INTERFERENCE AND RESOURCE MANAGEMENT STRATEGY FOR HANDOVER IN FEMTOCELLS

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Approval

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Dedication

I dedicate this effort to all those who have assisted me in any possible way to become what I am today. Their sacrifices seeded my success especially my parents and my Sister who showed their devoted attention and to faculty members who inspired me all the way.

Certificate of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at NUST RCMS or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST RCMS or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics which has been acknowledged.

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Madiha Rasheed

Contents

List of Abbreviations

3GPP	3rd Generation Partnership Project
eNB	E-Utran Node B
E-UTRAN	Evolved Universal Terrestrial Radio Access
FAP	Femto Access Point
FBS	Femto Base Station
FFR	Fractional Frequency Reuse
FUE	Femto User Equipment
HeNB	Home Enode B
LTE	Long Term Evolution
MBS	Macro Base Station
MILP	Mixed-Integer Linear Programming
MIS	Maximal Independent Set
MME	Mobility Management Entity
MUE	Macro User Equipment
OptCTSINR	Optimal Constant Threshold Signal To Interference Plus Noise Ratio
OptHO	Optimal Handover
PGW	Packet Data Network Gateway
TTS	Time To Stay
SINR	Signal to interference plus noise ratio
SGW	Serving Gateway
UE	User Equipment

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Abstract

Femtocells are short-range, low-power and low-cost cellular access points that support fewer users compared to macro-cells and operate in the mobile operators licensed spectrum. Femtocells are beneficial for both operators and consumers. They can provide good network performance at very low cost by increasing indoor coverage and capacity. Femtocells are typically installed and managed by the consumer in an unplanned manner. Since distance between macro base station (MBS) and Femto Access Point (FAP) is short, therefore, it is very hard to sustain low handover probability when macro user (MUE) moves from MBS to FAP. Installing femtocells within macrocell coverage can raise major challenges for handover, if deployed inefficiently. Interference from MBS and neighboring femtocells can degrade signal strength and create dead-zone area for femtocell User Equipments(FUEs) in the coverage area of FAP. Moreover, proper frequency allocation is crucial for avoiding interference. We proposed handover algorithm for uplink co-channel interference mitigation that will make decision of handover on the basis of time-to-stay (TTS) and Signal to interference plus noise ratio (SINR) thresholds. We are also using efficient resource management mechanism to reduce interference problem by using fractional frequency reuse (FFR) and a heuristic graph-based channel assignment algorithm to reduce the interference problem. In FFR scheme, the spectrum is partitioned in such a way that different sub-bands are allocated to different cells. Maximal Independent Set (MIS) scheme is used to avoid neighboring femtocells interference. The main objective is to avoid interference and unnecessary handovers by check either resources are available or not.

Chapter 1

Introduction

1.1 Overview

3rd Generation Partnership Project 3GPP introduced Long-Term Evolution (LTE) technology that aims to provide high data rates, low latency and high spectral efficiency. It also aims to provide improved coverage and throughput. It was expected that 4G will fulfill the needs of users. However, due to dramatic increase in number of users every year, it failed to fulfill user demands for high data rates, capacity and spectral efficiency. Cellular frequency consumes by network operators are limited from several hundred megahertz to several hundred gigahertz. Due to which, it is quite challenging for them to acquire more. Another challenge is deployment of advanced technology that can fulfill the upcoming demands in near future comes at the cost of high energy consumption. It has been reported that 70% electricity bills come from cellular base stations [3].

In cellular networks, 2/3 of voice calls and 90% of data usage occurs indoor e.g in homes, offices, airports, hospitals, restaurants etc. Unfortunately, due to indoor path loss, users experience bad indoor coverage. Mobile traffics of the whole mobile world are increasing exponentially due to instant increase of mobile users all over the world [4]. It is expected that it will keep on increasing in magnitude every year

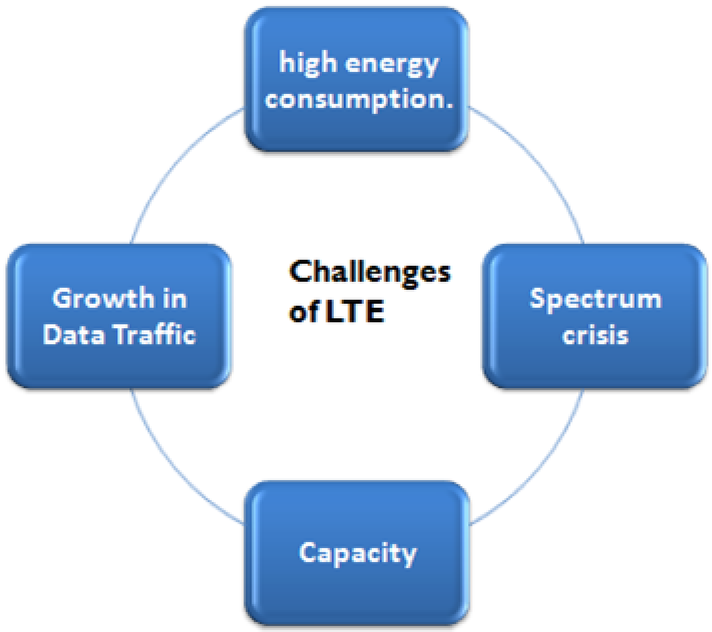


Figure 1.1: Challenges in LTE

[5]. Therefore, we need some solution for improving indoor coverage by installing small cells as suggested by cisco [6].

1.2 Long Term Evolution (LTE)

Demand for data rates are growing rapidly in the past decade due to increase in number of users. GPRS (General Packet Radio Service) was offering data rates up to 114 kbit/s. LTE is offering data rates of up to 300 Mbps in downlink and 75 Mbps in uplink. Due to new mobile applications and high demand for video streaming, demand for data rates is still increasing. Network operators are trying to invest in new network technologies to increase data rates and to provide better coverage. LTE improves spectral efficiency because it allows more data to exchange in available bandwidth.

The LTE system is considered as a flat architecture as shown in figure 1.2 [7], aims to provide support of mobility and high data rates. In LTE technology, nodes are of two types: the UE and the eNB. eNB is connected to all other eNB and is responsible for handling resources and control procedure in radio interface. While UE is connected to eNB for getting services [9].

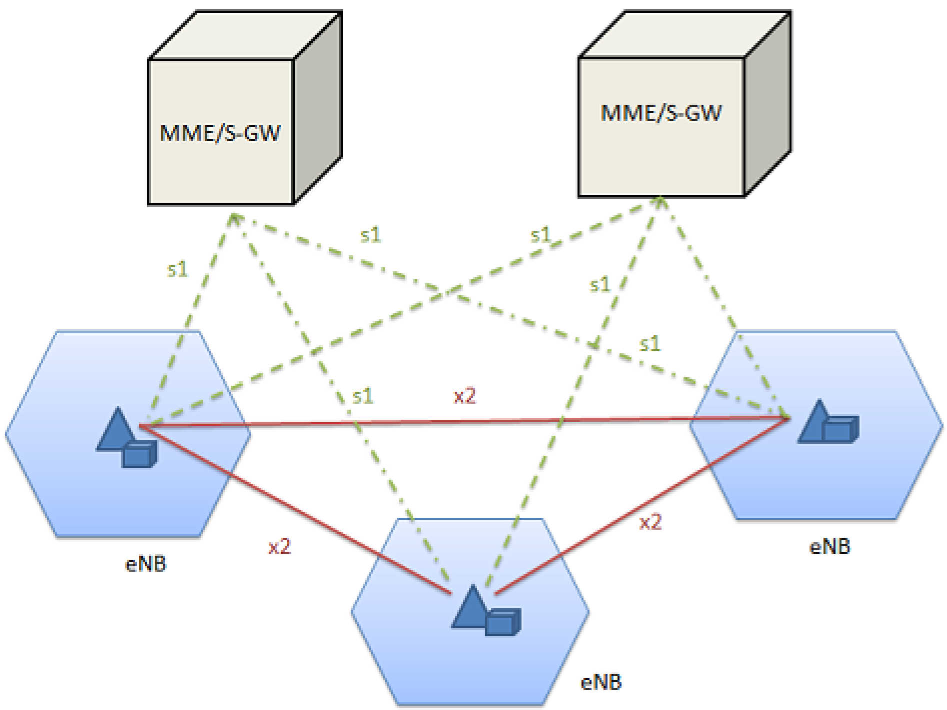


Figure 1.2: Architecture of LTE Network

1.3 Femtocells

A femtocell is a wireless access point that is used for improving signal reception in indoor environment. Femto access point is a device, which also resembles with a wireless router, can be installed in indoor environment. FUEs within femtocell coverage are connected to their respective FAP. The device communicates with the mobile phone and converts voice calls into voice over IP (VoIP) packets. The packets are then transmitted over a broadband connection to the mobile operator's servers.

Improvement of indoor coverage has been a challenge for all network operators. High frequency electromagnetic waves find it difficult to penetrate through walls and floor of building. Due to penetration loss, we receive poor indoor coverage of MBS. It is estimated that about 70% of total traffic is carried out inside in near future because usage of smart devices is increasing each year exponentially. Therefore, its very important for mobile operators to find solution for indoor coverage and for providing high data rates. Due to which femtocells is considered ideal. It is low power base station and is suitable for indoor as well as outdoor environment [10]. Femtocells can be used for improving system capacity by bringing mobile users closer to base stations and by increasing the signal-to-noise ratio (SNR). Femtocells use IP as backhaul architecture instead of using cellular network infrastructure [11].

Femtocells and macro cells users require user equipment UE, which is main feature of their technologies. As macrocells are already accommodating large number of customers, therefore, it would be difficult to manage new customers. Network operators need to focus on deploying femtocells through which we not only acquire high data rates in very low cost but also it will offload macrocells traffic to femtocells [12]. Therefore, installation of Femtocells is the ideal solution for resolving current issues. But apart from increasing spectral area efficiency, femtocells face interference issues due to random distribution of femtocells.

1.4 Handover and its Issues

When mobile station switches from one set of radio resources to another set, handover takes place. Handover needs resources for rerouting calls to new base station.

By decreasing number of handovers, the switching load can be decreased. Main purpose of handover is to provide seamless services without any interruption due to mobility of nodes. For example, if mobile user moves away from its serving base station, its signals starts to degrade which can results in poor signal reception and can also result in disconnection of services. Handover is performed when signal strength levels decrease below certain thresholds [13]. Handover process keeps the continuation of voice and data sessions connected even if a user moves from one base station to other. But it is not a simple procedure as it takes different parameters in account to avoid unnecessary handover to avoid usage of resources.

1.5 Resource Allocation

To maintain QoS, efficient resource allocation is required so that MUE can carry out its services without any interruption. The femtocells exist within the coverage area of a macrocell due to which resources should be allocated in a manner that can avoid interference between them. Carrier frequencies are officially issued to the mobile operator through a license. Several sub channels are included in each frequency that can be assigned to a femtocell and macrocell [14]. Resource allocation scheme can be separate or shared carrier allocation. In shared resource allocation, both macrocell and femtocells are using same frequency bands that can increase the risk of interference between femtocells and macrocells. Separate resource allocation is ideal to avoid any interference because exclusive slots are reserved for femtocells and macrocells separately. But frequency resources come at high cost. Also, resources are wasted in separate resource allocation when no one is accessing in either cell and it is needed by anyone in the other cell. So to avoid wastage of frequency, the shared resource allocation is preferred but with the efficient algorithm to avoid interference. In this research, we are using fractional frequency reuse-based graph connectivity (FFR-GC). In FFR-GC, frequency band is divided into sub-bands and allocated in a manner to avoid interference between macrocells and femtocells. In phase 1, 2/3 of the bandwidth is consumed by sub-band A, while 1/3 is consumed by sub-band B, C and D. In phase 1, frequency sub-bands are allocated to macrocell coverage. While in phase 2, rest 1/3 of band is allocated to femtocells. There is a high risk of interference between neighboring femtocells that can cause intercell interference. Due to which, maximal independent set (MIS) is used that will check whenever request of resource come from the femtocell from the set it is maintaining in its database. In MIS, independent set of each band is maintained that contains the set of independent femtocells that are not using same frequency band to avoid any interference in the neighboring femtocells [15].

1.6 Motivation

Femtocells can be deployed indoor for getting high data rates. Visiting macro users can enter within coverage area of femtocells and can start using their services by performing handover. But if macro user only stay within or near femtocell for relatively less time and its SINR value is greater than specific threshold due to less interference, then there is no need for handover. Because it can keep continuing its services with macro base station without causing any interference. But if TTS of MUE is greater than certain threshold, then due interference SINR starts degrading. So we need to define thresholds for SINR and TTS as well as need to work on resource management algorithm to avoid unnecessary handovers. Network planning is very important part because the connection between mobile user and base station is dependent on it. Due to which connection requirements should be fulfilled by taking capacity and data rates in account. In next few years, it is estimated that mobile traffic will increase exponentially, which can be create huge challenge for current

4G technology to handle. To improve capacity and to offload data and services within the heterogeneous cellular network, we need small cells deployment that could accommodate traffic demands in future [16]. We need a low power base station within the macrocell base station. The main advantage of low power base station such as Pico cell, micro cell and femtocells is that it bring network close to UE and they can enjoy high data rates [17]. Femto access point (FAP) or home base station which can extend indoor coverage and can integrate with existing technologies i-e. GSM, LTE, WiMax etc on radio access and backhaul connection can be made by using broadband connection i-e. optical fiber, DSL etc [18]. To deal with problem of how many small cell are required and how to resolve interference among these cells, an algorithm was proposed for obtaining best locations for deploying small cell and to increase spectral efficiency [19]. Co-channel interference can cause many technical problems because its a cross talk between femtocell and macrocell as well as interference between neighboring femtocells using same frequency bands.

1.7 Problem Statement

Installation of small cells is expected to increase user sum rate and capacity in densely populated areas. However, there are still some challenges in femtocells that needs to be addressed. Resource and interference management are the main issues that need to be focused. Otherwise it can lead to network degradation. Different strategies are proposed for solving these issues. Handover algorithm are needed to maintain seamless connectivity and selection for target cell. However, the proposed solutions still have some gaps that need to be addressed [20]. When MUE starts moving towards the femtocells coverage area, its distance from MBS starts increasing due to which it needs to transmit with high power which can be problem for the users which are already connected with the FAP as it creates dead zone areas for FUEs already connected by FAP. SINR received at FAP decrease due to the interference created by MUE. In return, FUEs transmit with high power to overcome interference caused at FAP, which increase interferences at MBS and thus decreases SINR received from MUE. These two types co-channel interferences cause severe interferences if not mitigated properly. Because they can create positive loop interference that can degrade network performance. To solve this problem, we can handover MUE when it enters in the coverage area of FAP after checking its SINR and predicted time of stay. Additionally, we can check either resource are available for fulfilling the services required by MUE. Otherwise, no handover takes place.

1.8 Scope

- In Pakistan, current 3G and 4G technologies failed to fulfill capacity and throughput requirement due to inefficient handover between MBS. By deploying femtocell and using proposed handover scheme, we can solve problem to extent.

- More than 60% of mobile voice call and 90% of the wireless data services are carried out indoor. Indoor mobile subscribers face the problem of poor signal reception due to indoor penetration loss through walls. Hence, the Femtocells can be used, they are simple low-power, low-cost and small-coverage femto base stations (FBSs). They can connect with to existing Internet over IP back-haul, therefore, they are considered as one of the most promising solutions.

- It not only improves network capacity but also fulfill the demands of high speed voice and data traffic for indoor mobile subscribers.

- It will reduce unnecessary handover as well as mitigate co-channel interference.

- It will increase capacity and throughput of overall network.

1.9 Contribution of Research

The main objective of this research is to analyze the number of handovers in femtocell network, when we consider occurrence of handover on the basis of SINR, TTS and availability of resources. In previous studies, handover decision is mostly carried out on the basis of either signal strength or resources. Most of the previous studies only consider interference between neighboring femtocell or between MBS and FAP while assigning resources ignoring the fact that movement of macro users can cause severe interference. In [21], handover cases are defined by considering different thresholds of TTS and SINR. From research, it is concluded that both signal strength and resource availability are extremely important. However, we cannot ignore the fact that TTS of MUE in the premises of femtocell and their movement are equally important. In this research, femtocells are deployed randomly and instead of taking movements of macro user from GPS, random way point model is used for mobility. We have considered different thresholds of SINR and TTS for analyzing preliminary conditions of handover. Resource availability is checked if and only preliminary conditions of handover are fulfilled. After fulfillment of preliminary conditions, if resources are available for respective femtocell, then handover takes place. Otherwise, no handover will takes place.

Chapter 2

Literature Review

2.1 Chapter Overview

In this chapter, the existing methodologies for handover in femtocells and the gaps that need to be filled. Discussion about the parameters and their importance is also discussed in this chapter.

2.2 Femtocell and its Architecture

Femtocell is a small base station for improving indoor voice and data quality by reducing transmit and receive distance and by using efficient resource reuse. An indoor femto user equipment (FUE) communicates with a femto Access point(FAP) that is using a radio link. The range of coverage in femtocell is 20-30 meters .

The architecture for LTE femtocells is shown in the figure 2.1 [7] discussed in section 1. According to figure 2.2 [22], N number of femtocells are randomly distributed within macrocell. MBS or enhanced base station (eNB) is located within the centre of macrocells and macro user equipments(MUEs) within that coverage are served by MBS. While in case of femtocells, home base station (eNB) or FAP are used for serving FUEs within the coverage of small cells. The eNBs are connected to mobility management entity (MME). MME is control node in LTE which

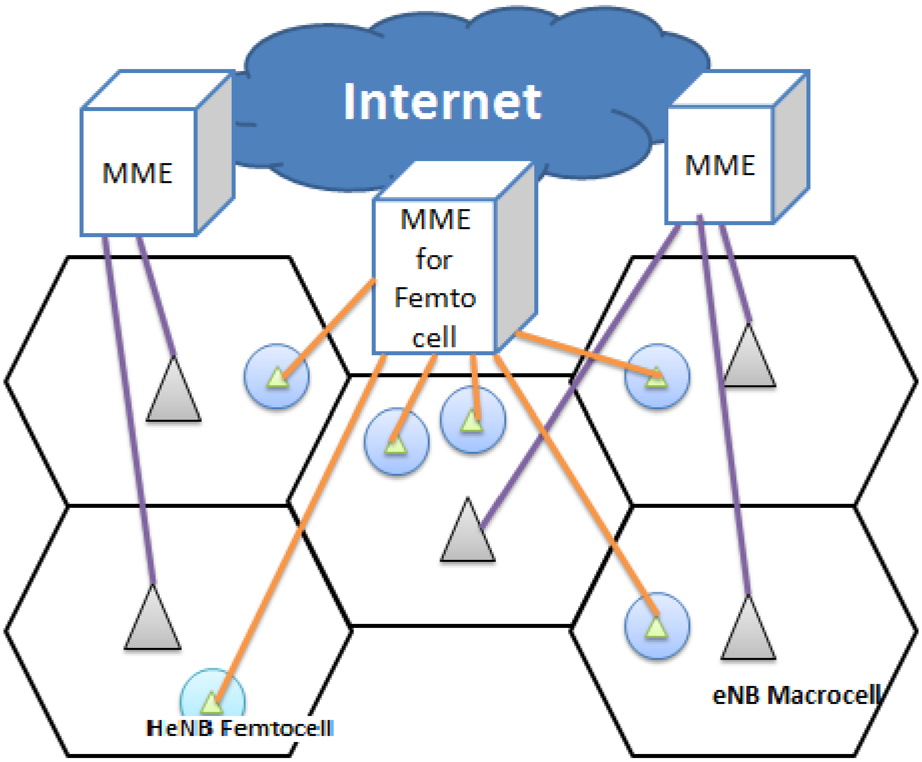


Figure 2.1: Architecture of LTE femtocell systems

is responsible for tagging and paging when user is in idle mode. eNB, which acts as a base staion in LTE, is responsible for data routing to serving gateways, resource management, MME selection etc. While, MME are responsible for paging, location updates, signaling between access networks, roaming etc [11].

Femtocells can allow and restrict their users in three possible ways. In Open access: all subscribed or non subscribed users are allowed to connect with FAP. In closed access: only subscribed users are allowed to establish connections. In Hybrid access: non subscribers can only use limited resource of the femtocell.

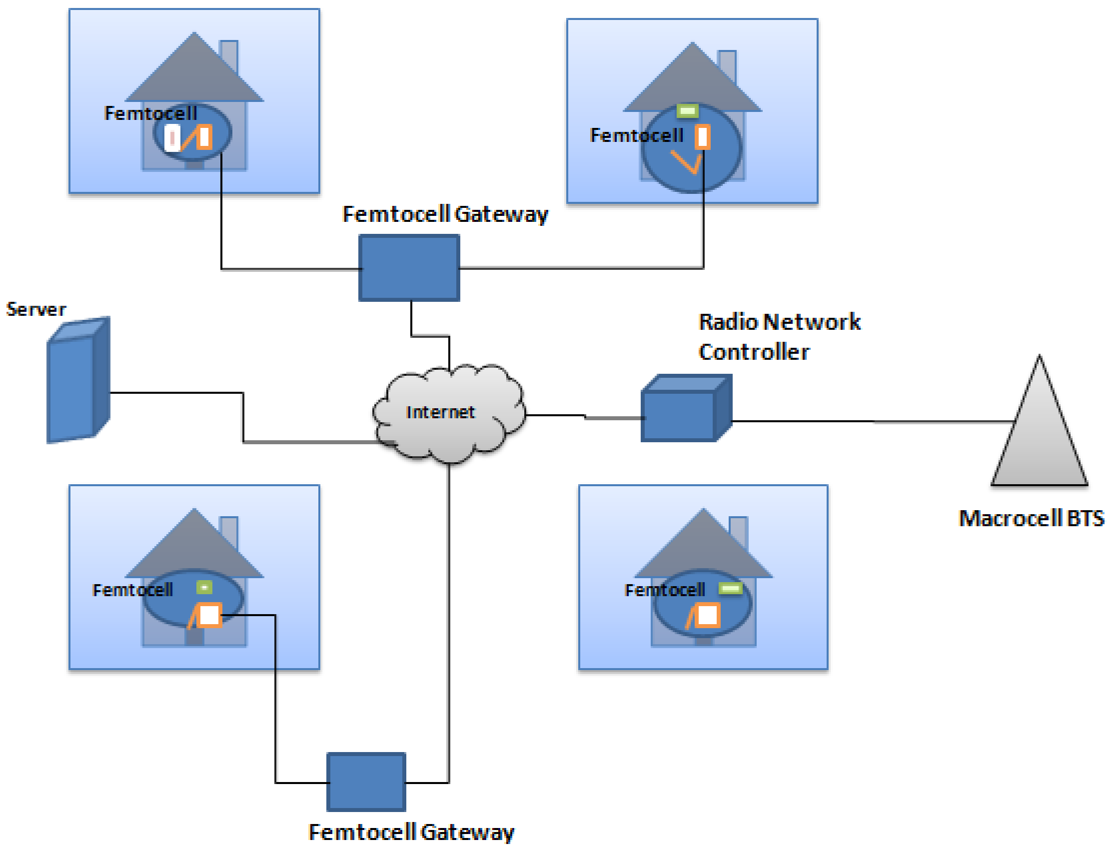


Figure 2.2: Femtocell Network

2.3 Handover in Cellular Network

Handover takes place when mobile user moves from its coverage area and enter to the premises of other cell. The basic aim of handover procedures is to maintain QoS all the time, both after handover and during handover. For example a voice call should be continued during and after handover [23].

Handover in Cellular Networks can take place due to several reasons :

- Different reasons are responsible for handover in telecommunications: 1) When the user is moving away from the coverage are of one cell to the coverage area of another cell, 2) the call is transferred to the another cell to avoid call termination .

- Non-CDMA networks transfer their new calls to different channel in same cell, when channel is interfered by another call, to avoid interference.
- In CDMA networks, a handover is performed due to near-far effect for reducing interference from neighboring cell.

There are two types of handover:

- Hard Handover : In hard handover, connection of user from old base station is first broken and then new connection is activated.
- Soft Handover : In soft handover, user is simultaneously connected to two or more cells.

In figure 2.3 , it is shown that standard handover algorithm used in LTE is known as the LTE Hard Handover Algorithm. Two variables for triggering handover process are handover margin (HOM) and time to trigger (TTT) timer. HOM is representing the threshold for triggering the handover (HO) and is calculated by taking difference of RSRP between the serving cell and targets cells. While, TTT is time for fulfilling HOM condition [2].

2.3.1 Types of Handover in Femtocells

Handoff management is necessary due to frequent movement of macro users to femtocells or vice-versa due to short distance. Deployments of femtocells are preferred to increase capacity and data rates. However, overlapping of femtocells are making handover operations more and more complex. Handover can be categorized as

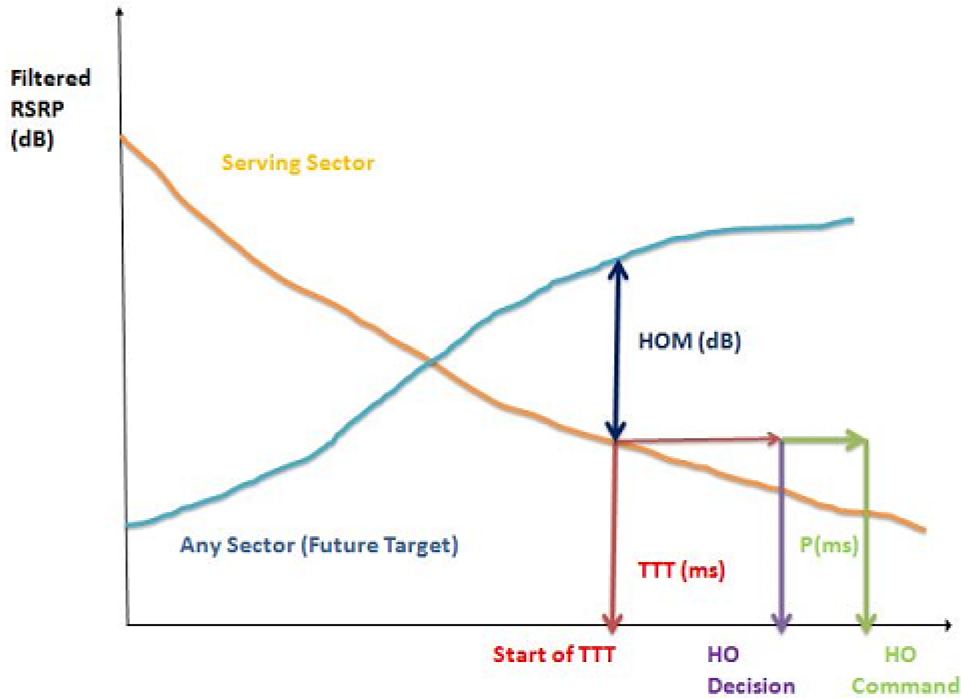


Figure 2.3: Handover in LTE according to technique in [2]

soft handover and hard handover. In hard handover, new resources can only be utilized after releasing current one while in soft handover new as well as existing resources can be utilize during handover process [24]. According to [25], handover can be categorized into three types in case of femtocells: Hand-in, Hand-out and Inter-FAP.

- **Hand-in**

  In hand-in, handover takes place from macrocell eNB coverage to FAP coverage. It is considered as the most complex scenario as compared to other handovers. We are assuming hand-in case in our research.

- **Hand-out**

  In case of hand-out, handover takes place from FAP to macrocell eNB. This procedure is not complex because UE doesnt have any except to handover its services to macrocell. It is just disconnecting from one base station and connecting to other as in normal telecommunication handover process.

- **Inter-FAP Handover**

  While, in case of Inter-FAP handover, handover takes place from one FAP to other. In this case, UE is switching from one femtocell to other, so it has to selection from cell selection. This process is as complex as hand-in procedure.

2.3.2 Handover Procedure in Femtocells

The handover procedure in femtocell which consist of 3 parts.

1. **Handover Preparation**

   - Scan and Measurement: Serving eNB continuously sending message to UE. In result of which UE scans for neighbor list and send Measurement report back to it in response.
   - Handover Decision: On the basis of Measurement Report (MR) report received by UE, serving eNB takes decision for handover. Also, it sends handover request to MME and MME sends it to serving gateway to get response.
   - Admission Control: On the basis of QoS information, target FAP will perform admission control and make preparation for handover with L1/L2.
   - Handover Command: Handover command is sent to UE by serving eNB.

2. **Handover Execution**

- In this phase, execution of handover takes place by detaching from cell and synchronize it with new cell. Serving eNB synchronizes itself with target HeNB and UE.

3. **Handover Completion**

   - This step is the confirmation step to indicate that handover procedure is completed by switching serving gateway to target FAP.
   - Also, serving eNB releases resources and executes control related resources. While target FAP sends downlink packet to UE.

2.3.3 Resource Management

Femtocell is an attractive approach for solving indoor coverage problem. Due to increase in usage of indoor voice and data services, it is expected that demand for capcaity and high data rates will increase exponentially in coming years.Therefore, one of the solution proposed is to install small cells in the existing LTE network.Femtocell uses LTE technology but as it is deployed on user's end Home eNodeB(HeNB): there is no coordination between eNB and HeNB and eNB is not aware of HeNB presence. Therefore, both entities uses same bandwidth and frequences that can raise severe interference. Interference problem needs to be mitigated between the femtocell and the macrocell. Femtocell is deployed in existing cellular network so it has to use same frequency allocated to network operators which can create severe problems if not allocated properly between macrocell and femtocells. Resource allocation scheme can be separate or shared carrier allocation. Separate frequency scheme can remove interference problem completely but it is uneconomical method because frequency is expensive and it has to be reuse for increasing capacity. Bandwidth in LTE is divided into equal size physical Resource bands(RBs). In time domain, each RB contains time slot of 0.5ms. While in frequency domain, it contains 180 kHz [26].

Femtocells are deployed unplanned as it can installed anywhere such as in homes, offices or airports and often turned off or on which can raised many interference problem. Also they are managed by end customers not by network operators due to which it is necessary to design algorithm. So, it can avoid interference and also resources can be used efficiently.

2.3.4 Comparison Femtocells with other technologies

- **Coverage and Capacity** Table 2.1 is showing different the cell types and their coverage area. Femtocells are classified as small cells having coverage area of less than 1 km and can be effective in case of increase in users and provide high data rates within its coverage area. They are most suitable and especially designed for indoor environment [1]. Table 2.2 shows that infrastructure cost is decreased as cell size is reduced. Small cells usually require small power for transmit and receive due to which they guarantee long battery life. However, due to decentralization, it has many challenges in deployment.

Table 2.1: Cells Range And Access Types according to [1]

Type of Cell	Radius (km)	Capacity	Type of Access
Macrocell	5 km	1000+ users	Open
Microcell	2km	32-100 users	Open
Picocell	2km	32-100 users	Open
Metrocell	200m	8-30 users	Hybrid/Open
Femtocell	10m	4-6 users	Closed

Using co-channel femtocells with existing macrocells shows promising results and it shows improvement in the spatial frequency and little impact on the throughput of macrocells. Previous studies show that despite of low power of femtocells, its small distance from UE and interferer, high throughput rates can be achieved for both uplink and downlink in femtocells coverage regions. For fulfilling future demands, it is recommended that mixture of small cells that can ensure reduction in deployment cost [1].

Table 2.2: Differences Between Different Cellular Architecture according to [1]

Type of cell	Installation	Technology	O&M cost
Macrocell	Outdoor	Licensed/Cellular	High
Metrocells	Outdoor	Licensed/Cellular	High
Picocells	Outdoor	Licensed/Cellular	High
Wi-Fi	Indoor	Unlicensed WLAN	Low
Distributed Antenna	Outdoor	Licensed and Unlicensed	High
Relay	Outdoor	Licensed/Cellular	Medium
Femtocell	Indoor	Licensed/Cellular	Low

- **Cost benefits**

  Femtocells deployment will decrease the infrastructure and operational cost. Because they are easy to install and dont require any maintenance from the operators. In urban areas, cost of site lease is about $1000/month excluding electricity and backhaul. Its operating cost increases with growth in subscriber because it becomes so stressful for operators to install new site. Femtocells can reduce the need of installing new towers because study shows that operating expenditure will reduce from $60,000/year for microcells to $2000/year for femtocells [24]. Also, it will reduce backhaul capacity requirements and can easily work with existing cellular system. It is also beneficial for customer as well because it will not only provide free calls at homes but also provide superior quality of coverage in indoor environment. Customers dont need to change phone number or handset and they also have no need to install expensive devices.

- **Improved macrocell reliability** Macrocell can redirect its traffic towards femtocells by allocating resources to femtocells. As a result, it can provide better reception to mobile user.

- **Reduced subscriber turnover**

  Poor indoor signal reception causes dissatisfaction, which results in switching network from one operator to other or to maintain separate wired phone. To cope with this problem, femtocell is the best solution because will reduce motivation of subscriber to switch their network by providing better coverage indoor.

2.4 Related Work

Recently due to demand of high data rates for mobile services, it is suggested that cell radius should be reduced. Due to which femtocells, microcells and picocells are emerging technologies. Its main purpose is to increase indoor coverage as well as to provide high data rates. Femtocells are low-power base stations that can be installed on the userss premises to provide cellular service within the home or enterprise environment. Typically, femtocells are connected to the Internet and the cellular operators network via a digital subscriber line (DSL) router or cable modem, which is why the users QoS guarantee is still an open issue. Femtocells offer benefits for both subscribers and operators. Subscribers can experience better voice service coverage and higher data throughput.

Handoff management is necessary due to frequent movement of macro users to femtocells or vice-versa due to short distance. A handover algorithm is proposed in [27] to avoid unnecessary handover from macrocells to femtocells in case of temporary femtocells visitors by using mobility pattern scheme. To overcome with problems of call dropping and handover failures, an optimization algorithm was proposed in [28] that change handover parameters of hysteresis varying between 0 and 10 dB as well as time to trigger values specified by 3GPP by measuring the performance of networks. But main problem with this algorithm was that it was limited for specific scenario and cannot be applied by assuming extreme cases.

A handover algorithm was proposed in [29] that will make the decision of handover on the basis of RSS, velocity and bandwidth w.r.t hand-in and hand-out. It will measure RSS level and on the basis of which compared the velocity of MS with two predefined values of velocity. If the velocity is less than certain threshold, it will check the bandwidth availability and type of service to take handover decision. This method was effective to reduce cross-tier interference but does not work for co-channel interference.

In [30], a handover algorithm was proposed by taking estimation of users state Rms in account, in terms of location as well as velocity of the MUE. Two classes are defined as: Real time for voice/video and elastic for data service. According to scheme, if SINR from FBS is greater than that of MBS and Rms is greater than 0, then handover takes place from femtocells to macrocell. Otherwise, UE will remain attached to its serving MBS. In [31], smart handover algorithm is proposed for slow moving UE in which threshold for received signal strength and time to stay is measured for visiting femtocells.

In [32], Dutch auction and stochastic approach is used for selecting femtobase station for handover. Dutch auction is used for selecting FBSs that are acting as bidder and MUEs are acting as auctioneer. Whenever, more than one FBS bid simultaneously, it results in collision. Therefore, auction continues until last FBS. While, stochastic election helps in narrow down the bidding area on the basis of resolution and separation distance.

In enterprise environment, building and walls are major attenuation factor that degrades signal power due to co channel interference. Mixed Integer Linear Programming (MILP) model is used for placing FBS for covering whole enterprise. Optimal Constant Threshold Signal to Interference plus Noise Ratio (OptCTSINR) Optimal Handover (OptHO) model are used for assuring SINR within certain limit and also minimize the need of FBS for the coverage of enterprise to avoid unnecessary handoff within buildings [33]. The handover scheme proposed in [34] depend on the speed and signal strength. If speed of UE is lower than 30km/hr, it is considered as slow moving UE and vice versa. Different scenario for hand-in and hand-out are considered. Hand-in is performed if speed of UE is lower than 30km/hr and signal strength is lower than -50 dBm. There are two further cases defined for hand-out: HTIH1 for Intra Handover and HTIH 2 for Inter handover. For HTIH1, the value is set to -56 dBm. Whereas, for HTIH 2, the value is set upto -70 dBm to initiate handover Hand-out take place only if speed of UE is greater than 30km.hr and signal strength is up to -50 dBm.

In [14], handover decision is made on the basis of data capacity available on the estimated path using probabilistic method. The probabilistic path and residence time in femtocell is measured and further decision for handover is made by comparison of available data capacity on the estimated path. Orthogonal frequency allocation of resources is proposed in [35] to avoid co-channel interference between macro cell and femtocells in LTE. Handover request initiated if signal strength from Femto Base station HenB is greater than handover threshold. Handover takes place from macro cell to femtocell only on the basis of available allocated resources to femtocell that are required for continuing services required by MUE. If requested resources are less than that allocated to femtocell, then request is done to resource management server RMS by FBS to allocated resource block (RB). If RB, after expansion, are lower than required, then handover is rejected.

In [15], efficient resource management mechanism for reducing interference problem , fractional frequency reuse (FFR) and a heuristic graph-based channel assignment algorithm in femtocell is introduced. By using this method, no channel can be used by both macrocells and femtocells or neighboring femtocells at same time for avoiding interference. FFR is applied by allocating sub-bands to macrocells and femtocells separately to define that MUE and FUE can used from these sub-bands respectively. While, heuristic graph based channel assignment is applied by using maximal independent set (MIS) to find sets of femtocells that can used reuse frequency in a way to avoid co-channel and cross-channel interference.

To reduce interference in two-tier network, resource management similar to cognitive radio was proposed but the resource blocks were controlled statistically. In this case, a table was maintained containing the interferer information among the cells and table is periodically updated. It aims to maximize throughput for femtocells in case of non real-time services while guarantee throughput for macrocell in case of real-time services. There are two types of physical resource block (PRB): primary and secondary. Primary PRB are allocated in a manner that macrocell allocates priority resources to serve its own user and remaining of them is orthogonally allocated among the femtocells. While secondary PRB are allocated to femtocells on demand to meet required throughput. There is a possibility that primary PRBs are already part of any secondary PRBs. So to deal with the problem of intercell interference among the neighboring femtocells using same frequent band, the look-up table will interferer and resource blocks are distributed in a way that can minimize the interference because additional PRBs are not orthogonally allocated among macrocell and femtocells [36].

In [21], handover strategy for hand-in and hand-out are proposed based on SINR and TTS of MUE/FUE in the macrocell/femtocells. The handover decision is initiated by comparing TTS of FUE/MUE within the premises of macrocell /femtocells with predefined threshold for TTS. If TTS is greater than threshold, SINR of MBS/FAP is compared with preliminary SINR and actual SINR threshold for making further handover decision. The simulation shows that optimal power when compared with minimal power will give more promising results for increasing SINR and improves network performance in terms of user rate, outage probability OP and network capacity.

In [37], handover is made by first determining the velocity of UE moving from macrocell to macrocell/Femtocells. If it goes below 30km/hr, then highest Received signal strength indication (RSSI) of femtocells/macrocell are determined. After that availability of bandwidth and SINR are compared for choosing best option among femtocells/macrocell for handover. The decision for hard handover is taken by taken Received signal strength (RSS) into account. The modification in handover process was also proposed by increasing TTS (time to trigger) window size that shows promising results by reducing handover while decreasing up-link SINR. Moreover, performance of network due to handover, measurement of bandwidth, margin and measurement update period was also taken into account for different parameters. But it doesnt provide any information on delay, signaling overheads and throughput of UE [38].

It has been seen [39], handover in heterogeneous networks on the basis of SINR for vertical handoff (VHO) is more effective then RSS with some limitations to user velocity. The criteria for handover proposed was to calculate the time of stay within the coverage area of WLAN for slow and fast moving vehicles to avoid unnecessary handoff. For which another SINR threshold was taken into account which first compare SINR of WLAN and WCDMA for checking handover conditions. If satisfies, handover will takes place Otherwise, there will be no handover .

The SFR scheme is used for the evenly distribution of resources among the cells but due to change of uneven traffic load among neighboring cells, it can cause problem in performance due to which soft frequency reuse scheme was proposed for semi distribution of resource . In this research, a fractional frequency reuse-based graph connectivity (FFR-GC) mechanism is used which not only reduce traffic load but also avoid interference among teh neighboring cells. [21] and [15] are followed for proposing new effective evaluation technique by considering SINR, TTS and resource availability for taking handover decision . Previously, these parameters are not taken in account together for decision but these are very important parameters and they should be evaluated for gaining good network performance.

2.5 Missing Link In Literature

Although femtocells are designed for indoor coverage and no mobility management is required for indoor users but due to two-tier cellular network, macrocells users also keep entering and leaving the coverage area of femtocells due to which handover algorithm is required for handling this problem. Neighboring femtocells can behave as interferers because when MUE try to connect with indoor femtocells. Due to which, the number of handoffs and security risk will increase. Unfortunately, in previous studies, the links between important parameters i-e SINR, TTS and resource allocation were missing. Main focus previously was either on received signal strength and time to trigger or on the resource allocation or available resources required for handover. But no one tries to sort out the optimized approach to access these three network parameters because they are equally important. In this research, mobility is also taken in account because greater speed of MUEs can cause unnecessary handover which can cause waste of resources. To make handover on the basis of only one parameter can raise many problems as it could give rise to unnecessary handovers. Moreover, network performance will degrades due to ignorance of important aspects of networks.

Chapter 3

Research Methodology

3.1 Chapter overview

In this chapter, there will be discussion about the interference in two-tier femtocell network and how they have impact on the network. Also, there will be discussion about different cases of handover. How to use resources effectively after checking necessary conditions of SINR, TTS and resources for avoiding any unnecessary handovers will also be discussed in this chapter.

3.2 Need Analysis

There are two types of interference that exist in heterogeneous network [21]: cross-tier and co-tier interference. Crosstier interference occurs between different tier networks e.g between elements of femtocells and macrocells. While co-tier interference takes places between elements of same networks e.g between neighboring femtocells. The co-channel interference in two tier femtocells network can be categorized in three types. In case of macrocell as shown in figure 3.1, there is intra-cell interference $I_{c,in}$ between MBS and MUEs, while cross-tier interference $I_{c,f}$ between MBS and FUEs. In case of femtocells, there is intra-cell interference $I_{f,in}$ between FAP and FUEs, while cross-tier interference between FAP and MUEs $I_{f,c}$. Moreover FAP also suffers from intra-cell interference $I_{f,f}$ from neighboring FUEs. When SINR of MUE become lower than the required threshold γ_{fo}, then disturbance is caused between FAP and MBS in uplink transmission. There are three types of interferences which are faced in two-tier femtocells network [21]:

- The neighboring femtocell interference $I_{f,f}$ at FAP_j
- The femtocell F_j intra-cell interference If,in at FAP_j
- The macrocell interference $I_{f,c}$ at FAP_j

In this research, a system model is proposed for LTE in uplink transmission and aim is to reduce co-channel interference in two-tier heterogeneous network. Which will perform handover on the basis of SINR and TTS as well as take account about the services demanded by user. If thresholds of SINR and TTS fulfillment will check the availability of resources. Otherwise, it will reject the handover request, which will reduce the ping pong affect as in previous studies handover is performed only on the by taking either signal strength or availability into account.

3.3 System Model

In two-tier femtocell network, small femto access points (FAPs) are installed within the coverage area of macrocell, so the users within femtocells coverage can connect to FAP for gaining high speed and capacity. Battery consumption of femto user will also be minimal as FAP is located near-by. But handover is required when macrocell user become close to the premises of femtocell by taking account different parameters due to the interference. When MUE starts moving towards the femtocell, its distance from macrocell start increasing due to which high power transmssion by MUE to MBS is required. This will result in dead zone area for near-by femtocells,

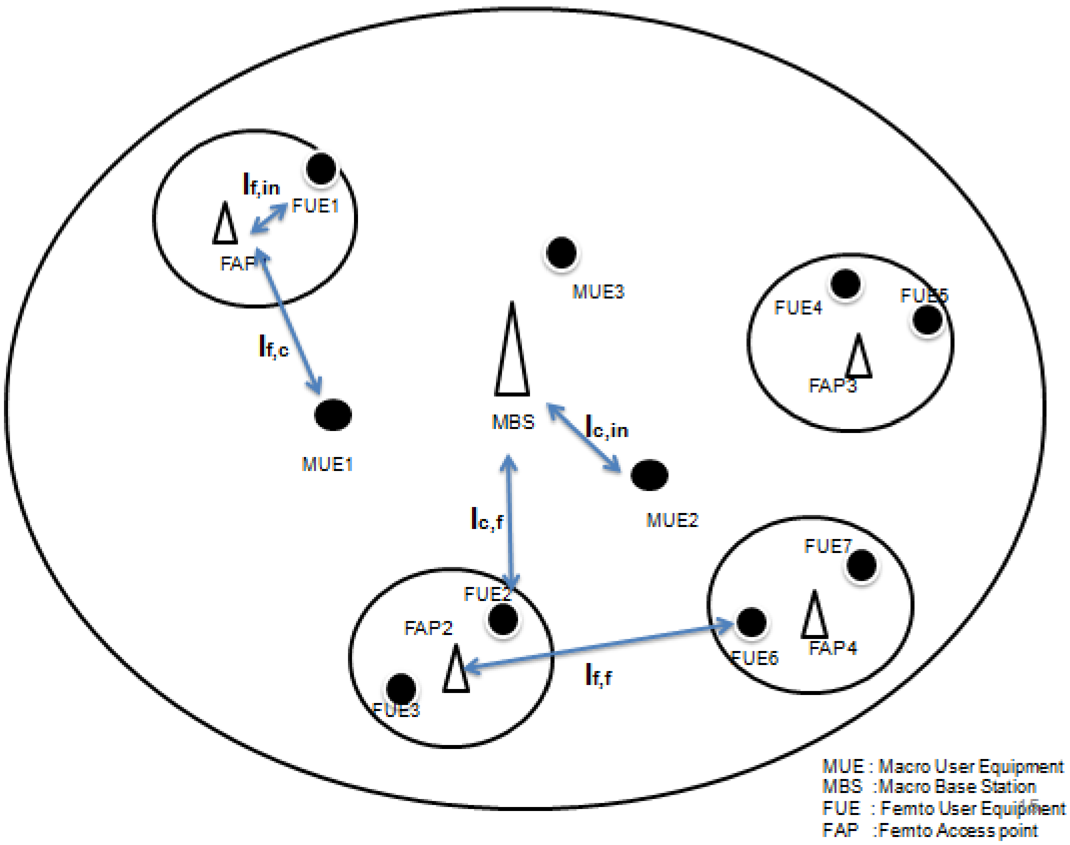


Figure 3.1: Co-Channel interference in Uplink Transmission

due to which SINR at FAP degrades. Femto users need to overcome interference caused by MUEs by increasing their transmitting power ,which in turn can cause interference at MBS. An efficient mitigation is required otherwise it will result in the formation of positive interference. For handling this situation, handover is required. But if handover of MUEs is made only on the basis of its location or signal strength, it would result in unnecessary handover. There is a need of some rules to check that whether handover is required or not. For that case, two thresholds for SINR are used: one is preliminary SINR threshold which is used for negotiation whenever handover request come while other is actual SINR threshold which is used for emergency handover to avoid degradation or discontinuation of services. Time to Stay (TTS) parameter is used along with SINR to check the predicted time that MUE stays in femtocell premises to decide whether to handover or not. TTS is necessary it will handover only to MUE when it stays longer in femtocell [21]. Another important factor which is mostly ignored in handover cases that either resources are available or not for handover is not mentioned in [21]. Most of the time ,when handover request comes, handover takes place without checking either assigned frequency in case of handover is used by near-by Femtocell or not which can cause severe interference. Due to which efficient resource allocation sceheme FFR-GC along with MIS algorithm is used to overcome interference [15].

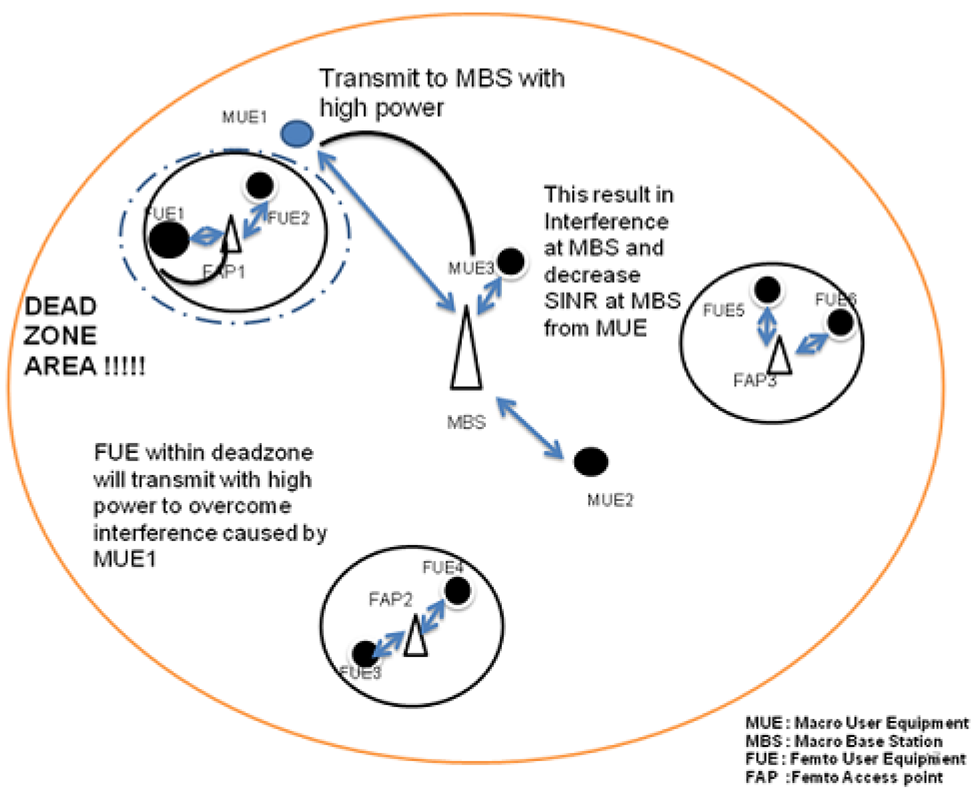


Figure 3.2: Cross-tier Interference in two-tier network

In macrocell, there are N numbers of nodes randomly distributed in the network. Each macrocell has eNB or MBS which is acting as a base station for macrocell user (MUE) is located outdoor within its coverage. While the nodes within the coverage of femtocells users (MUE) are located indoor and are served by femto access point (FAP) or femto HeNB. As shown in the figure 3.1, three MUEs are located in the macrocells. These MUEs are connected to MBS in outdoor environment. While for indoor environment, three femtocells each containing FAP as base station to serve their respective FUE within their coverage. In a figure, there are seven FUEs served by their own FAP.

Consider that MUE1 starts moving towards femtocells and away from MBS. As the distance between MUE1 and MBS increases, SINR decreases. When MUE moves into the premises of femtocells, especially within the indoor environment, it needs to transmit with high power due to walls penetration and high path loss. Which can cause severe interference for FUEs within femtocells and create dead-zone area for them To overcome the interference caused by MUE1, the FUEs within dead-zone area transmit with higher power. This causes severe interference at MBS and decreases received SINR from MUE1 and can create closed loop of positive interference, if interference is not mitigated properly.

To mitigate this problem, possible solution is to handover MUE to FAP when it enters into the household premises. The handover can be made on the basis of different SINR thresholds and TTS as well as taking resources in accounts to prevent any disruptions for already allocated or reserved resources in macrocell/femtocells. This would allow MUE to use small power and remain connected to FAP to carry out its transmission. The advantage of this strategy is to reduce unnecessary handovers and maintain the performance of network and optimize the throughput, data rates and networks capacity. Consider set of parameters to prevent unnecessary ping pong affect as well as allocate resources to only those nodes that require urgent handover to maintain their services.

According to [21], interferences at FAP and MBS can be due to different factors which can degrade the performance of network. Interference caused by the MUEs using same channel and neighboring FUEs in other FAP can be the main reason for causing interference on FAP. Along with that, FUEs within the same femtocells can also cause intra-cell interference. While MUEs and FUEs using same channel within the coverage area of macrocells are responsible for interference at MBS. Interference from different entities can be calculated from the given formulas. The characteristics of channel are determined by the log normal shadowing and path loss. In this case α and β are assumed as the outdoor and indoor path loss exponents respectively. P_r^f and P_r^c are the receiving power at FAP and MBS respectively, while G_m and G_f are the channel gains for MBS and FAP respectively. According to [21], we have X as the distance between MBS and MUE, therefore we have :

$$g_c(X)=K_c.(\frac{doc}{|X|})^{\;2}\;\;\Theta_c \tag{3.1}$$

$$10\log_{10}\Theta_c \sim \mathrm{N}\;(0,\,\sigma_{db}{}^{\;2}\;) \tag{3.2}$$

Where $g_c(X)$ the outdoor attenuation is factor and 10 $\log_{10}$ θ_c is the log-normal shadowing. d_{oc} is the reference distance for outdoor attenuation and c is the speed of light. In case of FAP, Y_i is representing the distance between FAP and FUE;

therefore we can calculate log-normal shadowing as [21]:

$$g_f(Y) = K_f \left(\frac{d_{of}}{|Y|}\right)^2 \Theta_c \tag{3.3}$$

$$10\log_{10} \Theta_c \sim \mathrm{N}\ (0, \sigma_{db}{}^2) \tag{3.4}$$

Where $g_f(Y)$ the outdoor attenuation is factor and $10\log_{10}$ θc is the log-normal shadowing.d_{of} is the reference distance for indoor attenuation and c is the speed of light.

3.3.1 The Neighboring Femtocell Interference I_{ff} at FAP_j

The interference caused at FAP due to the FUEs in nearby femtocells can be calculated as:

$$I_{f,f} = P_r{}^f \ \frac{g_c(Xi)}{g_f(R_f)} \tag{3.5}$$

Where X_i is the distance between one FAP to the other and Rf is radius of femtocells.

3.3.2 The Femtocell F_j Intra-Cell Interference $I_{f,in}$ at FAP_j

The interference caused by FUEs on the serving FAP also degrades SINR at FAP and calculated as:

$I_{f,in}$=(U_f-1) $P_r{}^f$

(3.6)

Where U_f is the number of FUEs within the Femtocell, while $P_r{}^f$ is the received power of FAP.

3.3.3 The Macrocell Interference $I_{f,c}(i)$ at FAP_j

The interference on FAP from each MUE can be calculated as:

$$I_{f,c}(i)=Pr^c \, \frac{gc(Yi)}{gc(Xi)} \tag{3.7}$$

The sum of all interferences from MUEs on FAP can be calculated from:

$$I_{f,c} = \sum_{i=1}^{Nc} I_{fc}(\mathrm{i}) \tag{3.8}$$

Where X_i is the distance between MUEs and MBS, while Y_i the distance between FAP and MUEs. N_c is the number of MUEs in the macrocell.

3.3.4 Macrocell Interference at MBS

MUEs using the same channel are responsible for causing interference at MBS. It can be calculated by assuming that N_c are the numbers of MUEs using same channel while P_r^c is the power received at MBS.

$$I_{f,in}=(N_c-1)\ {P_r}^c \tag{3.9}$$

3.3.5 Femtocell Interference at MBS

Femtocells within the coverage area of MBS have Uf number of FUEs which can cause interferences on MBS. Assume that interference of FUEs within the same femtocell has almost same affect because distance of those FUEs is almost same from FAPs. According to [21], indoor attenuation can be calculated by using:

$$g_f\ (Y_i)=g_f\ (R_f) \tag{3.10}$$

Assuming that X is the distance between FAP_i and MBS, the interferences at MBS from each $(FUE)_j$ in femtocell F_i can be calculated :

$$I_{c,f}\ (F_{i,j})=P_r^f\ \frac{g_c(X_i)}{g_f(R_f)} \tag{3.11}$$

Therefore, total interference at MBS from all FUEs from the femtocells within its coverage can be given as:

$$I_{c,f}=\sum_{i=1}^{N_f}\sum_{j=1}^{Ui}\ I_{c,f}\ (F_{i,j}) \tag{3.12}$$

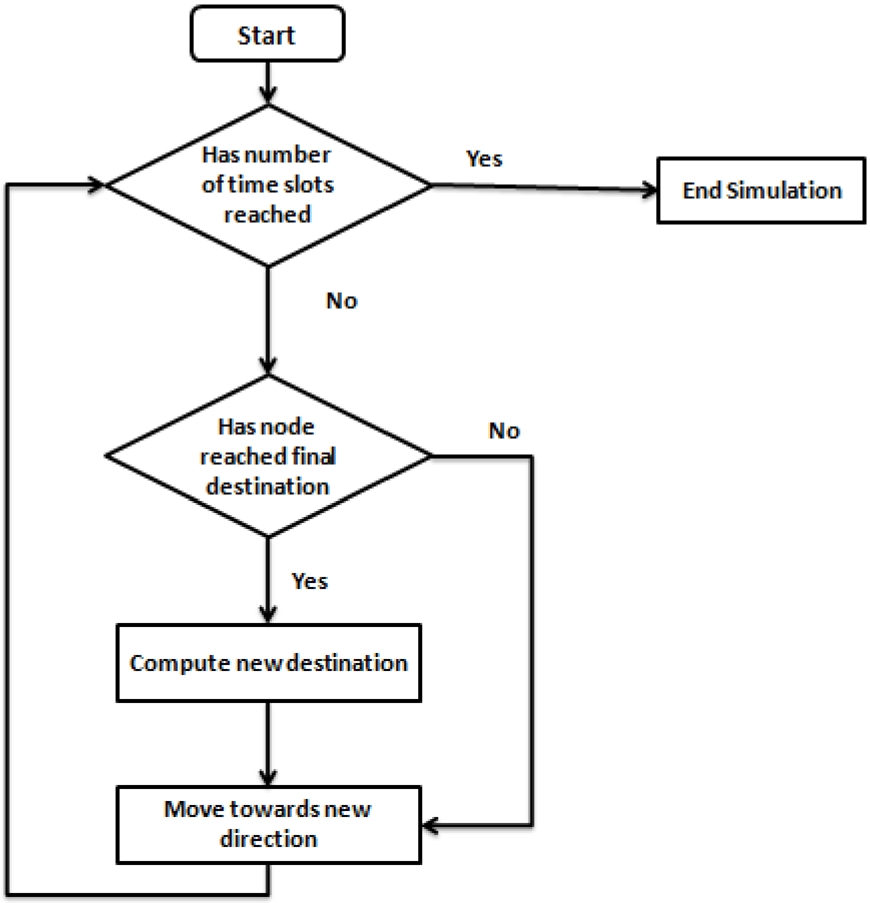


Figure 3.3: Flow Chart for Random WayPoint

3.4 Mobility Model

Accurate information about the mobility of users cane be find out by using realistic mobility patterns. However, since femtocells have not been deployed on a wide scale due to which obtaining real mobility traces is still a major challenge. As mobile nodes movements are unpredictable, so we need to design such mobility model that can meet real life scenario. The movement of nodes is described by the change in velocity, direction and angle. Random way-point model is assumed here so our mobile nodes can move freely without any restriction. Because in real life scenario, it is hard to predict the nature of mobile next moves as they move independent of each other. In this case, ignore the consideration of specific group [40]. In the random way point model , random destination is selected by mobile node for moving towards its direction, when simulation starts. The mobile nodes move with constant velocity which is selected from the range [0,V_{max}], where V_{max} is the maximum velocity with which mobile node can move. The mobile nodes can select velocity and direction independent from other nodes. When mobile node reaches the destination, it chooses another independent destination and start moving towards its direction with constant velocity from the range defined above [41].

Random waypoint model is considered because in this research, GPS data is not used. In the proposed model, mobile user is positioned initially random in the macrocell coverage area and movement is based on random waypoint model. Assumption is that all users are randomly distributed and cover distance of 4 meters in each slot to reach their chosen destination before they change their direction and choose new destination points. In this research, we have considered that velocity of MUEs should be equal to or less 15 km/hr for performing handover. We are only considering MUEs moving slowly to avoid unnecessary hangovers. Handover will be performed on those MUEs who are likely to stay longer in the premises of femtocell rather than those high speed MUEs that are just passing by femtocells.

3.5 Parameters

From the previous studies, conclusion can be made that there is a need of systems design which should be optimized and good enough for handling interference problem between macrocells and femtocells by using efficient handover technique. Now consider three parameters for making decision of handover because most of the pre-

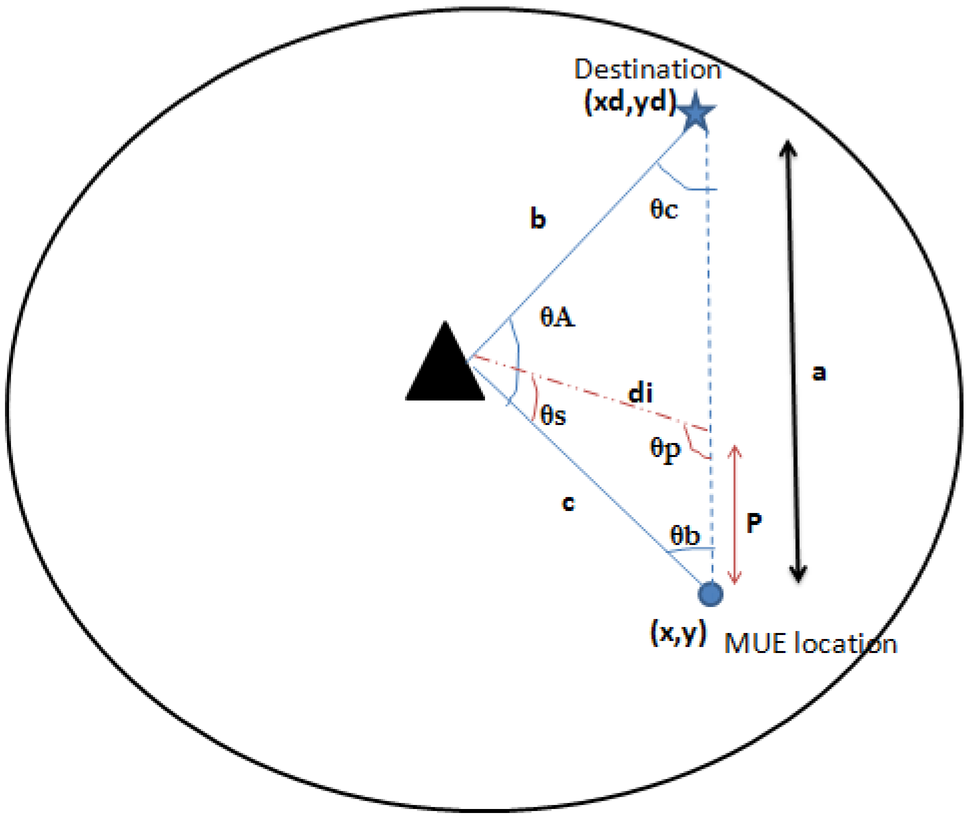


Figure 3.4: Random Waypoint Model

vious research has focus on these parameters independently. But this research aim to show that by considering all important parameters, improved solution can be achieved for reducing co-channel interference and unnecessary handover.

3.5.1 Time To Stay (TTS)

Time to stay is defined as the predicted time of stay of mobile user wtihin coverage area of FAP. When node enters into the coverage area of FAP, its TTS depends on its velocity. Consider that the distance covered by the node in two time span according to the predicted velocity of respective node. Calculate time to stay by considering both distance and velocity by following formula [21].

$$TTS_{i,j} = \frac{\frac{d_(i,j)^{tts}}{vi}}{\frac{max_{i,j}(d_{i,j}^{thf})}{vi}} \tag{3.13}$$

$$d_{i,j}^{tts} = \frac{R_f}{\sin\theta_{i,j}}.\sin(\theta_{i,k} + \arcsin(\frac{d_{i,j}}{R_f}).v_i) \tag{3.14}$$

Where $d_{i,j}$ is the distance between FAP and MUE, while $TTS_{i,j}$ is the time node has spent within the coverage of that FAP. TTS_{thF} is the normalized TTS that is required for FAP to carry out handover if threshold exceeds required limit which means that if node stays longer then it should handover to near-by FAP to avoid dead zone area and degradation of SINR at MBS. TTS depends on the distance and velocity of node. By using trajectory and velocity of node, $TTS_{i,j}$ can be calculated that can provide us the predicted stay of node. Handover will occur only if $TTS_{i,j}$ is greater than TTS_{thF}.

3.5.2 Signal-To-Interference-Plus-Noise Ratio (SINR)

SINR is defined as the quantity for channel capacity and it acts as the upper bound for the rate on which information is transmitted. It is power of signal of certain node divided by the sum of all interferer around that node and power of background noise. In wireless networks, it is used to check the quality of the connection. In telecommunication, UE is connected to the Base station with highest SINR for seamless connectivity and capacity.

Previously RSS was used as the measure of handover decision by comparing the

RSS of UE with predefined value. But it failed to provide the data rates demanded by the UE for carrying out its services. Due to which SINR is proposed as the indicator of handover decision because it ensure to meet required data rates. In this research, SINR is used instead of RSS as one of the parameter of handoff when MUE moves from MBS to FAP due to increase of distance between MUE and MBS, the received SINR at MBS decreases. Due to which MUE tries to transmit with high power. It also has adverse affect at FAP as MUE will create dead zone area for nearby FUEs already connected to that FAP. To overcome this issue, handover is being made by comparing different threshold of SINR to make decision.

In this research, two SINR thresholds are proposed [21]: actual SINR γ_{fH} and preliminary threshold γ_{fpH}. Actual threshold is the SINR threshold on which handover should be made without any other consideration. However, in this research preliminary SINR is introduced threshold because when system will check right from the moment when performance of network starts degrading and then both by comparing the SINR threshold depending upon its predicted time within that coverage, precise decision needs to be taken that either it is important to handover to nearby FAP or to wait little longer before conditions go worst. The values are dependent on the QoS provided by femtocells to MUE. For example, for real time services threshold is set much higher than non real time services because they need high bandwidth for smooth service, interference level and traffic load. SINR at FAP and MBS can calculated on the basis of co-channel interference discussed in section 3.1 is given as [21]:

$$(SINR)_{FAP}=\frac{(G_f.P_r^f)}{(I_{f,f}+I_{f,c}+I_{f,i})+\sigma_f)} \tag{3.15}$$

$$(SINR)_{MBS}=\frac{(G_m.P_r^c)}{(I_{c,}+I_{c,in}+\sigma_m)} \tag{3.16}$$

According to equation, all interferences at FAP and MBS from MUEs and FUEs should be taken into account.

3.5.3 Availability of resources

Radio resource management is very crucial for maximizing the efficient utilization of resources. As bandwidth is limited, there should be precise mechanism for handover decision is which UE should be handed over in the condition when resources are available in the cell. Any new request is only accepted if QoS conditions are met [42]. In this research, resource allocation method is proposed which takes decision for handover after checking SINR and TTS threshold in a way that there is minimum interference between the adjacent nodes because both macrocells and femtocells are using same frequency band. The algorithm used by us for resource assignment is fractional frequency reuse-based graph connectivity (FFR-GC). By using this algorithm, MUEs located on the edges will be less suffered by the interference. FFR-GC is divided into two parts. Firstly, sub-bands are allocated to macrocells and femtocells. Secondly, by using graph theory the requested band will be assigned in a way that will reduce interference among the nearby femtocells [15].

- **Macrocell Radio Resource Allocation**

  Technique of FFR-GC was proposed in [15] which is used in this research as a measure to identify either sub-band is available for handover and to make decision in a way that will help in optimizing the interference as much as possible. Firstly, macrocell is divided into a centre zone and three edge zones.

A band is divided into sub-bands in a way that 2/3 of bandwidth is allocated in the centre while 1/3 of remaining bandwidth is allocated to edges. In figure, it is shown that first four frequency sub-bands (A, B, C, D) are allocated to centre (c1, c2, c3) and edges (e1, e2, e3). According to FFR-GC method, there are interference between the adjacent cells in (a). While in (b), the method used is allocating bands in a way that will reduce the interference between macrocells and femtocells.

- **Femtocells Radio Resource Allocation**

  In this phase, resource is allocated to femtocells is such a way that sub-band A, which is 2/3 of total bandwidth, is further divided into 6 sub-bands and is allocated to the edges where it is used by femtocells. Along with this, sub-bands that are not allocated to macrocells in centre-zone and edges are used by femtocells to avoid interference between macrocell and femtocells. But the interference between femtocells due to reuse of sub-bands is still a problem.

- **Algorithm for assigning sub-bands to femtocells**

In this case, graph theory is used in which with the help of undirected colored graph the femtocells can be identified about the bands they are using, so that interference can be avoided by not allocating same channels to immediate neighboring femtocells. Maximal Independent Set (MIS) is proposed for finding the independent set and then by the help of those set resources can be allocated to femtocells for avoiding interference. MIS is a good algorithm for reduction of interference between the femtocells using same sub-bands but cannot use same channel [15]. For each simulation, how many sub-bands are used by FUEs within femtocells are recorded by maintaining matrix and check which sub-band can be allocated according to

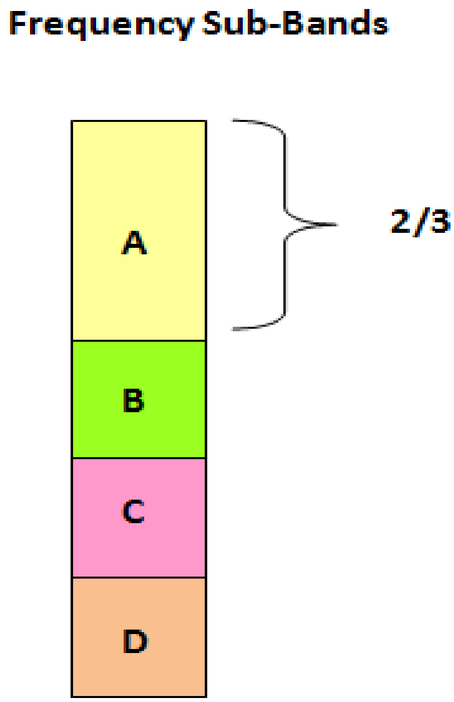


Figure 3.5: Frequency sub-bands for the allocation of Macrocell and Femtocells

geographical condition of femtocell in cellular environment to avoid any type of interference between MBS as well as neighboring femtocells.

3.5.4 Proposed Algorithm for resource allocation

An algorithm is proposed that aims to reduce interference among macrocells and femtocells by considering the threshold of SINR and TTS [21] along with the availability of resources to take decision of handover [15]. The focus of previous research was to assign bands to neighboring femtocell in a manner to avoid intereference and handover was not considered in that paper. The main advantages of proposed algorithm is that it is considering all important parameters altogether. The movement of MUEs will be based on random way point (RWP) for predicting the future movement of MUEs that would be effective for taking decision about the time MUEs

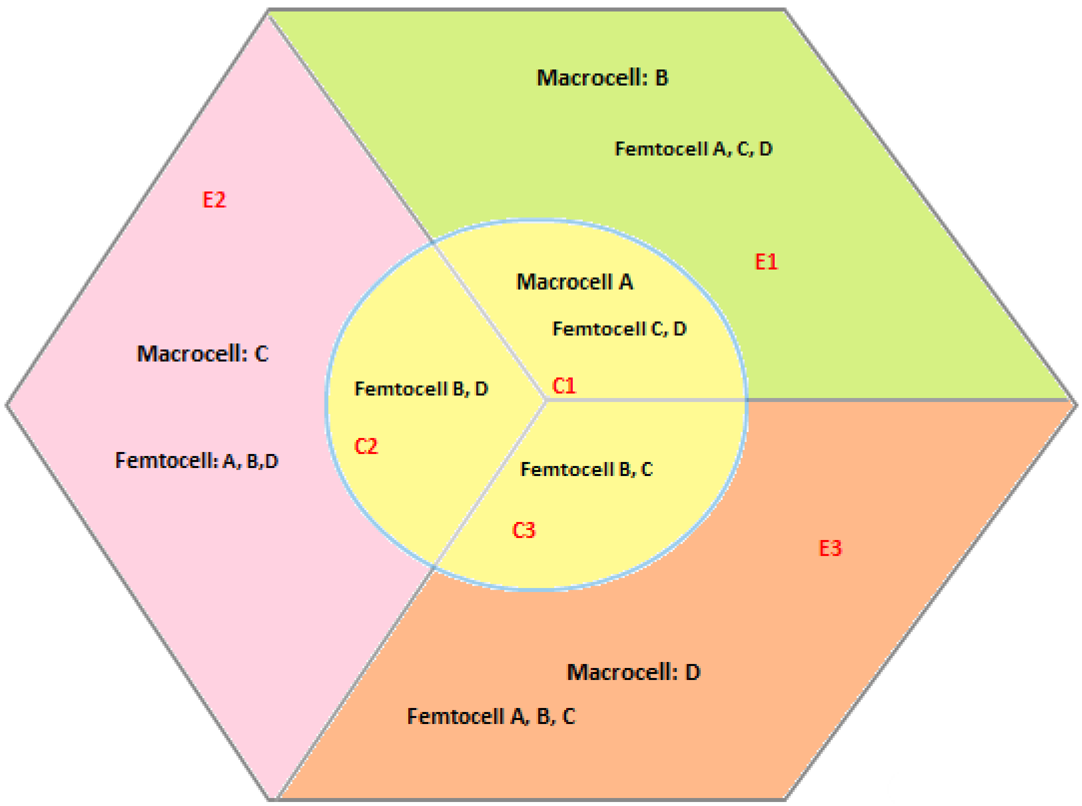
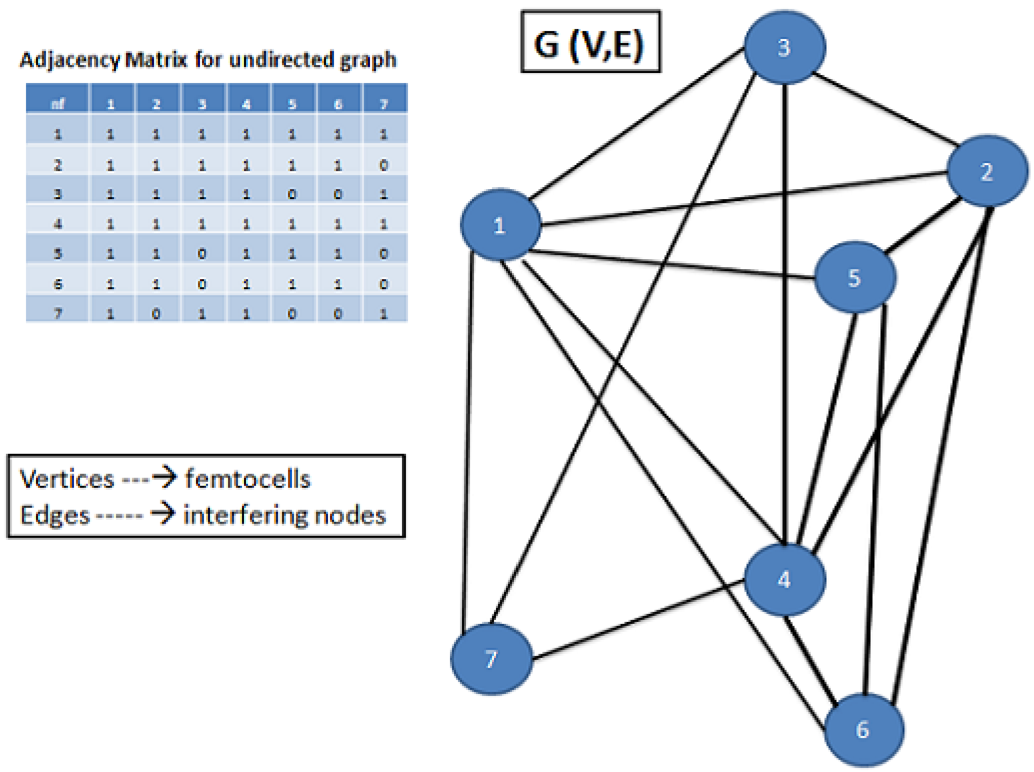


Figure 3.6: Allocation of frequency bands for UEs using FFR method

could stay within the coverage of femtocells. If TTS is greater than the required threshold time for FAP, then it will check for SINR and resources at FAP and further decision for handover will be based on their values.

In figure 3.8, undirected graph in shown in which vertices's are representing femtocells while edges are representing interference between femtocells. The undirected graph is formed on the basis of assumption i-e lets say distance threshold is 40 meters. If distance between neighboring femtocells is less than or equal to 40 meters, then there will be interference between femtocells according to assumption.Adjacent matrix is formed by checking which band can be used by femtocell according to geographical location i-e by taking edges and center band assignment as given in figure 3.6.



nf	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	0
3	1	1	1	1	0	0	1
4	1	1	1	1	1	1	1
5	1	1	0	1	1	1	0
6	1	1	0	1	1	1	0
7	1	0	1	1	0	0	1

Figure 3.7: Undirected Graph G(V,E) and respective Adjacency Matrix

Maximal Independent Set (MIS)

An independent set, in graph theory, is a set with no neighboring vertices [43]. Lets assume that G (V,E) is an undirected graph in which V is representing vertices while E is representing the edges.In this case , there is need to find set K in which no two adjacent vertices should be connected by an edge. The size of an independent set depends upon the the number of vertices it has. Independent sets are also called internally stable sets. In graph theory,finding maximal clique or maximal independent set is the basic problem and many algorithms are proposed for optimal solution. In the resource allocation method [15], undirected graph G(V,E) is formed first, where V is femtocells and E is showing interference between femtocells.This graph is formed on the basis of distance between the Femtocell. Assumption is made

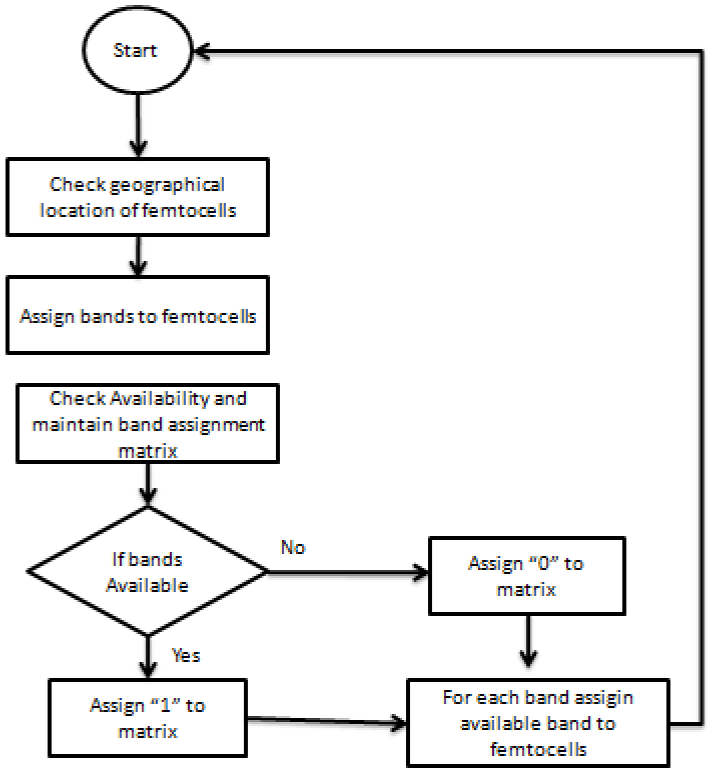
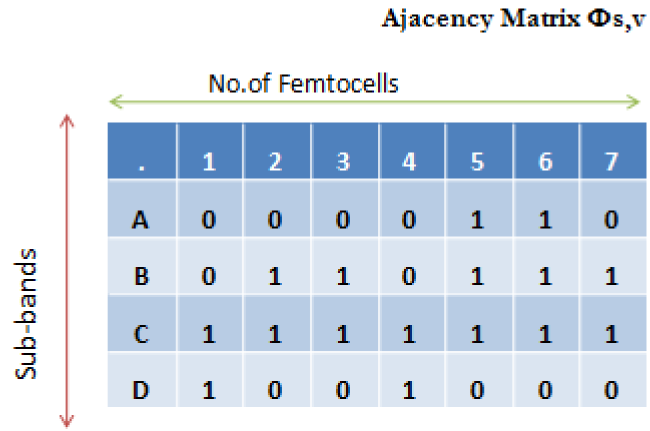


Figure 3.8: Flow chart for assigning bands to femtocells

that if distance is two times the radius of femtocells, then interference is happening between femtocells. Which band can be used by femtocells can be found by $\Phi_{s,v}$ .With reference to $\Phi_{s,v}$, sets of femtocells will be extracged that are independent to each other and can use same bands by using MIS algorithm. Following are the steps of MIS algorithm that are discussed in [15] that followed in this research for resource allocation :

- Convert the results into undirected graph g= (v, e). Where v denotes vertices and e denotes edges of graph.
- Then find a graph G_m (v_m, e_m) with each sub-band which tells the information



.	1	2	3	4	5	6	7
A	0	0	0	0	1	1	0
B	0	1	1	0	1	1	1
C	1	1	1	1	1	1	1
D	1	0	0	1	0	0	0

Figure 3.9: Matrix for sub-bands that can be assigned to femtocells

of femtocells to which sub-bands can be assigned.

- Femto gateway (FGW) will manage this information because all information regarding location, neighbors etc are managed by FGW.
- In this step a set k is find out on the basis of MIS which include all femtocells to which sub-bands can be assigned without interference.

3.5.5 Criteria Proposed For Handover

Let consider that MUE starts moving towards femtocells and away from MBS.As the distance between MUE and MBS increases, SINR decrease. When MUE moves into the premises of femtocells especially within the indoor environment, it needs to transmit with high power due to walls penetration and high path loss. When MUE starts transmitting with high power, it can create dead-zone area for near-by FUEs. Therefore, there is a need to initiate handover process and check the following conditions before it get worst.

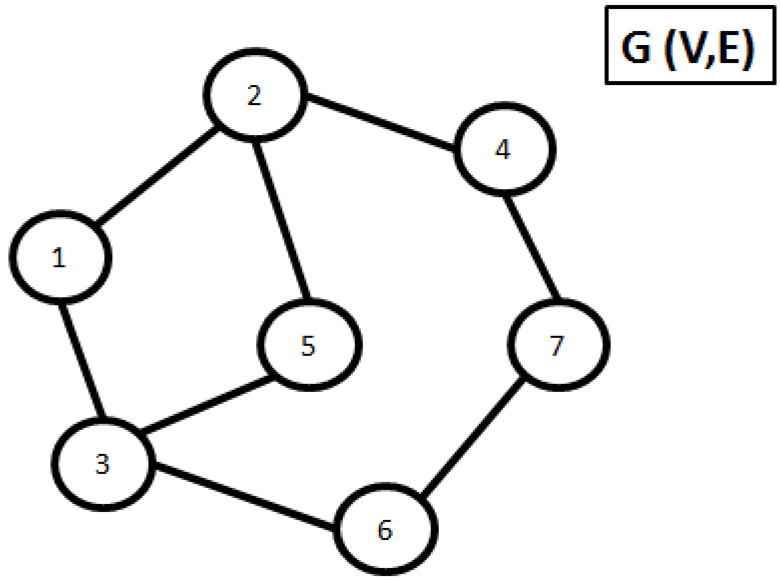


Figure 3.10: Initially undirected graph is formed.Edges are drawn on the basis of distance to avoid intereference between neighboring femtocells

Case 1 : If MUE is moving toward femtocells and SINR starts degrading. If the SINR at FAP $(SINR)_{FAP}$ is greater than preliminary SINR γ_{fH} as well as TTS of MUE $TTS_{i,j}$ in femtocells is greater than normalize TTS threshold TTS_{thF}, then MUE is eligible for handover. Otherwise in case where SINR at FAP $(SINR)_{FAP}$ is greater than preliminary SINR $\gamma_f pH$ but TTS of MUE $TTS_{i,j}$ in femtocells is lower than normalized TTS threshold TTS_{thF}, then there will be no handover.

- If $(SINR)_{FAP} > \gamma_{fpH}$ and $TTS_{i,j}$ $>TTS_{thF}$, then handover takes Place
- If $(SINR)_{FAP} > \gamma_{fpH}$ and $TTS_{i,j} < TTS_{thF}$, then no handover takes place

Case 2 : If the SINR at FAP $(SINR)_{FAP}$ becomes less than preliminary SINR $\gamma_f H$ but greater than actual SINR at FAP. Then check TTS of MUE $TTS_{i,j}$ within femtocells. If TTS of MUE $TTS_{i,j}$ in femtocells is also greater than normalized

TTS threshold TTS_{thF}, then MUE will be eligible for handover. Otherwise if TTS of MUE $TTS_{i,j}$ in femtocells is less than normalized TTS threshold TTS_{thF}, then no handover takes place.

- $\gamma_{fpH} < (SINR)_{FAP} < \gamma_{fH}$ and $TTS_{i,j} > (TTS)_{thF}$ then Handover occurs
- $\gamma_{fpH} < (SINR)_{FAP} < \gamma_{fH}$ and $TTS_{i,j} < (TTS)_{thF}$,no Handover occurs

Case 3 : If MUE keeps on moving toward femtocells then SINR will degrade at FAP $(SINR)_{FAP}$ and if it becomes less than actual SINR γ_{fH}, then handover will take place without further checking either TTS of MUE $TTS_{i,j}$ is less or greater than normalized threshold $(TTS)_{thF}$. There will be no further checking for resource as well.

- If $\gamma_{fH} < (SINR)_{FAP}$, handover will take place.
- This case is not independent on TTS and resource will be allocated on urgent basis for maintaining network performance

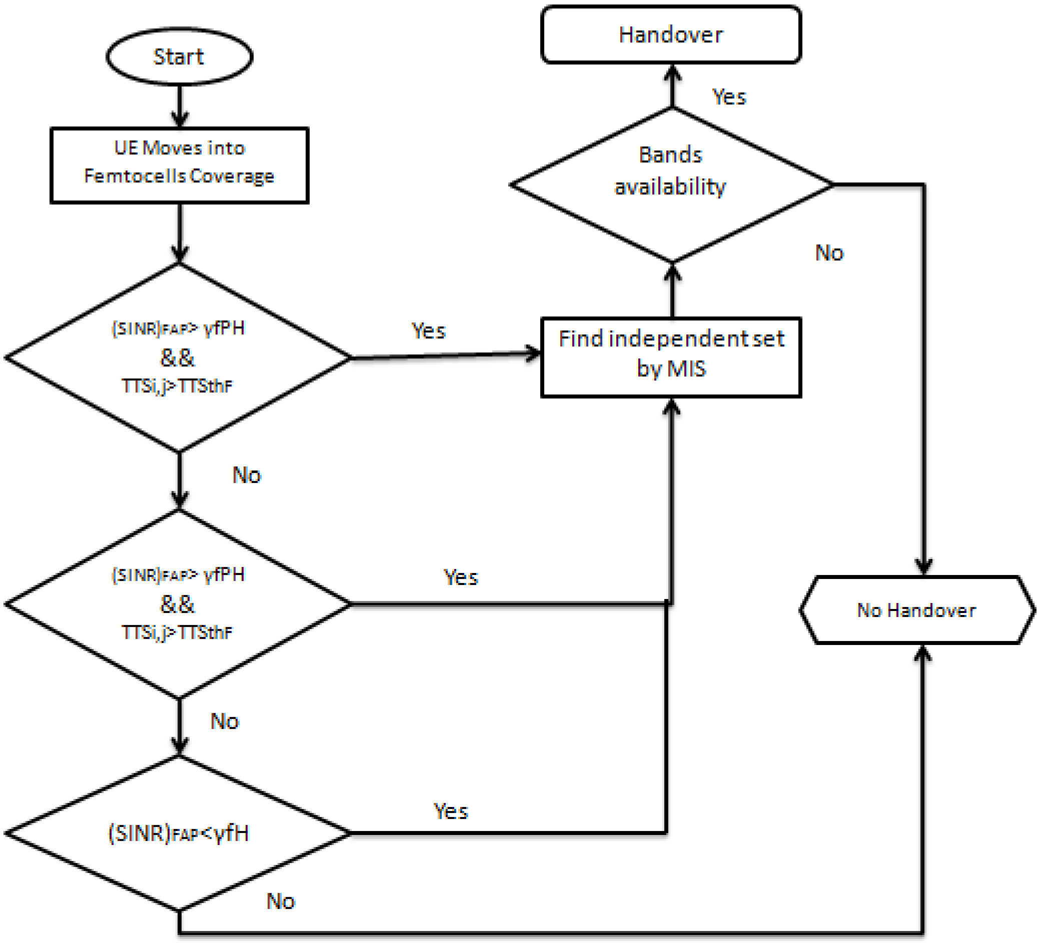


Figure 3.11: FlowChart for proposed Algorithm

Check For Resource Availability

After checking the all cases for SINR and TTS, check for preliminary conditions. If they satisfy the cases required for the handover except in Case 3, then further checking will be done for resources either available in femtocells for assigning to the MUEs that want to associate with FAP. For this, first identify the independent set by using MIS method. FGW has the information about the location, sub-bands availability in femtocells. According to the frequency allocation technique defined in [15], sub-bands allocated to femtocells cannot be used by macrocell. The resources are allocated among the femtocells in order that interference will be minimal and no two adjacent femtocells can use same sub-bands. This means that handover can be made only when resources are available in femtocells, otherwise there will be no handover.

The resource available decision is made by comparing the condition that if handover is necessary w.r.t SINR and time to stay but required resources are not available for FAP, according to MIS to avoid interference, on which handover is required, then no handover will be performed and vice versa.

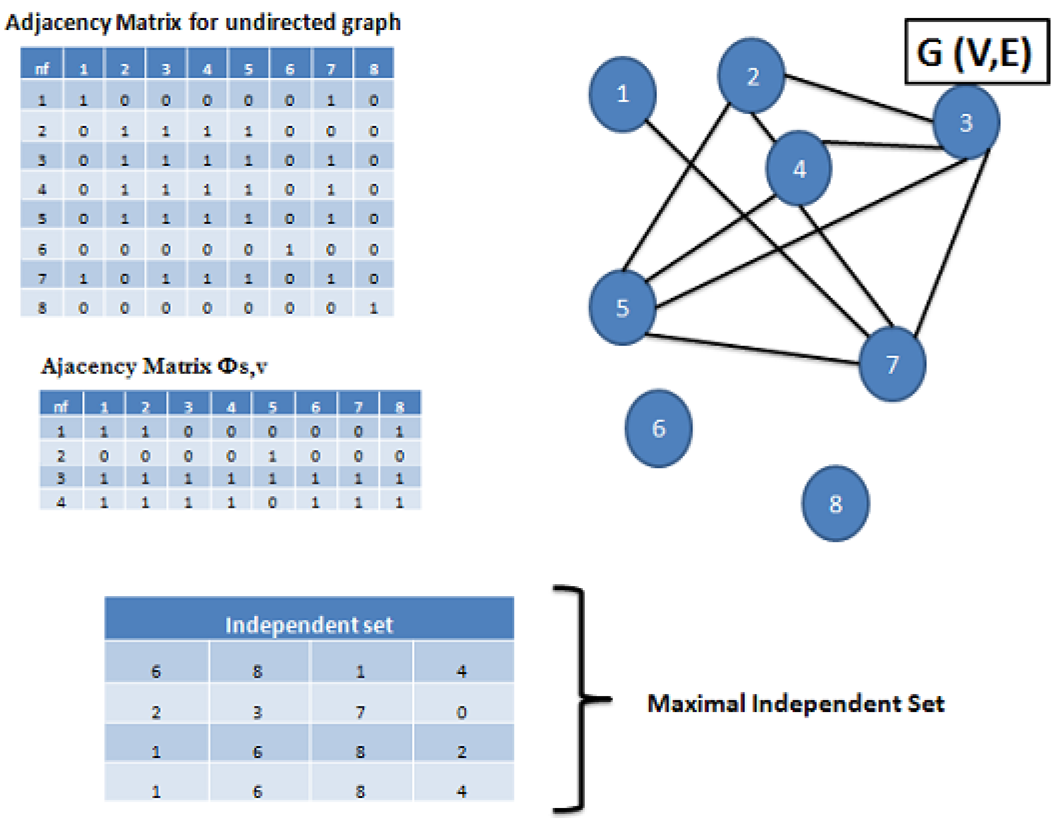


Figure 3.12: Proposed resource allocation algorithm

3.6 Performance Analysis of Network

3.6.1 Outage Probability at FAP

The connection between FUE and FAP will be outage if SINR received at FAP becomes less than minimum SINR threshold i-e $(SINR)_{FAP} \geq \gamma_{fo}$. Therefore, there should be more than one FUE $U_f$in femtocell, so they can transmit with minimum power for transmission. The outage probability at FAP can be calculated as:

$$P_{out}^{f} = P\left(\frac{(Gf.Pr^{f})}{(I(f,f)+I(f,c)+I(f,in)+\sigma_f)} \leq \gamma_{fo} \mid U_f \geq 1 \right) \tag{3.17}$$

$$\left\{ \begin{array}{ll} 0, & (SINR)_{FAP} \geq \gamma_{fo} \\ \frac{\gamma_{fo} - \frac{(G_f.P_r^f)}{(I_{f,f}+I_{f,c}+I_{f,in}+\sigma_f)}}{\gamma_{fo}} & (SINR)_{FAP} < \gamma_{fo} \end{array} \right\}$$

This subject to: $P_f^{out}(N_f, N_c) \leq \varepsilon_f$ Where ε_f denotes the requirement of outage probability at FAP. While σ_f is the log normal attenuation for FAP.

3.6.2 User Sum Rate

The user sum rate of all users using same channel n can be calculated as:

$$R_{MF}^{n}=\theta \sum_{i=1}^{Nf} \log_2[1 + \sin_{Mi}^{c(n)}.P_r^c] + (1-\theta) \sum_{i=1}^{Nf} \sum_{j=1}^{Ui} \log_2[1 + \sin_{Fkj}^{(n)}.Pr^f] \tag{3.18}$$

In this equation, $\log_2[1+\sin_{Mi}^{c(n)}.P_r^c]$ is the achievable rates of MUE_i in the macrocell while $\log_2[1+\sin_{Fkj}^{(n)}.Pr^f]$ is the achievable rates of FUE_{kj} in each femtocells as explained in [27] .

Chapter 4

Results and Comparison

4.1 Chapter overview

This chapter, the method with existing techniques of handover based on SINR, TTS only. Simulated results will be shown for evaluating the performance of the proposed handover algorithm for outage probability, user sum rate and network capacity. Results are aimed at showing reduction in handover based on unavailability of resources.

4.2 Numerical Results

This research shows the proposed schemes in terms of outage probability and SINR with existing techniques. The scenario is consisting of Cellular network in which MBS is covering that area and number of femtocells are varying from 1 to 100 in one macrocell coverage to find out the influence of this variation. The MUEs and FUEs are randomly distributed in the network and random way-point mobility model is used for MUEs movement for each time slot. To show the benefits, proposed algorithm will be compared with the results that are achieved in handover with the algorithms that are only considering handover on the basis of SINR and TTS [21].

Table 4.1: And Differences Between Different Cellular Architecture

Parameters	Value	Parameters	Value
R_c	500 m	R_f	20 m
P_r^f	10 mW	P_r^c	1 mW
G_m	50	G_f	10
d_{oc}	100 m	d_{of}	5 m
γ_{fH}	3	γ_{fPH}	5
TTS_{thF}	8 min	U_f	5
N_c	10	v	20 km/hr
α	4	β	2
$d_{threshold}$	40 m	f	2 GHz

In the figure 4.1, We can see that unnecessary handovers are increasing exponentially with increase in number of femtocell. While we can achieve significant reduction in handovers by using our proposed algorithm.

In figure 4.2, it is shown that SINR is decreasing with the increase in femtocells rapidly with our proposed method if we compare it with previous scheme [21]. This is because we are considering resources and we are not performing handover if resources are not available even if SINR is degrading. While SINR received from method proposed in [21] is not degrading rapidly because they are assuming infinite resources. In figure 4.3 , we can see that we are getting better results for user sum rate from our proposed scheme and it decay slowly than the previous scheme proposed [21].

In figure 4.4, femtocell outage probability calculated from our proposed scheme is increasing as number of femtocells are increasing and reaching 0.9. While outage probability calculated from previous scheme [21] is relatively low. Because we are considering resources due to which even if connection between FAP and FUE is an outage due to degradation of SINR at FAP, we cannot perform handover. Resources need to be taken into account while performing handover. The results of SINR and TTS based handover are better in terms of SINR at FAP and OP because it is

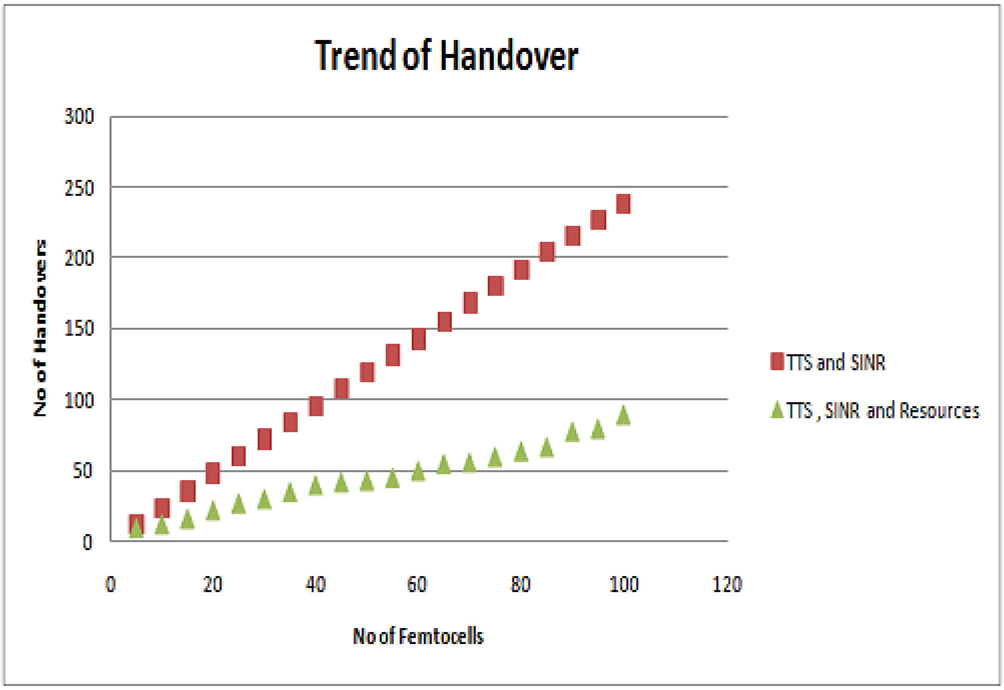


Figure 4.1: Handovers received at FAP vs SINR and TTS

assumed in the study that resources are available for handover. However, this is not a practical assumption. In the proposed scheme, since there are limited resources, therefore SINR falls below that of [21]

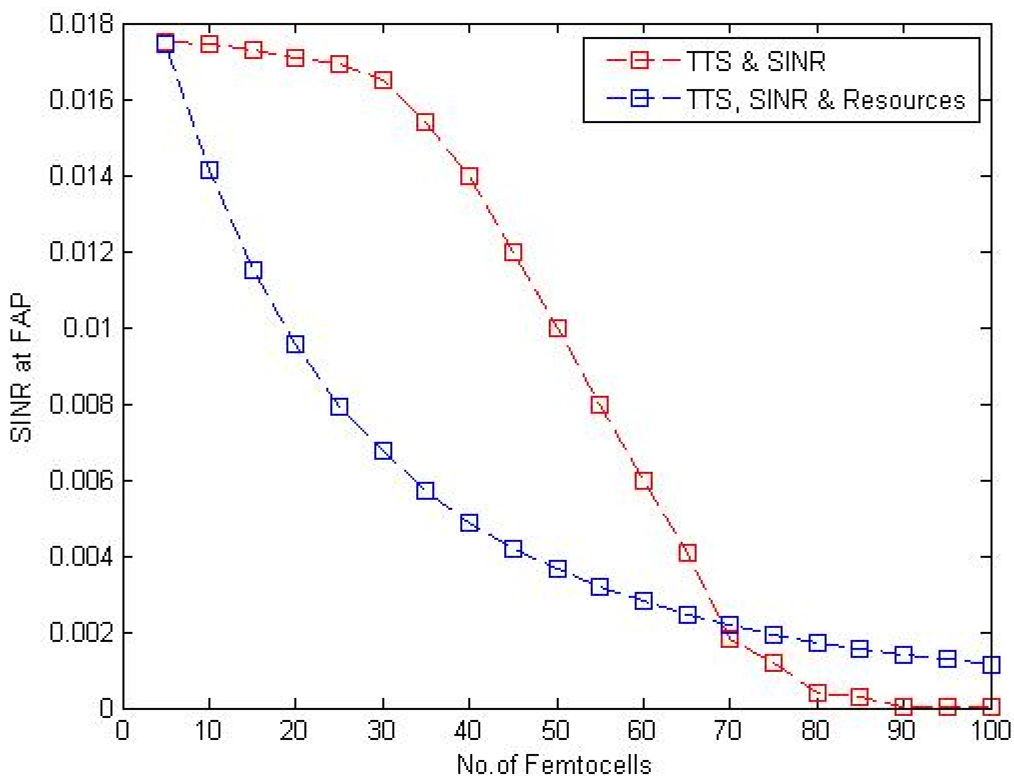


Figure 4.2: SINR received at FAP

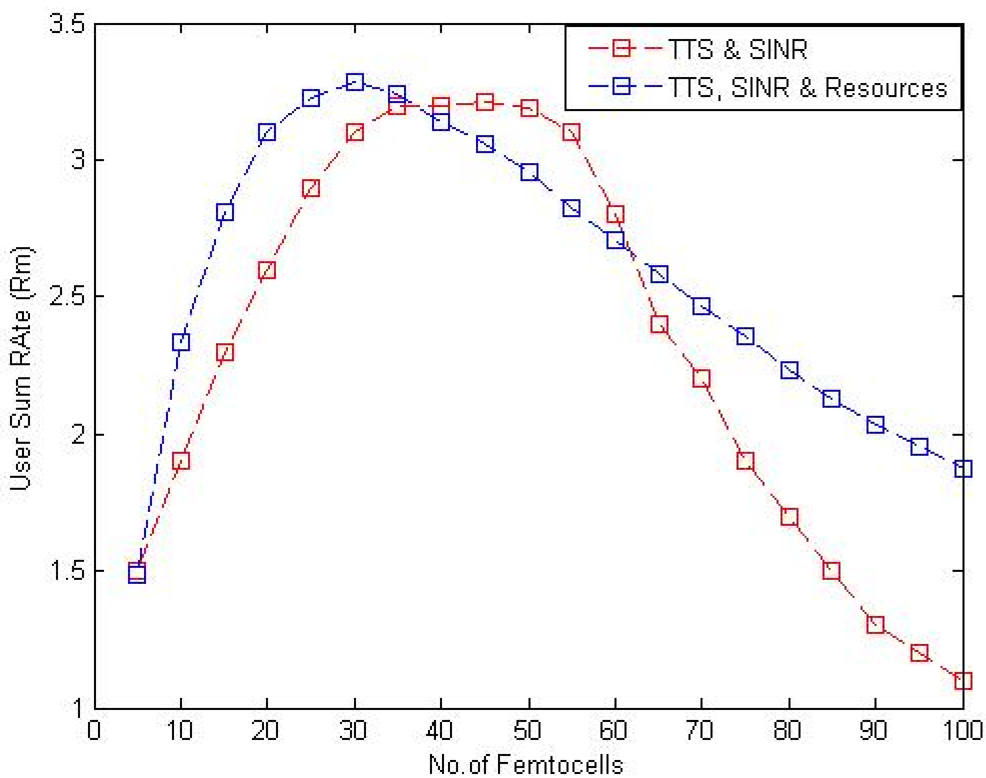


Figure 4.3: User Sum Rate

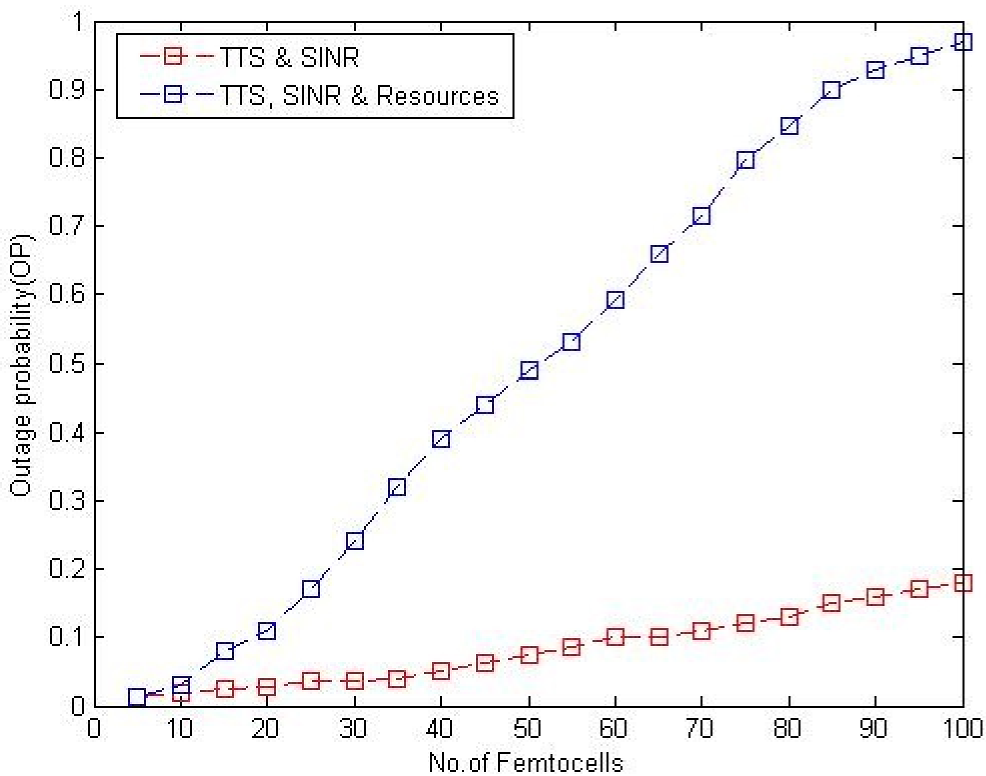


Figure 4.4: Femtocell Outage Probability

Chapter 5

Conclusion and Future Work

In this research, interference and resource allocation strategy is used for making handover decision to avoid unnecessary handovers.From the results ,it can be concluded that promising results can be achieved if handover is made on the basis of SINR ,TTS and resource availability. By comparing the proposed method with the previous research [21] which two important parameters i-e SINR and TTS are considered,conclusion can be made that there is a decrease in handover if resource availability is also considered because resource availability can't be ignored. From previous studies, this can be concluded that SINR,TTS and resources are three main parameters that need to be checked .In future, there is need to dig down about more important parameters that can be checked for improving results.In this research ,there is limitation because GPS data is not used, in future results can be improved by taking realistic approach. Secondly, RWP mobility model is used in this research, other mobility models can be used according to particular scenario. Number of FUEs and MUES can be increased in future research to check impact of proposed algorithm in populated area. In this research, femtocell are distributed in unplanned manner,in future if requirement is for planned femtocell architecture, then this proposed algorithm can be used according to the requirement.

Appendix A – Communication Systems Symbols

$\mathbf{P}_r^f$	Power received by the FAP,
$\mathbf{P}_r^c$	Power received by the MBS ,
$\mathbf{U}_f$	Number of Femto users
$\mathbf{N}_c$	Number of Macro users
$\mathbf{I}_{f,f}$	The neighboring femtocell interference
$\mathbf{I}_{f,c}$	The macrocell interference
$\mathbf{I}_{f,in}$	The femtocell intra-cell interference
$\mathbf{I}_{c,in}$	The macrocell interference at the MBS
$\mathbf{I}_{c,f}$	The macrocell interference at the MBS
$\mathbf{g}_f$	Indoor attenuation factor
$\mathbf{g}_c$	Outdoor attenuation factor
σ_{db}	log-Normal Shadowing is parameterized by standard deviation
γ_{fPH}	Preliminary Handover Threshold
γ_{fH}	Actual Handover
$\mathbf{TTS}_{i,j}$	Time to Stay of user within cell
$\mathbf{TTS}_{thF}$	Time to Stay for handover

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