Volume 2 No. 8, August 2012 ISSN 2223-4985

International Journal of Information and Communication Technology Research



http://www.esjournals.org

# Avoidance of Co-tier Interference between Femtocells with Different Access Modes

**Shahryar Saleem and Horace King**
School of Engineering and Science
Victoria University
P.O. Box 14428, Melbourne, Victoria, 8001
Australia

## ABSTRACT

Deploying Femtocells inside a macrocell network can significantly increase the macrocell capacity in terms of network optimisation. However, the deployment of femtocells within a macrocell coverage area causes severe femto-femto interferences, which may have an impact on the overall performance of femtocells. Avoiding such interference is very important for co-existence of femtocells. In this paper, we propose a novel femtocell resource allocation scheme to alleviate the problem of *Co-tier* interference. In the proposed scheme orthogonal resources are allocated to the closed access femtocells to avoid interference to other femtocells, while we divide the open access femtocell coverage area into two coverage area, an inner and an outer coverage area. The resources are allocated to both coverage areas of the open access femtocells in a way that avoids co-tier interference while increasing the spectrum efficiency.

**Keywords:** *Femtocell Networks, Co-tier Interference, Resource Allocation, Interference Avoidance*

## I. INTRODUCTION

Studies conducted on the usage of wireless networks indicate that more than 50% of voice calls and 70% of data traffic originate from users located indoors [1]. It is therefore more appropriate to have high capacity wireless links indoors. The increase in link capacity can be achieved by bringing the transmitter (T) and receiver (R) close to each other. Femtocells exploit this reduction in T-R separation to provide high quality wireless links and good spatial reuse [1]. Femtocell base stations (FBS) use broadband connections such as a digital subscriber line (DSL) or a cable modem [2] to backhaul to the operator.

Femtocells provide faster and more reliable data services, better quality voice calls and very high indoor signal levels [1]. Despite the advantages of femtocells, the deployment of femtocells in large numbers causes the femtocells to interfere with each other. This type of interference is called *co-tier* interference [3], [4].This interference is particularly strong when all femtocells operate in *co-channel* mode meaning that all femtocells share the same resources.

## II. RELATED WORK

Significant work has been done to avoid the cross-tier interference (between femtocell and macrocell) but little work is done to propose schemes to avoid co-tier interference. Authors in [5] propose an Adaptive uplink (UL) attenuation algorithm to mitigate the co-tier interference for uplink direction only. UL attenuation is applied at home node B (HNB) to attenuate the UL signal when the total received signal level at the HNB is saturating the receiver, or the UL is being jammed by a nearby non-associated user equipment (NAUE). The authors did not consider fast fading and shadowing in their channel model, which can have impact on the results. In [6], the authors propose that the victim user equipment (UE) establishes a control only connection with the aggressor HNB and submits the channel state information (CSI) to the aggressor HNB. The aggressor HNB uses transmit beamforming method to direct its signal towards its own UE and not towards the victim UE and thus the co-tier interference is avoided. The authors only consider path loss and log-normal shadowing while fast fading affect is completely neglected. In [7], a combination of frequency bandwidth dynamic division and clustering algorithm (CFCA) is proposed. The clustering algorithm allocates femtocells into different frequency reuse clusters and the FBS of the femtocells in the same cluster reuse the resources while different clusters use different resources. Thus, co-tier interference is avoided. Apart from the schemes discussed above, cognitive approach has also been suggested to mitigate the co-tier interference in [8], [9] AND [10]. In [8], the authors propose that all HNB use cognitive sniffing to detect whether a neighbour HNB is present or not. Then based on the sniffing result the HNB can pick any component carrier (CC) as the primary component carrier (PCC). If the PCC cannot satisfy the services required by the UE, then the HNBs choose a secondary component carrier (SCC) based on sharing path loss measurements among neighbouring HNBs and selecting the SCC according to the estimated mutual interference. In [9] and [10], the authors propose that each femtocell performs sensing of the frequency spectrum to obtain an interference signature. The interference signature tells the femtocell which resources are free of interference. Thus, the femtocell can use those resources and avoid interfering with its neighbouring femtocells.

Volume 2 No. 8, August 2012 ISSN 2223-4985

International Journal of Information and Communication Technology Research



http://www.esjournals.org

In this paper, we propose a novel resource allocation based scheme that avoids co-tier interference from femtocells with different access modes. In particular, we propose a femtocell network controller (FNC) connected to a large density of femtocells. The FNC acts as a ``virtual" macro- base station for the core network (CN) and as a ``virtual" CN entity for the HNBs. The FNC is responsible for allocating resources to all HNBs that are connected to it. Furthermore, we also propose that orthogonal resources are allocate to the closed access femtocells while we divide the coverage area of the open access femtocells into two separate coverage areas, inner coverage area and outer coverage area. The inner coverage area is allocated resources that are used by the nearest closed access femtocell while the outer coverage area is allocated resources that are used by the far away closed access femtocells. This resource allocation avoids the co-tier interference completely in the dense femtocell network while the scheme also increases the frequency reuse. The paper is organised as follows. Section II presents the proposed system model. Section III discusses about the different femtocell access modes. Section IV talks about the origination of interference in planned vs. unplanned femtocell deployment. In section V, the proposed scheme is discussed. Section VI provides the simulation parameters and the results are shown in section VII. Finally, we draw conclusions in section VIII.

## III. SYSTEM MODEL

The proposed system model consists of a large density of femtocells deployed in some area inside the macrocell as shown in Figure 1.

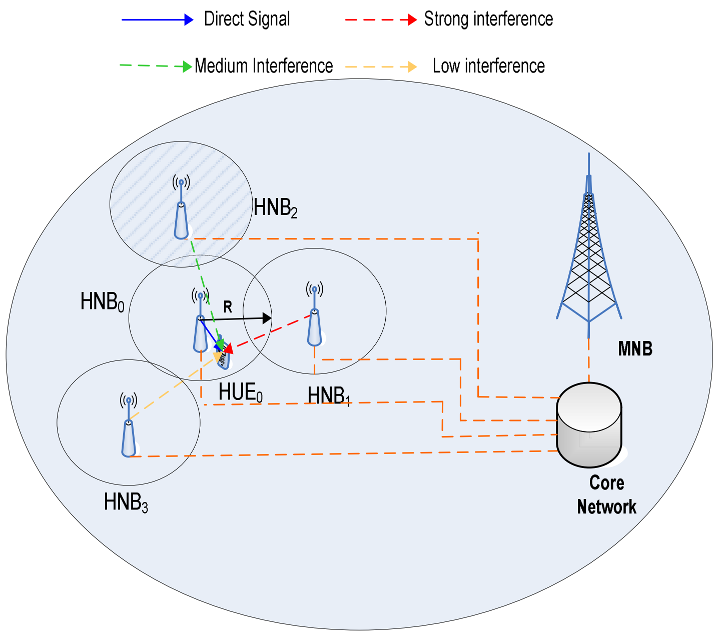


**Figure 1: System Model**

Specifically, N femtocells operating in open and closed access modes are deployed in the macrocell coverage area. The shaded femtocell corresponds to a closed access femtocell. In 3rd generation partnership project (3GPP) the femtocell base station is termed as a home node B (HNB) and a femtocell user equipment is termed as home user equipment (HUE). The macrocell base station is termed as macrocell node B (MNB). The total system bandwidth B is divided into M resource block (RB), $B=MB_{RB}$. A RB represents a basic time-frequency unit having bandwidth $B_{RB}$. Co-channel operation is assumed where each femtocell uses the same M RBs. This co-channel operation and the fact that the femtocells are closely located with each other give rise to extreme case of co-tier interference. The system model shows this co-tier interference scenario where HUE of femtocell of interest denoted by $HUE_o$ being served by the $HNB_o$ is interfered by HNBs of femtocell 1, 2 and 3. As $HNB_1$ is located in close proximity to the $HUE_o$, the interference from $HNB_1$ is considered very strong. $HNB_2$ and $HNB_3$ are located relatively far away and thus their contribution to interference at $HUE_o$ is from medium to low. The coverage area and transmit power is assumed to be constant for all HNBs. In our model we have only considered the downlink (DL) scenario. The $E_c/N_o$ received by $HUE_o$ at RB $m$ where m=1,...,M is given by

$$\frac{E_c}{N_o} HUE_o^m = \frac{p_{pilot} HNB_o^m}{(n_{rx}^m + i_{sc}^m + i_{oc}^m)} \qquad (1)$$

Where $p_{pilot} HNB_o^m$ is the received pilot power from the $HNB_o$ in (W). Thermal noise at the input to the mobile is $n_{rx}$ (W). The same cell interference is denoted by $i_{sc}^m$ and consists of wanted and unwanted signals. $i_{sc}^m$ is $\approx 0$ in our case. The out of cell interference is denoted by $i_{oc}^m$ and can be written as.

$$i_{oc}^m = \sum_n^N P^m HNB_n \qquad (2)$$

Where n=1,...N. The out of cell interference is the sum of all the signal power at RB m from n HNBs. Substituting equation (2) into equation (1) we get,

$$\frac{E_c}{N_o} HUE_o^m = \frac{p_{pilot} HNB_o^m}{(n_{rx}^m + \sum_n^N P^m HNB_n)} \qquad (3)$$

International Journal of Information and Communication Technology Research

http://www.esjournals.org

It is evident from equation (3) that the quality of the pilot is drastically compromised as the out of cell interference increases.

### a. Channel Models

In this paper we consider two types of channel models. These are ITU indoor-to-indoor (between HNB to its serving HUE) and indoor-to-outdoor (between HNB to HUE in different femtocells), where

***Indoor to Indoor channel model***

$$PL_{dB} = 38.6 + 20\log_{10}(d) + 0.7(d) \quad (4)$$

***Indoor to Outdoor channel model***

$$PL_{dB} = 15.3 + 37.6\log_{10}(d) + WL \quad (5)$$

Distance (d) is in meters, and WL the is loss due to walls assumed to be 20dB. In addition to the path loss models described above we have also included Rician fading (for indoor to indoor transmissions) and Rayleigh fading (for outdoor to indoor transmissions). Log-normal shadowing is also added to obtain realistic results as highlighted in [11].

## IV. FEMTOCELL ACCESS MODES

In two tier networks, the access mode of femtocells can have a significant impact on the Cross-tier interference. The access mode defines which users are allowed to use each femtocell. A short description of the two modes are given below. In this paper we consider both access mode.

### a. Open Access Mode

If a femtocell has *Open Access* mode [3] and [12], all users either registered or unregistered can access that femtocell. Thus every user (macrocell or femtocell) is always connected to the femtocell having the best signal quality. The open access mode avoids cross-tier interference completely. However, the main disadvantage of this access mode is the increased number of handovers and signalling overhead associated with it.

### b. Closed Access Mode

If a femtocell has *Closed Access* mode [3] and [12], only registered users are served by that femtocell. These types of femtocells are mainly deployed by private owners. Unregistered users do not have access to a close access femtocell even if it provides the best signal quality. The disadvantage of this type of access mode is that it leads to high cross-tier interference.

## V. CO-TIER INTERFERENCE IN AN IDEAL (PLANNED) VS REALISTIC (UNPLANNED) FEMTOCELL NETWORK

In this section, we shall discuss how the co-tier interference originates between femtocells. Furthermore, we will show how the severity of such interference increases due to close deployment of femtocells to each other. An ideal (planned) femtocell network consists of femtocells whose coverage area does not overlap with the coverage area of other femtocells. An example of such a planned configuration is shown in Figure 2.

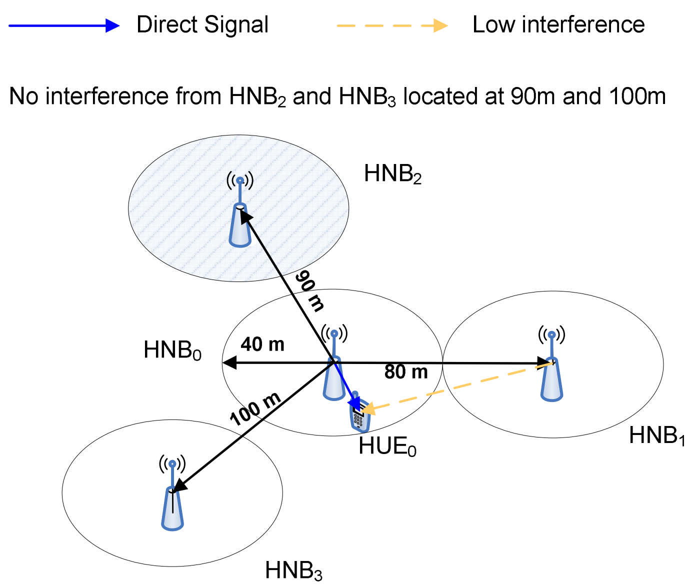


**Figure 2: Ideal Femtocells Configuration**

The minimum distance between two HNBs is 80 m. At 80 m, the HNB $_1$'s coverage area is just touching the coverage area of $HNB_o$. $HNB_2$ and $HNB_3$ are located at 90 m and 100 m away from $HNB_o$. The effect of co-tier interference at $HUE_o$ is observed as it moves away from its serving HNB ($HNB_o$) towards the coverage edge (assumed 40 m). $E_c/N_o$ is used as a measure of signal strength received by the $HUE_o$ from $HNB_o$ and also from $HNB_1$, $HNB_2$ and $HNB_3$. The distance between $HUE_o$ and the interfering HNB (consider only $HNB_1$) is calculated if we denote the distance between $HNB_1$ to $HNB_o$ as $d_1$ and distance between $HNB_o$ and $HUE_o$ as $d_2$, thus the distance between $HNB_1$ and $HUE_o$ denoted by $\Delta D$ is written as,

Volume 2 No. 8, August 2012 ISSN 2223-4985
International Journal of Information and Communication Technology Research

http://www.esjournals.org

$$\Delta D = \sqrt{d_1^2 + d_2^2 - 2d_1 d_2 Cos\theta} \quad (6)$$

Where θ is the angle between $HUE_o$ and $HNB_1$ and can have value from 0 to 360 degrees. Figure 3. shows the distance calculation.

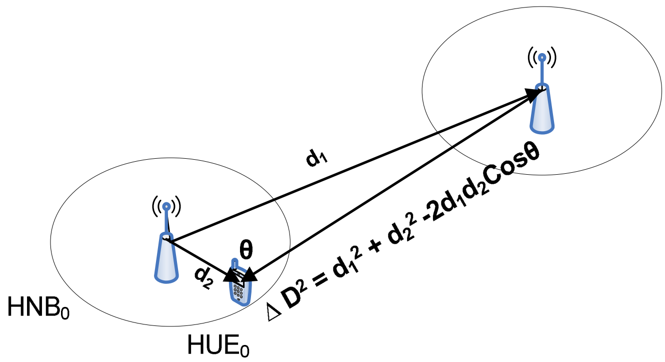


**Figure 3: Distance Calculating Geometry**

From equation (6), the distance between the interfering HNBs and the victim $HUE_o$ can be found. The co-tier interference from $HNB_1$, $HNB_2$ and $HNB_3$ to $HUE_o$ can be seen from Figure 4. From the figure we can see that when the nearby $HNB_1$ is almost twice the distance of the $HNB_o$ coverage area, the signal from $HNB_1$ still leaks into the coverage area of $HNB_o$ and causes interference to $HUE_o$ when it is located within 38 to 40 m. However, $HNB_2$ and $HNB_3$ have no effect on $HUE_o$ as they are located quite far from $HUE_o$. Thus in an ideal (planned) femtocell network configuration, there are very low chances of occurrence of co-tier interference.

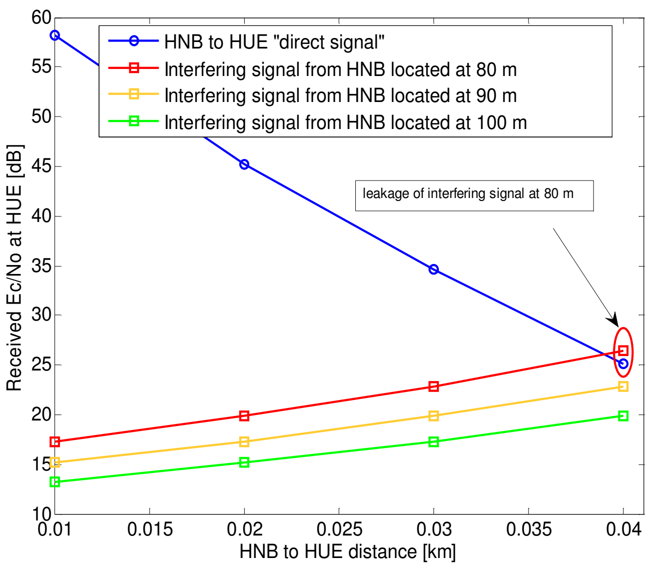


**Figure 4: Interference due to Planned Femtocell Configuration**

However, in reality, the femtocells are deployed by home users and there is no network planning performed as done for macrocells, thus the co-tier interference becomes a greater concern. Figure 5. shows how the random deployment of femtocells results in co-tier interference. In the figure, HNBs are deployed at random distance around $HNB_o$. $HNB_1$ is located right at the coverage edge of $HNB_o$. $HNB_2$ and $HNB_3$ are also overlapping the $HNB_o$ coverage area and are located at 50 m and 60 m away from the $HNB_o$ respectively.

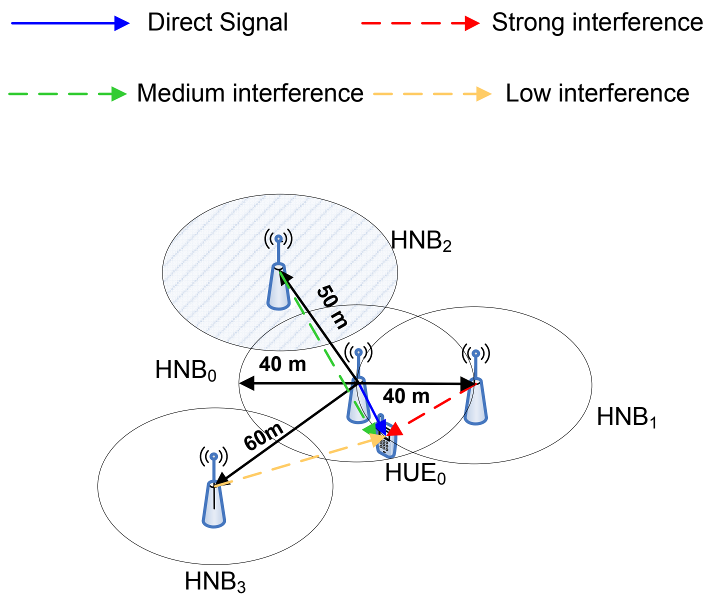


**Figure 5: Unplanned Femtocell Configuration**

The co-tier interference arising from this unplanned femtocell deployment is shown in Figure 6.

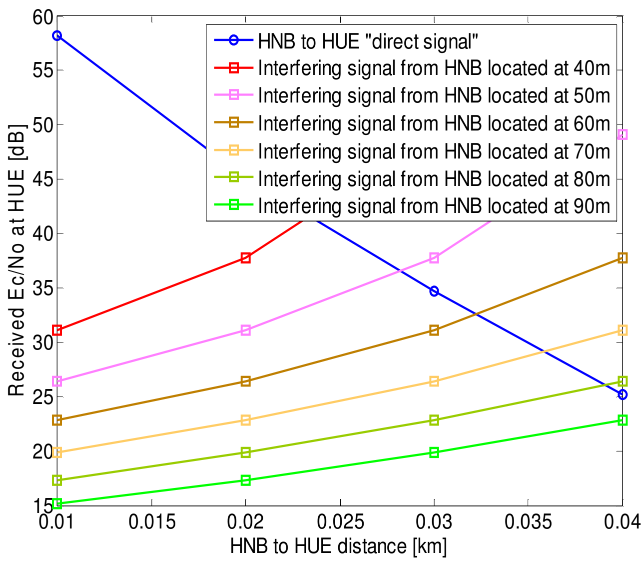


**Figure 6: Interference due to Unplanned Femtocell Configuration**

International Journal of Information and Communication Technology Research

http://www.esjournals.org

From the figure, one can see that when the $HUE_o$ is just under 25 m away from $HNB_o$, the $E_c/N_o$ from $HNB_1$ becomes strong. This is because $HNB_1$ is located at the coverage edge of $HNB_o$. The $E_c/N_o$ from $HNB_2$ and $HNB_3$ become strong when the $HUE_o$ is about 30 m and 32 m away from $HNB_o$ respectively. One interesting observation from Figure 4 and Figure 6 is that any HNB located at 90 m away from the $HNB_o$ (having a 40 m coverage area) causes no interference to the $HUE_o$. This is due to the high path loss between the interfering HNB and $HUE_o$. Conversely, any HNB located within the 90 m region around the $HNB_o$ will cause interference to the $HUE_o$. We call this region the region of interference (RoI). Thus, in our case RoI = 90 m when only path loss is considered. An illustration of the RoI for $HNB_o$ is shown in Figure 7.

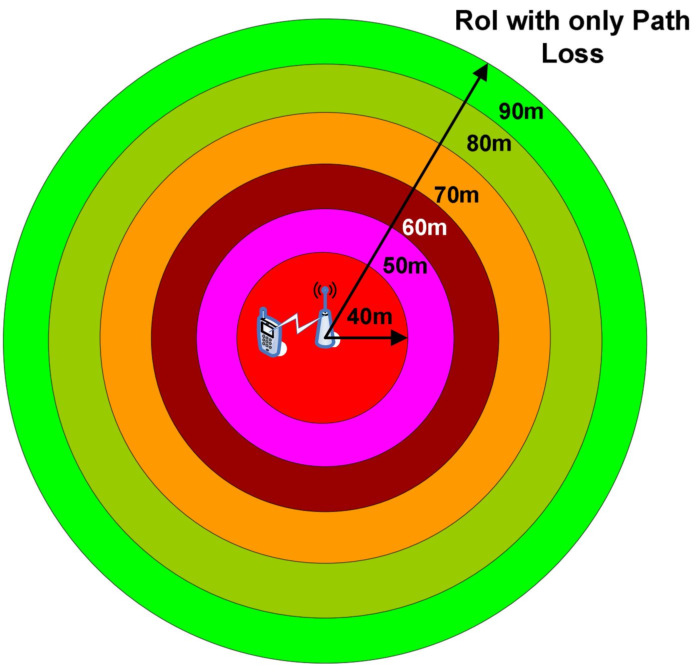


**Figure 7: RoI with Path Loss only**

The out of cell interference received by the $HUE_o$ at RB m from n HNBs can be written in terms of RoI as:

$$i_{oc}^{m} = \sum_{n}^{m} P^{m} HNB_{n} \qquad for\ d_1 < RoI \qquad (7)$$

and

$$i_{oc}^{m} \approx 0 \qquad for\ d_1 \geq RoI \qquad (8)$$

Where n=1,...,N is the number of HNBs inside the RoI. From the above equations, it is clear that if the distance between $HNB_o$ and the interfering HNBs denoted as $d_1$ is less than RoI (90m), the $HUE_o$ will be interfered by them. On the other, hand if $d_1$ is greater than the RoI (90m), no out of cell interference is caused to the $HUE_o$.

## a. Path Loss, Log-Normal Shadowing and Fast Fading

Up until this point, we have analysed the co-tier interference, and also found the RoI for the $HNB_o$ based on only the path loss between the interfering HNBs and the $HUE_o$. However, as we know that there are two other important parameters that can change the channel conditions. These parameters are lognormal shadowing and fast fading. Thus, there is also a need to study the effects of co-tier interference on $HUE_o$ when these two channel parameters are also included in the channel model. In this section, only the unplanned femtocell network configuration of Figure 3. is assumed as unplanned deployment is the focus of our paper. Figure 8 shows the $E_c/N_o$ plots for both the direct signal and the interfering signal received from an interfering HNB located at 40, 50, 60, 90, 110 and at 130 m from $HNB_o$. From the figure it is evident that when shadowing and fading are included in the channel model even the HNB located at 90 m away from the $HNB_o$ will cause interference to the $HUE_o$. This was not the case when only

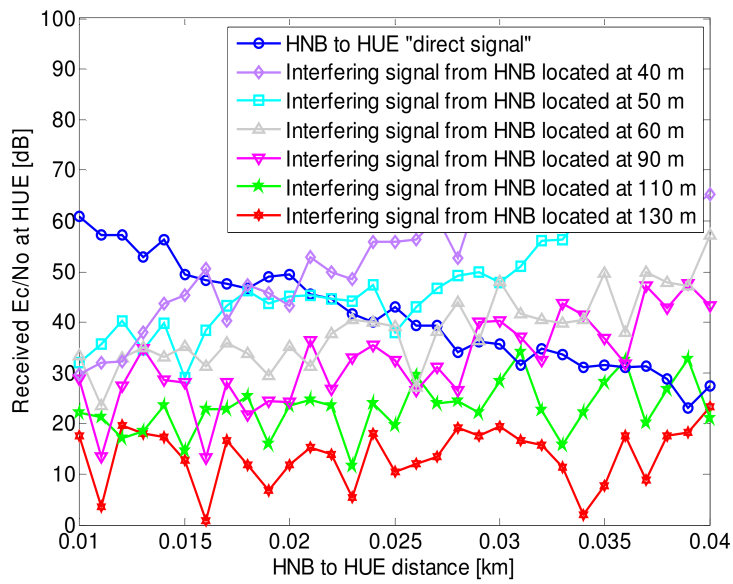


**Figure 8: Interference due to Unplanned Femtocell Configuration with Path Loss, Log-normal Shadowing and Fast Fading**

International Journal of Information and Communication Technology Research



http://www.esjournals.org

path loss was considered (see Figure 6, $HNB_2$ at 90 m did not cause any interference to $HUE_o$. This shows that shadowing and Rayleigh fading have a great impact on the amount of co-tier interference received by the $HUE_o$. From Figure 8, the RoI for $HNB_{0}$ is found to be 130 m. One can clearly see the effect that the shadowing and fast fading caused in increasing the RoI from 90 m (path loss only) to 130 m with path loss, shadowing and fading. An illustration for RoI for $HNB_o$ is shown in Figure 9.

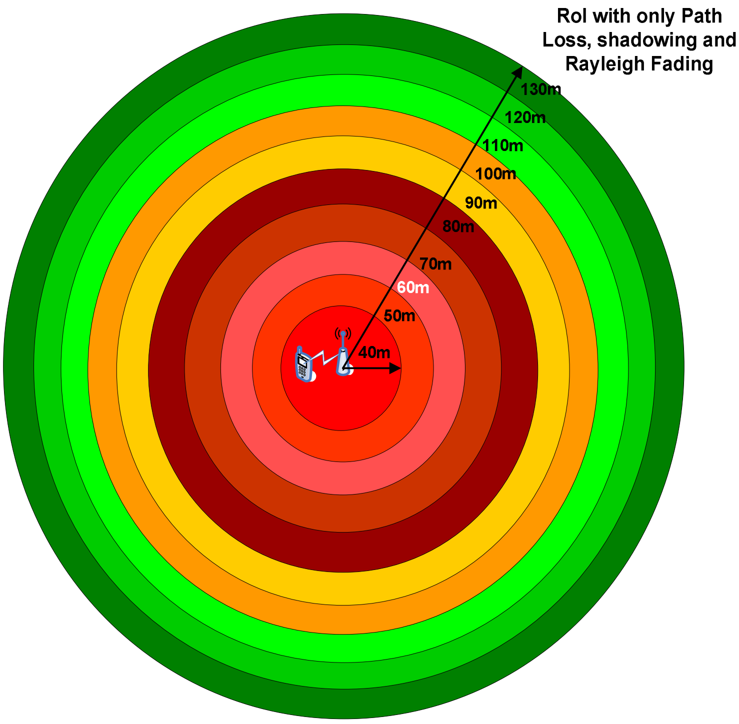


**Figure 9: RoI with Path Loss, Log-normal Shadowing and Fast Fading**

It is to be noted here that the RoI for a $HNB_o$ can vary depending upon its coverage area as shown in Figure 10. It can be seen from the figure that as the $HNB_o$ coverage area increases, the RoI also increases. This is because as the distance between $HUE_o$ and the $HNB_o$ increases, the $E_c/N_o$ from the $HNB_o$ reduces further and thus the interfering HNBs located further away will start to interfere with $HUE_o$. Rayleigh fading and log-normal shadowing in addition to path loss also play an important role in increasing the RoI for an HNB as shown in the figure.

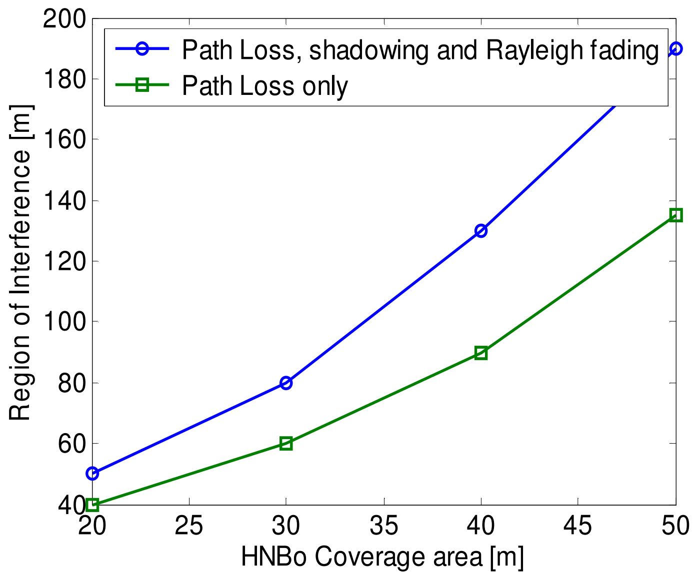


**Figure 10: Region of Interference Vs $HNB_o$ Coverage Area**

From the above discussion we can conclude that in a unplanned femtocell network deployment in which the communication channel between the femtocell devices consists of path loss, fading and shadowing, a femtocell located at $d_1 <$ 130m will cause interference to the $HUE_o$ when same RBs are used by both the HNBs. The probability of interference of the $HUE_o$ is shown in Figure 11 when only a single interfering HNB is placed at $d_1$ = 40m, 50m, 60m, 70m, 80m and 90m around the $HNB_o$.

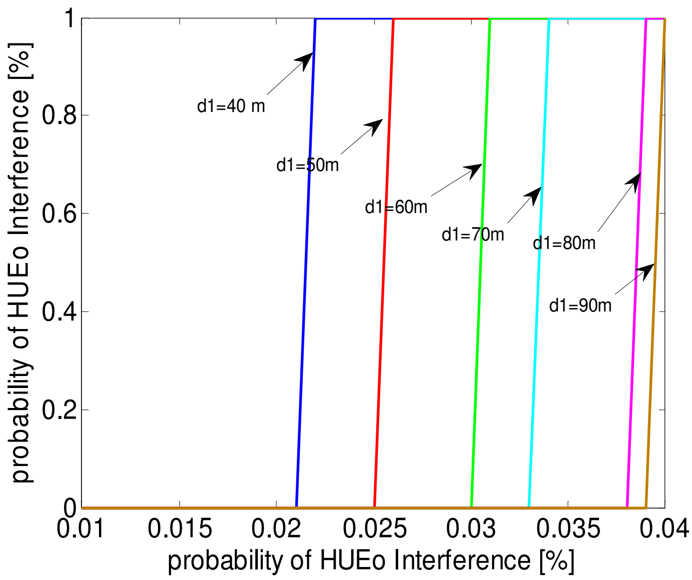


**Figure 11: Region of Interference Vs $HNB_o$ Coverage area**

Volume 2 No. 8, August 2012 ISSN 2223-4985
International Journal of Information and Communication Technology Research

http://www.esjournals.org

The interference probability is ``0" when the $E_c/N_o$ from $HNB_o$ towards $HUE_o$ is higher than the $E_c/N_o$ from the single interfering HNB and jumps to ``1" as soon as the $E_c/N_o$ from $HNB_o$ towards $HUE_o$ is below the $E_c/N_o$ received from the single interfering HNB. The effect of the interfering HNB at $d_1$= 100m, 110m and 120m is the same as that of the effect around 90m. From the figure we can see that when $d_1$=40m the $HUE_o$ gets interfered by the HNB at $d_2$=21 m. Note that $d_1$ and $d_2$ are defined in section V. Similarly, when the interfering HNB is at 50m, 60m and 70m, the $HUE_o$ receives interference at $d_2$=25, 30 and 33 m. At $d_1$= 90m, the $HUE_o$ still receives high interference but we think that the case where $d_1$=40, 50 60, 70 and 80m is of most significance. Thus, we change the RoI value from that of 130m to that of 80m. The probability of interference from multiple HNBs located in the RoI of 80 m towards $HUE_o$ is shown in Figure 12. From the figure, it is evident that the $HUE_o$ experience interference even when the $HUE_o$ is close to $HNB_o$ approximately 5% interference. As the $HUE_o$ moves away from $HNB_o$ the interference gets severe (approximately 80% at 35 m distance away from $HNB_o$. Thus, it is crucial to avoid this interference for efficient operation of every HNB.

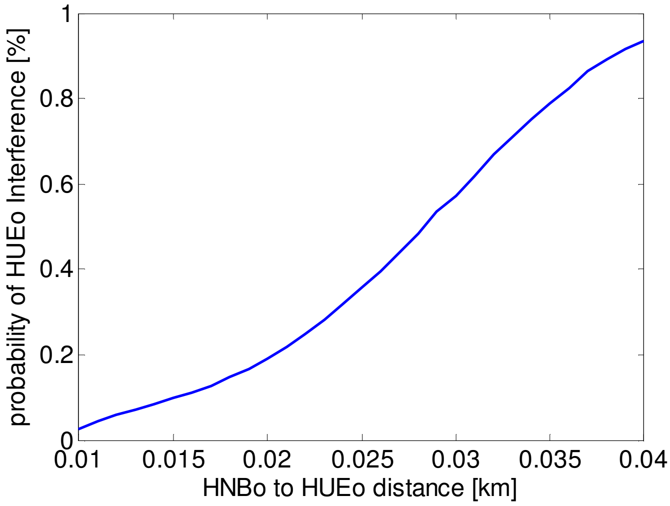


**Figure 12: Probability of $HUE_o$ Interference from Multiple HNBs at RoI=80m**

## V. PROPOSED SCHEME TO AVOID CO-TIER INTERFERENCE

In this section, a solution to avoid co-tier interference is proposed. The solution consists of implementing a femtocell network controller (FNC) in areas inside the macrocell where dense femtocell deployment exists as shown in Figure 13.

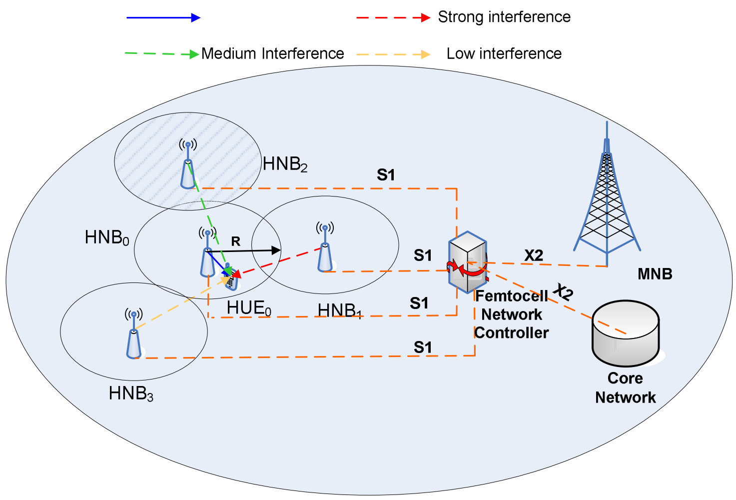


**Figure 13: Proposed Solution Incorporating a FNC inside the Macrocell**

A dense femtocell network can contain 15-20 HNBs located close to each other. The FNC can be a network entity or a software process inside a network entity. The FNC acts a ``virtual" macro-base station for the core network (CN) and as a ``virtual" CN entity for the HNBs. We assume that the FNC has the knowledge of the positions of all the HNBs and their HUEs connected to it. We also assume that the MNB can provide the location information of its MUEs that are near the dense femtocell network area. Furthermore, the MNB also informs the FNC which RBs are used by those MUEs. This information will be used to allocate resources to the HNBs as discussed in the next paragraph. The FNC has the control over the HNB configuration such as transmit power and resource allocation. The HNBs are connected to the FNC through S1 interface and the FNC is itself connected to the CN and to the MNB via the X2 interface as defined in the long term evolution (LTE) standard.

The HNBs connected to the FNC provides it with their access modes identity (AMI). The AMI tells the FNC whether the HNB connected to it is an open access or a closed access HNB. The FNC forms two lists and puts the open access HNBs to one list and the closed access HNBs to the other list. As closed access HNBs do not allow HUEs from other HNBs to connect to it thus it is crucial that the FNC allocates different RBs to the closed access HNBs. This is important as two or more closed access HNBs can be located close together, thus causing interference if same RBs are used among them. This different RB assignment utilises a major portion of RBs. To overcome this and to increase the RB reuse efficiency we propose that the open access HNBs divide their coverage area into two separate coverage area i.e. inner coverage area and outer coverage area. In this scheme the open access HNBs use the RBs allocated to the nearby closed access HNBs in their inner coverage area while they use the RBs allocated to closed access HNBs located far away in their outer coverage area as shown in Figure 14.

Volume 2 No. 8, August 2012 ISSN 2223-4985

International Journal of Information and Communication Technology Research



http://www.esjournals.org

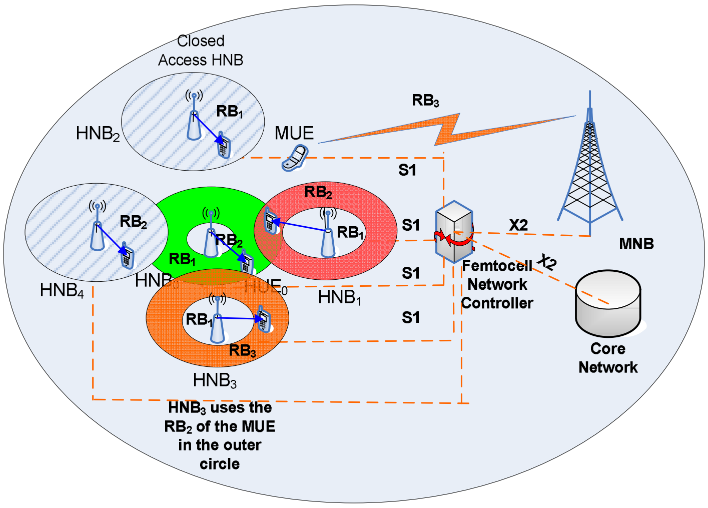


**Figure 14: Proposed RB Allocation Scheme**

In the figure there are two closed access HNBs ($HNB_2$ and $HNB_4$) and two open access HNBs ($HNB_1$ and $HNB_3$) surrounding the femtocell of interest ($HNB_o$). The closed access HNBs are allocated different RBs as proposed above, while the open access HNBs reuse the RBs allocated to the closed access HNBs. In the figure, $HNB_o$ is allocated the $RB_2$ of the closed access $HNB_4$ in the inner coverage area while it is allocated $RB_1$ of the closed access $HNB_2$ in its outer coverage area. Similarly, $HNB_1$ is allocated $RB_1$ of closed access $HNB_2$ in the inner coverage area while it is allocated $RB_2$ of $HNB_4$ in its outer coverage area. $HNB_3$ can be allocated either $RB_1$ or $RB_2$ in its inner and outer coverage area as both the closed access HNBs are away from it. Another way of improving the RB reuse efficiency is that if an open access HNB can also use the RBs that are allocated to the MUEs near the dense femtocell network area. This can only happen when the MUE is far away from the open access HNB. The open access HNB can use the RB either in the inner coverage area or outer coverage area as shown in Figure 14. In the figure, $HNB_3$ is allocated $RB_3$ of the MUE as the MUE is far away from $HNB_3$. However, in situations where the MUE is near to the open access HNB, the HNB can only use the RB allocated to the MUE in the inner coverage area in order to avoid it interfering with the MUE. The sizes of the two coverage areas depends upon the distance between the open access HNB and the closed access HNB and the MUE. The closer the open access HNB is to the closed access HNB or the MUE the smaller will be the size of the inner coverage area and the larger will be the size of the outer coverage area. Note that all of the RB allocation to the closed and open access HNBs are performed by the FNC. The FNC also keeps record of the RBs allocated to the HNBs in its area so that if a new HNB becomes active it can allocate sufficient resources to that HNB.

In the Figure 15 we show how the FNC allocates RBs to closed and open access HNBs. The red stars represent closed access HNBs while the blue squares represent the open access HNBs. The green circle represents $HNB_o$ of the femtocell of interest. In the figure the closed access HNBs are allocated orthogonal RBs while the open access HNBs close to the closed access HNBs reuse the RBs of the closed access HNBs in their inner coverage area while using RBs of far away closed access HNBs in their outer coverage area, thus avoiding co-tier interference and increasing the RB reuse efficiency.

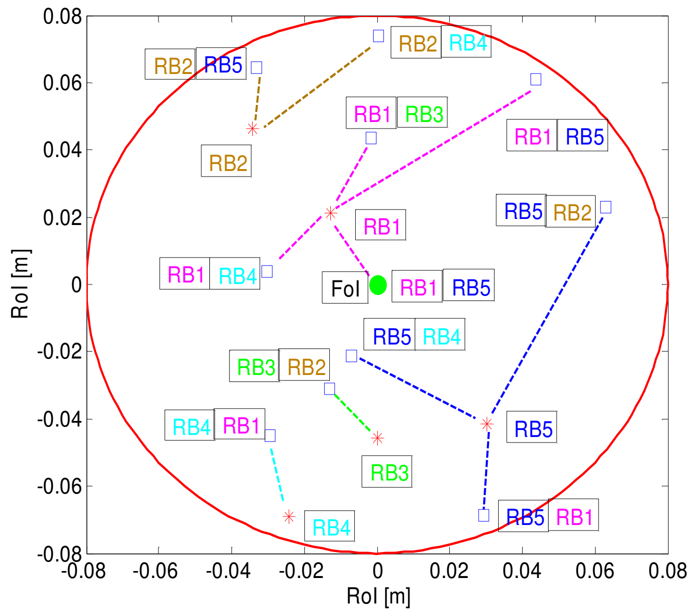


**Figure 15: RB Allocation to Open and Closed Access HNBs**

## VI. SIMULATION PARAMETERS

All of the simulations were obtained by using Matlab software. In our simulations a large density of femtocells were considered inside the macrocell network. Specifically we chose 15-20 femtocells randomly deployed around $HNB_o$. The radius of all HNBs including $HNB_o$ was set to 40m with a transmit power of 13dBm. The $HUE_o$ was moved from near the $HNB_o$ to the coverage edge of the $HNB_o$. Snapshots of the simulation are shown in Figure 16 and Figure 17. In the figures the green dots represent the $HNB_o$ and $HUE_o$ and the red dots represent the interfering HNBs. Path loss, Rayleigh fading, Rician fading and log-normal shadowing were also used in the simulations to achieve accurate results.

International Journal of Information and Communication Technology Research

http://www.esjournals.org

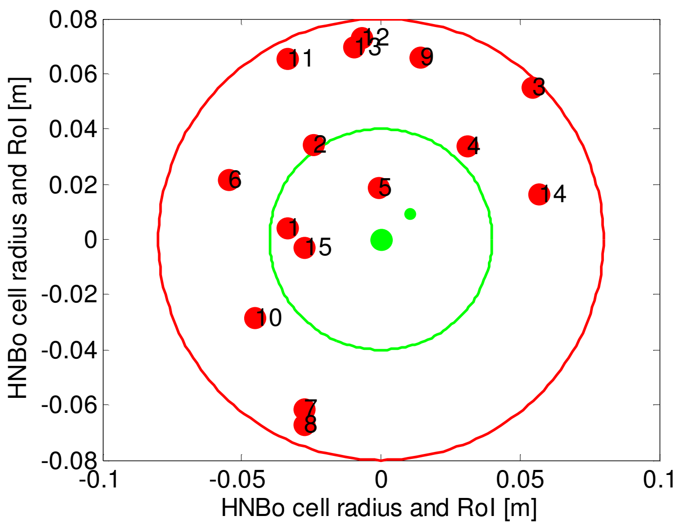


**Figure 16: Snapshot of $HUE_o$ near $HNB_o$**

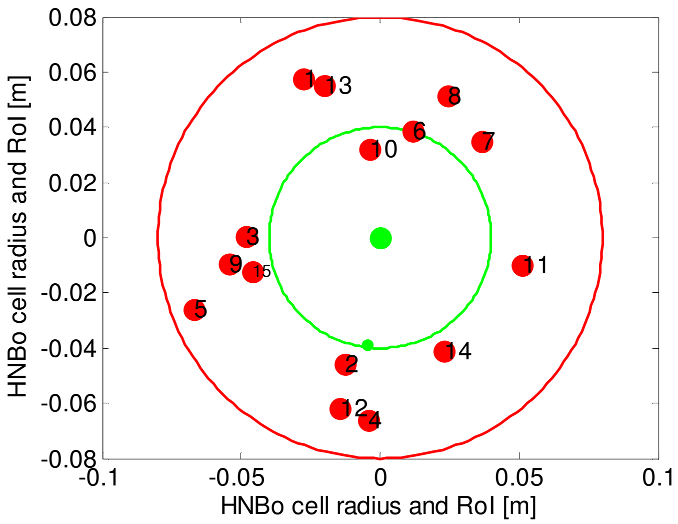


**Figure 17: Snapshot of $HUE_o$ at the Coverage Edge of $HNB_o$**

A table of the major simulation parameters is also given below. In our simulations we consider 5 closed access HNBs and 10 open access HNBs. The ratio of the closed and open access femtocells can be different. The FNC knows the positions of all the closed access HNBs and allocates orthogonal resources to all of them. The FNC then looks for open access HNBs near those closed access HNBs. The open access HNBs closer to the closed access HNB are allocated the same RBs in their inner coverage area that are allocated to the closed access HNBs, while the RBs of far away closed access HNBs are allocated in the outer coverage area of open access HNBs.

**Table 1: Simulation Parameters**

| Simulation Parameters | Notation | Value |
|---|---|---|
| MNB radius | $R_{MNB}$ | 2 Km |
| Number of HNBs | $N$ | 15-20 |
| HNB radius | $R_{HNB}$ | 40 m |
| Noise Figure | $NF$ | 5 dB |
| HNB Transmit Power | $P_{HNB}$ | 13 dBm |
| Outdoor Fading | $F_{out}$ | Rayleigh |
| Indoor Fading | $F_{in}$ | Rician |
| Outdoor Shadowing | $\sigma_{out}$ | 6 -10 dB |
| Indoor shadowing | $\sigma_{in}$ | 3-6 dB |
| Region of Interference | $RoI$ | 80 m |

Furthermore, the femtocell of interest is also allocated resources according to the procedure above to make sure no interference is caused from the femtocell of interest to other closed or open access femtocells. This novel resource based scheme completely avoids co-tier interference between femtocells having different access modes. RB reuse efficiency is also increased.

## VII. RESULTS

In this section the effectiveness of the proposed scheme is viewed in terms of avoiding co-tier interference and the RBs requirement probability. In Figure 18, the interference probability to the $HUE_o$ with our proposed resource allocation scheme is reduced from 90% at the $HNB_o$ coverage edge to just 20%. This small amount of interference is due to the Rayleigh fading environment between the $HNB_o$ and interfering HNBs using the same RBs in the outer coverage area. The Rayleigh fading sometimes boosts up the signal from the interfering HNB although the distance between the HNBs is large.

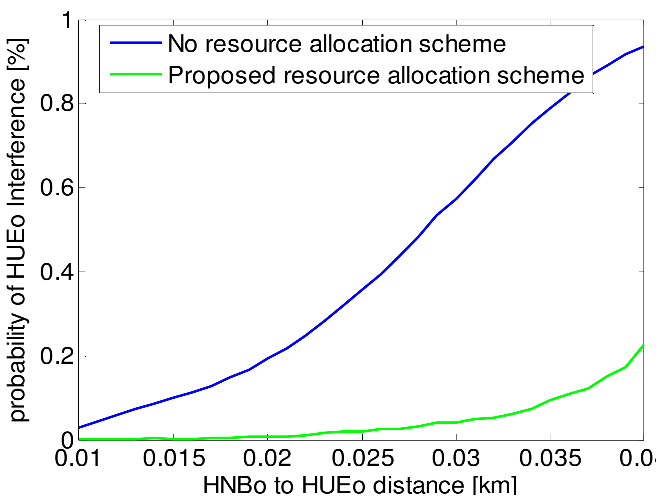


**Figure 18: Avoidance of Interference to $HUE_o$ from our Proposed Resource Allocation Scheme**

International Journal of Information and Communication Technology Research



http://www.esjournals.org

In terms of RB requirement probability we can see that in the case where each HNB either closed or open was to be allocated a different RB then for 15 HNBs the FNC needed 15 RBs. The RB requirement was (15/15) x100 = 100%. Whereas, with our proposed scheme in which 5 HNBs are closed access and the rest 10 are open access, the RB requirement probability is reduced to (5/15) x 100= 33%.

## VIII. CONCLUSIONS

In this paper a resource allocation scheme is presented that completely avoids co-tier interference among femtocells of different access modes. In the scheme, a femtocell network controller (FNC) is proposed to manage resource allocation among dense femtocells deployment. The FNC allocates orthogonal resources to closed access HNBs while the coverage area of the open access femtocell is divided into two separate coverage area i.e. inner and outer coverage areas. The FNC allocates the same RBs in the inner coverage area that are allocated to the closed access HNB nearby while the outer coverage area is allocated those RBs which are used by far away closed access HNBs. This resource allocation among the closed and open access HNBs completely avoids co-tier interference and also increase the RB reuse efficiency.

## REFERENCES


[1] Chandrasekhar, J. Andrews, and A. Gatherer, ``Femtocell networks: a survey," *IEEE Commun. Mag.*, vol.46, no.9, pp.59-67, Sep. 2008.

[2] "Interference Management in UMTS femtocell," FemtoForum, Dec. 2008. Available: http://www.scribd.com/doc/47418770/Interference-Management-in-UMTS-Femtocells

[3] D. Lopez-Perez, A. Valcarce, A. Ladanyi, G. De La Roche, J. Zhang,``Intracell handover for interference and handover mitigation in OFDMA two-tier macrocell-femtocell networks,"*EURASIP J. Wireless Commun. Net.*, vol.2010, 2010, pp. 16.

[4] D. Lopez-Perez, A. Valcarce, G. De La Roche, J. Zhang,``OFDMA Femtocells: A roadmap on interference avoidance,"*IEEE Commun. Mag.*, vol.47, no.9, pp. 41-48, Sep.2009.

[5] Y. Tokgoz, F. Meshkati, Y. Zhou, M. Yavuz, S. Nanda,``Uplink interference management for HSPA+ and 1xEVDO femtocells,"*IEEE GLOBECOM*, 2009.

[6] M. Husso, Z. Zheng, J. Hamalainen, E. Mutafungwa,``Dominant interferer mitigation in closed femtocell deployment," *in proc. PIMRC 2010*, pp. 169-174, 26-30 Sept. 2010.

[7] H. Li, X. Xu, D. Hu, X. Tao, P. Zhang, S. Ci, H. Tang,``Clustering strategy based on Graph method and power control for frequency resource managment in femtocell and macrocell overlaid system," *Journal of Commun. and Netw.*, vol. 13, no. 6, pp. 664-677, Dec. 2011.

[8] L. Zhang, L. Yang, T. Yang,``Cognitive interference management for LTE-A femtocells with distributed carrier selection," *IEEE VTC 2010*, pp. 1-5, 6-9 Sept. 2010.

[9] Y.-Y. Li, M. Macuha, E. S. Sousa, T. Sato, and M. Nanri, ``Cognitive interference management in 3G femtocells," *in proc. PIMRC 2009*, pp.1118-1122, 13-16 Sept. 2009.

[10] Y.-Y. Li, E. S. Sousa,``Cognitive uplink interference management in 4G cellular femtocells," *IEEE PIMRC 2010*, pp. 1567-1571, 26-30 Sept. 2010.

[11] F. Pantisano, K. Ghaboosi, M. Bennis and M. Latva-Aho,``Interference avoidance via resource scheduling in TDD underlay femtocells," *IEEE PIMRC 2010*, vol., no., pp. 175-179. Sep. 2010.

[12] G. Gur, S. Bayhan, and F. Alagoz, ``Cognitive femtocell networks: an overlay architecture for localized dynamic spectrum access [Dynamic Spectrum Management]," *IEEE Wireless Commun.*, vol. 17, no. 4, pp. 62-70, Aug. 2010.