Non-Unanimous Power Inter-cell Interference Coordination in Heterogeneous Networks

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***Abstract*—Heterogeneous Networks (HetNet), particularly Femto cells, were introduced to meet the exigent need for higher network capacity. Although Femto cells increased the network capacity, they increased the interference to the Macro Indoor users.In order to avoid the high decrease in cell edge throughput different interference mitigation techniques were introduced like Inter-Cell Interference Coordination and Power Control techniques. In this paper, Non-Unanimous Power Inter-cell Interference Coordination (NUP-ICIC), and Non Unanimous Power Control with Constraint (NUP-C) algorithms are proposed . The schemes can achieve high spectral efficiency with an increase the cell-edge and with high power efficiency.**

***Index Terms*—Heterogeneous Networks, Femto cells, Interference Mitigation, Power-Control, ICIC**

I. Introduction

The increasing demand on high-end communication devices such as smart phones and tablets, with all their services, necessitates an increase in capacity and coverage of networks. The advancement of the technology alone cannot fill in for the expected increase in the capacity demanded by users. Heterogeneous Networks (HetNet) are introduced to the market as a solution to the high-demand problem without costly installation or high increase in the Macro stations power. Currently, there is a huge interest in Heterogeneous Networks both by the 3GPP Long Term Evolution (LTE), and Worldwide Interoperability for Microwave Access (WiMAX) standardization communities [1][2]. In Heterogeneous networks, low-power nodes are deployed in the Macro cell area to provide coverage and capacity increase to a set of User Equipment (UE)[3]. The low-power nodes could vary between Micro cells, Pico cells, Femto cells, relays or distributed antenna.

Of special interest, in this work, is the Femto cells deployment. Femto stations (FS) are designed to serve indoor subscribers, who are part of a closed subscription group (CSG). Although, having Femto cells can significantly improve the network performance, there are some challenges that would be faced to guarantee making the best use of the FSs. One of the main challenges is interference between Macro and Femto stations. In particular, Macro Indoor subscribers in the network, who are not part of the CSG of the FS, would not be able to associate with the FS even if the Femto station can improve the user performance. Consequently, such Macro Indoor UE would be associated to the nearest Macro station. This will result in high interference from the Femto stations to Macro Indoor UEs [4]. There are some previously introduced Interference Mitigation techniques , namely, Inter-cell Interference Coordination (ICIC) and power adaptation [5] [6].For ICIC, the Femto station shuts off its transmission on some of the time or frequency Physical Resource Blocks (PRBs).The ICIC algorithms decrease the Femto UE throughput.The power-control technique depends on adjusting the Femto Station power to satisfy either Macro or Femto Quality of Service (QoS), or simply broadcast a unanimous fixed power threshold to all FSs according to their density [6]. When it is fixed power, all station are unanimously sending with same transmission power, while if it is Non-Unanimous every Femto station decides on the amount of power it will transmit its signal based on the feedback from the UE attached to it. There are two types of Non-Unanimous power (NUP) adaptation algorithm as it either focuses on favoring Femto users (FF-NUP)or favoring Macro users (MF-NUP). FF-NUP is used to adjust the Femto transmission power to satisfy the Femto SINR bench mark, hence improve the network capacity. MF-NUP algorithm is used to adjust the Femto transmission power to satisfy the Macro SINR bench mark [6]The idea of working over the two dimensions of power and resource management was introduced in [4] as Femto Focused Non Unanimous Power with ICIC was proposed in order to increase capacity while insuring a good performance of cell edge UEs.

In this paper,Non-Unanimous Power Inter Cell Interference Co-ordination (NUP-ICIC), and Non-Unanimous Power with Constraint (NUP-C) are introduced. NUP-ICIC applies ICIC by shutting off the Femto transmission for a percentage of the PRBs. Non unanimous Power with constraint (NUP-C) is used to avoid the jeopardize of the group out of focus.So, in FF-NUP, a Macro SINR level constraint would be enforced (FF-NUP-MC) so Femto Stations will not be able to increase their power more than a certain level in case it is affecting a Macro, hence it does not decrease cell edge. While, in MF-NUP, a Femto SINR level constraint would be enforced (MF-NUP-FC) so Femto Stations will not be able to decrease their power below a certain level to avoid harming associated Femto UE, hence it does not degrade capacity. Non Unanimous Power with its different variations would be applied along with different variations of ICIC in order to achieve best values for both cell edge and cell capacity.

The rest of the paper is organized as follows. In the next section, the system model of the Femto HetNet environment is presented. The Non-Unanimous Power algorithms are introduced in Section III. In Section IV, the performance of the various presented algorithms is analyzed. Finally, Section V concludes the paper.

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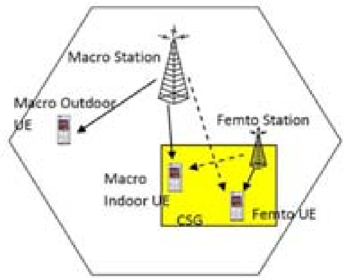

Figure 1. Simple Network: Desired signals are in solid lines, and interference signals are in dashed lines. Yellow square represent a Femto cell.

II. System Model

The model adopted for this paper is a simple heterogeneous cellular network. A simplified model of the network is shown in Fig. 1. The network has two types of stations Macro and Femto station, and three types of user, Macro outdoor UE , Macro Indoor UE and Femto UE. Macro Outdoor user is located out side of buildings, while Macro indoor and Femto UE both are located inside a building. The main difference between macro indoor and Femto UE is the Femto UE being a part of the Closed Subscriber Group associated to a Femto station while the Macro indoor is not.

In this paper a practical network is considered, which consists of L Macro stations and M FSs. The received signal at macro user served by the k^{th} Macro station (referred to as macro-user k) can be given by

$$\mathbf{y}_k = \sqrt{\alpha_k}\mathbf{H}_k\mathbf{W}_k\mathbf{x}_k + \sum_{\substack{i=1\\ i\neq k}}^{L}\sqrt{\alpha_i}\mathbf{H}_{i,k}\mathbf{W}_i\mathbf{x}_i + \sum_{j=1}^{M}\sqrt{\beta_j}\mathbf{H}_{j,k}\mathbf{Q}_j\mathbf{s}_j + \mathbf{n}_k, \tag{1}$$

where $\mathbf{H}_k, \mathbf{H}_{i,k}, \mathbf{H}_{j,k}$ denote channels from the serving macro station, the i^{th} macro station, and the j^{th} FS to k^{th} macro-user, respectively, of size $N_r \times N_t$. α and β represent the path loss attenuation factor. The path loss model used are depicted in [1].

$\mathbf{x}_k$ denotes the transmitted signal to the k^{th} macro-user of size $N_t \times 1$ and $\mathbf{s}_j$ denotes the transmitted signal to the j^{th} Femto user of size $d \times 1$, where d depends on the transmission technique. $\mathbf{n}_k$ denotes zero mean additive white Gaussian noise (AWGN) of the k^{th} macro user and $\mathbf{Q}$ is Femto precoding matrix of size $N_t \times d$. $\mathbf{W}$ is a standard 3GPP macro precoding matrix of size $N_t \times N_t$ [2].

Let

$$\tilde{\boldsymbol{Q}} = \mathbf{HQ} \text{ and} \tilde{\boldsymbol{W}} = \mathbf{HW}. \tag{2}$$

It is assumed that there is one spatial stream only being transmitted from any of the macro or Femto stations. It can be shown from (1) that the SINR of the k^{th} macro-user can be represented as

$$\gamma_k = \frac{\alpha_k \| \sum_{n=1}^{N_t} \tilde{\boldsymbol{W}}_{\boldsymbol{k}}(:,n) \|}{\sum_{\substack{i=1\\ i\neq k}}^{L} \alpha_i \| \sum_{n=1}^{N_t} \tilde{\boldsymbol{W}}_{\boldsymbol{i}}(:,n)\| + \sum_{j=1}^{M} \beta_j \| \sum_{n=1}^{d} \tilde{\boldsymbol{Q}}_{\boldsymbol{j}}(:,n)\| + \sigma_k^2}, \tag{3}$$

where σ_k^2 denotes the variance of n_k. Similarly the received signal of j^{th} Femto user can be represented as

$$\mathbf{y}_j = \sqrt{\beta_j}\mathbf{H}_j\mathbf{Q}_j\mathbf{s}_j + \sum_{k=1}^{L}\sqrt{\alpha_k}\mathbf{H}_{k,j}\mathbf{W}_k\mathbf{x}_k + \sum_{\substack{i=1\\ i\neq j}}^{M}\sqrt{\beta_i}\mathbf{H}_{i,j}\mathbf{Q}_i\mathbf{s}_i + \mathbf{n}_j, \tag{4}$$

and its SINR is given by

$$\gamma_j = \frac{\beta_j \| \sum_{n=1}^{d} \tilde{\boldsymbol{Q}}_{\boldsymbol{j}}(:,n) \|}{\sum_{k=1}^{L} \alpha_k \| \sum_{n=1}^{N_t} \tilde{\boldsymbol{W}}_{\boldsymbol{k}}(:,n)\| + \sum_{\substack{i=1\\ i\neq j}}^{M} \beta_i \| \sum_{n=1}^{d} \tilde{\boldsymbol{Q}}_{\boldsymbol{i}}(:,n)\| + \sigma_j^2}. \tag{5}$$

Table I
Network configuration parameters.

Parameter	Value
Number of cells	19
Sectors per cell	3
Inter-cell distance	1500
UEs per sector	14
Frames per trial	100
Number of trials	20
Carrier frequency	2.5 GHz
Frequency Reuse factor	Reuse 1
Cell load	100%

Table II
System model parameters.

Parameter	Value
Channel model	Extended ITU PedB (3km/h)
Antenna configuration	4×2
Base station (BS) tx power	47 dBm
FS tx power	20 dBm
BS antenna pattern	70 (-3 dB) with 20 dB front-to-back ratio
BS antenna gain	17 dB
FS antenna gain	5 dB
BS antenna spacing	0.5 wavelength
SS antenna pattern	Omni-directional
SS antenna gain	0 dB
SS antenna spacing	0.5 wavelength
Cable loss	2 dB
Detection	MMSE
Scheduling	Proportional fairness
Noise figure	7 dB
MCS	QPSK (R=1/12, 1/8, 1/4, 1/2, 3/4), 16-QAM (R=1/2, 3/4), 64-QAM (R=1/2, 2/3, 3/4, 5/6)

In order to model the complete HetNet,a proprietary system level simulator is used. The System level simulator follows the IEEE 802.16 Evaluation Methodology document [7] for the downlink. In addition, the dual strip deployment model [8] is used to model the Femto cell deployment.

A. System Level Simulations (SLS)

The SLS simulates the deployment of 19 hexagonal cells. Each cell is formed of a Macro base station at the center and three non-overlapping sectors. The network configuration parameters are shown in Table I. All UEs are subjected to slow fading phenomenon and fast fading channel behavior. Types of

Table III
OFDMA parameters.

Parameter	Value
System bandwidth	10 MHz
FFT size	1024
Subcarrier spacing	10.9375 KHz
Data sub carriers	768
CP length	1/8
OFDMA symbol duration	102.86 u sec
Permutation	LRU
Frame duration	5 ms
Sub-channels/Frame	48

slow fading phenomenon experienced by users are shadowing and path loss. The desired signal and interference received by the UE in time simulated by the SLS model.

In order to estimate the link layer performance, the SLS employs a PHY abstraction model. Based on the SINR value, a suitable Modulation and Coding Scheme (MCS) is assigned to the UE. Table II shows the system model parameters. PRBs are allocated to user based on proportional fairness (PF) scheduling criterion. A single frame consists of 12 resource blocks (RBs), where each RB has 4 frequency sub channels and 24 OFDM symbols.The OFDMA parameters are shown in Table III.

The SLS provides a list of performance criteria that includes the Cumulative Distribution Function (CDF) of the users' SINR distributions, users' average throughput, and aggregate sector throughput. The aggregate sector throughput is defined as the number of information bits per second that the sector can successfully deliver. The user and sector spectral efficiency (SE) (in bps/Hz) are calculated by dividing the respective throughput by the channel bandwidth. In addition, the cell-edge user SE is calculated which corresponds to the 5% level of the CDF of the users' spectral efficiency.

B. Femto Dual Strip Deployment Model

Dual Strip model proposed in [8] is used to model Femto stations deployment. Blocks like the one shown in Fig. 2 are distributed randomly all over the network. Each block has two apartment strips with 2xN apartments in each strip. Each apartment has an area of 10x10m^2. Between the two strips of apartments there is a 10m wide street. Also streets surround the two strips as shown in Fig. 2. Macro Indoor users are distributed randomly across the Femto block floors, and the rest of the Macro users are outdoors. Femto stations are installed in the apartments according to the deployment ratio from the apartments. Some of Femto stations are activated and some are deactivated according to the activation ratio. In the model proposed, each Femto station would have one Femto UE located in the same apartment. Table IV shows the Femto deployment model parameters.

III. Non-Unanimous Power techniques

It was shown in [4] that Femto UEs experience high desired signal power from its Femto Station, and low interference power from other Macro and Femto stations. Hence, the Femto UEs have high Signal-to-Interference-and-Noise ratio (SINR). On the contrary, Macro indoor UEs are dramatically affected by the presence of the interfering Femto Stations. Therefore, the Macro Indoor UEs experience low SINR and they represent the victim UEs who suffer the most from deploying the FSs. This results in low throughput for the Macro Indoor UEs.

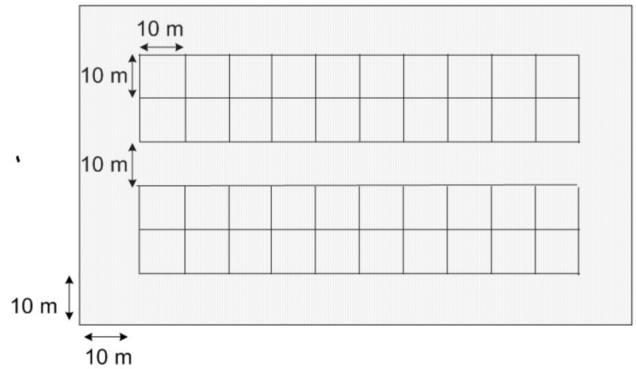

Figure 2. Femto Dual Strip Model

Table IV
Femto Deployment Model

Parameter	Value
N(Number of cells per row)	10
M (number of clusters per sector)	1
L(number of floors per cluster)	1
R(deployment ratio)	20%
A(activation ratio)	80%
Indoor percentage of Macro UEs	60%

The proposed algorithms are targeting to serve the macro users either through ICIC techniques and either MF-NUP technique or forcing a macro constraint over the FF-NUP.First stage in the algorithm is to provide for a lower interference over Macro UEs communication whether through ICIC (conventional or adaptive) and second stage is performing the Non-Unanimous Power adaptation. The NUP power adaptation can be , FF-NUP, MF-NUP, FF-NUP-MC or MF-NUP-FC.

A. Favoring Macro Users through ICIC

As shown in Fig. 3, in ICIC a certain percentage of the PRBs assigned to the Femto UEs are forced to be zero, in order to create an-interference free zone for Macro UEs [5]. Hence, the ICIC can provide higher SINR to the Macro UEs. The ICIC scheme used in the NUP-ICIC assigns the free resources to macro indoor users only as they are the weakest users. The percentage of shut off resources would highly degrade the capacity even if the cell is not interfering with any macro user. In order to avoid unnecessary decrease in capacity, Adaptive ICIC technique(A-ICIC) was proposed where only Femto cells affecting Macro Users apply ICIC while other Femto cells fully utilize their resources [4]. The adaptive algorithms use power-based approaches to identify the FS neighborhood. The power based approach uses the interference power from the different Femto stations over the macro users to determine whether there is a macro user or not in the vicinity of the Femto cells. In this paper, the power-based adaptive approach is used to decrease the interference over the users as much as possible without causing huge degradation to capacity . As shown in [4] Femto Stations could be in different apartments but could still have high effect on Macro UEs.

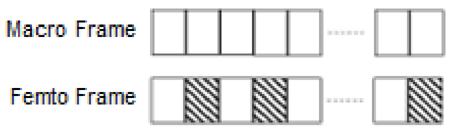

Figure 3. ICIC frame structure for Macro and Femto stations

B. Favoring Femto Users through Femto Focused Non-unanimous Power Adaptation (FF-NUP)

While ICIC would target better service for Macro Users, power adaptation technique was used to serve Femto Users [6]. The Power control algorithms depend on varying the transmission power of the Femto station to satisfy a certain Quality of Service (QoS) of the Femto UEs which is the SINR. The Non-Unanimous Power scheme depends on some variables. As shown in Fig. 4, Femto stations would all be given a minimum Power. If any Femto UE SINR is below target SINR and the power of the FS associated to the user is less than maximum power, then the power of the station will be incremented. In case of any change in FS power, re-association is done to all users in the network based on the new power plan. Then, the loop goes on till either all Femto UEs satisfy the required SINR or their attached Femto cells reached their maximum allowed power.This technique was proposed in [6]. A main issue with FF-NUP is that it does not take into consideration the effect of the power increase over the Macro UEs SINR, which may lead to sinking the Macro UEs. To over come this problem, this paper proposes adding a Macro constraint over the FF-NUP as in III-D.

C. Favoring Macro Users through Macro Focused Non-unanimous Power Adaptation

MF-NUP was proposed by [6] .In MF-NUP Femto stations would all be given maximum Power.If the Femto station is interfering with a Macro UE, it should decrease its power, hence decreasing noise over Macro UEs, till the Macro UEs reach the SINR needed. In case of any change in FS power, re-association is done to all users in the network based on the new power plan. Then, the loop goes on till either all Macro UEs satisfy the required SINR or their attached Femto cells reached their maximum allowed power. But, this technique could lead the Femto UEs to suffer greatly due to a high decrease in the FS power.To avoid that, MF-NUP-FC is suggested III-E

D. Favoring Macro Users through Macro SINR constraint over the FF-NUP (FF-NUP-MC)

The Femto Focused Non-Unanimous Power with macro constraint scheme is very similar to NUP scheme but it adds

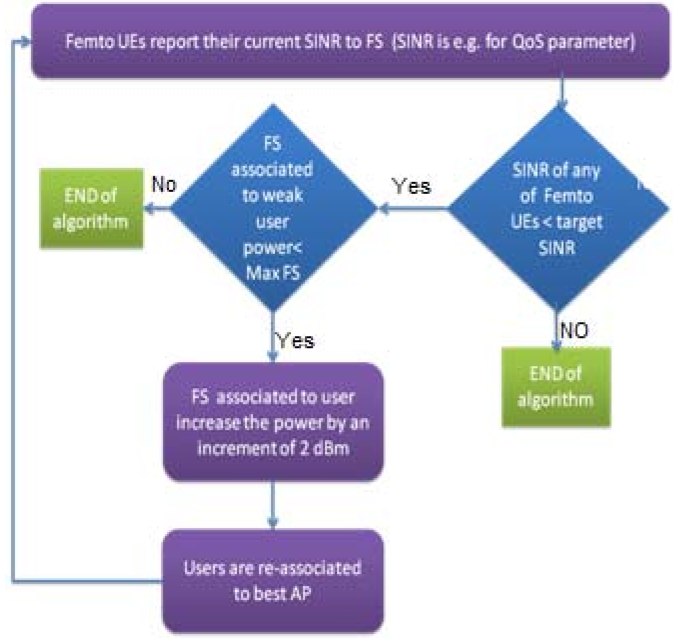

Figure 4. The Non-Unanimous Power Algorithm

one variable into consideration, the Macro UE SINR. If any Macro UE SINR is below a threshold value of Macro SINR, FSs causing interference to the Macro UE cannot increase its power and hence no more interference occur over the Macro UE. The constraint should not be based over the Macro-Only scenario or else there would be a risk of disassociating the Femto UE as the Femto station power will not be allowed to increase to an acceptable level. In this paper the constraint considered is 30% of the SINR CDF of Macro UEs in the Femto baseline. to improve Macro, A-ICIC would be added to the scheme.

E. Favoring Femto Users through Femto SINR constraint over the MF-NUP (MF-NUP-FC)

As Macro constraint is applied to FF-NUP, Femto constraint is applied to MF-NUP. All Femtos start transmitting at their maximum power level, and will decrement to reach the Macro SINR level. But in case the SINR of the Femto UEs attached to the station went below a certain threshold , Femto stations does not lower its power.

IV. Performance Analysis

Table V shows the results of running different simulations for 20 runs. The Femto cells and UE deployment differ from one run to the other to cover different states of randomization. Each run simulates 100 frames. The proposed Non-Unanimous Power schemes are evaluated against various scenarios: Macro-Only, Femto baseline, ICIC and NUP basic algorithms. These algorithms are evaluated in terms of total area SE and the cell-edge SE. The total area SE is the SE achieved over the sector area which includes one Macro station and six Femto stations. In the Macro-Only scenario, none of the Femto stations transmits data. While, the Femto-baseline case represents the scenario in which all the Femto

Table V
SIMULATION RESULTS

Scenario	Cell Capacity (b/s/Hz)	Cell-edge (b/s/Hz)	% of FS affected
Macro Only	2.206	0.035	N/A
Femto baseline	12.320	0.020	N/A
ICIC	7.434	0.039	100
Adaptive ICIC	10.356	0.027	36.9
FF-Non-Unanimous Power	12.568	0.037	N/A
MF-Non-Unanimous Power	10.433	0.041	N/A
FF-Non-Unanimous Power-MC	12.371	0.041	N/A
MF-Non-Unanimous Power-FC	10.601	0.037	N/A
FF-Non-Unanimous Power- ICIC	7.622	0.058	100
MF-Non-Unanimous Power- ICIC	6.546	0.043	100
FF-Non-Unanimous Power-A- ICIC	11.371	0.042	24.4
MF-Non-Unanimous Power-A- ICIC	9.583	0.027	24.4
FF-Non-Unanimous Power-MC-A-ICIC	11.19	0.047	23

stations are transmitting with no interference coordination. Non-Unanimous Power technique had a maximum FS power of 20 dbm, minimum FS power of -10 dbm, Femto SINR target of 25% of CDF of Femto UEs SINR before doing NUP which was 10, and increment of change of 2 dbm. All A-ICIC and ICIC are based on 50% shut off resources.

Comparing the Femto-baseline with the Macro-Only, it is found from Table V that adding Femto stations and assigning Closed Subscriber Group Femto UEs to the Femto stations has increased the area SE by 458.51%, however, it has decreased the cell edge SE by 33%. Hence, there is a need to improve the cell edge SE of the Femto-based heterogeneous network. In order to compensate for the decrease in cell edge SE that occurred due to adding Femto stations, different interference mitigation techniques are considered.The Macro Focused Non-Unanimous Power technique provided for a minimal Macro SINR level which led to an improvement in the performa nce of the Macro UEs that were below the target SINR. Hence, the MF-Non-Unanimous Power algorithm decreased the gap between Femto baseline and Macro-Only cell edge to 16% with an area SE of 372.98% compared to the Macro-Only scenario. The Femto Focused Non-Unanimous Power technique gave a guarantee of a Femto SINR level which led to an improvement in the performance of the Femto UEs that were below the target SINR. Consequently, the FF-Non-Unanimous Power algorithm achieved higher area SE of 469.78%, and a cell-edge SE increase of 22.33% compared to the Macro-Only scenario. The increase in cell edge is justified for the decrease in power of Femto Station which led to an increase in the SINR of the Macro UEs. Also ICIC algorithms are used in interference Mitigation.In Table V, it is shown that the ICIC algorithm has increased the Macro station SE, but have highly reduced the Femto station SE. On one hand, the increase in cell edge SE change is 31% with an increase in area throughput of 237% compared the Macro-Only scenario. Although, the decrease in cell edge was low compared to Femto baseline, ICIC alone gave only half the increase in capacity that was made in Femto Baseline.A-ICIC improved the capacity to 369% while the cell edge decrease went to -10% which is a high decrease.

The NUP-ICIC technique depend on applying a type of NUP followed by conventional ICIC. The FF-NUP-ICIC base technique produced the best cell edge over all techniques with 94% increase over the macro only scenario, and with an increase in capacity of 246%. Although the increase in capacity was nearly half the increase from the Femto baseline it is the only technique that provided for an increase in capacity with such a large increase in cell edge.The MF-NUP-ICIC was not as good as it lead to an increase of 43% in cell edge but with a increase of only 197% in capacity. MF- NUP-A-ICIC produced a higher increase in capacity than NUP-ICIC as it provided a 334% increase over the Macro Only but NUP-A-ICIC could not maintain the increase in cell edge as it gave a cell edge decrease of around 10%. The 10% decrease is around 30% the decrease in the A-ICIC without Non-Unanimous Power and such a decrease in cell edge could be considered an acceptable sacrifice for the increase in capacity. However, FF-NUP- ICIC, provided for an increase in capacity of around 415% and an increase in cell edge of around 43%. After considering the NUP-ICIC all scenarios, NUP-MC results would be assessed. It is shown in Table V in FF-NUP-MC that Femto throughput is lower than that of Unanimous Power because not all Femto users were able to satisfy their SINR condition , as some of them were restricted by the macro constraint, but because the macro constraint was low as it was based on Femto Baseline and not Macro only scenario, Femto stations were able to provide a good increase in cell edge of of 460% which is very close to the 463 % increase provided by the Non-Unanimous power. This technique is also less complex than adding ICIC and depends on best resource utilization, as it allow all Femto resources to be used by Femto users allocated to them originally consequently they will be given to low interference users, same time the technique provides for very low Femto power in comparison to constant power as the mean power is around -4 to -2 dBm while in the Femto baseline power used is 20 dBm in all cases. Even when comparing power shown in Fig. 5 decrease with NUP it is found that the power decrease is slightly higher because the constraint leads to not increasing power to satisfying the SINR value for Femto. The MF-NUP-FC, improved ove the MF-NUP by increasing the cell edge and throughput over those of the MF-NUP. MF-NUP, because it did not take into consideration Femto UEs, it lead Femto UEs to disattach from the very low power Femto station and instead attach to the Macro Station without a guarantee of their SINR level because they would be considered by the network as Femto UEs. Consequently, Femto UEs acted as the cell edge UEs with a decrease of around 15% cell edge from the Macro Only. However, in MF-NUP-FC presented in this paper, the limit of the FC constraint guranteed that all Femto stations can serve their UEs and their would be no need to disassociate.

Consequently, cell edge greatly increased above that of MF-NUP to reach around 23% increase from macro only instead of a decrease of 15% in MF-NUP. Also it increased cell capacity by around 380% compared to macro only which is 7% higher from the MF-NUP increase.

In NUP-MC-A-ICIC, A-ICIC is done after applying FF-NUP-MC. The performance of FF-NUP-MC is the best in conserving good cell edge from the power control techniques, same time A-ICIC was chosen to avoid sacrificing unnecessary capacity to improve already acceptable cell edge.In NUP-MC-A-ICIC,the Macro constraint does not prohibit interference over Macro resources, so Macro users improvement can be achieved through applying ICIC. Applying ICIC it is noted that the FSs affected percentage decrease from 24.4% in NUP-A-ICIC to 23% in NUP-MC-A-ICIC. This decrease happened because SINR of Macro UEs is already adjusted not to be below a certain level, consequently, the interfering FS would be less. The NUP-MC-A-ICIC gave an increase in capacity with 407.340% which is lower than NUP-MC because of applying ICIC to 23% of FSs, same time cell edge increase is around 55% compared to Macro Only. This refers that NUP-MC-A-ICIC comes second in providing cell edge after the 90% increase from the NUP-ICIC technique Moreover, it gives a very satisfying increase in capacity of around 4 times the capacity provided by the Macro Only technique. comes . It can be concluded that no other technique was able to achieve such a high cell edge as the NUP-MC-A-ICIC with such a high increase in capacity.

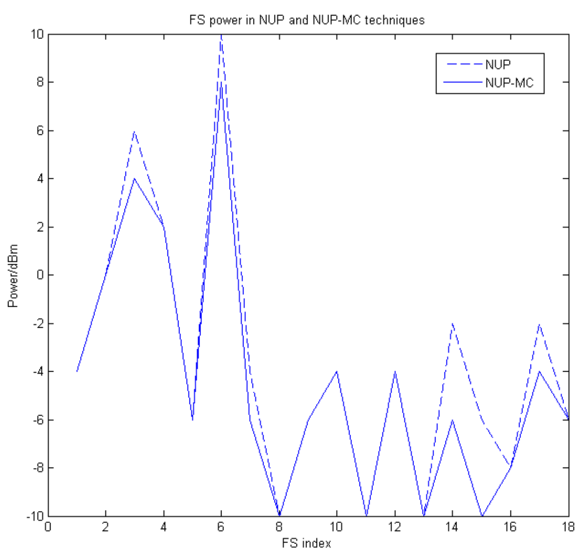

Figure 5. Power of FS after applying NUP and NUP-MC

V. CONCLUSION

Heterogeneous networks are needed to increase the capacity and performance of the network. It mainly depends on adding low power nodes to increase the capacity of the network. One type of low power nodes is Femto cells. A major challenge facing HetNet is the interference between different power nodes and its dramatic effect on the Macro UEs. The NUP-ICIC and the NUP-C algorithms were proposed in an attempt to solve this problem. For the NUP-ICIC, on one hand, it shuts off some of the Femto PRBs or direct the Femto transmission away from the Macro transmission to increase the Macro Indoor UEs SE and hence increases the cell-edge SE. On the other hand, NUP-ICIC algorithm adjusts the Femto stations transmission power to achieve the desired Femto UEs QoS and hence increases the area SE. It was shown that the NUP-ICIC can produce increase area SE of 245% over Homogeneous network with Macro stations only and produces a cell edge increase of 94% versus a decrease in cell edge of 60% produced when adding Femto cells with no interference mitigation technique. Then FF-NUP-MC, MF-NUP-FC wer introduced in an attempt to solve for the main issue with the FF-NUP, MF-NUP schemes respectively, which is not taking the other UE group into consideration. The technique depended on adding a constraint over the NUP technique to avoid putting high interference over the Macro indoor UEs. FF-NUP-MC gave an increase in capacity of 460% with a cell edge increase of 37% compared to Macro Only with a much lower complexity than ICIC performing techniques and with high power saving. Also MF-NUP-FC was able to highly improve over the MF-NUP as it gave a 380% increase in capacity and a 23% increase in cell edge. A better cell edge was produced by this technique when adding A-ICIC to the technique to have NUP-MC-A-ICIC. NUP-MC-A-ICIC gave a cell edge increase of 55 % with an in capacity of 407% which ranks second best in cell edge and increase capacity by four times compared to Macro Only techniques beside saving power as most Femtos would be sending at much lower than their maximum power but same time it has high complexity.

VI. ACKNOWLEDGMENT

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