Australian Journal of Basic and Applied Sciences, 6(10): 76-87, 2012
ISSN 1991-8178

Interference Minimization Schemes in OFDMA-based Femtocells

Mohamed Hadi Habaebi, Jalel Chebil, Zulfadli Zainal and Afiq Muzaini

Department of Electrical and Computer Engineering, Kulliyah of Engineering, International Islamic University Malaysia (IIUM).

Abstract: Femtocells are deployed to improve the cellular coverage and network capacity in indoor area. Despite their great indoor coverage, the implementation of femtocell by high number of subscribers causes serious interference problem between femto Base Stations (fBSs) and cellular macro Base Stations (mBSs). In order to achieve interference avoidance in a two-tier femtocell network, self-organizing interference avoidance schemes are usually employed. In this paper, channel selection interference avoidance schemes are used to improve network performance. Simulation studies indicate that cumulative interference from macrocell and other femtocells reduces femtocell performances. However, by properly applying the channel selection schemes in conjunction with femtocell antenna beamforming technique, Signal to Interference and Noise Ratio (SINR) and the throughput of the femtocell are positively increased ensuring better network performance.

Key words: Femtocell, fBS, interference, channel selection, beamwidth shaping.

INTRODUCTION

Femtocell is a home base station that connect standard mobile devices to mobile operator's network using residential Digital Subscriber Line (DSL), cable broadband connections, and optical fibres. The femtocell unit incorporates the functionality of a typical base station. A femtocell unit looks like a Wi-Fi access point except it also contains the core network elements needed in base stations. Thus, it does not need a cellular core network, but it requires only a data connection to the DSL or cable to the Internet so that it can be connected to the mobile operators' core network (Jie Zhang, 2010).

The main advantages of using femtocell are to provide better indoor coverage and to offload traffic from the macrocell layer, hence, improving macrocell capacity. The fBSs indoor path loss is much smaller than that of the outdoor mBSs, thus providing high speed data services while prolonging the user equipment (UEs) battery lifetime since the UE's uplink is much shorter.

Since data services in many households and businesses experience poor indoor coverage problems (Cullen, J., 2008), it is imperative to use fully functioning fBSs instead of coverage extention picocells to offload mBSs heavy traffic and simultaneously provide excellent indoor coverage.

Related Works:

Probably the most important problem in femtocell networks is the presence of interference between neighbouring femtocell networks, thus it provides a platform for researchers to investigate and come out with solutions to mitigate the interference. In (S. Park and S. Bahk, 2011), the authors investigated the high network density because of the large portion of users to inter-cell interference (ICI). They proposed distributed dynamic ICI which not only works in fully distributed manner but also controls interference link connectivity of users with high agility so that it is suited for self-organizing networks (SON). However the authors only analysed the interference occurrence between base stations in general perspective which neglects the real interference situation that might arise when femtocells are deployed in many homes. In (A.D. Domenico and E.C. Strinati, 2010), a novel resource scheduling algorithm was proposed to improve spectral reuse while reducing the transmission power in each resource block. The proposed scheme efficiently exploits the wireless spectrum in a two tier network where they implemented two versions of Resource Scheduling Algorithm for Self-Organizing Femtocell. The first approach employed the blind round robin scheme that is used when femtocells were not aware of the presence and allocation strategy of neighbour cells. Meanwhile, the second approach used the matrix-based chunk allocation where it enables fBS to utilize momentary state information of the wireless environment.

In (V. Chandrasekhar, 2009), the investigation of an uplink capacity analysis and interference avoidance strategy in a two-tier CDMA network was developed. The capacity analysis provides an accurate characterization of the uplink outage probability thus accounting for the feasible usage of power control, path loss and shadowing effect in the network system. This approach provides guidelines for the design of robust shared spectrum two-tier network, hence a better performance with low interference occurrence can be obtained.

The work in (Chiao Lee, 2010) is based on developing the distributed channel selection principles for the OFDMA- based femtocell network with considering two-tier interference. The authors proposed an approach of

Corresponding Author: Mohamed Hadi Habaebi, Department of Electrical and Computer Engineering, Kulliyah of Engineering, International Islamic University Malaysia, (IIUM).
E-mail: <habaebi@yahoo.com

channel-gain oriented and interference avoidance oriented channel selection to improve capacity and link reliability. Basically, channel gain oriented schemes aims to transmit data in the sub channel with higher link gain while the interference avoidance oriented schemes aims to transmit data in the sub channel with lower interference.

In (Mika Husso, 2010) the scheme of transmitted beam-forming based interference control was applied where it utilized multiples antenna in the fBS in conjunction with a control-only connection established between UEs and interfering fBS. It is shown that even simple and practical transmit beam-forming methods can be used effectively in interference mitigation purposes. However the drawback of this approach was that if the transmitted antenna resources are used to suppress the interference in adjacent cells, there will be loss in the beam-forming gain in the targeted cell. Nevertheless this shortcoming only will occur if the fBS are suffering from heavy interference.

From (Hussein Saad, 2012) a distributed reinforcement learning technique called distributed power control using Q-learning was implemented in order to manage the interference caused by the femtocells on macro-users in downlink. It was used to identify the sub-optimal pattern of power allocation which strives to maximize femtocell capacity while guaranteeing macrocell capacity level in an underlay cognitive setting.

Meanwhile, in (Hui Zeng, 2009) the performance evaluation of WiMAX (802.16e) femtocell system was analysed in term of the network coverage and the system capacity. The paper investigated the effect of the transmit power at fBSs, cell radius and loading factor that focused on the performance of UEs in the indoor environment. The paper suggested several heuristic frequency assignment schemes and compared them along with the random assignment schemes that randomly assigned one of three segments for each fBS.

Finally the work in (D.L. Perez, 2010), proposed two novel approaches for the self-organization of OFDMA femtocells in which the femtocell is able to dynamically sense the air interface and tune its sub-channel allocation in order to reduce inter-cell interference and enhance system capacity. The sensing phase technique will make use of either message broadcast by the femtocells or measurement reported by the users. While in tuning phase, it will provide a good solution for the frequency assignment problems. However, the paper only showed that using self-organization leads to better system performance rather than using random assignments.

In order to successfully react to the changes of the traffic and channel hence minimizing interference in femtocell deployments, the use of sophisticated self-organization techniques is needed.

System Model:

This model considers the OFDMA based femtocell system with two tier interference scenario. The network architecture of this system model is shown in Fig 1. Based on the layout, the system model contains one Macro Base Station (mBS) with a coverage radius of 1000 meters (Sara Moftah Elrabiei, 2010; Sara Moftah Elrabiei, 2010). Inside this coverage radius, there are 100 femtocells network is being deployed randomly by Small Office Home Office. Every Femto Base Station (fBS) has the capability of supporting 4 User Equipments (UEs) at a time. To simplify the model, all fBSs are assumed to operate as a Close Subscriber Group (CSG) femtocells with 30 meters coverage radius. All the UEs in the layout are randomly distributed inside every fBSs network.

Each fBS in this model can be recognized according to its unique identification number. The UEs for every fBSs is being initialized with different colours plot. In this model, no mobility condition is assumed. Every UE is static and being served by its own fBS. To simplify the model, as all the UEs stays on the static condition inside their own fBS coverage, all the UEs are served by their own fBS, which are able to serve only one sub-channel to the UEs per time. In this model, interference due to both neighbouring fBS and mBS is defined as a function of distance. Fig 2 shows the close up view of the network layout.

The system model is based on the OFDMA femtocell system. Because of that, certain configuration of OFDMA femtocells need to be implemented during the simulation. Table 1 shows the OFDMA-based femtocell parameters that are used for this model (Chiao Lee, 2010).

Channel Propagation models are used for calculation of electromagnetic field strength for the purpose of wireless network planning during preliminary deployment (Sara Moftah Elrabiei, 2011; 2012). It describes the signal attenuation from transmitter to receiver antenna as a function of distance, carrier frequency, antenna heights and other significant parameters like terrain profile such as urban, suburban and rural area (Mohammad Shahajahan, 2009).

The considerations of femtocell channel propagation model include the assumptions and effects of the environment to the system. These requirements are based on the requirements suggested in (Usage Models, 20074) and (Indoor MIMO WLAN., 2003). For the propagation model in femtocell system, the desired path loss formulas are stated as in Equation 1 and Equation 2 in (Hui Zeng, 2009).

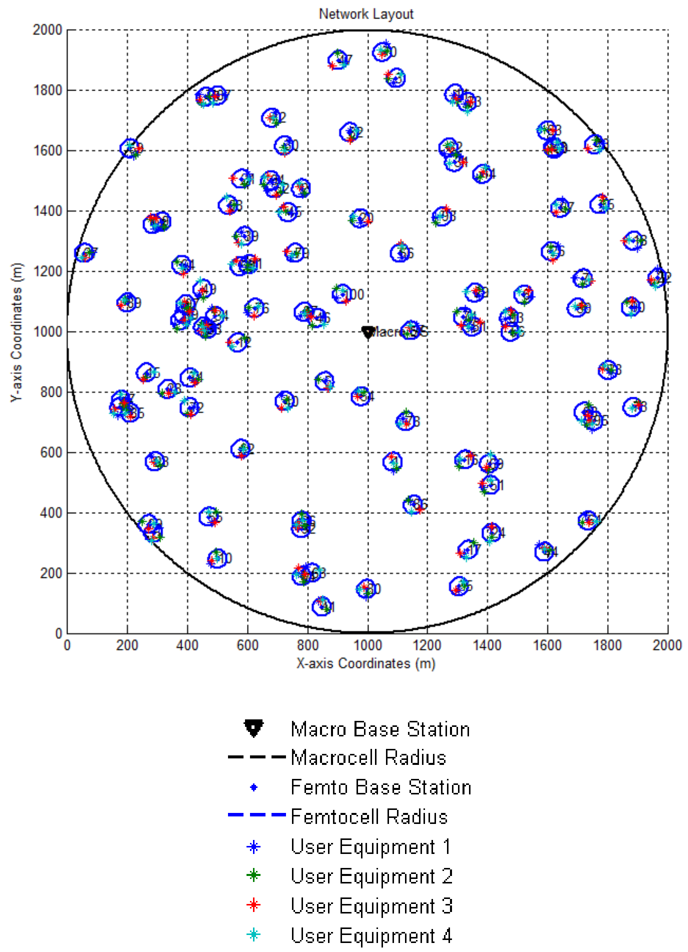

Fig. 1: Two - Tier Interference Network Layout.

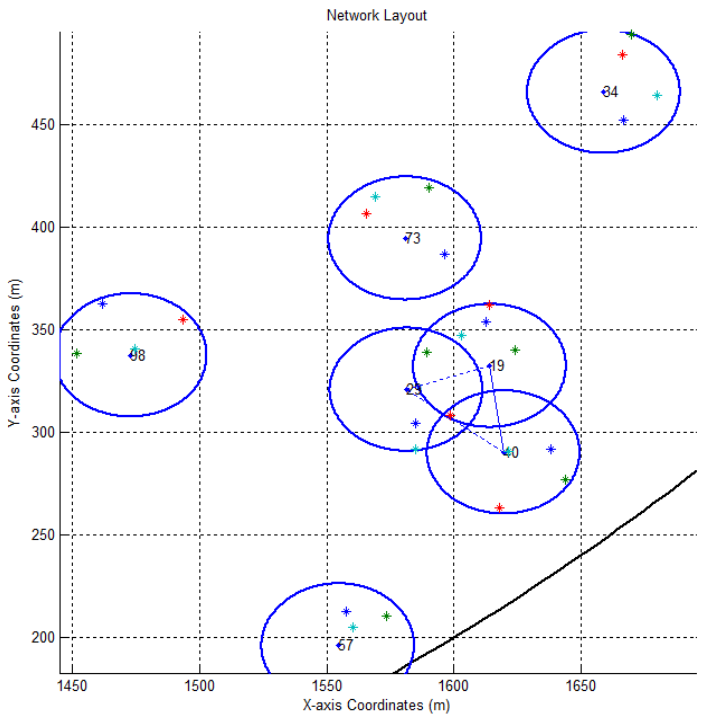

Fig. 2: Close Up view on the Network Layout.

Table 1: OFDMA-Based Femtocell Configuration.

Parameters	Value
Carrier Frequency	2.5 GHz
Macro Base Station (mBS) Tx Power	43 dBm
Femto Base Station (fBS) Tx Power	20 dBm
Macro Base Station (mBS) Radius	1000 m
Femto Base Station (fBS) Radius	30 m
Macro Base Station (mBS) Antenna Gain	8 dB
Macro Base Station (fBS) Antenna Gain	3 dB
System Bandwidth	10 MHz
Sub Carrier Bandwidth	10.9375 kHz
Number of Sub Channels	40
Number of Sub Carrier	18

$$L(d) = 20\, log_{10}\left(\frac{4\pi d}{\lambda}\right) for\, d \le d_{BP} \tag{1}$$

$$L(d) = L\,(d_{BP}) + 35\, log_{10}\left(\frac{d}{d_{BP}}\right) for\, d > d_{BP} \tag{2}$$

$L(d)$ is the free space path loss for a distance d between the transmitter and the receiver, λ is the wavelength in meter, and d_{BP} is the break point distance that can be assumed as 10 m for indoor to outdoor link (Chiao Lee, 2010).

The channel propagation model for macrocell is the Stanford University Interim (SUI) model for suburban terrain type *B*. This model is proposed by IEEE 802.16 Broadband Wireless Access working group for the frequency band below 11 GHz and is defined for the Multipoint Microwave Distribution System for the frequency band from 2.5 GHz to 2.7 GHz (V.S. Abhayawardhana, 2005).

Performance Matrices:

Based on the two tier interference problem, the Signal to Interference Noise Ratio, $SINR_{j,m}$ formula is optimized. The general formula for $SINR_{j,m}$ of m^{th} sub-carrier on the j^{th} sub-channel of the femtocell can be written as (Chiao Lee, 2010).

$$SINR_{j,m} = \frac{\dfrac{p^{i}_{j,m} G_{FBS} h^{i}_{j,m}}{L(d_i)}}{\dfrac{P_{j,m} G_{MBS} H_{j,m}}{L(D)} + \sum_{k=1,k\neq i}^{K} \dfrac{p^{k}_{j,m} G_{FBS} h^{k}_{j,m}}{L(d_k)} + N_0} \tag{3}$$

$P_{j,m}$ and $p^{k}_{j,m}$ is noted as the transmission power of mBS and interfering fBS of k^{th} fBS in the m^{th} sub-carrier and j^{th} sub-channel. G_{MBS} and G_{FBS} on the other hand are the antenna gains of mBS and fBS. $H_{j,m}$ is defined as the channel gain between the mBS and the UE while $h^{i}_{j,m}$ is defined as the channel gain between k^{th} fBS and UE. N_0 is the term in which describing the Additional White Gaussian Noise (AWGN). For this model, the system is assumed to be Interference Limited System which means that the noise can be neglected as the interference from the mBS and fBS can dominates the whole performances of the system (Andreas F. Molisch, 2011).

The channel gain between the mBS and the UE, $H_{j,m}$ and the channel gain between k^{th} fBS and UE, $h^{i}_{j,m}$ is expressed as a function of distance. Equation 4 (R. Jain, 1998) shows the basic channel gain equation between transmitter, fBS and the receiver, UE on m^{th} sub-carrier while Equation 5 (R. Jain, 1998) shows the basic channel gain equation between transmitter mBS and the receiver UE on m^{th} sub-carrier (Hussein Saad, 2012).

$$h^{m}_{fBS,UE} = d^{(-k)}_{fBS,UE} \tag{4}$$

$$H^{m}_{mBS,UE} = d^{(-\Upsilon)}_{mBS,UE} \tag{5}$$

The physical distance between transmitter, fBS and the receiver UE is $d_{fBS,UE}$, while $d_{mBS,UE}$ is the physical distance between transmitter, mBS and the receiver, UE. The path loss exponent ,k, is set to k=2 for UE which is inside the break point distance, d_{BP} and k=3.5 for UE that located outside the break point distance. On the other hand, γ is the path loss exponent for mBS that is extracted from the SUI model.

By having the optimized $SINR_{j,m}$ formula, the throughput of the performance can be evaluated. as in Equation 6 (S. Park and S. Bahk, 2011).

$$Throughput_{j,m} = W\ log_2\ (1 + SINR_{j,m}) \tag{6}$$

where W is the bandwidth of j^{th} sub-channel in m^{th} sub-carrier.

Proposed Model:

This section proposes to use the distributed channel selection schemes usually employed to mitigate the interference in two-tiered networks. Then, beamforming techniques is added to improve the performance of network.

Distributed Channel Selection Schemes:

In this section, two distributed channel selection schemes will be used to analyse the system performances. They are channel gain oriented schemes and interference avoidance oriented schemes (Chiao Lee, 2010). Channel gain oriented schemes aim to transmit data in the sub channel with higher link gain. Channel gain oriented schemes introduce two methods which are Max-Min Channel Gain Oriented Selection scheme and Max-Avg Channel Gain Oriented Selection Scheme. Equation 7 (Chiao Lee, 2010) shows the expression of channel gain, h_j in calculating the average channel gain for the whole femtocell network.

$$h_j = \frac{1}{M}\sum_{m=1}^{M} h_{j,m}^{i}\ for\ j = 1, 2, \dots, J \tag{7}$$

The Max-Min Channel-Gain Oriented Selection scheme performs the following procedure

1. Compare the individual sub-carrier gain in a sub-channel, h_j.
2. Sort h_j as $h_1 \geq h_2 \geq \cdots h_j$.
3. Select the first sub-carrier with higher link gain.

For the Max-Avg Channel-Gain Oriented Selection scheme, the following procedures are carried out.

1. Compute the average sub-carrier gain of each sub-channel, h_j.
2. Sort h_j as $h_1 \geq h_2 \geq \cdots h_j$.
3. Select the first sub-carrier with higher link gain.

The interference avoidance oriented schemes aim to transmit data in the sub channel with lower interference. Interference Avoidance Oriented Selection Schemes introduce two methods which are Min-Max Interference Avoidance Oriented Selection Scheme and Min-Avg Interference Avoidance Oriented Selection Scheme. Equation 8 (Chiao Lee, 2010) shows the expression of interference, I_j in the whole femtocell network. Equation 9 (Chiao Lee, 2010) on the other hand shows the expression of interference, I_j in calculating the average interference for the whole femtocell network.

$$I_j = \left\{ P_{j,m}H_{j,m} + \sum_{k=1,k\neq i}^{K} p_{j,m}^{k} h_{j,m}^{k} \right\} \tag{8}$$

$$I_j = \frac{1}{M}\sum_{m=1}^{M} (P_{j,m}H_{j,m} + \sum_{k=1,k\neq i}^{K} p_{j,m}^{k}\ h_{j,m}^{k}) \tag{9}$$

The Min-Max Interference-Avoidance Oriented Selection scheme performs the following actions

1. Compare the interference for each sub-carrier of a sub-channel, I_j.
2. Sort I_j as $I_1 \leq I_2 \leq \cdots Ih_j$.

3. Select the first sub-carrier with lower interference.

For the Min-Avg Interference-Avoidance Oriented Selection scheme, the next actions are taken

1. Compute the average interference of a sub-channel, I_j.
2. Sort I_j as $I_1 \le I_2 \le \cdots Ih_j$.
3. Select the first sub-carrier with lower interference.

Beamwidth Shaping Technique:

The idea of using the beamwidth shaping technique is to develop a scenario where the fBSs will limit the beamwidth of its radiation pattern in order to avoid interference between its neighboring fBSs. The purpose is to allow only needed beamwidth by the UEs to transmit and receive between fBS. Such technique is widespread in cellular networks that operates in interference-limited (e.g., CDMA-based) systems. Fig 3 shows the concept of beamwidth shaping in femtocells technology using directional antennas. The motivation of this idea is coming from (Mika Husso, 2010) that proposed to reduce interference problems between femtocells by using practical transmit beamforming method. Theoretically, by controlling radiation pattern beamwidth angle, this approach will reduce antenna's beam coverage area thus making its radiation pattern more directive and less interfering with neighboring fBSs radiation pattern.

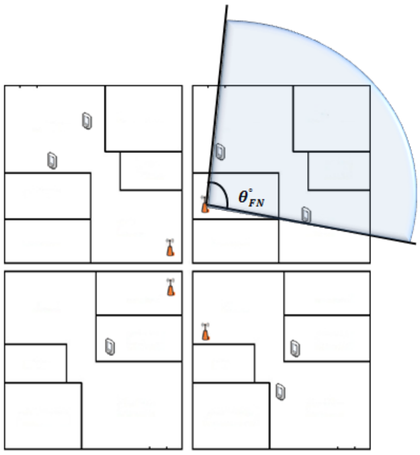

Fig. 3: Beamwidth Shaping in Femtocells using Directional Antennas.

An antenna's beamwidth is the half-power beamwidth. Equation 10 shows the expression of antenna's directivity in terms of half power beamwidths (John Daniel Kraus, 2002).

$$D = \frac{40\,000}{\theta^{\circ}_{HP}\varnothing^{\circ}_{HP}} \tag{10}$$

D is assigned as an approximate directivity of an antenna by neglecting the minor lobes while 40000 is the number of square degrees in sphere. θ°_{HP} is assigned as the half power beamwidths of the θ principal plane while $\varnothing^{\circ}_{HP}$ is assigned as half power beamwidths of the $\varnothing$ principal plane. The expressions θ°_{HP} and $\varnothing^{\circ}_{HP}$ is further explained in Equation 11 and Equation 12 in (John Daniel Kraus, 2002). θ°_{FN} and $\varnothing^{\circ}_{FN}$ is the full null beamwidths in both θ and $\varnothing$ principal plane.

$$\theta^{\circ}_{HP} \cong \frac{\theta^{\circ}_{FN}}{2} \tag{11}$$

$$\varnothing^{\circ}_{HP} \cong \frac{\varnothing^{\circ}_{FN}}{2} \tag{12}$$

To simplify the problem, it is assumed that each fBSs are transmitting in 3 sectors which mean each sectors can propagate signals from 0^o to 120^o. When beamwidth θ°_{FN} is equal to 0^0, it can be considered that there is no propagation while when beamwidth θ°_{FN} is equal to 120^0, it can be considered that the antenna pattern propagating in the full sector area. By assuming that both fBS and UE will always be on the Line of Sight (LOS) position, both antennas are somewhat aligned properly using the beam tracking at least at the fBS. By implementing this procedure, the Inter-Cell Interference (ICI) will only occur on the femtocell along the link or within the range of the gain and beamwidth. In other words, only the femtocell that dots the range of the antenna beamwidth will be affected. Assume the scenario given on Fig 4.

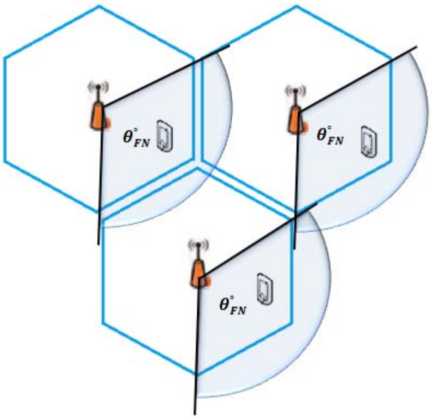

Fig. 4: Interference Avoidance Using Directional Antenna.

The beamwidth θ°_{FN} used by the fBS in Fig 4 which equal to 120^0 will reduce the interference of neighboring fBS by 2/3. By analysing Fig 3, the fBSs will be spared from interference by considering two cases.

Case 1: Channel is spared from interference on Uplink and Downlink.

In this case, both fBS and the UE will use the directional antenna with proper tracking and alignment.

Case 2: Channel is spared from interference on Downlink only.

In this case, only the fBS will use the directional antenna with proper tracking and alignment.

For the downlink condition, this model will evaluate the performances of the fBSs considering Case 2. By applying the concept of directivity antenna at the fBS, it can be considered that this model is using an approach to increase the antenna gain by reducing the beamwidths thus increasing the antenna's directivity. Gain is an antenna property dealing with an antenna's ability to direct its radiated power in a desired direction, or synonymously, to receive energy preferentially from a desired direction. The gain of the antenna is described in Equation 13 (John Daniel Kraus, 2002).

$$G_{FBS} = kD \tag{13}$$

G_{FBS} is the antenna gain of the fBS while k is the antenna efficiency factor which can be assigned from 0 to 1 respectively. In many well designed antennas, k may be close to unity value but in practice, G_{FBS} is always less than D the maximum idealized value. In this model, it is assumed that the antenna is 100% efficient which means k is equal to 1. D on the other hand is the directivity evaluated in Equation 10 by assuming θ°_{HP} is always equal to $\emptyset^{\circ}_{HP}$ in both principal plane.

Simulation Platform:

This model is simulated using MATLAB software. The network layout will be plotted randomly through this software and the performance metrics such as $SINR_{j,m}$ and $Throughput_{j,m}$ is evaluated numerically and then analysed.

Results:

Fig 5 shows the relation of pathloss and distances between the fBS and the UEs. The figure plotted the distances of all 400 UEs from its serving fBSs. As shown in the figure, it can be seen that the pathloss between the fBS and the UEs are exponentially increasing with the increasing distances of the UEs. The result suggests that as the distances of the UE is farthest from the fBS which is 30 meters, the pathloss can be as maximum as 77 dB. From the figure, it can be concluded that the transmitted signal from the fBSs will face higher losses if the location of the UEs are far from their serving fBSs, but the signal will preserve most of its information when the location is near to their serving fBSs. This is due to the pathloss effect on the downlink transmitted signal from the fBSs.

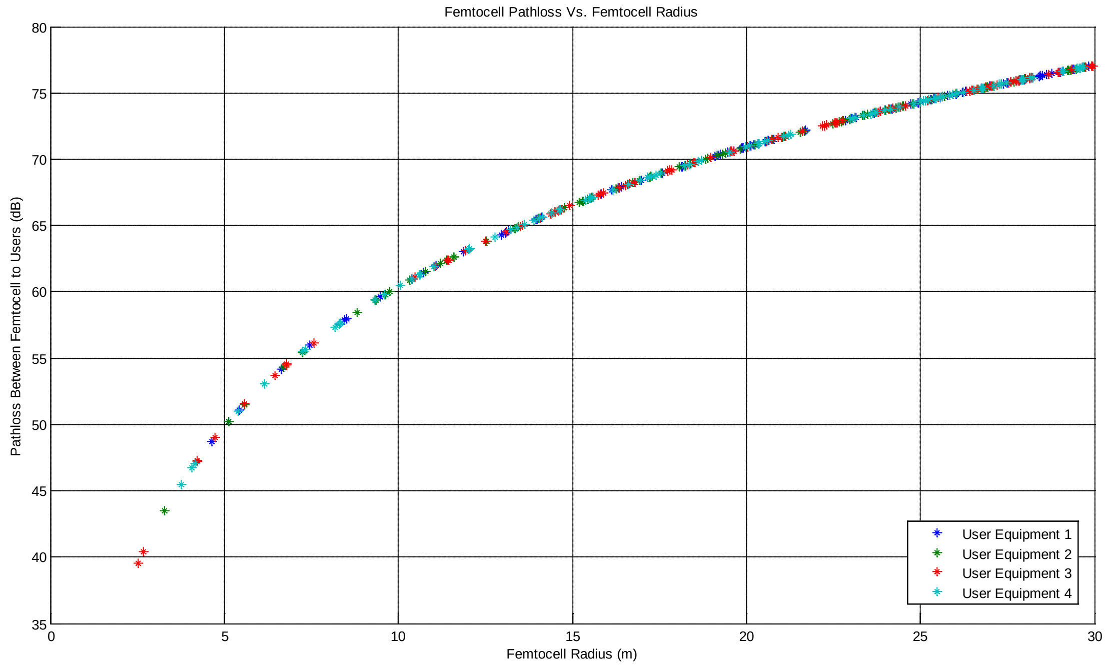

Fig. 5: Femtocell Pathloss Effect on Femtocell Radius.

Same approach being adapted in order to examine the mBS signal losses. Fig 6 shows the relation of pathloss and distances between the mBS and the UEs.

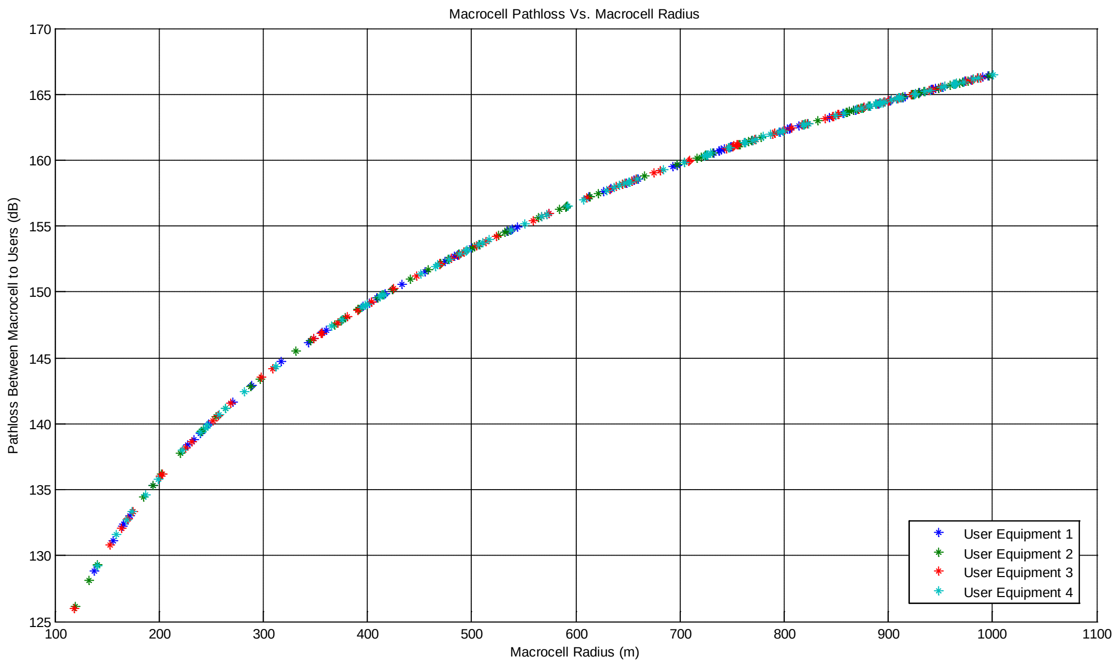

Fig. 6: Macrocell Pathloss Effect on Macrocell Radius.

To measure the stability of the downlink signals propagation, the numerical results of the femtocells downlink SINR is being plotted. Result in Fig 7 shows the downlink SINR of the fBSs against the distance between the fBS and the UEs. From the figure, it can be seen that the downlink SINR of the fBSs are exponentially decreasing with the increasing distances between the fBS and the UEs. With Random Distribution system model, the SINR is decreasing dramatically as the distance between the fBS and the UEs are increasing.

This is due to the two tier interference scenario developed on the environment. By applying Distributed Channel Selection schemes, the downlink SINR decrement is being improved. The Max Min Channel Selection scheme shows the best performance followed by Max Avg Channel Selection scheme, Min Max Interference Avoidance scheme, and Min Avg Interference Avoidance scheme. Finally, by applying the technique of beamwidth shaping using directional antenna concept, the downlink SINR decrement is totally improved. Furthermore, the technique shows the best performance compared to all other interference avoidance schemes. On the other hand, Fig 8 shows the downlink SINR of the fBSs against the pathloss between the fBS and the UEs.

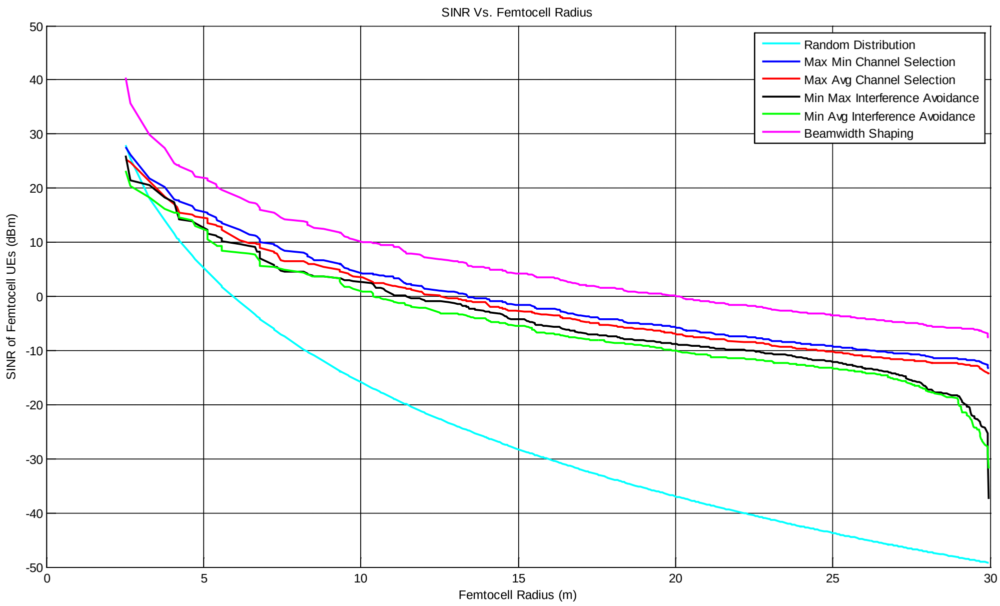

Fig. 7: Femtocell Downlink SINR Effect on Femtocell Radius.

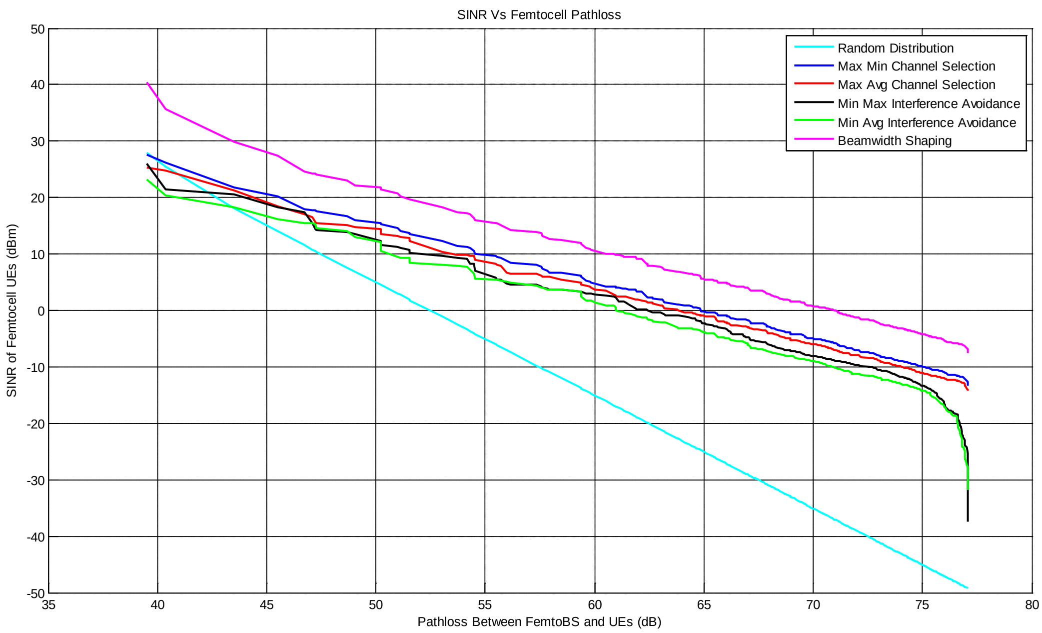

Fig. 8: Femtocell Downlink SINR Effect on Femtocell Pathloss.

To measure the capacity or the throughput produced by the of the downlink signals of the fBSs, the numerical results of the femtocells throughput is being plotted. Result in Fig 9 shows the throughput of the fBSs against the distance between the fBS and the UEs. From the figure, it can be seen that the throughput of the fBSs are exponentially decreasing with the increasing distances between the fBS and the UEs. With Random Distribution system model, the throughput is decreasing dramatically as the distance between the fBS and the UEs are increasing. This is due to the two tier interference scenario developed on the environment. By applying Distributed Channel Selection schemes, the throughput decrement is being improved. The Max Min Channel Selection scheme shows the best performance followed by Max Avg Channel Selection scheme, Min Max Interference Avoidance scheme, and Min Avg Interference Avoidance scheme. Finally, by applying the technique of beamwidth shaping using directional antenna concept, the throughput decrement is totally improved. Furthermore, the technique shows the best performance compared to all other interference avoidance schemes. On the other hand, Fig 10 shows the throughput of the fBSs against the pathloss between the fBS and the UEs.

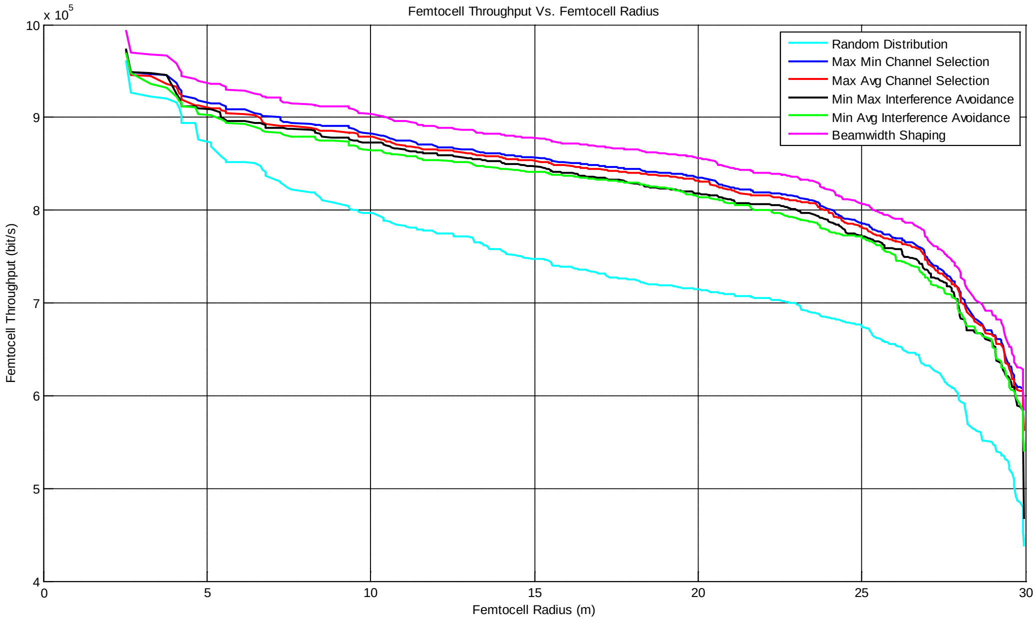

Fig. 9: Femtocell Throughput Effect on Femtocell Radius.

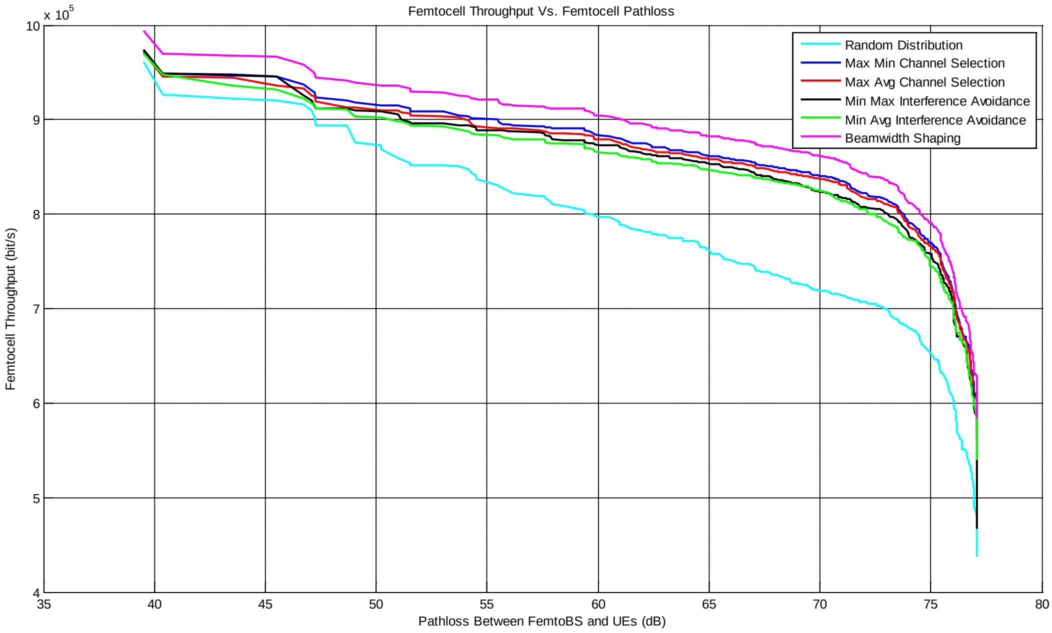

Fig. 10: Femtocell Throughput Effect on Femtocell Pathloss.

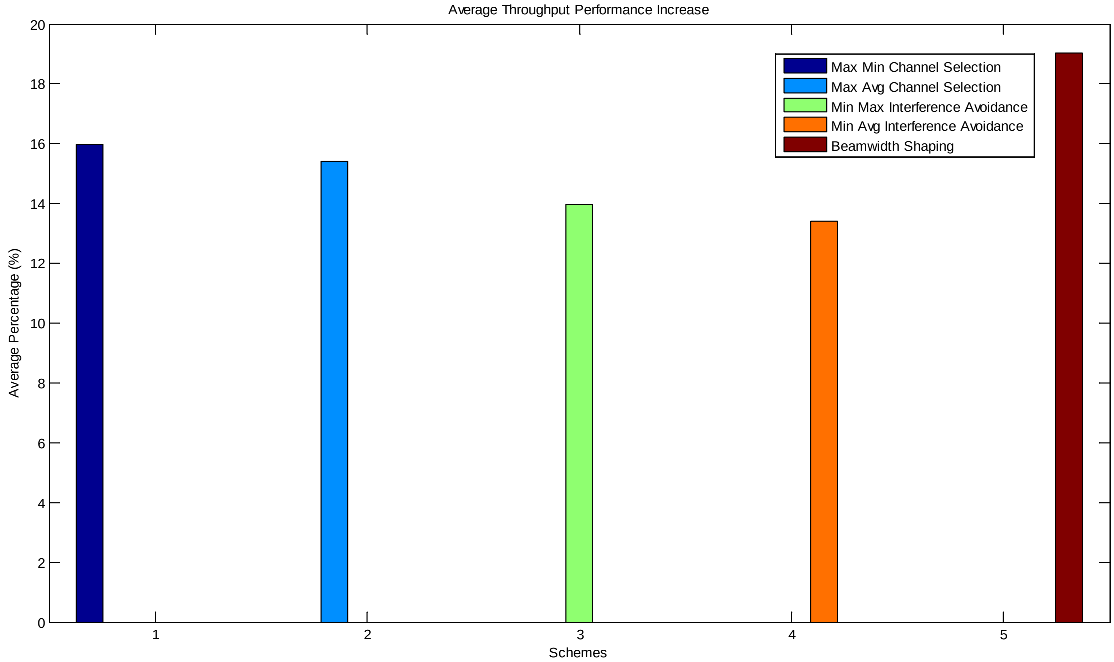

Fig. 11: Average Throughput Performance Increase.

The best method or scheme in avoiding two tier interference problems can be evaluated by comparing the percentage of performances increase in each schemes referring to the Random Distribution system model. Fig 11 shows the average throughput performance increase according to different schemes and technique. Min Avg Interference Avoidance scheme shows an increase of 13% of throughput performance followed by Min Max Interference Avoidance scheme with 14% of increase. Next, the Max Avg Channel Selection scheme shows an increase of 15% of throughput performance followed by the Max Min Channel Selection scheme with 16% of increase. The best performance showed by the beamwidth shaping technique with an increase of 19% of femtocell throughput performance.

Conclusion:

In this project, self-organizing interference avoidance schemes were proposed where Distributed Channel Selection schemes and Antenna Beamwidth Shaping technique were applied , and evaluated using simulation models in order to achieve interference avoidance in two tier femto-macro cellular network. Based on the results, any of the interference mitigation techniques shows an increment of performance in the network. For Distributed Channel Selection schemes, The Max Min Channel Selection scheme shows the best performance followed by Max Avg Channel Selection scheme, Min Max Interference Avoidance scheme, and Min Avg Interference Avoidance scheme. However, by applying the Antenna Beamwidth Shaping technique, the system model shows the best performances compared to all other schemes. For further future work, it is suggested that the research is need to be done on developing the algorithms for UEs tracking in order for the fBSs to provide only minimal beamwidth to the coverage area. Furthermore, the effect of antenna radiation pattern irregularities on the interference can be studied.

REFFERENCES

Abhayawardhana, V.S., I.J. Wassel, D. Crosby, M.P. Sellers, M.G. Brown, 2005. “Comparison of empirical propagation path loss models for fixed wireless access systems,” 61th IEEE Technology Conference, Stockholm, pp: 73-77.

Andreas, F. Molisch, 2011. ‘Wireless Communications,’ John Wiley and Sons Publications.

Chandrasekhar, V., J.G. Andrews, 2009. Uplink Capacity and Interference Avoidance for Two-Tier Femtocell Networks,’ IEEE Transactions on Wireless Communications, 8(7).

Chiao Lee, Jane Hwa Hung and Li Chun Wang, 2010. ‘Distributed Channel Selection Principles for Femtocells with Two-tier Interference,’ IEEE 978-1-4244-2519-8/10.

Cullen, J., 2008. ‘Radioframe presentation,’ in Femtocell Europe, London, UK.

Domenico, A.D. and E.C. Strinati, 2010. ‘A Radio Recource management Scheduling Algorithm for Self-Organizing Femtocells,’ Indoor and Mobile radio Communications Workshops, IEEE 21st International Symposium on Personal.

Hui Zeng, Chenxi Zhu and Wei-Peng Chen, 2009. ‘System Performance of Self-Organizing Network Algorithm in WiMAX Femtocells (Invited Paper),’ Fujitsu Laboratories of America.

Hussein Saad, Amr Mohamed and Tamer ElBatt, 2012. ‘Distributed Cooperative Q-learning for Power Allocation in Cognitive Femtocell Networks,’ Wireless Intelligence Network Center, Nile University.

Indoor MIMO WLAN Channel Models, 2003. IEEE 802.11n Working Group, IEEE 802.11-03/162r2.

Jain, R., D.M. Chiu and W. Hawe, 1998. “A quantitative measure of fairness and discrimination for resource allocation in shared computer systems,” CoRR,.

John Daniel Kraus, Ronald J. Marhefka, 2002. “Antennas for All Applications,” McGraw-Hill.

Mika Husso, Jyri Hamalainen, Riku Jantti, Juan Li, Edward Mutafugwa, Risto Wichman, Zhong Zheng, and Alexander M. Wyglinski, 2010. ‘Interference Mitigation by Practical Transmit Beamforming Methods in Closed Femtocells,’ EURASIP Journal on Wireless Communication and Networking, Hindawi Publishing Coorperation.

Mika Husso, Jyri Hamalainen, Riku Jantti, Juan Li, Edward Mutafugwa, Risto Wichman, Zhong Zheng, and Alexander M. Wyglinski, “Interference Mitigation by Practical Transmit Beamforming Methods in Closed Femtocells, 2010. ”EURASIP Journal on Wireless Communication and Networking, Hindawi Publishing Coorperation.

Mohammad Shahajahan and A.Q.M. Abdulla Hes-Shafi, 2009. “Analysis of Propagation Models for WiMAX at 3.5 GHz,” Department of Electrical Engineering Blekinge Institute of Technology.

Park, S. and S. Bahk, 2011. ‘Dynamic Inter-Cell Interference Avoidance in Self-Organizing Femtocell Networks,’ IEEE ICC.

Perez, D.L., A. Ladanyi, A. Juttner and Jie Zhang, 2010. ‘OFDMA Femtocells: A Self Organizing Approach for Frequency Assignment,’ Center for Wireless Network Design, University of Bedfordshire.

Sara Moftah Elrabiei, Mohamed Hadi Habaebi, 2010. "Energy Efficient Cooperative Communication in Single Frequency Networks", Accepted for publication in The 21st Annual *IEEE* International Symposium on Personal, Indoor and Mobile Radio Communication , *IEEE PIMRC’’2010*, Istanbul Turkey.

Sara Moftah Elrabiei, Mohamed Hadi Habaebi, 2010. "Energy Efficient Cooperative Multicasting for MBS WiMAX Traffic", *IEEE International Symposium on Wireless Pervasive Computing*, IEEE ISWPC’ Modena Italy.

Sara Moftah Elrabiei, Mohamed Hadi Habaebi, 2011. "Reliable Battery-Aware Cooperative Multicasting for MBS WiMAX Traffic", Scientific Research Publishing Int. J. Communications, Networks and System Sciences, USA. doi:10.4236/ijcns.2011.410079, 4(10): 648-655.

Sara Moftah Elrabiei, Mohamed Hadi Habaebi, 2012. "Energy Efficient Cooperative Multicasting for MBS WiMAX Traffic", *Elsevier J. Computer Networks*, 56(11): 2600-2613.

Usage Models., 2004. IEEE 802.11n Working Group, IEEE 802.11-03/802r14.

Zhang, Jie., Guillaume de la Roche, 2010. ‘Femtocells Technologies and Deployment,’ Wiley and Sons Ltd. (2010), West Sussex, PP: 2-5.