at which handoff is to be initiated is determined. Then a particular signal level is specified as minimum usable signal for acceptable voice quality at the base station receiver. A slightly signal is used as a threshold at which a handoff is made. The difference between handoff power and minimum usable power , “ $\Delta$ ” cannot be too large or too small because if  $\Delta$  is too large, lot of handoff occurs which burdens MSC and if it is too small there may insufficient time to complete the handoff before call is dropped due to weak signal.

### **3.3 Handover in Femtocells:**

Handover in Femtocells are mainly hard handoffs as they use different and variable frequency range for the service which includes both licensed and unlicensed frequency bands. Handover in Femtocells are of following types:

- Macrocell to Femtocell
- Femtocell to Macrocell
- Femtocell to Femtocell

#### **Macrocell to Femtocell Handover:**

This type of handover occurs when a user equipment transfers the call from a macro-cell on the standard external network to a femtocell. It is most Common type of handover. But because the macrocell and the femtocell have different backhaul routes, they are challenging.

The basic principle of Macrocell to Femtocell Handover is same as macrocell to macrocell Handover but with the difference that handover signaling occurs through backhaul route.

#### **Femtocell to Macrocell Handover:**

It is also similar to Macrocell to Macrocell handover with the exception of non existence of direct interface between base stations. The Signaling takes place over the backhaul link to the core network for both the macrocell and the femtocell, though femtocell routing includes femtocell gateway.

#### **Femtocell to Femtocell Handover:**

In this type of Handover the signaling is handled entirely by Femtocell Gateway.

There is no Soft Handover in Femtocells, regardless of the radio technology used. Instead, all calls switch instantly to or from the femtocell and the external outdoor cellular network i.e. Hard Handover. Typically it is not audible or noticeable to the caller.

### ***3.4 Effects of femtocell handover for the user:***

There can be two aspects for consideration as effects. They are :

#### *Usability :-*

It answers whether the user is receiving a proper service by the use of femtocell network.

#### *Cost:-*

It is associated with the cost a user pays when using the femtocell service. If the cost is too high from that of standard macrocell network then, there is failure of femtocell concept. The femtocell user is charged on the basis of origin of the call. A call originating in the macrocell area will be charged according to its pricing scheme even though the user has moved to Femtocell area for that call and similarly for that originating in Femtocell area.

### ***3.5 Handover Call Flow:***

The Handover procedure implemented here has two steps. They are:

- Pre-Handover
- Handover Implementation

#### *Pre-Handover:*

In this step of Handover Procedure the information required for making handover decision is obtained and Handover decision is made. For obtaining information, the Base Station collects information about handover candidates and authenticates it for security purposes. The information collected includes Signal level, Interference, User ID. For making decision, the best Handover candidate is determined.



### *Handover Implementation:*

After making decision for the handover candidate, the Mobile Station initiates the handover implementation by connecting to the Access Point ( Femtocell / Macrocell Base Station ).

### **3.6 Handover Procedure in Femtocell:**

Here, we are interested in Macrocell to Femtocell only so the discussion presented is regarding that particular type of handover only.

Macrocell to femtocell handover is complex and most challenging procedure in the femtocell network compared to Femtocell to Macrocell Handover. It is because there are many possible target femtocells for handover. So, in this handover Mobile Station needs to **choose the** proper target Femtocell Base Stations among many candidate FBSs. Serving Node B coordinates the handover of Mobile Station from Macro BS to a Femto BS by providing information of allowed FAPs .Here, we assume mostly Closed Access Femtocell are present. So, the Serving Node B scans the area for making a FBS neighbor list.

To reduce the unnecessary handovers, the velocity and angle of movement of the user is obtained and hence approximate stay time of the user in femtocell is calculated. A threshold stay time is set by the service provider crossing which the handover is allowed. This is called Call Administration Control.

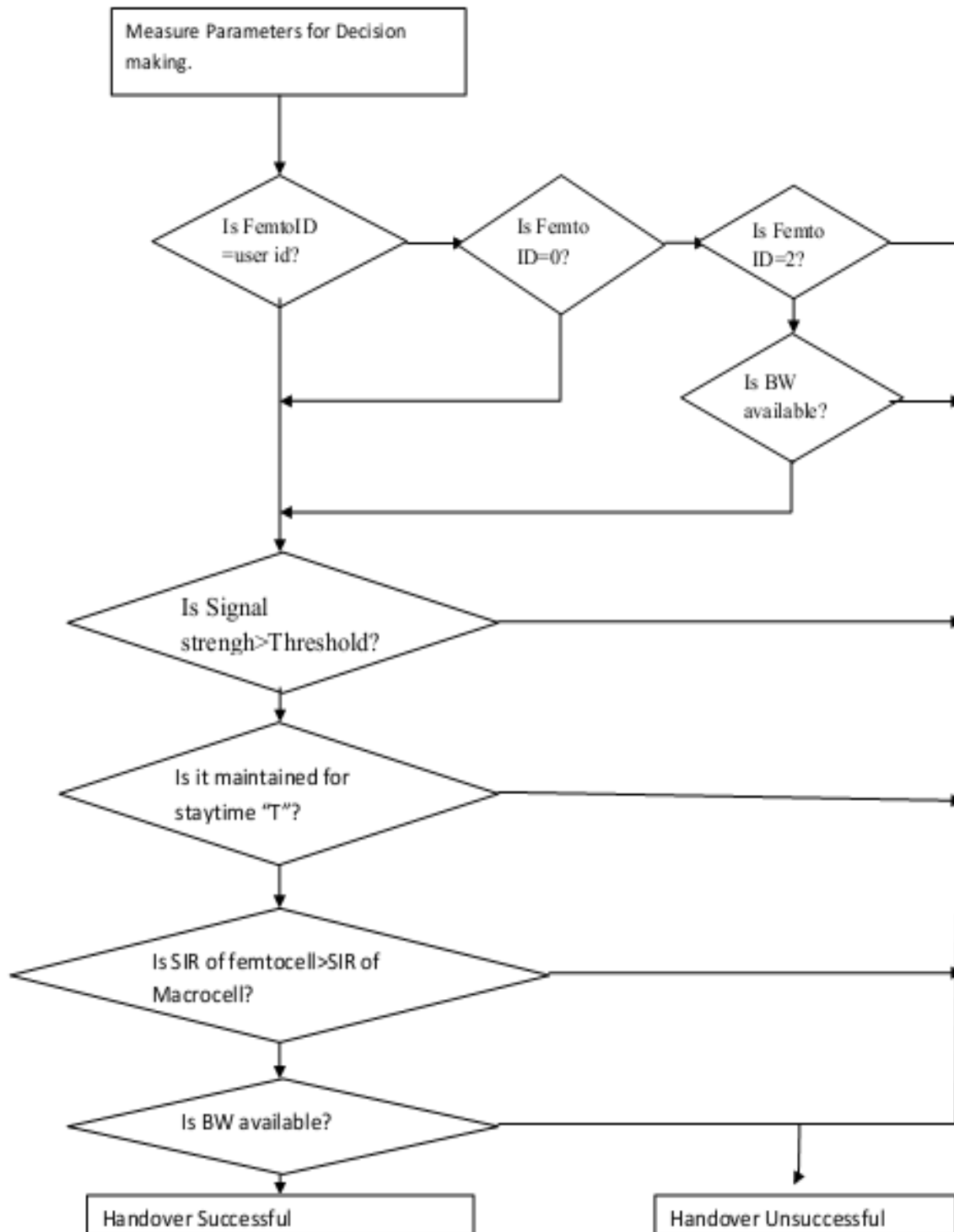
In the proposed algorithm for making handover decision following are the meaning of acronyms used:

FemtoID:- Femtocell Identification Code.

User id:- Mobile Identification Code.

T:- Threshold staytime in femtocell coverage area & BW is Bandwidth.

### 3.7 Algorithm:



Using the above algorithm ,the number of handovers are obtained for number of calls seeking handover from the femtocell. The simulation results are obtained for three different threshold staytime and for three different access modes.

Also ,probability of unnecessary handovers made for the number of users seeking the service of femtocell is plotted for different threshold staytime and for different access modes.

### **3.8 Simulation:**

*The Simulation Parameters used are as follows:*

**Table1: Simulation Parameters for Handover Algorithm:**

<i>Radius of macrocell :</i>	<i>500m</i>
<i>Radius of Femtocell :</i>	<i>10m</i>
<i>Cell Shape:</i>	<i>Circular</i>
<i>Threshold stay time:</i>	<i>0, 10 or 20 secs.</i>
<i>Femtocell type ID:</i>	
<i>Open :</i>	<i>0 or No ID</i>
<i>Closed:</i>	<i>1</i>
<i>Hybrid:</i>	<i>2</i>
<i>Maximum no. of calls FBS can handle per hour :</i>	<i>130</i>

### 3.9 RESULTS:

#### Open Access Mode:

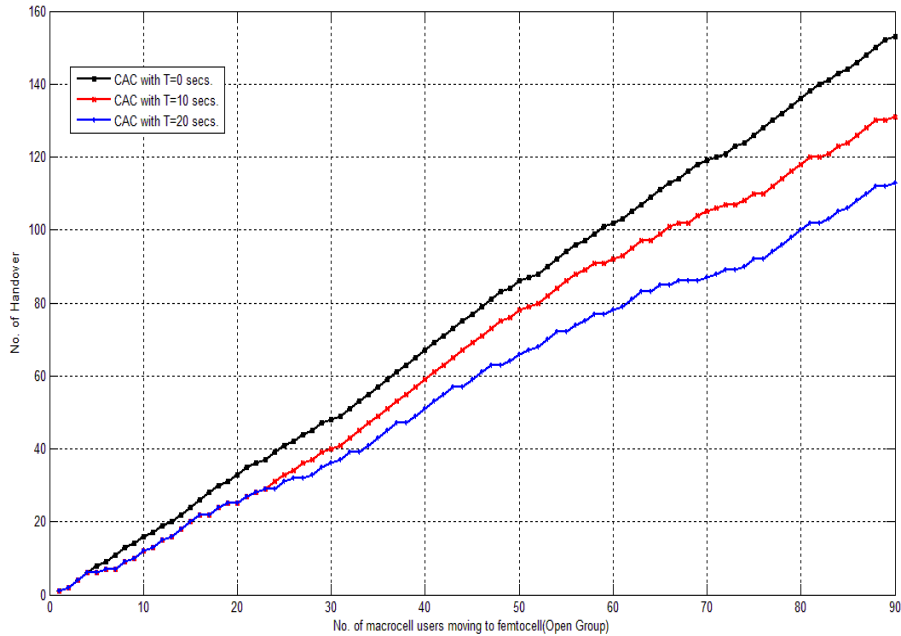


Fig7: Plot for No. of Handovers Vs. No. of Handover Candidates in Open mode

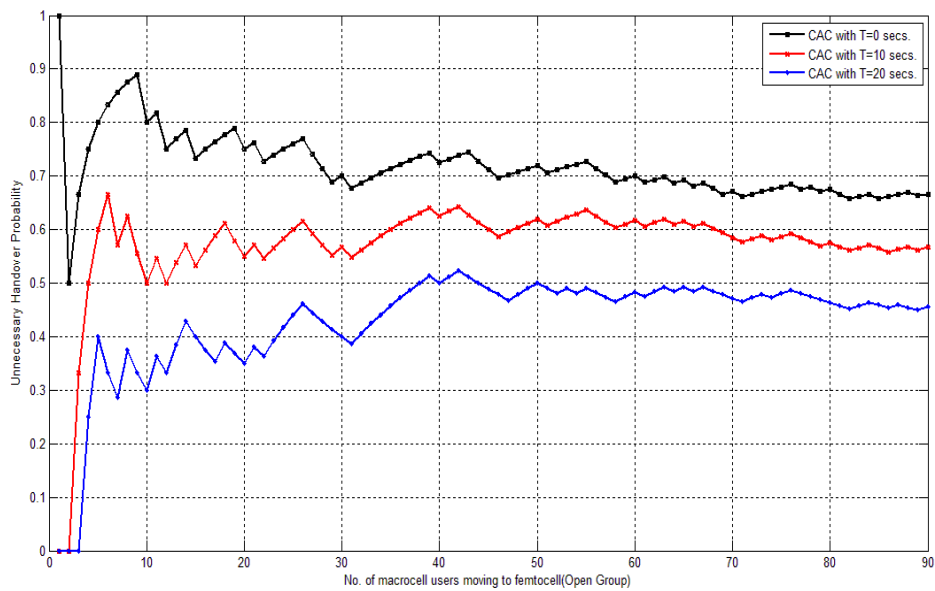
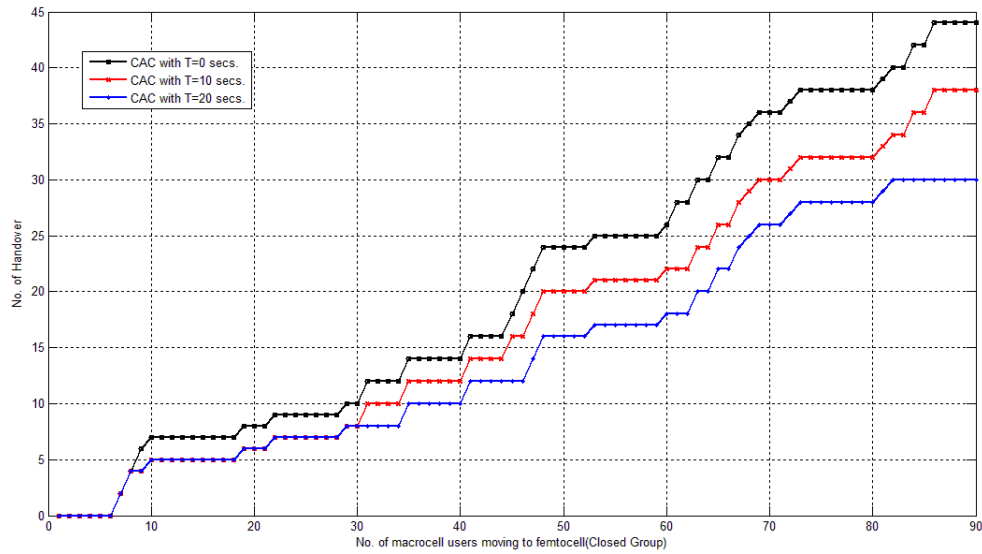
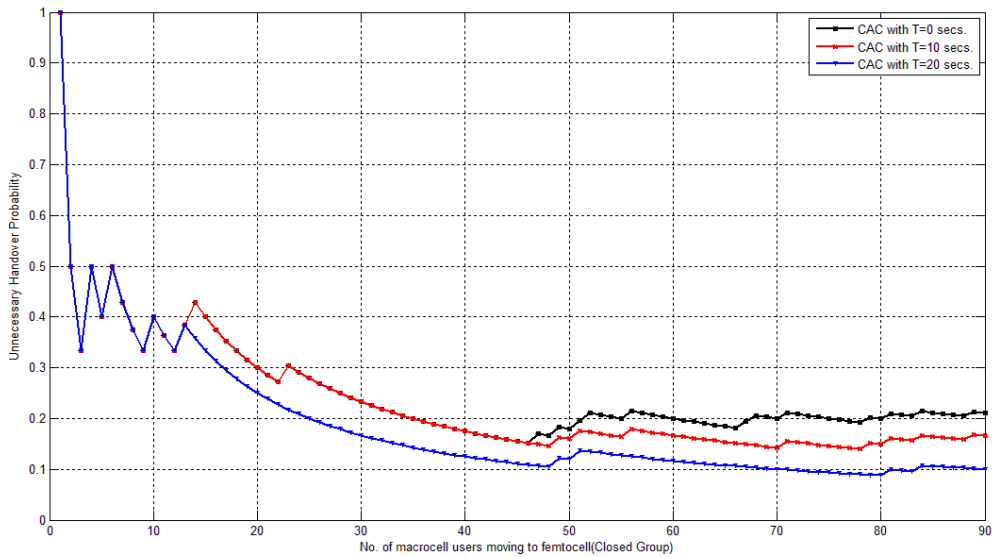


Fig8: Plot for Unnecessary call probability vs. No. of Handover Candidates in Open mode

**Closed Access Group:**

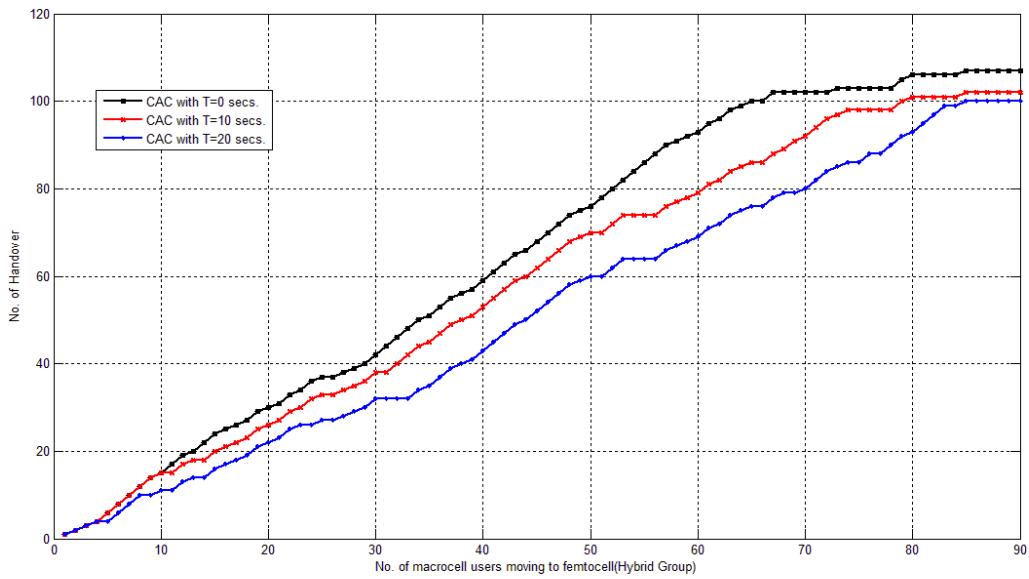


**Fig9: Plot for No. of Handovers Vs. No. of Handover Candidates in closed mode**

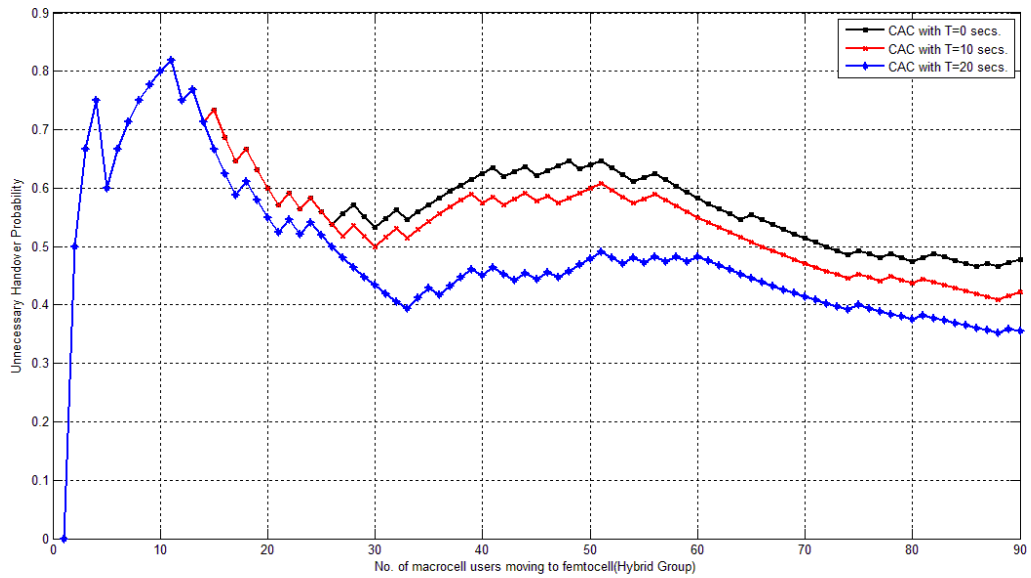


**Fig10: Plot for Unnecessary call probability vs. No. of Handover Candidates in Closed mode**

**Hybrid Access mode:**



**Fig11: Plot for No. of Handovers Vs. No. of Handover Candidates in hybrid mode**



**Fig12: Plot for Unnecessary call probability vs. No. of Handover Candidates in hybrid mode**

### **3.10 Inferences:**

Following Inferences can be drawn from above simulation results:

- *With CAC (Call Administration Control) the number of handover rate is minimized.*
- *Also the unnecessary Handover probability decreases with CAC.*
- *CAC is mostly dependent on the time of stay of Mobile Unit in the Femtocell coverage area.*
- *With increase in value of threshold staytime the handover decreases.*
- *In Closed Femto Group the number of handover decreases significantly.*
- *In Hybrid Femto Group the number of handover depends on availability of Bandwidth.*

### **4.CONCLUSION:**

*Hence the Interference suffered by Primary User in a two tier femtocell network can be reduced using this dynamic spectrum allocation approach. This also helps in maintaining the network traffic and keeps it at check.*

*The Handovers in Femtocell can be controlled using the above algorithm . This minimizes the unnecessary handover and thus reduces the load on Switching Network. Also by making the access of Femtocell spectrum selective, the load on Parent Macrocell can be reduced and thus increasing the Quality of Service for both Femtocell User and Macrocell User.*

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