A Novel Protocol for Interference Mitigation in MIMO Femto Cell Environment

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***Abstract*—In this paper, a novel protocol to mitigate co-channel interference issue acquiring higher diversity gain is introduced in Multiple Input Multiple Output (MIMO) femto cell environment. The scheme works under three time slots using Alamouti Space-time block code (STBC) and MIMO gains to achieve full diversity order of four. A network based on wireless access consists of two femto users points, and destination terminals as femto base stations each equipped with two antennas respectively. The performance is analyzed using 16-Quadrature Amplitude Modulation (QAM) modulation scheme. The results are investigated over independent and identical ($i.i.d$) fading channel. Subsequently, the obtained results by simulation show that the proposed novel transmission protocol provides interference mitigated and better signal quality of uplink femto users in cooperative wireless networks.**

***Keywords*–Femto Cooperative (Fe-COPE); Interference mitigation; MIMO-Femto environment; Alamouti Coding.**

I. Introduction

People all over the globe are stepping ahead to the revolution of wireless broadband services in the form of 5G networks [1]. As fifth generation networks deal with the ultra high frequency regions of the spectrum, hence they consequently characterize by shorter wavelengths and the original signal tends to dissipate even after traveling up to tens of meters due to several penetration losses that leads to a situation of retaining smaller cell size. Furthermore, many shadowed and non-coverage regions could be found under the macrocells coverage areas such as at the edge of the cell, thick walls, indoor environment and basements, etc. It is a big challenge for the network operators to find an efficient solution to deal with this increasing data traffic demand and satisfy their customers by providing high quality services.

Femtocell deployment is a hot research stream for the researchers striving to improve the quality of service within a macrocell. These are low power tiny base stations installed within an office or a residential area to improve cellular coverage within a building. Commercially, it is sold with different brand names like Airave (Sprint), Microcells (AT&T) and Network Extender (Verizon) in the market [2]. The connectivity of smart phones, cellular phones and portable devices is increased through femtocells for cellular networks especially in those areas where coverage of large cells is weak or intermittent. There are many potential advantages of femtocells for both users and network operators. It provides better coverage and many additional services to the users and enables them to add the enhanced experience and extra capabilities to the existing broadband services. However, despite of all these characteristics, the main drawbacks include the higher interference issues and increased in the number of handovers that results in faster battery discharge. Network operators can generate more revenue by providing many additional services and better coverage to users up to their contentment. Therefore, the demand of femtocell has been increased since last decade and many commercial mobile operators have shown their keen interest to expand this technology through 3G to 4G and LTE/5G.

Multiple Input Multiple Output (MIMO) systems are widely considered to provide greater spectral efficiency and enhanced capacity. The transmission rate is badly affected due to the several limitations on the modulation scheme with a limited frequency band despite of offering guaranteed high Signal-to-Noise Ratio (SNR) in short range communications. MIMO systems have drawn researchers' [3][4] attention because of the fact that they can increase the data rate without even expanded frequency band by the use of multiple antennas over the whole transceiver design. The proposed protocol exploits this advantage of MIMO by achieving twice the gain achieved in conventional femtocells to mitigate the interference occurred in the overlapping areas of adjacent cells.

As femtocells are in microcells, there is a greater probability of incurring interference between two adjacent femtocells, especially in the overlapping areas of consecutive cells. Interference severely degrades the quality of service affecting the actual gain of the transmitted signal. Researchers have put serious efforts on the board to mitigate this interference in last couple of years using various schemes [5][6], but all these techniques cover different aspects and have not considered MIMO in three time slots for the minimal interference in femtocells [7][8].

This work analyzes the effect of interference on overall antenna gain in overlapping areas of two adjacent femtocells in MIMO environment and proposes a protocol for mitigating this interference in MIMO femto environment using three time slots. Antenna gain is finally achieved four times given by equations in the overall system model by the exploitation of MIMO. Simulation results using MATLAB clearly argue that the proposed protocol is an efficient technique for mitigating the interference in MIMO femto environment using three time slots as compared to many others.

To the best of our knowledge, no one has yet investigated MIMO femto cells scenario with Alamouti coding technique and exploits the cooperative scenario to mitigate interference issue in femto cell environment. The remainder of the pa-

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per is organized as follows: Section 2 presents the model of the system, transmission scheme and the channel of the model considered. Sections 3 and 4 discusses in detail the input-output and closed-form expressions of a system at the respective base stations and then will derive the expression for SNR for both users respectively. Section 5 depicts the closed-form expressions for Nakagami-m fading channel using error probability analysis of a system. Section 6 discusses the simulation results obtained in terms of a comparison with analytical and Matlab obtained curves. Finally, Section 7 draws the conclusions of the prosposed scheme.

II. System Model

In this section, a novel approach is used to mitigate co-channel interference in MIMO scenario in order to exploit much higher diversity gain. Multiple antennas are assumed to be equipped at the user's terminals. For our system in consideration, we assume two (2) number of antennas equipped at the transmitter and receiver end.

For simplicity, MIMO based Fe-COPE system is furnished with two nodes at transmitter and receiver end. Both nodes are equipped with two antennas to make 2x2 MIMO system and exploit the gain after mitigating the interference from interferer node using three time slots. The communication is done in such a way that user nodes act as a relay in the third slot. The femto user 1 (node 1) has antennas S_1 and S_2 whereas, femto user 2 (node 2) has antennas S_3 and S_4 respectively. Both nodes will work as a relay and will follow Alamouti coding in the final slot of transmission to exploit MIMO and Alamouti gain. The transmission protocol is explained in the Table I.

The transmission takes place in three separate slots between source and end terminals. It is also assumed that the energy is normalized and at the respective source terminals, the power of the signal is normalized to unity with E = { $|{S_i}^2|$ }. Assuming equal noise variance N_o for the additive white Gaussian Noise (AWGN). The perfect channel condition is assumed at destination ends. The mathematical expressions for the input-output (I/O) equations, SNR relationship, & moment generating function (MGF) expressions will be discussed in the next section for different fading environments.

A. Cooperative Transmission and Channel Model

In this section, the equivalent expression for end-to-end transmission of SNR for both users at femto base terminals is derived. The I/O relationship is discussed. MRC is used at receiver to accumulate and add-up the desired signals and with utilizing SNR equations, MGF expressions for both users are derived. The transmission can be clearly explained with the help of the system model picture. The detail schematics picture of channel distribution associated with each time slot is shown in Figure 1.

The figure clearly depicts that in the first time slot, both the first antennas of both nodes will transmit whereas, in the second time slot, the respective second antennas of both mobile stations (MS-1 and MS-2) will transmit. In the third slot, both antennas of the mobile stations will transmit using Alamouti scheme approach to the respective femto base stations (BS-1 and BS-2), respectively.

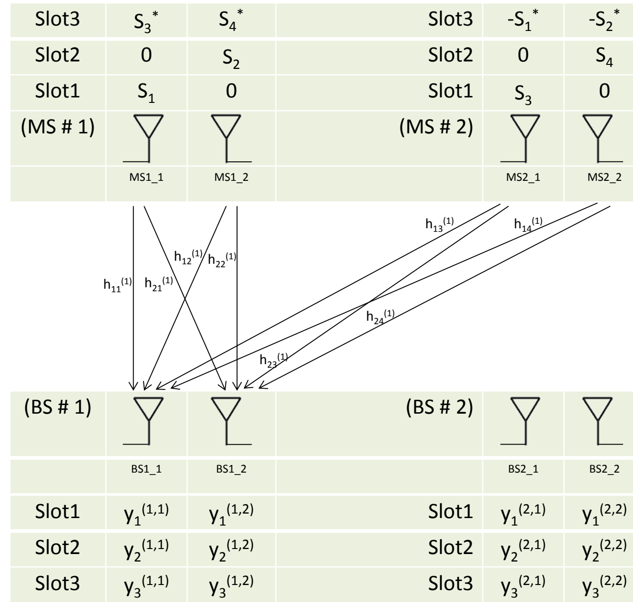

Figure 1. Schematic picture of channel distribution associated with each time slot

III. I/O and Closed-form Expressions

The mathematical expressions for an equivalent SNR relationship and respective closed-form expression for both femto stations are derived in this section, as follows.

A. I/O Expression

The received signals for both antennas, i.e., ANT1 and ANT2, etc., at both femto base stations (BS-1) in three different slots from respective two femto users is mathematically elaborated below.

Considering receptor BS1:

I/O for ANT1:

$$y_1^{(1,1)} = h_{11}^{(1)} S_1 + h_{13}^{(1)} S_3 + n_1^{(1,1)} \quad (1)$$

$$y_2^{(1,1)} = h_{12}^{(1)} S_2 + h_{14}^{(1)} S_4 + n_2^{(1,1)} \quad (2)$$

$$y_3^{(1,1)} = h_{11}^{(1)} S_3^* + h_{12}^{(1)} S_4^* - h_{13}^{(1)} S_1^* - h_{14}^{(1)} S_2^* + n_3^{(1,1)} \quad (3)$$

I/O for ANT2:

$$y_1^{(1,2)} = h_{21}^{(1)} S_1 + h_{23}^{(1)} S_3 + n_1^{(1,2)} \quad (4)$$

$$y_2^{(1,2)} = h_{22}^{(1)} S_2 + h_{24}^{(1)} S_4 + n_2^{(1,2)} \quad (5)$$

$$y_3^{(1,2)} = h_{21}^{(1)} S_3^* + h_{22}^{(1)} S_4^* - h_{23}^{(1)} S_1^* - h_{24}^{(1)} S_2^* + n_3^{(1,2)} \quad (6)$$

whereas, the received signals $y_k^{(i,j)}$ is at k-th time slots from both users, where $(k \in 1, 2, 3)$, i denotes the respective base station 1, and j denotes the number of receiving antenna $(j \in 1, 2)$. The noises $n_k^{(i,j)} \in \mathcal{N}(0, N_o)$, following AWGN, where

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TABLE I. MIMO FEMTO PROTOCOL

Time Slot/Source Node	S_1	S_2	S_3	S_4	R_1	R_2	R_3	R_4
1	√		√					
2		√		√				
3					√ (S_3^*)	√ (S_4^*)	√ $(-S_1^*)$	√ $(-S_2^*)$

$(k \in 1, 2, 3)$ time slots respectively. Without loss of generality, assuming the level of the energy of the signal normalized to unity. The channel co-efficients undergoes the Nakagami-m fading [9] environments respectively. Rayleigh fading [3][6][9] is experienced as a special case when for Rician [6], K goes to 0, and for Nakagami, m goes to 1.

1) Algorithm: **Step 1: MIMO Detector (ML or SML Methods)**

Now, if $Norm(H_1^{(1)}) > Norm(H_2^{(1)})$, the detection process includes:

$$\begin{bmatrix} y_1^{(1,1)} \\ y_1^{(1,2)} \end{bmatrix} = \begin{bmatrix} h_{11}^{(1)} & h_{13}^{(1)} \\ h_{21}^{(1)} & h_{23}^{(1)} \end{bmatrix} \begin{bmatrix} S_1 \\ S_3 \end{bmatrix} + \begin{bmatrix} n_1^{(1,1)} \\ n_1^{(1,2)} \end{bmatrix} \quad (7)$$

whereas, $H_1^{(1)} = \begin{bmatrix} h_{11}^{(1)} & h_{13}^{(1)} \\ h_{21}^{(1)} & h_{23}^{(1)} \end{bmatrix}$. Using ML method, $\widehat{S}_1$, and $\widehat{S}_3$ will be detected.

else

$$\begin{bmatrix} y_2^{(1,1)} \\ y_2^{(1,2)} \end{bmatrix} = \begin{bmatrix} h_{12}^{(1)} & h_{14}^{(1)} \\ h_{22}^{(1)} & h_{24}^{(1)} \end{bmatrix} \begin{bmatrix} S_2 \\ S_4 \end{bmatrix} + \begin{bmatrix} n_2^{(1,1)} \\ n_2^{(1,2)} \end{bmatrix} \quad (8)$$

whereas, $H_2^{(1)} = \begin{bmatrix} h_{12}^{(1)} & h_{14}^{(1)} \\ h_{22}^{(1)} & h_{24}^{(1)} \end{bmatrix}$. Using ML method, $\widehat{S}_2$, and $\widehat{S}_4$ will be detected.

Step 2: Decision Feedback Cancellation

If $Norm(H_1^{(1)}) > Norm(H_2^{(1)})$, the algorithm is processed as,

$$\tilde{y}_3^{(1,1)} = y_3^{(1,1)} + h_{13}^{(1)}\widehat{S}_1^* - h_{11}^{(1)}\widehat{S}_3^* = -h_{14}^{(1)}S_2^* + h_{12}^{(1)}S_4^* + \tilde{n}_3^{(1,1)} \quad (9)$$

$$\therefore \begin{bmatrix} y_2^{(1,1)} \\ \tilde{y}_3^{(1,1)^*} \end{bmatrix} = \begin{bmatrix} h_{12}^{(1)} & h_{14}^{(1)} \\ -h_{14}^{(1)*} & h_{12}^{(1)^*} \end{bmatrix} \begin{bmatrix} S_2 \\ S_4 \end{bmatrix} + \begin{bmatrix} n_2^{(1,1)} \\ \tilde{n}_3^{(1,1)^*} \end{bmatrix} \quad (10)$$

$$\tilde{y}_3^{(1,2)} = y_3^{(1,2)} + h_{23}^{(1)}\widehat{S}_1^* - h_{21}^{(1)}\widehat{S}_3^* = -h_{24}^{(1)}S_2^* + h_{22}^{(1)}S_4^* + \tilde{n}_3^{(1,2)} \quad (11)$$

$$\begin{bmatrix} y_2^{(1,2)} \\ \tilde{y}_3^{(1,2)^*} \end{bmatrix} = \begin{bmatrix} h_{22}^{(1)} & h_{24}^{(1)} \\ -h_{24}^{(1)*} & h_{22}^{(1)^*} \end{bmatrix} \begin{bmatrix} S_2 \\ S_4 \end{bmatrix} + \begin{bmatrix} n_2^{(1,2)} \\ \tilde{n}_3^{(1,2)^*} \end{bmatrix} \quad (12)$$

Using Joint STBC Decoder, it gives the four (4) times diversity gain $\widehat{S}_2$ and $\widehat{S}_4$ are the detected signals with good diversity gains.

else

Similar to above equations in step number 1 and 2, using joint STBC decoder, $\widehat{S}_1$ and $\widehat{S}_3$ can be detected (4 diversity gain).

end

Step 3: Iterative cancellation to enhance detection performance

If $Norm(H_1^{(1)}) > Norm(H_2^{(1)})$, the algorithm is processed as,

$$\bar{y}_3^{(1,1)} = y_3^{(1,1)} + h_{14}^{(1)}\widehat{S}_2^* - h_{12}^{(1)}\widehat{S}_4^* = -h_{13}^{(1)}S_1^* + h_{11}^{(1)}S_3^* + \bar{n}_3^{(1,1)} \quad (13)$$

$$\therefore \begin{bmatrix} y_1^{(1,1)} \\ \bar{y}_3^{(1,1)^*} \end{bmatrix} = \begin{bmatrix} h_{11}^{(1)} & h_{13}^{(1)} \\ -h_{13}^{(1)*} & h_{11}^{(1)^*} \end{bmatrix} \begin{bmatrix} S_1 \\ S_3 \end{bmatrix} + \begin{bmatrix} n_1^{(1,1)} \\ \bar{n}_3^{(1,1)^*} \end{bmatrix} \quad (14)$$

$$\bar{y}_3^{(1,2)} = y_3^{(1,2)} + h_{24}^{(1)}\widehat{S}_2^* - h_{22}^{(1)}\widehat{S}_4^* = -h_{23}^{(1)}S_1^* + h_{21}^{(1)}S_3^* + \bar{n}_3^{(1,2)} \quad (15)$$

$$\therefore \begin{bmatrix} y_1^{(1,2)} \\ \bar{y}_3^{(1,2)^*} \end{bmatrix} = \begin{bmatrix} h_{21}^{(1)} & h_{23}^{(1)} \\ -h_{23}^{(1)*} & h_{21}^{(1)^*} \end{bmatrix} \begin{bmatrix} S_1 \\ S_3 \end{bmatrix} + \begin{bmatrix} n_1^{(1,2)} \\ \bar{n}_3^{(1,2)^*} \end{bmatrix} \quad (16)$$

Using Joint STBC Decoder, gives the four (4) times diversity gain $\widehat{S}_1$ and $\widehat{S}_3$ are the detected signals with good diversity gains.

else

Similar to above equations in step number 1 and 2, using joint STBC decoder, $\widehat{S}_2$ and $\widehat{S}_4$ can be detected (4 diversity gain).

end

Step 4: Final step
In order to enhance the detection process, i.e., receive the signal after multiple trials resulting in higher performance gain, the output can be feedbacked to step number 2, and then go ahead with step number 3. This feedback process ensures the better detection probability.

IV. SIGNAL TO NOISE RATIO EXPRESSION

The approach is followed by the algorithm steps and this section will conclude the SNR expression for user one at respective base station $BS-1$.

Using the final derived equations and summing up the received signals after detection, following steps can be used to derive SNR expression.

$$\tilde{y}_1^{(1,1)} = \begin{bmatrix} h_{11}^{(1)^*} & -h_{13}^{(1)} \end{bmatrix} \begin{bmatrix} y_1^{(1,1)} \\ \bar{y}_3^{(1,1)^*} \end{bmatrix} = \left(|h_{11}^{(1)}|^2 + |h_{13}^{(1)}|^2\right) S_1 + \left(h_{11}^{(1)^*} n_1^{(1,1)} - h_{13}^{(1)} n_3^{(1,1)}\right) \quad (17)$$

Similarly, for the second antenna, the received signal can be formulated as,

$$\tilde{y}_1^{(1,2)} = \begin{bmatrix} h_{21}^{(1)^*} & -h_{23}^{(1)} \end{bmatrix} \begin{bmatrix} y_1^{(1,2)} \\ \bar{y}_3^{(1,2)^*} \end{bmatrix} = \left(|h_{21}^{(1)}|^2 + |h_{23}^{(1)}|^2\right) S_1 + \left(h_{21}^{(1)^*} n_1^{(1,2)} - h_{23}^{(1)} n_3^{(1,2)}\right) \quad (18)$$

Accumulating the both antenna received signals at respective base station (BS-1) can be derived as follows,

$$\begin{aligned} \therefore \tilde{y}_1 &= \tilde{y}_1^{(1,1)} + \tilde{y}_1^{(1,2)} \\ &= \left(|h_{11}^{(1)}|^2 + (|h_{13}^{(1)}|^2 + |h_{21}^{(1)}|^2)|h_{23}^{(1)}|^2\right) S_1 + \\ &\left(h_{11}^{(1)^*} n_1^{(1,1)} - h_{13}^{(1)} n_3^{(1,1)} + h_{21}^{(1)^*} n_1^{(1,2)} - h_{23}^{(1)} n_3^{(1,2)}\right) \end{aligned} \quad (19)$$

Now, calculating the received signal power as follows,

$$Signal\ power = \left(|h_{11}^{(1)}|^2 + (|h_{13}^{(1)}|^2 + |h_{21}^{(1)}|^2) + |h_{23}^{(1)}|^2\right)^2 S_1 \quad (20)$$

Taking into account of the noise terms. The expectation of AWGN with zero mean i.i.d. noise, the noise power can be expressed as follows,

$$\begin{aligned} Noise\ power = E[(&h_{11}^{(1)^*} n_1^{(1,1)} - h_{13}^{(1)} n_3^{(1,1)} + h_{21}^{(1)^*} n_1^{(1,2)} \\ &- h_{23}^{(1)} n_3^{(1,2)})^2] \end{aligned} \quad (21)$$

$$NP = \left(|h_{11}^{(1)}|^2 + (|h_{13}^{(1)}|^2 + |h_{21}^{(1)}|^2) + |h_{23}^{(1)}|^2\right) \mathcal{N} \quad (22)$$

Hence, the final output SNR expression can be presented as follows,

$$Output\ SNR = \left(|h_{11}^{(1)}|^2 + (|h_{13}^{(1)}|^2 + |h_{21}^{(1)}|^2) + |h_{23}^{(1)}|^2\right) S/\mathcal{N} \quad (23)$$

This is the final expression of output SNR for user 1 at respective base station, BS-1. Similarly, using the similar approach, the output SNR for user 2 can be elaborated as follows,

$$Output\ SNR = \left(|h_{12}^{(1)}|^2 + (|h_{14}^{(1)}|^2 + |h_{22}^{(1)}|^2) + |h_{24}^{(1)}|^2\right) \frac{S}{\mathcal{N}} \quad (24)$$

After getting the desired SNR expression, the next step is to use the Q-function and MGF based approach to derive the close form expression for Bit Error Rate (BER) over Nakagami fading channels for both respective users.

V. PERFORMANCE ANALYSIS

A. Error Probability Analysis

In this section, the performance evaluation is done by taking into account the error probability (average SER) over Nakagami-m Fading Channel. The closely approximated Q-Function given in [9] as,

$$Q(x) \simeq \frac{1}{12} e^{-\frac{x^2}{2}} + \frac{1}{6} e^{-\frac{2x^2}{3}} \quad (25)$$

The probability of symbol error in the M-QAM system can be closely approximated as [9],

$$\overline{P}_{N_t \times N_r}(\gamma) \simeq \left(1 - \frac{1}{\sqrt{M}}\right) \left(\frac{1}{3} e^{-\frac{3\gamma}{2(M-1)}} + \frac{2}{3} e^{-\frac{2\gamma}{M-1}}\right) \quad (26)$$

The average SER can be tightly approximated by using close equation as,

$$\begin{aligned} P_{N_t \times N_r} &= \int_0^\infty \overline{P}_{N_t \times N_r}(\gamma) f_{N_t \times N_r}(\gamma) d\gamma \\ &\simeq \left(1 - \tfrac{1}{\sqrt{M}}\right) \left(\tfrac{1}{3} M_{N_t \times N_r}\left(\tfrac{3}{2(M-1)}\right) \right. \\ &\quad \left. + \tfrac{2}{3} M_{N_t \times N_r}\left(\tfrac{2}{M-1}\right)\right) \end{aligned} \quad (27)$$

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Nakagami-m Fading Channel

To evaluate the average SER for our proposed system, we have adopted the MGF based approach. Thus we need to compute the MGF first for Nakagami-m fading channel by using the following expression,

$$\begin{aligned} M_{N_t\times N_r}(g)|_a &= \int_0^\infty e^{-g\overline{\gamma}(a+b+c+d)} f_{N_t\times N_r}(a)da \\ &= e^{-g\overline{\gamma}(b+c+d)} \int_0^\infty e^{-g\overline{\gamma}(a} \left(\frac{m}{\Omega}\right)^m \\ &\frac{1}{\Gamma(m)} a^{m-1} e^{-\frac{ma}{\Omega}} da \\ &= \left(\frac{m}{\Omega}\right)^m \frac{e^{-g\overline{\gamma}(b+c+d)}}{\Gamma(m)} \int_0^\infty a^{m-1} e^{-a\left(g\overline{\gamma}+\frac{m}{\Omega}\right)} da \end{aligned} \tag{28}$$

By using identity eq. 3.381.4 from [10], (28) become,

$$\begin{aligned} M_{N_t\times N_r}(g)|_a &= \left(\frac{m}{\Omega}\right)^m \frac{e^{-g\overline{\gamma}(b+c+d)}}{\Gamma(m)} \frac{1}{\left(g\overline{\gamma}+\frac{m}{\Omega}\right)^m} \Gamma(m) \\ &= \left(\frac{m}{\Omega}\right)^m \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-m} e^{-g\overline{\gamma}(b+c+d)} \end{aligned} \tag{29}$$

Also, by computing the MGF with respect to b, we get,

$$\begin{aligned} M_{N_t\times N_r}(g)|_b &= \int_0^\infty M_{N_t\times N_r}(g)|_a f_{N_t\times N_r}(b)db \\ &= \left(\frac{m}{\Omega}\right)^{2m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-m} \frac{e^{-g\overline{\gamma}(c+d)}}{\Gamma(m)} \\ &\int_0^\infty b^{m-1} e^{-b\left(g\overline{\gamma}+\frac{m}{\Omega}\right)} db \end{aligned} \tag{30}$$

By using identity eq. 3.381.4 from [10], (30) become,

$$\begin{aligned} M_{N_t\times N_r}(g)|_b &= \left(\frac{m}{\Omega}\right)^{2m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-m} \frac{e^{-g\overline{\gamma}(c+d)}}{\Gamma(m)} \frac{1}{\left(g\overline{\gamma}+\frac{m}{\Omega}\right)^m} \Gamma(m) \\ &= \left(\frac{m}{\Omega}\right)^{2m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-2m} e^{-g\overline{\gamma}(c+d)} \end{aligned} \tag{31}$$

By computing the MGF with respect to c, we get,

$$\begin{aligned} M_{N_t\times N_r}(g)|_c &= \int_0^\infty M_{N_t\times N_r}(g)|_b f_{N_t\times N_r}(c)dc \\ &= \left(\frac{m}{\Omega}\right)^{3m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-2m} \frac{e^{-g\overline{\gamma}(d)}}{\Gamma(m)} \\ &\int_0^\infty c^{m-1} e^{-c\left(g\overline{\gamma}+\frac{m}{\Omega}\right)} dc \end{aligned} \tag{32}$$

By using identity eq. 3.381.4 from [10], (32) become,

$$\begin{aligned} M_{N_t\times N_r}(g)|_c &= \left(\frac{m}{\Omega}\right)^{3m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-2m} \frac{e^{-g\overline{\gamma}(d)}}{\Gamma(m)} \frac{1}{\left(g\overline{\gamma}+\frac{m}{\Omega}\right)^m} \Gamma(m) \\ &= \left(\frac{m}{\Omega}\right)^{3m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-3m} e^{-g\overline{\gamma}(d)} \end{aligned} \tag{33}$$

Now, by computing the MGF with respect to d, we get,

$$\begin{aligned} M_{N_t\times N_r}(g)|_d &= \int_0^\infty M_{N_t\times N_r}(g)|_c f_{N_t\times N_r}(d)dd \\ &= \left(\frac{m}{\Omega}\right)^{4m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-3m} \frac{1}{\Gamma(m)} \\ &\int_0^\infty d^{m-1} e^{-d\left(g\overline{\gamma}+\frac{m}{\Omega}\right)} dd \end{aligned} \tag{34}$$

By using identity eq. 3.381.4 from [10], (34) become,

$$\begin{aligned} M_{N_t\times N_r}(g)|_d &= \left(\frac{m}{\Omega}\right)^{4m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-3m} \frac{1}{\Gamma(m)} \frac{1}{\left(g\overline{\gamma}+\frac{m}{\Omega}\right)^m} \Gamma(m) \\ &= \left(\frac{m}{\Omega}\right)^{4m} \left(g\overline{\gamma}+\frac{m}{\Omega}\right)^{-4m} \end{aligned} \tag{35}$$

The average SER can be found after substituting the MGF expression in (27), as,

$$\begin{aligned} P_{N_t\times N_r} &\simeq \left(1-\frac{1}{\sqrt{M}}\right) \left(\frac{1}{3}\left(\frac{m}{\Omega}\right)^{4m} \left(\left(\frac{3}{2(M-1)}\right)\overline{\gamma}+\frac{m}{\Omega}\right)^{-4m}\right) \\ &+ \left(\frac{2}{3}\left(\frac{m}{\Omega}\right)^{4m} \left(\left(\frac{2}{M-1}\right)\overline{\gamma}+\frac{m}{\Omega}\right)^{-4m}\right) \\ &\simeq A_1 \left(\frac{1}{3}\left(\frac{m}{\Omega}\right)^{4m} \left(A_2\overline{\gamma}+\frac{m}{\Omega}\right)^{-4m}\right) \\ &\left(+\frac{2}{3}\left(\frac{m}{\Omega}\right)^{4m} \left(A_3\overline{\gamma}+\frac{m}{\Omega}\right)^{-4m}\right) \end{aligned} \tag{36}$$

where $A_1 = \left(1-\frac{1}{\sqrt{M}}\right) = \left(1-\frac{1}{\sqrt{16}}\right) = 0.75$, $A_2 = \left(\frac{3}{2(M-1)}\right) = \left(\frac{3}{2(16-1)}\right) = 0.1$, and $A_3 = \left(\frac{2}{M-1}\right) = \left(\frac{2}{16-1}\right) = 0.1333$.

The above equation gives the theoretical average SER over Nakagami-m Fading Channel and in the results section, the theoretical average SER is plotted against the average SNR. The special case has been investigated also for Nakagami fading when m goes to one. So, that is the special case experienced as Rayleigh fading ($m = 1$).

VI. SIMULATION RESULTS AND DISCUSSION

In this section, the performance of the MIMO based Fe-COPE protocol by plotting the analytical curves along with the simulated results is analyzed. The obtained theoretical results elaborate the performance evaluation of our proposed MIMO based Fe-COPE system for co-channel interference mitigation technique. The exact BER performance are analytically derived with the help of SER expression by using the MGF expressions under Nakagami-m and (Rayleigh fading as a special case) fading distributions respectively. The respective mathematical expressions in the form of theoretical results are drawn by using Mathematica 8 software and compared together with the obtained simulated results from Monte Carlo simulations using MATLAB over Rayleigh, and Nakagami fading environments, respectively. The conclusive obtained results for average performance parameter of BER are drawn w.r.t obtained SNR (E_b/N_o) in dB over 16-QAM constellation technique.
Figure 2 shows a good agreement between the analytical and simulated results over Nakagami fading channel. The figure presents the average BER analysis vs SNR in dB curve. It can be clearly seen that the performance improves in case of Fe-COPE proposed scheme due to gains of MIMO technique with diversity. Fe-COPE system helps in mitigating the co-channel interference in femto scenario but the interesting thing is that it exploits the channel gain of the interfered signal as well by using cell as a relay so this protocol is exploiting robust by taking into account the advantage of MIMO diversity gains and Alamouti gain, as well at both femto base stations. The results obtained showed that at value of BER = 10^{-2}, the performance of MIMO based Fe-COPE is better than normal Fe-COPE system due to four times diversity gain whereas in Fe-COPE the gains are of order two. The interesting part is that the BER curves go gradually better for the high SNR values as the value of m goes higher i.e. $m > 1, m = 2, 3$. The special case when $m = 1$ of Rayleigh fading is experienced and it can be verified with the theoretical and simulation results for MIMO based Fe-COPE protocol.

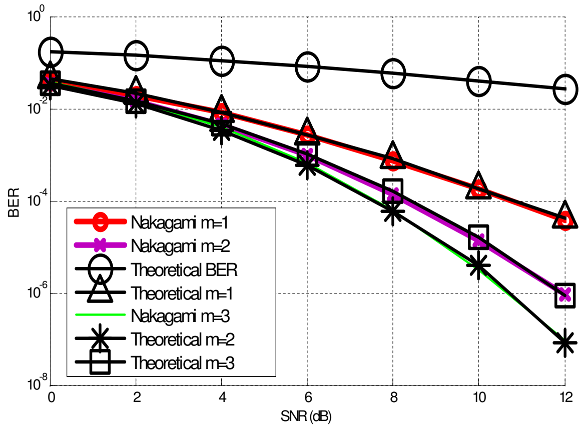

Figure 2. Simulation results for MIMO based Fe-COPE protocol over Nakagami Fading Channel

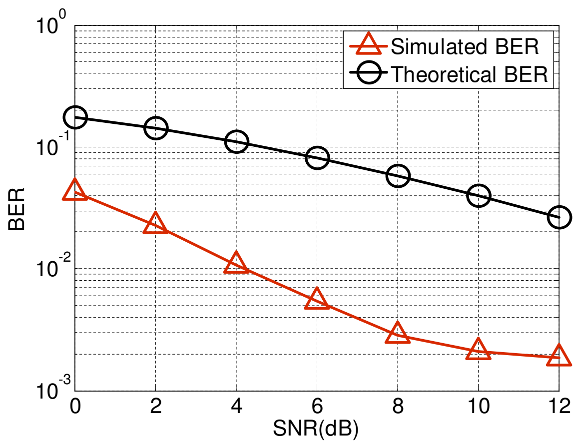

Figure 3. Simulation results of MIMO based Fe-COPE system in terms of BER Vs SNR curves for Rayleigh fading from S-D node over Rician fading environment

The results obtained for the Figure 3 are for the case when Rayleigh fading is considered from source nodes to destination in a Rician fading environment. It can be clearly seen that due to the MIMO and Alamouti gains, the results get better but for the high SNR values, the values reach to the saturation point and does not change much. It is a good solution for the low SNR values and depending on the different channel conditions, different approach can be adopted.

VII. Conclusion

A compact investigation on the performance is performed for MIMO-based femto cells over different fading channels. A novel protocol has been designed in order to mitigate interference issue in two users femto cell scenario by exploiting Alamouti coding gain as well as MIMO gains for 16-QAM modulation scheme. The closed form expressions are derived for the MIMO based Fe-COPE system over Rayleigh as special case, and Nakagami-m fading channels. The protocol involves five steps algorithm in order to reach full diversity (order of four) and then derive the I/O relationship to calculate SNR expression. Using the expression of SNR, closed form expression is calculated using MGF based approach for MIMO based Fe-COPE system. Later, the simulation results show the effectiveness of the protocol. The results are obtained using Mathematica and Matlab softwares in order to verify the results. The BER vs SNR curves are obtained for higher values of Nakagami factor m, it has been seen that for higher values there is a dramatic change in the results. The high SNR regime shows the promising results for the protocol and provide the maximum diversity order.

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