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Interference Reduction in Heterogeneous Wireless Network Using FFR

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ABSTRACT

Heterogeneous wireless network deploying lower power nodes like Pico nodes and Femto nodes to meet the requirement of current users like high user data rate and throughput. Deployment of femto cells in a macro cell for extension of indoor coverage for users causes high interference, considering downlink performance of users. As soon as number of femto cell is increases interference is increases. However interference problem between macrocell and femtocell should take care in advance. In this paper we discuss some interference management technique to mitigate the interference between macro and femtocells. In this project I have discussed two method FFR1 and Soft FFR. This two method is compared with respect to without FFR scheme in terms of two parameter throughput and outage probability. And the results shows that the performance of proposed method is above in terms of Total/Edge throughput and outage probability.

Keywords: **Femto cells, HetNets, LTE, FFR, HeNB, MeNB, MUE, and FUE**.

1. INTRODUCTION

Femtocells have been proposed as a solution for poor coverageand unreliabledataservicesthattypicallyoccurindoors.Femtocellsare low power wireless access points that can bedeployed by users indoors to extend the coverage of the cellularnetwork. Femtocells can provide high data services aswell as offload traffic from the cellular network air interface toa residential cable broadband connection or DSL. Changingthe network topology by deploying smaller cells such asfemtocells can alleviate possible problems of scarce resourcesin LTE [3]. The deploying of a HeNB over the pre-existingmacrocell network represents a major challenge. Inefficientdeployment of the femtocell network may lead to a degradationof the overall performance of the cellular system. One example of this performance degradation is coverage holes for indoor macro UEs (MUEs) due to interfering transmissions by nearby femtocells. Efficient frequency allocation for both macrocell and femtocell networks is a major step towards efficient network deployment. Co-channel allocation of frequency resources leads to high spectral efficiency at the expense of quality of service (QoS), while orthogonal channel allocation leads to a high quality of service at the expense of poor spectral efficiency. Hybrid co-channel and orthogonal channel allocations are more efficient frequency allocation schemes. There are so many frequency allocation schemes are studied for macro cell network. Allocation of frequency with high frequency reuse can reduce the interference significantly. Here we compare to technique FFR 1 and Soft FFR with respect to full frequency reuse method. We compare the results for different femto cell density. We assumes the allocation of frequency is fixed and there is no coordination between maco and femto base station. Comparing the schemes on the basis of throughput and outage probability we found that Soft FFR is best among all schemes.

2. HETEROGENEOUS WIRELESS NETWORK

Macro only network deploying same type of cells require large power at each base station and not a flexible deployment model. It require prior planning before set up a network. Another method is deploying lower power nodes Pico, Femto and relay base station to improve the network coverage and data rates in macro cell coverage [5]. The network containingMacro cell (MeNB), Pico cell (PeNB), femto cell (HeNB) and rely nodes are known as heterogeneous wireless network refer figure 1. Theplacement of Pico/relay base stations may or may not be ad hoc, based on just arough idea of coverage issues and traffic density in the network.Due to their lower transmit power and smaller physical size, Pico/Femto/relay basestations can offer flexible site acquisitions. Relay base stations offer additionalflexibility in backhaul where wire line backhaul is unavailable or not economical.Usually lower power nodes are deployed depending upon network requirement. Pico nodes are deployed at coverage hole, HeNB is deployed inside the large buildings like shopping malls, schools, universities, colleges and corporate offices. One or many femto nodes can be deployed in a macro cell.

Table 1. Different base stations and there output power

Base Station Class	Range	Output power per TX Antenna
Macro BS	Few tens of Km	46dBm
Pico BS	200 m	Up to 30dBm
Femto BS	10 m – 30m	Up to 20dBm

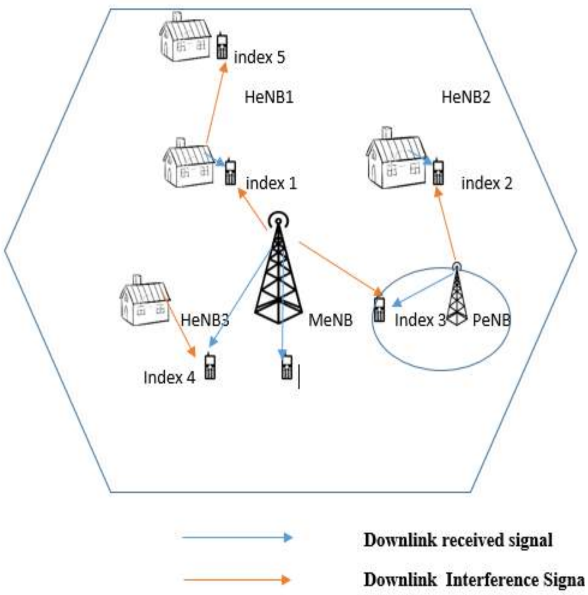

Fig.1 Heterogeneous Wireless Network with Interfrence scenario

3.INTERFERENCE IN HETNET'S

Strongest signal received from base station to user treated as desired signal and other signal from other base stations is treated as interference signal. In HetNets deploying macroand femto nodes only there are two types of interference that may occur.

3.1Cross-tier Interference

This types of interference occur between two femto cells and macro cell for example in figure 1 index 1 shows that FUE get interfered by maco base station. Similarly in index 4 MUE is get interfered by femto node. In index 2 we can see that FUE getting interference signal from macro BS. Table shows the different interference scenario index as shown in figure 1.

3.2 Co-tier Interference

This types of interference occur between two femto cells. For example in figure 1 index 5 shows that FUE aggressor causes downlink co-tier interference from neighboring femto cell. In OFDMA based heterogeneous networks (Here HetNets including femto nodes), interference occur only when the aggressor (source of interference) and victim use the same subchannel Therefore, it is necessary to adopt the robust and effective channel allocation technique that will mitigate the co-tier interference and reduce cross-tier interference considerably in order to achieve increased throughput performance. Different techniques such as coordination among MeNB and HeNB and frequency scheduling [14], time domain based intercell interference coordination is used also known as eICIC (Enhanced Intercell Interference Coordination) in [24]. However here we concentrate on FFR based technique while network involving femto cell only in a macro cell. This method is comparatively less complex, and is well suited for OFDMA based LTE-Advanced systems.

Table 2. Represents the interference scenario of Figure 1

Index	Aggressor	Victim	Interference Type
1	MeNB	HeNB	Downlink cross-tier
2	PeNB	HeNB	Downlink cross-tier

3	MeNB	PeNB	Downlink cross-tier
4	HeNB	MeNB	Downlink cross-tier
5	HeNB	HeNB	Downlink co-tier

4. PROPOSED METHOD

The basic mechanism of FFR corresponds to partitioning the macrocell service area into spatial regions in cell edge region and cell center region,and each sub region is assigned with different frequency subbands. Therefore, cell edge-zone MUE devices do not interfere with cell center –zone MUE devices, and with an efficient channel allocation method cell edge zone MUE may not interfere with neighboring cell edge-zone MUE. As a result cell edge-zone MUE devices receives an acceptable quality of signal quality and reduces the outage probability furthermore throughput is increases. This type FFR schemes based on large time scale is known as static FFR. We provide comparison among all schemes based on performance metrics such as outage probability and network sum rate. Here we discuss two methods of FFR used in OFDMA based HetNets FFR1 and Soft FFR then we compare the results with without FFR scheme.

4.1Fractional Frequency Reuse-1

The basic mechanism here to apply a frequency reuse factor of one to center-zone MUE and FRF of N at edge-zone MUE. The available frequency band is partitioned in such a way that in cluster of N cells, the center-zone MUE devices in each macrocell are allocated with common subbands of frequencies while the rest of the subbands are partitioned equally and allocated to the cell edge-zone MUE depending upon the FRF of edge zone. Therefore total of N+1 subbands are required as shown in figure 2(i). Figure 2(ii) shows the cellular structure with FFR1. Figure 2(ii) illustrate FRF of one at cell center and FRF of N = 3 at cell edge-zone. Figure 2(iii) represents the vertical bar of subbands used by MeNB and HeNB at cellular structure. In this scheme, MUE devices in macrocell are not interfered by any other MeNB. This significantly reduces the intercell co-tier interference. Also the cell edge-zone and cell center-zone MUE uses the different subbands therefore intracell co-tier interference is reduces. To reduce intracell cross-tier interference, a HeNB located in the center zone needs to choose a subband that is assigned to the MUE in the edge zone. Since in each cluster in a cell we can choose only two subbands therefore edge zone HeNB has to select the subband that is used by thecenter zone MUE as in figure 2. In such technique the cross tier interference is significant near the transition area of the center and edge zone in a macrocell. Also the at cell edge zone HeNB uses the same subbands the cross tier interference is significant between HeNB. One of the important design parameter is here the radius of center zone of the macro cell. The result is obtained using Monte Carlo simulation in [17] that, for uniformly distributed MUE, if the radius of center zone ($\boldsymbol{r_{centre}}$) is 0.65 times the total radius R then total throughput can be maximized. From [17] total number of channel that can be allocated to center zone MUE is given by

$$\boldsymbol{k_{centre}} = [\boldsymbol{k_{total}}\{\boldsymbol{r_{centre}}|\boldsymbol{R}\}^2].$$

Here $\boldsymbol{k_{total}}$ is the total number of available subchannel in a macrocell. The total number of available channels allocated to the cell edge zone MUE is given by

$$\boldsymbol{k_{edge}} = [(\boldsymbol{k_{total}} - \boldsymbol{k_{centrel}})/\boldsymbol{N}]$$

Where N is reuse factor at cell edge zone.

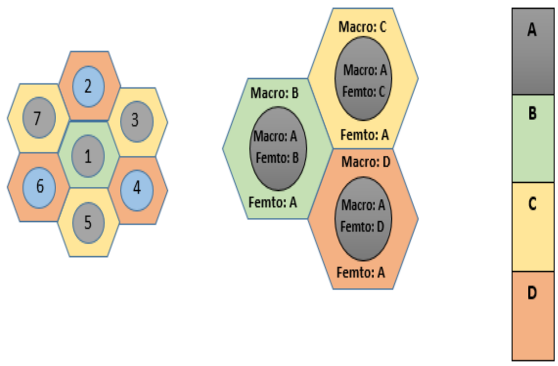

Fig.2 FFR1 Scheme

4.2 Soft FFR Scheme

This uses similar cell partitioning technique as in FFR1. However, the center zone MUE device can use the subband allocated to cell edge zoneMUE of any of the neighboring cell within a cluster. For a cluster of dimension N, the total availablebandwidth is divided into N number of subbands and one subband is assign to the edge zone. Figure 3(ii) shows deployment of a soft FFR. In figure we can see that the cell 1, 2, 7 assigned with the subchannel A, B, and C respectively at edge zone. While center zone of cell 1 can be assigned with the subchannel B and C. Similarly center zone of cell 2 are allowed to use subband A and C (Subbands of edge zone MUE of macrocell 1 and 7). Therefore soft FFR is more spectrum efficient then FFR1. In this scheme interference is increased. Both the cell edge and center zone MUE experience interference from the tier 1 macro cell. A power control factor is introduced for the cell edge zone MUE to reduce intercell interference. Therefore if MUE device m located at center zone then transmitted power is $\boldsymbol{P_m^k}$on subchannel k, and if MUE devices located at cell edge zone of macrocell then transmitted power is $\boldsymbol{\varepsilon P_m^k}$where $\boldsymbol{\varepsilon}$ power control factor its value is $\boldsymbol{\varepsilon} > 1$. One of the major advantage of this technique is better spectrum efficiency with good sum throughput. Cell edge users have more option to select the subband.

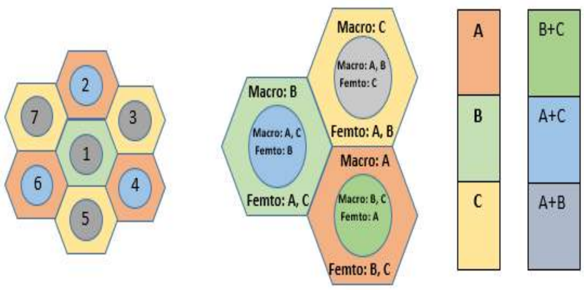

Fig. 3 Soft FFR

5. PERFORMANCE FORMULATION AND SIMULATION PARAMETER

We evaluate the performance of the different static FFR schemes in a HetNet scenario by simulations (in MATLAB) in terms of outage probability, network throughput (or network sum rate), and spectral efficiency. We formulate downlink Signal to Interference and Noise Ratio (SINR) and system throughput. The overall network is composed of two- tier19 macrocells. A macro user is interfered by 18 macro cell and all of the adjacent femto cells.

5.1.1 SINR

The signal to noise interference ratio for downlink transmission to MUE $\boldsymbol{x_m}$ from MeNB m on subchannel k then$\boldsymbol{SINR_{x_m,m}^k}$, is given by

$$\frac{\boldsymbol{P_m^k h_{x_m,m}^k G_{x_{m,m}}^k}}{\boldsymbol{N_o \Delta B + \sum_{m \in M''} P_{m'}^k h_{x_m m'}^k G_{x_{m,m'}}^k + \sum_{f \in F} P_f^k G_{x_{m,f'}}^k}}$$

Where p_m^k and $P_{m'}^k$ transmit power from MeNB m and neighbouring MeNB m' on subcarrier k, respectively. $h_{x_m}^k$ is the exponentially distributed channel fading power gain associated with subchannel k, and $G_{x_m,m}^k$ is the channel gain associated sub channel k between MUE x_m and serving MeNB m. Channel gain from neighbouring macro cell is given by which is given by $G_{x_{m,m'}}^k$. $Where\ G_{x_m,m}^k = 10^{-PL\ OUTDOOR\ /10}$.In case of femto user, it is interfered by all the 19 macrocells and adjacent femtocells. The received SINR of a femto user f on subcarrier k can be similarly given by

$$\frac{P_f^k h_{x_f,f}^k G_{x_{f,f}}^k}{N_o \Delta B + \sum_{m \in M} P_m^k h_{x_f m}^k \ G_{x_{f,m}}^k + \sum_{f \in F} P_{f'}^k G_{x_{fm,f'}}^k}$$

Channel gain is dominantly affected by path loss, which is different for outdoor and indoor. Path loss for outdoor environment is given as: - $P_{Loutdoor} = 28 + 35 \log_{10} d$. Here wall loss is zero. Path loss for indoor environment is 38.5 + 20log10 (d) + $L_{wall\ loss}$ and given as below

$$L_{wall\ loss} = 3\ dB\ for\ 0 \leq d \leq 10;$$

$$= 5\ dB\ for\ 10 \leq d \leq 20;$$

$$= 7\ dB\ for\ 20 \leq d \leq 30;$$

Wall loss is varying here depending upon distance from HeNB. Here d is the Euclidean distance between MeNB and MUE in meters. However, $G_{x_m,f}^k$is affected by both indoor and outdoor path loss. In this case, *d* would be the Euclidean distance between HeNB *f* and the edge of the indoor wall in the direction of MUE, x_m. After the wall, the path loss will be based on an outdoor path lossmodel.

5.1.2 Maximum achievable capacity

For an MUE $x_m$on sub-channel *k* is then given by

$$C_{m.k} = \Delta B\left(1 + \ \alpha\ SINR_{x_m}^k\right) Bits/second.$$

Where $SINR_{x_m}^{k}$ is the signal to interference noise ratio for different user position when using the subchannel k.
$Where\ \alpha = -1.5/\log(5 * BER)$Here BER $= 10^{-6}$.

5.1.3 Outage Probability

We define the outage probability as the probability that a UE device's instantaneous SINR a given subchannel k fallsbelow the SINR threshold γ given as

$$P\ (outage) = P\ (SINR_{x_m}^{k} < \gamma)$$

5.1.4 Spectral Efficiency

We define the spectral efficiency (bits per second per hertz) in terms of average bits per second successfully received by a UE device per unit spectrum. The spectral efficiency of transmission to MUE x_m is given by

$$S=(1 + \alpha\ SINR_{x_m}^{k})bits/second/Hz.$$

$$Where\ \alpha = -1.5/\log(5 * BER).$$

HereBER $= 10^{-6}$.

5.1.5 Overall Throughput (Sum throughput):

Practical capacity of serving macro cell is given by [1]

$$T = \sum_{m}\sum_{k} \beta_{m,k}\ C_{m.k}$$

Where $\beta_{m,k}$ is notify the subcarrier assignment for macro user. When $\beta_{m,k} = 1$ subcarrier k is assigns to macro user m. Otherwise$\beta_{m,k} = 0$. From the characteristics of the OFDMA system, each subcarrier is allocated only one macro user in a macrocell in every time slot. This implies that$\sum_{m=1}^{N} \beta_{xm,k} = 1$, where N is the number of user in a macrocell. Similar expression for femto users related to the practical capacity and overall throughput is possible except $\sum_{m=1}^{N} \beta_{xf,k} = 3$, here N is the number of femto user in a macrocell

5.2 Simulation parameter

In this particular chapter simulation parameters and mathematical models are described. In our simulation we compare three techniques without FFR, FFR1 and soft FFR.

Table 3 Simulation parameter

S.N.	Parameter	Value
1	Network size	2-tier (19 macro cells)
2	Radius of a macro cell	280 m
3	Radius of a Femto cell	30 m
4	SNR at an MUE device	10 dB
5	Number of Femto cells in a macro cell	30 to 180 per macro
6	HeNB transmit power	20 dBm
7	MeNB transmit power	46 dBm
8	Number of MUE devices in a Macrocell	50
9	Size of center zone	0.65 times of macro cell radius
10	Maximum number of FUE devices per Femtocell	1
11	Channel bandwidth	10 MHz
12	Number of sub channels	50
13	Subcarrier spacing	15 kHz
14	White noise power spectral	-174dbm/Hz
15	Power control factor	4

We consider 19 cell structure scenario in rural macro area. All the base stations are operated by the OFDMA technology. Table 3 shows the parameters we used in our simulation.

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6. RESULTS

In macro femto scenario we create the 19 cell structure (2 tier cellular network). Users are deployed randomly in macro cell. Femto cells are also deployed randomly within a macro cell. Figure 4 shows the result when we deployed the 50 users and varying number of femto cell (from 30 to 180 in an interval of 30) in a macro cell coverage of radius 280m. In figure 4 icompared three schemes Without FFR, FFR1 (Frequency at cell edge and center user is different and cell edge user is using one frequency) and Soft FFR (Power factor is introduced for cell edge users).In our simulation we assumes that all the users are macro users and only first macro cell is serving macro cell. When we deployed the femto cells within a serving macro cell overall performance is degraded in terms of overall throughput. Initially when no FFR technique is used all the first macro cell users are interfered from remaining 18 macro cells and from all of the femto cells within that macro cell. So the interference is very high when FFR technique is not applied. And as we can see in figure 4 as soon as the number of femto nodes are increasing the sum throughput is decreases.

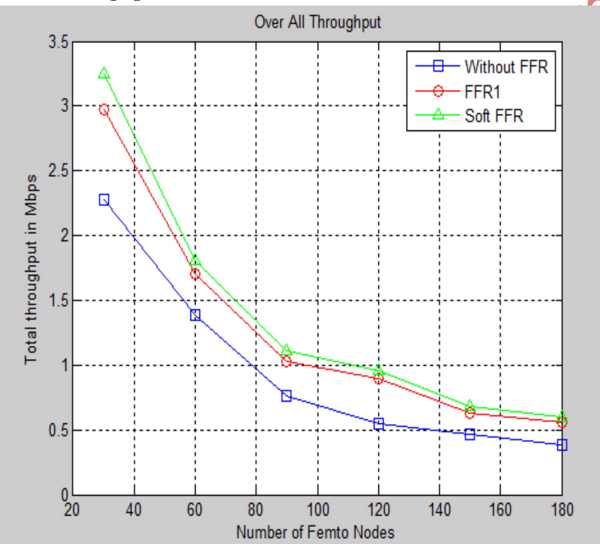

Fig.4 Sum Throughput of all the users inside a macro cell for varying number of HeNB

To apply FFR1 first we have to decide the either users are cell edge users or cell center users. Decision is based upon SINR threshold or macro cell radius, in our simulation we use the threshold radius to separate the users. Once we find the location of users FFR1 can be applied. The user at cell center are not interfered by the cell edge femto cells. They interfere only from cell center femto cells and from remaining cell center macro cells (18 macro cells). While cell edge users are not interfere by cell center femto cells and all of the macro cells, since they are using different frequency subband from center and other macro cells. Therefore the interference at cell edge users is less as compared to cell center users. From figure 4 it has been clear that Soft FFR is best method among three in terms of total throughput. Soft FFR scheme is more spectrum efficient then FFR scheme as we have seen in chapter 5 at the cost of more interferences. To reduce the effect of interference in this scheme power factor is introduce between cell edge zone and cell center zone, i.e at cell edge zone more power is transmitted as compared to cell center zone depending upon the percentage of users in each of the zone. Figure5 shows the performance of cell edge users in terms of throughput and varying number of femto nodes. As users are moved towards the edge of the cell they get affected more from interferers and power received is also decreases with distance. The performance of edge users is degraded due to interference. This performance can be improved by transmitting more power to edge users. Figure shows edge users have better performance while using FFR1 and SFR.

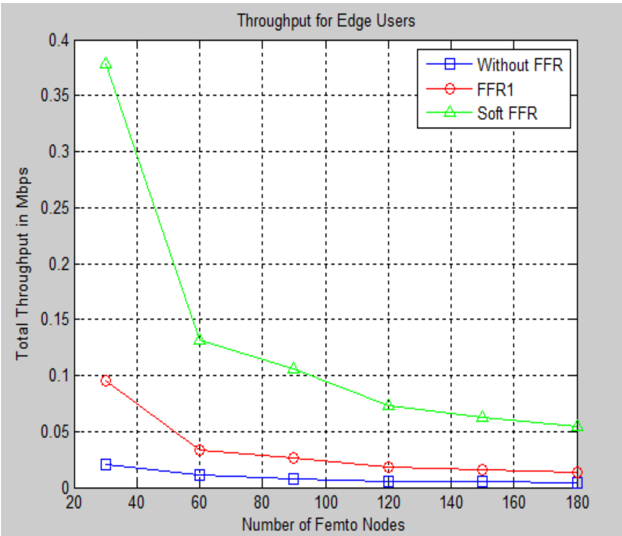

Fig.5 Sum Throughput of Edge users inside a macro cell for varying number of HeNB

The performance of without FFR and FFR1 is almost constant as compared to soft FFR, thus soft FFR gives better performance at cell edge zone. The figure 6 shows the overall throughput of center user is almost same and coinciding for SFR and FFR1 due the fact that we are transmitting same power to center user in both the schemes. But both the scheme have better result as compared to without FFR. Soft FFR have better spectral efficiency as compared to FFR1. In my simulation I compared all the schemes in terms of overall throughput and outage probability. Spectral efficiency is not measure concern throughout my simulation. Figure 7 shows the performance of cell center and edge users for outage probability, and as we can see again soft FFR has better then remaining schemes

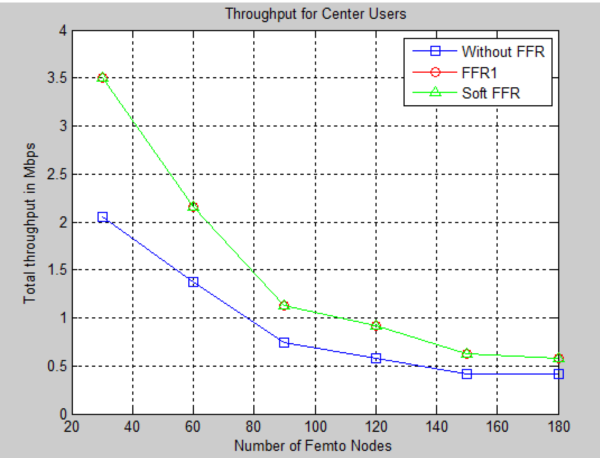

Fig.6 Sum Throughput of Center users inside a macro cell for varying number of HeNB

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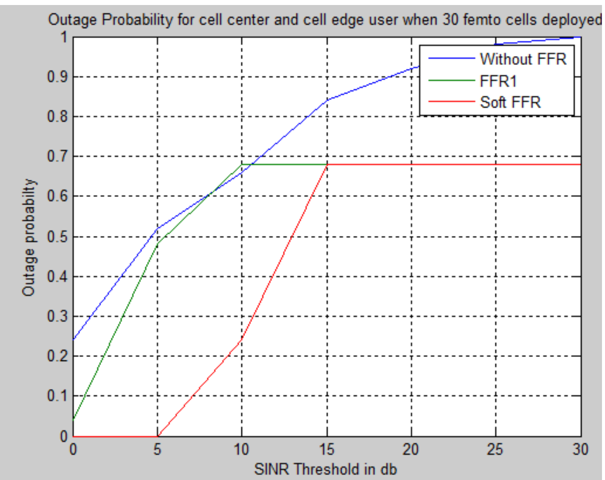

Fig. 7 Outage Probability for cell center and edge users for 30 femto node

7. CONCLUSION

In this project we have seen Interference is major issue in Heterogeneous wireless network that need to be resolve. Lower power nodes are deployed to enhance the network coverage inside the buildings and at coverage hole. In our project we focus only on femto cells to improve indoor coverage. As soon as the number of femto cells are increased the interference is increased. We compare two techniques Soft FFR and FFR1 with respect to without FFR. And we got better result for soft FFR in terms of outage probability and sum throughput. Conclusion can be drawn for edge users and center user's separately as in figure 4 and 5 that Soft FFR is best among three methods we are comparing. Interferences can be further reduce by sectorization of existing cell area, i.e. in 3 sector or in 6 sector. Some of the research are based upon this technique is under process.In next evaluation of LTEi.e. in LTE-Advanced, time domain based technique is used to mitigate the interference in HetNet's. Almost blank subframe technique is used to reduce the interference in HetNet's.

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