Interference Mitigation in Femto-Cell Using Power Control Scheme

Muhammad Arif[1], Sadique Ahmad Bugti[2], Asad Ali[3], Atifullah Khan[4], Saeed Ahmed Magsi[5]

[1]Department of Eletronic Engineering, [2]Department of Computer Science, [3]Department of Information Technology, [4]Department of Electronic Engineering, [5]Department of Telecom Engineering, Faculty of Information and Communication Technology Balochistan University of Information Technology, Engineering and Management Sciences, Quetta, Pakistan

Abstract

Femto-cell Networks are low-cost, low-range, low-power home base-stations installed at end-user premises like large buildings. However, the low-cost of femto-cells is associated with reusing the frequency used by the macro-cell base-transceiver-station (BTS). This reuse frequency gives rise to interference issue. In this study, we propose a novel power control scheme technique to avoid interference among the macro-cell and micro-cell of a femtocell. The proposed technique not only takes wall penetration into account but also does not degrade uplink and downlink performance. Simulation results show a significant decrease in interference and considerable increase in throughput.

Keywords: Interference; Femto-Cell; Macro-Cell; Micro-Cell; Power Control; Mitigation

Corresponding author's email: *muhammad.arif@buitms.edu.pk*

INTRODUCTION

Every day hundreds of bandwidth hungry applications are introduced, Thousands of new nodes are induced into a network, which makes the existing infrastructure incapable of fulfilling the demands of those applications and end users. The increase in demand for higher bandwidth, better quality of service (QoS), ubiquity, mobility and flexibility lead to the development of new standards such as WiMAX, 3GPP, 4G-LTE and 5G etc. In order to cope up with such a huge traffic, a alternative way is to use Wi-Fi inside buildings but problem with the Wi-Fi is that it cannot provide the same level of coverage, mobility and flexibility as cellular network does. Another alternate to improve the wireless capacity and signal strength eventually to reduce cell size and transmission distance (Chandrasekhar et al., 2008). This method will provide 1600X gain because of spatial reuse of spectrum or in other words, higher area spectral efficiency (Alouini and Goldsmith, 1999). The main drawback of this method is the high cost. Moreover, if the signal strengths are not good, it is very likely that the QoS and voice quality inside large buildings will be affected. So in order to give the user a seemless quality of service inside large buildings, Femto-cells were proposed. Femto-cells are low-cost, low-range, low-power home base station installed by the end users at their home, office, or any small buildings to increase data reception and voice quality. Different studies show that 50 percent of all voice calls are generated from inside the buildings while more than 70 percent of data traffic generated are indoors (Chandrasekhar et al., 2008; Andrews et al., 2012). Attenuation and losses make it very difficult to achieve high signal quality and high data rates.

Femto-cell not only improves indoor coverage quality but also reduces the traffic load on macro-cell (offload macro-cell BS). There are several advantages of Femto-cells like better coverage, capacity, prolong handset battery life, higher signal to noise ratio (SNR), higher Signal to interference ratio (SIR), improved macro-cell reliability, cost benefits and reduced subscriber turnover. These parameters can be verified through Shannon's Law. In femto-cell networks, we make a micro-cell inside or adjust to the larger macro-cell. Femtocell access point is used in the newly built microcell. Because of economy, same frequency is used in both macro and microcells. Despite of the so many advantages of Femto-cells discussed above, use of same frequencies in both the cells cause interference between the two cells. We cannot take full advantage of Femto-cell unless the issue of interference between the two tiers is addressed. The cross-tier interference is a capacity limiting factor that deteriorates link quality when both tiers operate in the same spectrum. In this paper, we have worked on power control scheme in femtocells. There are three advantages of the proposed scheme. First of all, the interference is avoided, wall penetration is considered and finally uplink and downlink performance are not affected.

MATERIALS AND METHODS

A large Femto-Cell with multiple users and adjacent microcell consisting of Femto-Cell with its own users is shown in Figure 1.

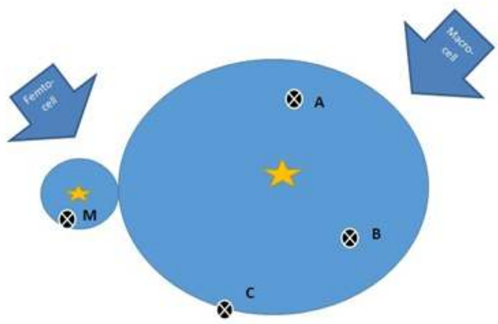

Figure 1: A Macro-cell and Micro-cell with their Corresponding Nodes

The users of macro-cell will keep transmitting through macro-cell base station. As the user transmit, the base station will calculate the channel gain between Femto-cell and macro-cell base station. This calculated channel gain is advertised to the Femto-cell. Thus upon receiving channel gain from the macro-cell base station, the Femto-cell access point will so prescribed the SINR of the microcell such that the coverage area of microcell does not overlap with macro-cell. Femto-cell access point calculate the SINR based on the channel gain. Both femto-cell access point and its users would accordingly use the Signal-to-Interference-and-Noise-Ratio (SINR) prescribed and calculated by femto-cell access point. The proposed scheme is elaborated step-by-step in the following section.

The proposed solution is elaborated through fig 2. The process is carried out as following.

1. Different macro-user transmits packet through macro-cell base station.
2. Macro-cell base station estimates the gain of the channel and sends feedback to the Femto-cell access point. Based on the feedback from the macro-cell, it so adjust its channel gain and SINR such that the coverage area of the microcell does not overlap with the macro-cell. Calculation of the channel gain and SINR is discussed in the subsequent section.
3. The Femto-cell access point prescribes the target SINR to its users on the basis of the feedback from macro-cell base station.
4. Accordingly Femtocell adjusts the SINR for its users and thus users communicate by transmitting the packets through intended access point. In this way, the SINR of femto-cell users is kept below the SINR prescribed by the femto-cell access point; therefore it guarantees that the signal would not reach the macro-cell.

In this way, we see a smooth, seemingles communication and handoff of Femto-cell user with macro-cell user. Conditions of the channel vary with time; therefore macro-cell base station will send periodic channel advertisements to Femto-cell access points.

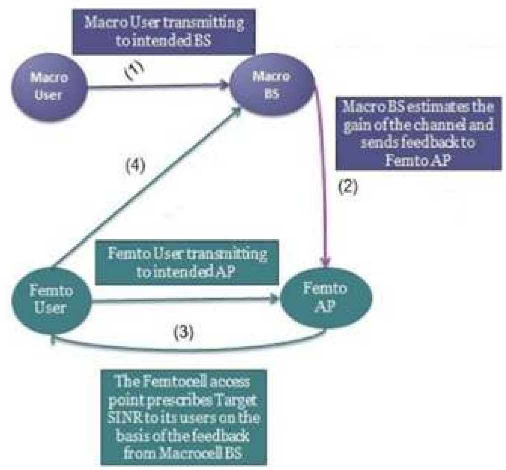

Figure 2: Elaboration of Proposed Power Control Scheme

Since our proposed scheme will calculated the SINR based on the channel gain information advertised by macro-cell base-station, therefore the SINR value calculated is more accurate and authentic. Calculating the SINR on the basis of the information provided by the macro-cell base-station ensures that resultant SINR would not cause interference and would provide the highest transmission power thus; making it easy for the receiver to decode the information. Moreover, since the target SINR is enough for the signal to reach just the coverage area of macrocell, so it is obvious that the signal would penetrate any walls coming in its way.

Let M_i denotes the macro-cell base-station located at the center of the cell that is, the coverage area. Let F_i be the Femto-cell where $i \geq 1$, that is, there exist at least one femto-cell. Let the vector P_i represent the transmission power of the user i and σ^2 represents the variance of the Additive White Gaussian Noise at femto-cell F_i. When a transmitter associated to a particular femto-cell

F_i intends to transmit, the received SINR Γ_i at F_i is given by;

$$\Gamma_i = \frac{P_i G_{i,i}}{\sum P_j G_{i,j} + \sigma^2} \quad (1)$$

Here j represents the adjacent cell and $G_{i,i}$ is the channel gain for transmitter i to its intended F_i. The channel gain depends upon two factor that is, path loss and Rayleigh Fading. The link i should maintain the SINR as advertised by the femto-cell access point. If the current SINR is below the advertised SINR, the receiver will not be able to decode the message. On the other hand, if the current SINR is greater than the advertised SINR, the signal will reach the coverage area of the macro-cell and thus; there will be interference in the communication.

Channel gain and the transmission power can be adjusted using the equation below.

$$P \geq \Gamma G_P + \eta \quad where......P \geq 0 \quad (2)$$

Here is normalized Additive White Gaussian Noise (AWGN) and is given by

$$\eta_i = \frac{\sigma^2 \Gamma_i}{G_{i,i}} \quad (3)$$

Gain can be calculated by macro-cell base-station upon the signal received from transmitter as follow;

$$G_R = P_T + G_T - P_R - L_T - L_F - L_M - L_R \quad (4)$$

Where in equation 4, P_T is Transmission Power, G_T is the Transmission Gain, P_R is received Power, L_T is Transmission Loss, L_F is Free Space Loss, L_M is the Miscellaneous Loss, L_R is Received Loss.

Similarly, we can easily calculate the SINR using the following equation;

$$SINR(x) = \frac{P}{I + N} \quad (5)$$

Here P is the power of incoming signal, I is the interference of power of the interfering signal while N is noise. So during transmission, macro-cell base-station will calculate the channel gain on the basis of equation 4. Once the channel gain is calculated, it is advertised to the femto-cell access point. Based on the channel gain received from macro-cell base-station, femto-cell access point will calculate the SINR based on the equation 1. Then on the basis of computed SINR, transmission power is kept according to the equation 2. If we decrease the transmission power from this computed power, the receiver would not be able to decode the transmitted message. On the other hand, if the transmission power is increased than there will be interference with the macro-cell.

RESULTS AND DISCUSSION

MATLAB is used for simulation and modeling purpose. The effect of distance from the base-station on the channel gain is studied. The effect of buildings and other obstacles on the channel gain were also studied. After that the effect of calculated SINR according to the channel gain were studied and finally comparison was made between the proposed Interference Mitigation (InMig) scheme with Co-Channel Power Control Scheme (CPC) (Li et al., 2009) and Uplink Power Control Scheme (UPC) (Jo et al., 2009). UPC is based on the Open-Loop and Close-Loop approach discussed above while CPC is based on co-channel interference. Simulation results show that proposed Interference Mitigation (InMig) scheme outperforms CPC and UPC schemes. Same simulation setup as shown in the figure 2 is used for simulation. Rest of the parameters are summarized in the table 1.

Table 1: Parameters and their corresponding values used for simulation purpose

Parameters	Value
Macrocell Radius	1.5 Kilometers
Femtocell Radius	45 meters
Carrier Frequency	1800 MHz
Macrocell BTS Transmission Power	100 W (Maximum)
Femtocell AP Transmission Power	5 W (Maximum)
Cellphone Transmission Power	500 mW (Maximum)
SINGR Target Range	5500dB
Indoor Loss	45 dB
Partition Loss	5 dB
Outdoor Path-Los Exponent	4 dB
Indoor Path-Loss Exponent	3 dB
Miscellenouse Path-Loss	3 dB
Free Space Loss	3dB

Figure 3 shows the channel gain for various distances of the mobile nodes from the macro-cell base-station. X-axis shows the distance of the nodes from the macro-cell base-station while Y-axis shows the corresponding channel gain. If we observe the curve, although overall there is a decrease in channel gain as we increase the distance of the node from the macro-cell base-station but the decrease in channel gain is not

uniform. There is slight decrease and increase in channel gain alternatively. This alternation of increase and decrease is because of the various obstacles in the path of the mobile node and macro-cell base-station. At the distance of 100 meters, the channel gain starts from 17dB which slightly increase at 300 meters distance and reaches to 19 dB. This is because at the beginning when the node was at 100 meters distance, there might be some obstacles on the way like huge buildings but with the passage of time when node move and reaches a distance of 300 meters, at that point there was a direct contact between the
macro-cell base-station and the mobile node.

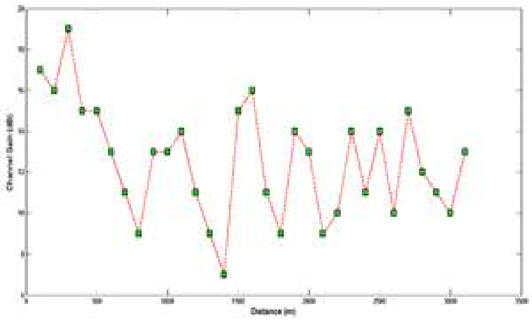

Figure 3: Channel Gain for Different Distances from the Macro-cell BTS

Figure 4 shows the average femto-cell SINR in Decibels (dB) along with Cellular SINR. A higher SINR value translates to a better performance (Jim Geier). Figure shows the results for a scenario where the femto-cell is co-located or located at the edge of the macro-cell. Figure 4, shows that the proposed interference mitigation scheme outperforms CPC and UPC. The proposed interference mitigation scheme achieve up to 50% better performance as compared to CPC and UPC which corresponds to the improvement of at least 5 dB in SINR. The performance gets enhanced as we increase the target SINR of femto-cell. For instance, when the average target SINR is 10 dB, the cellular SINR is for proposed scheme is slightly higher than UPC and CPC. However, as we increase the Target SINR, the femto-cell users get more flexibility and thus the cellular SINR increases significantly as compared to CPC and UPS. When average target SINR is 23 dB, the cellular SINR for UPC and CPC is below 10 dB whereas it remains at 15 dB for the proposed interference mitigation scheme which is a significant improvement over CPC and UPC. The reason is that in the proposed scheme the value of SINR is based in information obtained from the macro-cell base-station.

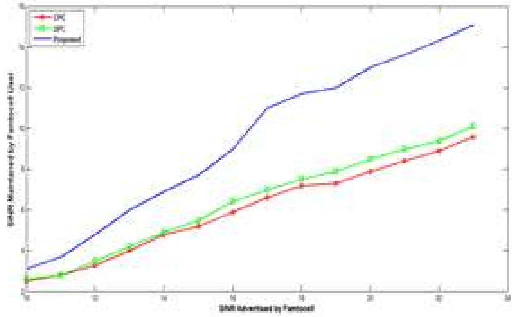

Figure 4: Average Target SINR Vs Cellular SINR

CONCLUSION

Power control scheme was proposed in order to mitigate interference in femtocells. The proposed mechanism calculates the SINR based on the information of channel gain obtained from macro-cell BTS. We showed that the proposed mechanism outperforms all the contemporary algorithms in terms of interference and throughput. It was also shown that the calculated SINR is more accurate as it is calculated on the basis of channel gain information obtain from BTS.

REFERENCES

- Chandrasekhar, Vikram, Jeffrey G. Andrews and Alan Gatherer. (2008). Femto-cell networks: a survey. Communications Magazine IEEE 46(9):59-67.

- Alouini MS and Andrea J. Goldsmith. (1999). Area spectral efficiency of cellular mobile radio systems. Vehicular Technology, IEEE Transactions 48(4):1047-1066.

- Andrews, Jeffrey G, Holger Claussen, Mischa Dohler, Sundeep Rangan and Mark C. Reed. (2012). Femto-cells: Past, present, and future. Selected Areas in Communications, IEEE Journal 30(3):497-508.

- Claussen, Holger, Lester TW Ho and Louis G. Samuel. (2008). An overview of the Femto-cell concept. Bell Labs Technical Journal 13(1):221-245.

- De La Roche, Guillaume, Alvaro Valcarce, David López-Pérez and Jie Zhang. (2010). Access control mechanisms for Femto-cells. Communications Magazine, IEEE 48(1):33-39.

- Golaup, Assen, Mona Mustapha and Leo Boonchin Patanapongpibul. (2009). Femto-cell access control strategy in UMTS and LTE. Communications Magazine, IEEE 47(9):117-123.

- Jo, Han-Shin, Cheol Mun, June Moon, and Jong-Gwan Yook. (2009) .Interference mitigation using uplink power control for two-tier Femto-cell networks. Wireless Communications, IEEE Transactions 8(10): 4906-4910.

- Chandrasekhar, Vikram and Jeffrey G. Andrews. (2009). Uplink capacity and interference avoidance for two-tier Femto-cell networks. Wireless Communications, IEEE Transactions on 8(7): 3498-3509.

- Chan, Wai-Chung, Evaggelos Geraniotis, and Diakoumis Gerakoulis. (2000). Reverse link power control for overlaid CDMA systems. In Spread Spectrum Techniques and Applications, IEEE Sixth International Symposium 2:776-781.

- Andrews, Jeffrey G. (2005). Interference cancellation for cellular systems: a contemporary overview. Wireless Communications, IEEE 12(2):19-29.

- Madkour, Mohamed F., Someshwar C. Gupta, and Y-PE Wang. (2002). Successive interference cancellation algorithms for downlink W-CDMA communications."Wireless Communications, IEEE Transactions 1(1): 169-177.

- Berggren, Fredrik and Ben Slimane S. (2003). Successive interference cancellation in multi-rate ds-cdma systems. In Personal, Indoor and Mobile Radio Communications, PIMRC. 14th IEEE Proceedings 2:1752-1756.

- Weber, Steven P, Jeffrey G. Andrews, Xiangying Yang, and Gustavo De Veciana. (2007). Transmission capacity of wireless ad hoc networks with successive interference cancellation. Information Theory, IEEE Transactions 53(8): 2799-2814.

- Quan, Shan Guo, Jian Xu, and Young Yong Kim. (2009). Utility-based Rate Allocation Scheme for Mobile Video Streaming over Femtocell Networks. JIPS 5(3):151-158.

- Chandrasekhar V, Andrews J G, Muharemovic T, Shen Z and Gatherer A. (2009). Power control in two-tier femtocell networks, IEEE Trans. Wireless Commun 8(8):4316–4328

- Lee HC, Oh DC and Lee YH. (2010). Mitigation of inter-femtocell interference with adaptive fractional frequency reusein Proc. IEEE ICC’10, Cape Town, South Africa, pp. 1–5.

- Rangan S. (Dec. 2010). Femto-macro cellular interference control with subband scheduling and interference cancelation, in Proc. IEEE GLOBECOM’10 Workshops, Miami, FL, , pp. 695–700.

- Bharucha Z, Haas H, Auer G and Cosovic I. (Dec. 2009) Femto-cell resource partitioning,” in Proc. IEEE GLOBECOM Workshops, Honolulu, HI, pp. 1–6.

- R. Madan, A. Sampath, A. Khandekar, J. Borran, and N. Bhushan, (Dec. 2010). Distributed interference management and scheduling in LTE-A femto networks,” in Proc. IEEE GLOBECOM’10, Miami, FL, pp. 1–5.

- Li, Xiangfang, Lijun Qian, and Deepak Kataria. (2009). Downlink power control in co-channel macrocell femtocell overlay." In Information Sciences and Systems, 2009. CISS 2009. 43rd Annual Conference on, pp. 383-388. IEEE,

- Jo, Han-Shin, Cheol Mun, June Moon, and Jong-Gwan Yook. (2009) "Interference mitigation using uplink power control for two-tier femtocell networks." Wireless Communications, IEEE Transactions on 8, no. 10: 4906-4910.