# Soft Frequency Reuse-based Interference Mitigation in Irregular Geometry Heterogeneous Networks

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**Abstract**
To counter the exponential data traffic growth, the fifth-generation (5G) communication system has significantly improved the system capacity and spectral efficiency. A heterogeneous network (HetNet) has been investigated recently as a potential evolved underlying network. In HetNet, the random deployment of small cells has overcome the hindrance of indoor coverage and capacity. However, at the cost of increased co-tier and cross-tier interference. Therefore, effective resource allocation (RA) algorithms are crucial to minimize mutual interference and achieve spectrum sharing in HetNets. A notable ICI mitigation strategy is the Soft Frequency Reuse (SFR) technique, however, in literature, SFR has been used mostly in perfect geometry networks such as Hexagonal geometry networks. Each cell in a realistic deployment seems to have a different ICI as well as an uneven cellular topology. In this work, a dynamic SFR scheme has been proposed for irregular geometry-based HetNet. To handle indoor coverage problems due to propagation path loss, Femtocells are deployed randomly in Macro base stations. SFR scheme is used for heterogeneous networks where cell structures are irregular and the partitioning of cells is based on the average threshold SINR value. Frequency Bands are allocated dynamically with a different number of users in the cell center and cell edge. To avoid cross-tier interference, the frequency bands are assigned in a manner that no same frequency bands are shared by Femto users and Macro users in the cell center and the cell edge. The proposed SFR scheme is analyzed and compared with the traditional SFR scheme. The obtained results show that Proposed SFR significantly improved the SINR and achievable throughput of both Macro and Femto users.

***Keywords:***
*Heterogeneous Networks, Irregular Geometry Model, Dynamic Spectrum Allocation, Soft Frequency Reuse.*

## 1. Introduction

The fifth-generation (5G) mobile communication system is intended to increase capacity 1000 times compared to the fourth-generation (4G) while the spectrum efficiency (SE) of the 5G system improves 5–15 times, in response to the exponential growth of mobile data traffic [1]. Cellular system deployment has reached practical limits in many dense urban areas whereas; the data traffic continues to proliferate. Cellular operators are left with few alternatives to enhance the most significant metric: area spectral efficiency. Unfortunately, radio link improvements such as coding, cognitive transmission, and multiple antennas are feats to their theoretical limits[2]. Consequently, network operators are revisiting typical cellular system topologies and are considering a new paradigm [2]. Wireless networks rehabilitated from homogeneous networks (HomNets) to heterogeneous networks in terms of network architecture (HetNets). Third Generation Partnership Project (3GPP) had originally implemented HetNet in Release 12. By sharing the same spectrum resources (SRs), HetNet enables various kinds of small cells to cohabit alongside macrocells, greatly enhancing SE and coverage [3].

The unplanned deployment of small cells in HetNets has significantly increased the network capacity and coverage, however, but it also increases Inter-Cell Interference (ICI). To mitigate ICI, frequency utilization is the main technique being followed. The problem in frequency utilization is interference which occurs when the same spectrum is used throughout HetNet. Normally there are two types of interferences, co-tier interference and cross-tier interference [4]. Co-tier interference exists between two same cells which share the same sub-channels for communication. To increase the performance of a cell such interference must be decreased with proper interference mitigation schemes. Cross-tier interference occurs between two different cells that are in the Macrocell and Femtocell network. Femtocells when deployed within a Macrocell environment and using the same spectrum as Macro-cell, might create a problem of cross-tier interference. Here Macro cell User Equipment (MUE) experiences ICI due to nearby FBS or nearby FUE. Similarly, FUE experiences ICI due to nearby MUE or nearby MBS as shown in Figure 1. The main focus of this work is to mitigate cross-tier interference in HetNets while considering irregular geometry cellular networks.

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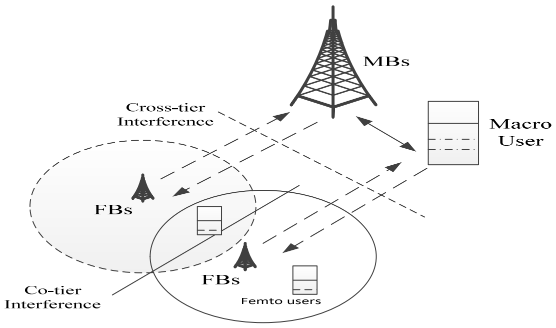


Fig. 1. Co-tier and Cross-tier Interference in Macro and Femto Cells

## 2. Related work

Frequency Ruse-based ICI mitigation schemes are proposed in the literature to reduce inter-cell interference and improve the performance of the system. In this regard, Fractional Frequency Reuse (FFR) and Soft Frequency Reuse (SFR) have gained considerable attention in the recent past [5].

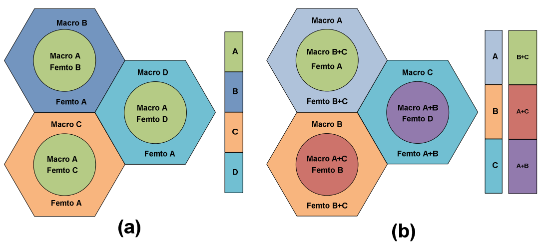


Fig. 2. (a) FFR for HetNet, (b) SFR for HetNet

The underlying feature of FFR is the partitioning of the service area into spatial regions, where each sub-region is offered a unique set of frequency sub-bands. Each cell's interior region is allocated a common frequency band, however, the bandwidth for the cell's edge users is redistributed across the cell based on the frequency reuse factor, therefore in strict FFR terms, a total of $\delta + 1$ sub-bands is needed. Basic-FFR scheme for HetNet with two tiers is illustrated in Figure 2(a), where the vertical bar represents different sub-band that is used by both MUs and FUs in the cell. Since MUs at the cell center don't really share any bandwidth with MUs at the edge of the cell, interference both for cell-edge as well as cell-center users has been considerably reduced.

Figure 2(b) shows the SFR scheme for the same HetNet with a frequency reuse factor of $\delta = 3$, just use the same spectrum partitioning mechanism as Strict FFR. The only distinction is that in SFR, cell edge users at other cells are permitted to share their allowed bandwidth with users in the cell center. There are a total of $\delta$ sub-bands available in SFR since no distinct band is intended for users of cell centers. SFR is more effective than Strict FFR in the perspective of resource utilization. However, the cell-center and cell-edge region consumers experience increased interference as a result [6].

The Fractional Frequency Reuse (FFR) is adopted [7] which uses the same power for both edge and center users thus reducing interference at cell-center and cell edge regions but low bandwidth efficiency. In [8] the Soft Fractional Frequency Reuse [SFFR] is used to increase FFR throughput but the scheme was for perfect cell geometry. Further Dynamic Fractional Frequency Reuse (DFFR) is used where the resource allocation is done depending on users in a cell, both at the cell center and cell edge but this scheme is carried out with perfect cell geometry.

The Soft Frequency reuse scheme is used in which a cell is divided into center and edge zone. The spectrum is divided into three bands where one-third of the band is used for the cell edge with the greater transmission power and the remaining band is used by the cell center with lower transmission power [9]. In a real scenario, SFR Scheme is used for irregular cell geometry [10], where the cell edge and cell center users are differentiated on basis of distance from MBs. In the proposed model the center and edge users are differentiated on basis of average received SINR. Here the irregular heterogeneous model of the cellular system is considered which shows the realistic scenario of different users in different Base Stations. User capacity demand and ICI issue due to dense and unplanned deployment of FBs are taken into account with dynamic spectrum allocation based on SFR scheme for Femto and Macro users.

The frequency reuse algorithm concept in cellular networks allows the users in different cellular cells to use the same frequency band, because of available bandwidths. Thus increasing the spectral efficiency and capacity of the system. Proper planning must be needed to avoid interference as the same bands were reused by different users. The parameters used to examine the performance of any cellular network using the FR algorithm are center radius, power ratio (to set different power at center and edge), and users' density at an area. These parameters affect the interference of BS to users, users' equipment (UE) bandwidth, and calculating the SINR and Capacity/Throughput of UE. Different research works were carried out in the literature review to show the performance of FR schemes. In [11] the FR scheme varies over different center radii and power ratios. In [12] capacity of users is calculated using SFR with different densities of users and power ratios. Different FR schemes are compared and analyzed, where probabilistic calculations were made to calculate SINR, capacity, and spectral efficiency with different center radii and power ratios.

In [3] FFR scheme was considered where irregular heterogeneous networks are considered where cell partition is considered on basis of SINR, the resources are allocated on basis of center and edge users. In [13] a dynamic FFR algorithm is proposed for realistic cellular networks. The spectrum is divided based on the diverse traffic demand generated at each sector of the cell. In [14] SFR is considered as a frequency reuse scheme where irregular heterogeneous cellular cells are considered realistic assumptions for BS deployments. The center and edge regions in a cell are considered based on specific radii. The deployments of the users are considered randomly where SINR and capacity are calculated based on varying cell center radii and varying power ratios. In [15] the FR-1, FR-3, FFR, and SFR are compared with hexagonal cellular cells and irregular homogeneous cellular cells. The users' performance is calculated in terms of SINR in dB and Throughput in Mbps.

In [3], [13], [16], the FFR scheme is introduced for irregular multi-cellular networks, the cell partitions were based on Threshold SINR *(Γ)*, the SINR greater than *Γ* is considered to be cell center users, and SINR smaller than *Γ* is considered to be cell edge users. Further cell sectoring is also considered to allocate frequencies based on the FFR scheme. The frequencies are shared among the cell center and cell edge sectors are in such a manner that no adjacent sectors are allocated with the same frequencies. The MBs and FBs are allocated with different frequencies and also cell center and cell edge shared different frequency bandwidths to avoid interference.

In [10], the SFR scheme is used for irregular heterogeneous networks, where Macro and Pico base stations are defined. Here the Cell is partitioned into cell-center and cell-edge based on the distance from MBs. The users nearer to MBs are termed cell-center users and at the boundary are edge users. The frequency allocation is based on SFR, where the probabilistic nature of ICI is taken into account. The given model extended my work where the cell partition is based on average received SINR, threshold SINR (*Γ*). Here in the proposed model the threshold SINR is considered 11dB. A different spectrum is allocated to Femto and Marco BS. The allocation of spectrum is based on user demands and to avoid Interference. In the proposed model the distances of a user from its MB and neighbor MB are considered randomly.

Besides Frequency Allocation techniques, Power allocation techniques are carried out to mitigate interference in Multi-tier networks. Mainly two Power allocation strategies are found in different frequency mitigation techniques. One in FR-1, FR-3, and FFR scheme where the transmission power is the same for both the center and edge users. Second in SFR where the transmission power is lower for cell center users and high for cell-edge users. The same spectrum can be allocated to edge and center users as they have different power levels.

## 3. System Model

The system model considers a two-tier multi-cellular network with the irregular geometry of the cell region to capture the realistic deployment. The proposed network topology is shown in Figure 3, where the inverted triangle shows the Macro Base Stations (MBs) distributed according to Poisson Hard Core Point Process (HCPP) [17], and the small dots represent the randomly distributed Mobile Stations (MSs), the orange circles with a dot represent the randomly deployed Femto-cells with a Femto Base Station(FBSs) at the center.

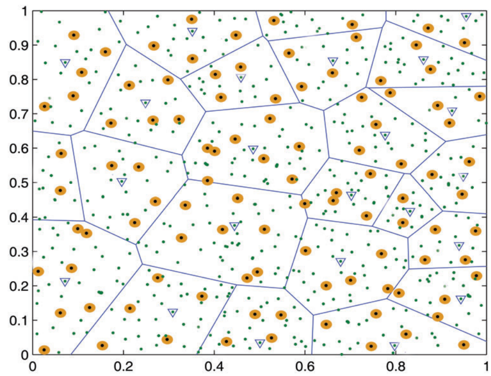


Fig. 3. Two-tier network topology

A Femto-cell is a short-range, low-cost, and small power base station that are placed to improve indoor coverage to the users where macro cell signals are weak. A Femto-cell is considered to have a coverage radius of 10m and a transmission power of 5 dB. For the scenario, Femto-cells are deployed randomly, both at the cell center and cell edge regions. Femto-cell deployment is further elaborated in Figure 4. Four users are considered for each Femtocell. The Femtocells are deployed in such a manner so that no interference is assumed for macro users with Femto eNB. In Figure 4 the macro users are distributed in cell center and cell edge regions randomly along with Femto users.

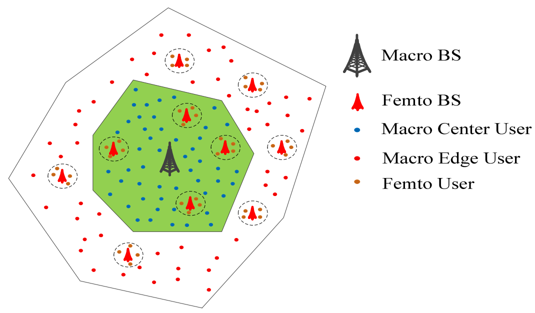


Fig. 4 Macro and Femto users' deployment

As to follow Soft Frequency Reuse (SFR) the cell region must be divided into two portions the cell center region and the cell edge region. SFR method is used to distribute users into the cell center region and cell edge region. To do this a threshold SINR value is considered which differentiates center and edge users. The threshold

SINR is calculated by considering a scenario where three Macro Base Stations (MBs) are randomly selected as shown in Figure 5. One BS is considered as a reference for which SINR is to be calculated for mobile users. Two other BSss are considered as interference base stations. A fixed distance between two macro base stations is considered equal to two times the coverage radii of the cell. A reference line $L_R$ is considered which makes an angle θ (θ = 0° and θ=60°) between reference base station and interference base stations.

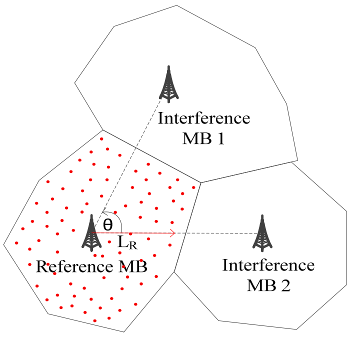


Fig. 5. Proposed Scenario for Center and Edge users

The SINR for a macro user is calculated randomly with two interfering macro base stations randomly, using Equation (1).

$$SINR_{MU} = \frac{P_{MBs} H_{MBs} D_{MBs}}{N_P + \sum P_{I_{MBs}} H_{I_{MBs}} D_{I_{MBs}}} \quad (1)$$

Where $P_{MBs}$, $H_{MBs}$, $D_{MBs}$ are transmitting Power, fading component between, and path loss difference between a macro user and reference MB respectively. $P_{I_{MBs}}$, $H_{I_{MBs}}$, $D_{I_{MBs}}$ are transmitting power, fading component, and path loss related to interference MBs. $N_P$ is considered to be unwanted signal (noise) power which is considered 0 dB for the scenario. $D_{MBs}$, in terms of distance is calculated by using Equation (2).

$$D_{MBs} = (y)^{-\alpha} \quad (2)$$

Where y is the distance between the macro user and reference base station and $\alpha$ is the path loss exponent [19]. Similarly $D_{I_{MBs}}$is calculated by using Equation (3).

$$D_{I_{MBs}} = (d)^{-\alpha} \quad (3)$$

where $d$ is the distance between a macro user and interference MB and is termed as the interfering distance that is calculated by graphical addition of vectors for a user or by using cosine mathematical equation for an oblique triangle as shown in figure 3.3, ϕ is the angle between macro user and $L_R$ which ranges for the proposed model between [-90, 90], $d$ can be calculated by using Equation (4) as in response with the Figure 6.

$$d = \sqrt{y^2 + (2R)^2 - 2 * y(2R) * \cos(\theta - \phi)} \quad (4)$$

Where R is the coverage radii of macro base stations. The interfering distance, d varies between Macro BS as it depends on θ and ϕ so for a user, d changes with interference Macro BS. Normally its value ranges between [R, 3R]. Where x presents the distance between a macro user and its BS.

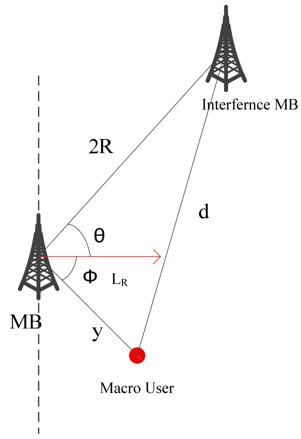


Fig. 6. Interfering distance

## 4. Proposed SFR Scheme

In the proposed SFR scheme, the partition of the cell is based on threshold SINR where frequency bandwidth is allocated randomly depending on the number of users at the center or edge region. Here the comparison is made between General SFR and Proposed SFR. The frequency is allocated to Femto users following the Macro users to avoid interference. Figure 7 represents dynamic frequency allocation for macro users. The Macro users are allocated randomly with several different subcarriers to improve the users' capacity (Mbps). The dynamic frequency bandwidth indicated with $f_{ce}$ that varies randomly following the number of macro users in the cell center and cell edge regions. More users at the center will get more bandwidth and vice-versa.

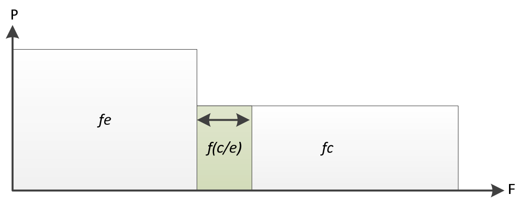


Fig. 7. Dynamic Frequency Partition for Macro Users

To check the performance of mobile users, SINR and capacity are two terms that are used to be calculated in terms of dB and Mbps respectively. SINR is considered to express the quality of cellular networks. Better SINR means a user can receive better signal quality. SINR depends upon the transmitting power of the antenna and interference from the interfering antenna. Where capacity is considered to express data rate in Mbps that depends upon the available bandwidth allocated to mobile users and SINR. Here SINR equations and capacity equations are expressed to define the performance of a mobile user. As the cellular cells are divided into center and cell regions, SINR is calculated separately for both regions. To apply a simple formula for SINR that depends upon transmitting power and interference from a base station is shown in equation (5).

$$SINR = \frac{Transmitting\ Power}{Noise + Interference} \quad (5)$$

SINR is calculated for Macro users in the center and the edge, following bandwidth allocation to users that are shown in Figure 8. For calculating SINR for different macro users consider the scenario as shown in figure 3.7. Similarly, SINR for Femto users at the center of the Macro cell and Femto users at the edge of the Macro cell is calculated based on the same scenario.

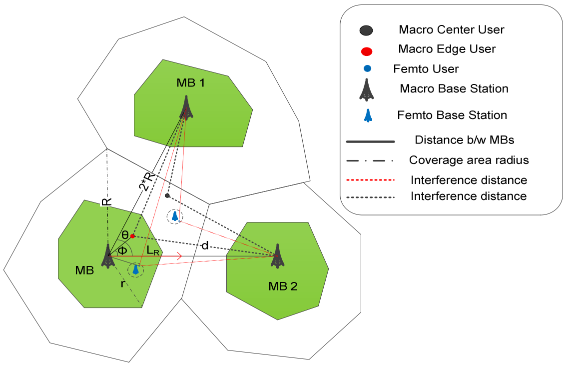


Fig. 8. Proposed Model for Macro and Femto users

Where $R$ is the coverage distance of Macro BS, $r$ is the center coverage radii of the corresponding Macro cell, $d$ is the distance between a user in reference Macro cell and interfering Macrocell (MB 1 or MB 2). The distance $d$ can be calculated using Equation (4) for both Macro or Femto users. The noise component is considered 0 dB for all users. SINR for Macro users is calculated in such a manner that Femto base stations are positioned in such a way that no Femtocell interference is considered for the scenario. Transmitting power depends upon the antenna of MB and interference is considered with the interfering MB with the cell region. SINR for $g$ number of Macro center users is calculated using Equation (6) and for $g'$Macro edge users using Equation (7).

$$SINR_{m_c}^{g} = \frac{P_m^c * H_m^c * (y_m^c)^{-\alpha}}{N_p + \sum_{i=1}^{I_m} P_m^{I_c} * H_m^{I_c} * (d_i)^{-\alpha} + \sum_{i=1}^{I_m} P_m^{I_e} * H_m^{I_e} * (d_i)^{-\alpha}} \quad (6)$$

$$SINR_{m_e}^{g'} = \frac{P_m^e * H_m^e * (y_m^e)^{-\alpha}}{N_p + \sum_{i=1}^{I_m} P_m^{I_c} * H_m^{I_c} * (d_i)^{-\alpha}} \quad (7)$$

Where $SINR_{m_c}^{g}$ and $SINR_{m_e}^{g'}$ represent SINR of Macro center and Macro edge users. $P_m^c$, $H_m^c$, $y_m^c$ represent transmitting power, fading component, and distance between Macro center users and reference Macro cell. $'\alpha'$ represents the path loss exponent. $I_m$ represents the number of interfering Macro base stations, here only two are considered. $P_m^{I_c}$, $H_m^{I_c}$ are transmitting power and fading component between a macro center user and interfering MB. $P_m^{I_e}$, $H_m^{I_e}$ are transmitting power and fading component between a Macro center user and interfering MBs but with the edge, power is considered. $d_i$ represents the interfering distance following Equation (4) which varies from user to user and from interference MB to MB. $P_m^e$, $H_m^e$, $y_m^e$ are transmitting power, fading component, and distance of edge user with corresponding MB.

Macro center power and Macro edge power varies following the power ratio (μ). Using SFR edge power is taken greater than center power as shown in Equation (9).

$$P_T = P_m^c + P_m^e \quad (8)$$

Where $P_T$ is the total transmitting power for a Macro cell.

$$P_m^e = \mu * P_m^c \quad (9)$$

Putting Equation (9) in Equation (3.8) so to get,

$$P_T = P_m^c + \mu * P_m^c \quad (10)$$

$$P_T = (1 + \mu)\, P_m^c \quad (11)$$

The total power is divided into center and edge power by using Equation (11).

Similarly, SINR for $h$ number of Femto users is calculated in the same scenario by using equation (12) at the center of the macro cell and equation (3.13) for $h'$ number Femto users at the edge of a macro cell.

$$SINR_{f_c}^{h} = \frac{P_f^c * H_f^c * (y_f^c)^{-\alpha}}{N_p + \sum_{i=1}^{I_m} P_m^{I_c} * H_m^{I_c} * (d_i)^{-\alpha} + P_m^e * H_m^e * (d_f)^{-\alpha}} \quad (12)$$

$$SINR_{f_e}^{h'} = \frac{P_f^e * H_f^e * (y_f^e)^{-\alpha}}{N_p + \sum_{i=1}^{I_m} P_m^{I_c} * H_m^{I_c} * (d_i)^{-\alpha} + \sum_{i=1}^{I_m} P_m^{I_e} * H_m^{I_e} * (d_i)^{-\alpha} + P_m^c * H_m^c * (d_f)^{-\alpha}} \quad (13)$$

In Equation (12), interference includes a macro interfering base station and reference MB as interference for Femto users. Similarly, in equation (13) the interference includes the center and edge of interfering MB and reference MB. Where $SINR_{f_c}^{h}$ is the SINR of Femto users present at the center region of the macro cell. $SINR_{f_e}^{h'}$ is the SINR value of Femto users present at the edge region of the macro cell. $P_f^c$, $H_f^c$, $y_f^c$ and $P_f^e$, $H_f^e$, $y_f^e$ are the transmitting power, fading component, and distance of a Femto user and its corresponding Femto Base station (FB). $d_f$ is the distance between a Femto user and reference MB, calculated using equation (3.4). The SINR in dB is calculated using equation (3.14).

$$SINR\ (dB) = 10 * \log(SINR) \qquad (14)$$

Another important parameter is considered that affects the performance of a mobile user is data rate or capacity, measured in Mbps. For the proposed model the capacity for macro and Femto users is calculated by using Shannon's equation. The capacity for $g$ numbers of Macro center users is calculated by using Equation (3.15).

$$Cap_{m_c}^{g} = \Delta f * log_2\left(1 + SINR_{m_c}^{g}\right) \quad (15)$$

Where $Cap_{m_c}^{g}$ are the capacity (Mbps) for g Macro center users and $\Delta f$ is the available subcarrier to a user. The overall capacity (Mbps) of $g$ macro center users with k number of subcarriers is calculated using Equation (3.16).

$$R_{m_c}^{T} = \sum_{k=1}^{k}\sum_{g=1}^{g} \delta_k^g\ Cap_{m_c}^{g} \qquad (16)$$

Where $R_{m_c}^{T}$ is the total capacity of macro center users, $\delta_k^g$ represent k subcarriers allocated to $g$ macro users, these $k$ subcarriers are allocated depending on user demand to improve the capacity of a user.

$$\delta_k^g = \begin{cases} 1; & if\ k\ subcarrier\ is\ allocated\ to\ user\ g \\ 0; & otherwise \end{cases} \qquad (17)$$

Similarly, the Data rate for macro edge users is calculated by using Equation (18).

$$Cap_{m_e}^{g'} = \Delta f * log_2\left(1 + SINR_{m_e}^{g'}\right) \qquad (18)$$

Where $Cap_{m_e}^{g'}$ is capacity for $g'$ macro edge users. The overall capacity (Mbps) for $g'$ macro edge users with $j$ number of subcarriers are calculated using equation (19).

$$R_{m_e}^{T} = \sum_{j=1}^{j}\sum_{g=1}^{g'} \delta_j^{g'}\ Cap_{m_c}^{g'} \qquad (19)$$

Where $R_{m_e}^{T}$ is the total capacity (Mbps) for macro edge users, $\delta_j^{g'}$ shows j subcarriers allocated to $g'$ macro edge users.

similarly by using Equation (20) and Equation (21).

$$Cap_{f_c}^{h} = \Delta f * log_2\left(1 + SINR_{f_c}^{h}\right) \qquad (20)$$

$$Cap_{f_e}^{h'} = \Delta f * log_2\left(1 + SINR_{f_e}^{h'}\right) \qquad (21)$$

Where $Cap_{f_c}^{h}$ is capacity of h Femto users at center and $Cap_{f_e}^{h'}$ is the capacity of $h'$ femto users at the edge. Similarly, the overall data rate for Femto users is calculated by using Equations (22) and (23), respectively. Where $R_{f_c}^{T}$ is the total capacity for Femto users at the center, $\delta_j^h$ is j subcarriers allocated to h Femto users and $R_{f_e}^{T}$ is the total capacity for Femto users at the edge, $\delta_k^{h'}$ is k subcarriers allocated to $h'$ femto users. The k subcarriers are allocated to center macro users and Femto users at the edge to avoid interference. Capacity (Mbps) for the Femto users center is calculated

$$R_{f_c}^{T} = \sum_{j=1}^{j}\sum_{h=1}^{h} \delta_j^h\ Cap_{f_c}^{h} \qquad (22)$$

$$R_{f_e}^{T} = \sum_{k=1}^{k}\sum_{h'=1}^{h'} \delta_k^{h'}\ Cap_{f_c}^{h'} \qquad (23)$$

Simulation and designing of the proposed model are carried out in MATLAB. The step-by-step process of the proposed SFR algorithm is presented in a detailed flow chart as shown in Figure 9.

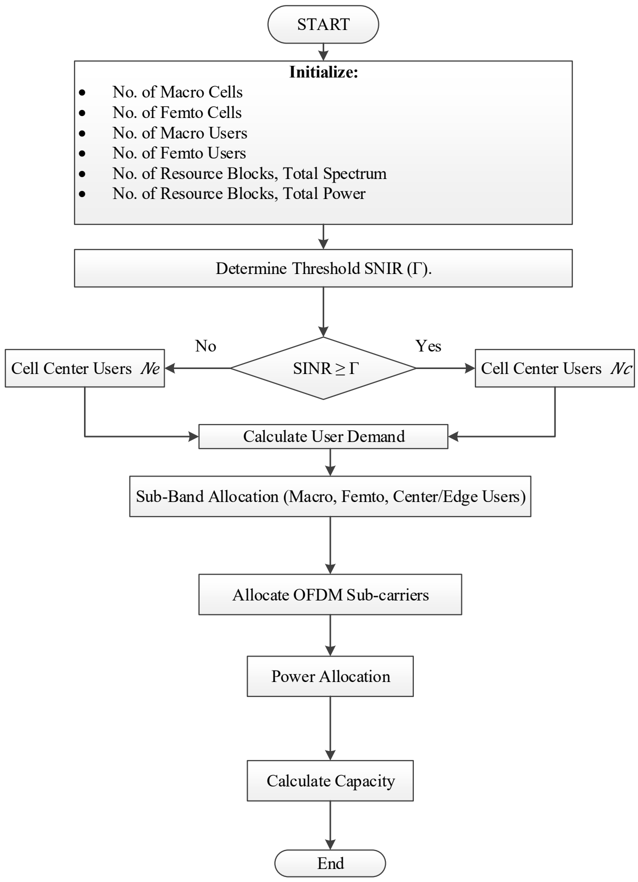


Fig. 9. Detailed Flow Chart of the proposed SFR scheme.

## 4. Performance Evaluation of the proposed SFR

In this section, the results obtained for the performance of mobile users in terms of SINR, capacity, and average sum rate are discussed.

### 4.1 Simulation Parameters

The simulation parameters are shown in Table 1. For the scenario, 100 numbers of Macro mobile users are considered that are randomly arranged in an irregular pattern. SINR is calculated randomly to decide the number of users in the cell center and cell edge areas. A threshold SINR ($\Gamma = 11dB$) is considered to decide cell center and cell edge mobile users. The distance between two Macro BS is kept constant with 2R.

Table 1: Simulation parameters

| ***Parameters*** | ***Values*** |
|---|---|
| LTE Downlink Configuration | OFDMA |
| Available System Bandwidth | 10 MHz |
| Number of Macro Users | 100 |
| Number of Femto BS | 10 |
| Number of Femto Users | 40 |
| Total Transmitting Power, $P_T$ | 43 dB |
| Macro Cell Center Power, $P_m^c$ | 15.93dB |
| Macro Cell Edge Power, $P_m^e$ | 27.07dB |
| Femto Cell Power, $P_f^c$ | 5dB |
| Macro Cell Coverage Radius, R | Variable |
| Macro Cell Center Radius, r | Variable |
| Interference Distance, d | [R, 3R] |
| Femto Cell radius | 10m |
| Fading Component, H | 1 |
| Path loss Exponent, α | 3 |

### 4.2 Performance of Macro Users

For the SFR algorithm, the Macro cell is divided into two regions the cell center and cell edge. Here the Macro users' performance on SFR is compared with fixed distance partition and threshold-based partition of the cellular cell. For distance-based partition a fixed distance is considered from MBs which is taken as radii for the cell center, the fixed distance partition is termed as general SFR for which 50 macro users are considered in the cell center and 50 macro users are considered at cell edge region. And for the threshold value partition that is considered to be the proposed model, has 40 macro users at the center and 60 users at the edge region. The comparison is based on general SFR with the proposed allocation of bands in SFR. Same subcarriers are allotted to users in general SFR while in the proposed scheme the frequency bandwidth is allocated to users randomly with a different number of subcarriers to improve their capacity or data rate.

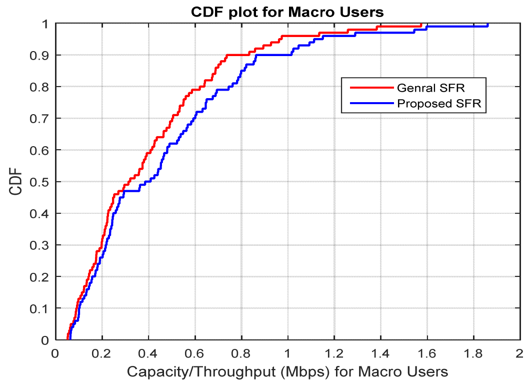

Fig. 10. Throughput for General and Proposed SFR Macro users

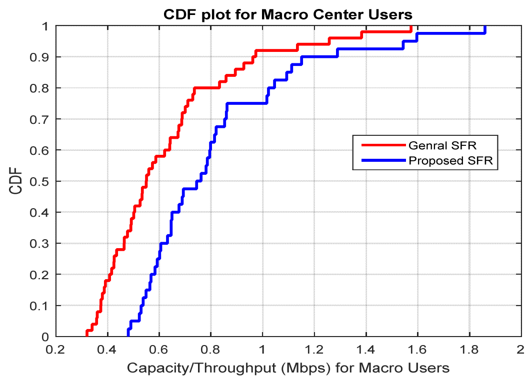

Fig. 11. General and Proposed SFR comparison for Macro Center users

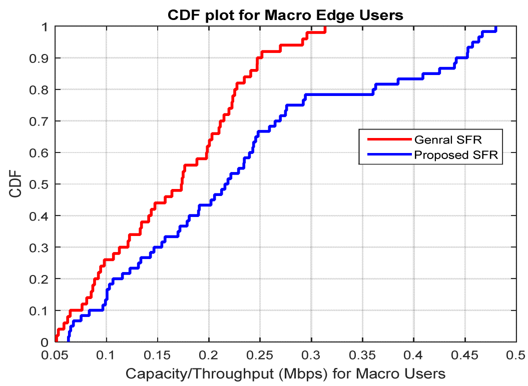

Fig.12. General and Proposed SFR comparison for Macro Edge users

Cumulative Distributive Function (CDF) is considered to compare general SFR and the proposed SFR scheme. In Figure 10, all macro users' performance is presented where the proposed scheme shows better performance in terms of throughput (Mbps). Similarly, the throughput for macro users at the center and the edge are shown in Figures 11 and 12, respectively.

The results show that Proposed SFR shows a better performance in the capacity as compared to General SFR for macro center users. By taking the mean values of capacity (Mbps), the proposed SFR improved the performance by 28.8%. The result shows that the proposed SFR for macro edge users improved by 39.7% in terms of throughput.

### 4.3 Femto Users Performance

Femto users are randomly allocated within Macro cell in such a manner so no interference among Femto users is considered. Here the General SFR is compared with the proposed SFR. In general SFR, 10 Femtocells are considered for the scenario, each with four Femto users. 5 Femtocells are considered at the center and 5 Femtocells are considered at the edge of MB. For general SFR 20 Femto users are considered in each region where for proposed SFR on basis of threshold SINR 24 Femto users are at the center and 16 Femto users are at the edge and the frequency is allocated dynamically following Macro cell, so no Macro users at center and Femto users at the center get same available bandwidth. Figure 13 shows the SFR comparison of Femto users, where the proposed SFR shows better results. Similarly, throughput for Femto center users and Femto edge users are shown in Figures 14 and 15, respectively. The obtained results show that the proposed SFR shows better performance as compared to general SFR by a percent improvement of 19.6%. The proposed SFR for Femto users at edge improved by 12.7% as compared to general SFR.

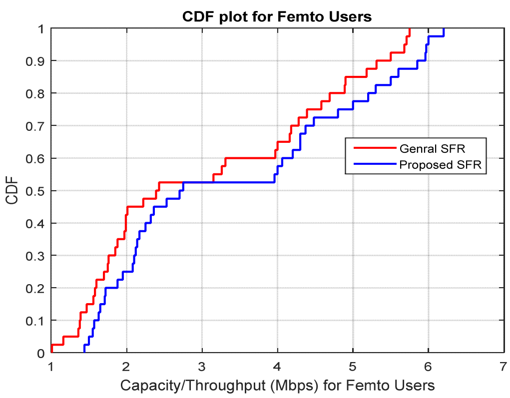


Fig. 13. General and Proposed SFR comparison for Femto users

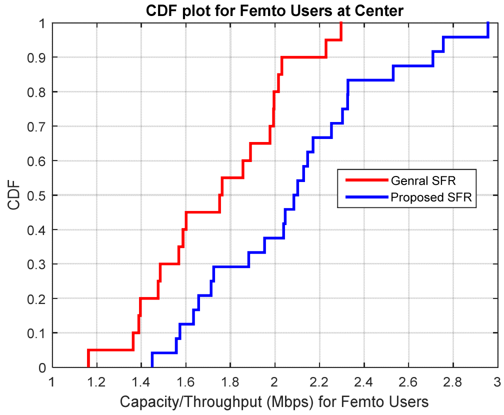


Fig. 14. General and Proposed SFR comparison for Femto at the center

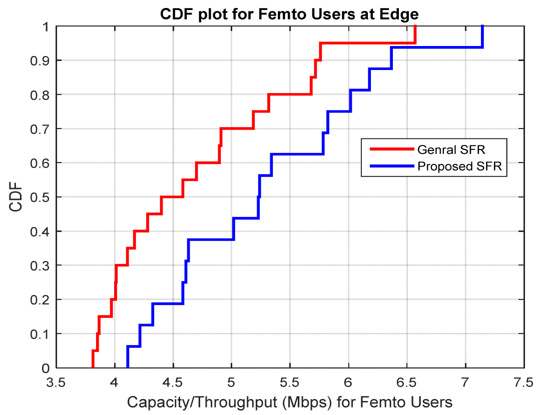


Fig. 15. General and Proposed SFR comparison for Femto at the edge

### 4.4 Average Sum Rate for Proposed SFR

The average sum rate of Macro is plotted in Figure 16, for the cell, cell-center, and cell edge for macro users. The obtained results show that the average sum rates are improved for the proposed SFR. Particularly, the average sum rate is improved for macro users in the cell by 24.84%, cell-center by 28.8%, and cell-edge by 39.7% compared to the obtained results for the general SFR schme. Similarly, the average rate for Femto users is shown in figure 17, which shows that the average sum rate is improved in the cell by 13.8%, cell-center by 19.6%, and cell-edge by 12.7% for the femto users, compared to the obtained results for the general SFR scheme.

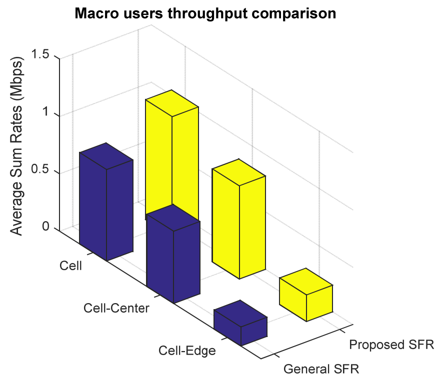


Figure 4.7 Average sum rate for Macro Users

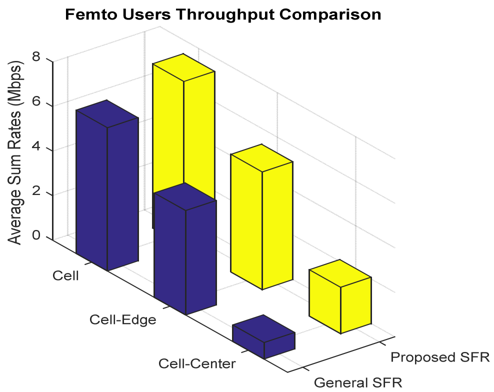


Figure 4.8 Average sum rate for Femto Users

## 5. Conclusion

In this paper, SFR based interference mitigation algorithm is developed for irregular geometry HetNet. The Femto BSs are randomly deployed in the coverage area of the Marco BSs. The macro users are classified as cell-center or cell-edge users based on threshold SINR. The spectrum is dynamically partitioned as per the requirement or number of users in each region. Two regions, center and edge are presented so as to allocate different frequencies bandwidth to these regions to avoid overlapping and interference. The proposed and general SFR scheme are analyzed. The obtained results show that the proposed SFR scheme outperforms the traditional SFR scheme in terms of cell throughput and average sum rate, both for Macro and Femto users.

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